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Intellectual Property Rights, Migration, and Diaspora

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Intellectual Property Rights, Migration, and Diaspora*

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Abstract

In this paper we study theoretically and empirically the role of the interaction between skilled migration and intellectual property rights (IPRs) protection in determining innovation in developing countries (South). We show that although emigration from the South may directly result in the well-known concept of brain drain, it also causes a brain gain effect, the extent of which depends on the level of IPRs protection in the sending country. We argue this to come from a diaspora channel through which the knowledge acquired by emigrants abroad can flow back to the South and enhance the skills of the remaining workers there. By increasing the size of the innovation sector and the skill-intensity of emigration, IPRs protection makes it more likely for diaspora gains to dominate, thus facilitating a potential net brain gain. Our main theoretical insights are then tested empirically using a panel dataset of emerging and developing countries. The findings reveal a positive correlation between emigration and innovation in the presence of strong IPRs protection.

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Keywords: Intellectual property rights; Migration; Technology transfer; Brain gain; Diaspora.

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1 Introduction

International trade and foreign direct investment (FDI) have often been identified as the main determinants of innovation and growth in developing countries (South) (Saggi, 2002; Keller, 2004). While the significance of trade and FDI has been confirmed by a two- and three-fold increase in their ratio with respect to world output during the 1990s, high-skill migration to developed countries (North) has witnessed an even faster increase (Docquier and Rapoport, 2010). The resulting surge in the outward transfer of the human capital embedded in migrants has created controversial debates about the threats and opportunities that skilled emigration may pose to the South. On the one hand, the traditional literature on migration and brain drain presents mechanisms through which skilled emigration could be detrimental to growth.[1] On the other hand, a growing branch of contributions argues that skilled emigration need not harm the South and may even increase the potential for development.

The so-called brain gain effect derives from an incentive channel that works through the increased expected returns to education brought about by migration prospects (Mountford, 1997; Stark et al. 2007; Beine et al., 2001, 2008).[2] An additional channel is return migration, which can induce innovation through the knowledge embodied in migrants returning from more advanced economies (Domingues Dos Santos and Postel-Vinay, 2003; Mayr and Peri, 2009; Dustmann et al. 2011). Finally, cross-border diaspora networks among skilled emigrants and natives may also promote access to foreign-produced-knowledge and foster innovation by encouraging trade, investments and the recirculation of information back into the sending countries (Agrawal et al., 2011; Kerr, 2008).[3] Research in other disciplines such as Meyer (2001) suggests such informal networks to be crucial in turning brain drain into a net brain gain. Despite a large number of studies on diaspora networks, however, little formal research in the economic literature directly examines the potential link between the knowledge absorbed by emigrants abroad and innovation in their home countries.[4]

[1] Seminal works are those of Berry and Soligo (1969), Bhagwati and Hamada (1974) and Miyagiwa (1991). For a recent complete survey of the literature on brain drain and development, see Docquier and Rapoport (2010).

[2] The possibilities of such gains from emigration were first referred to by Bhagwati and Rodrigues (1975).

[3] Student/scholarly networks, local associations of skilled expatriates, short-term consultancies by high-skilled expatriots in their country of origins, and other not established intellectual/scientific diaspora networks are a few examples of such networks (Meyer and Brown, 1999).

[4] Williams (2007) and Oettl and Agrawal (2008) focus on the externalities of international migration to emphasize their role in knowledge and technology transfer. More recently, Beine et al. (2011) show the influence of diasporas on the evolution of migration flows and their composition in terms of skills.

What are the consequences of skilled emigration for innovation in developing countries? Do diaspora networks play a role in this process? Referring to Agrawal et al. (2011), the Economist writes: "[...] having many scientists leave India does harm innovation there. But Indian researchers also refer to [work by] scientists of Indian origin in America more than very similar work by scientists with whom they do not share ethnic ties. So a scientific diaspora gives countries of origin a leg-up in terms of access to the latest research, mitigating some of the problems of a 'brain drain'. And given that the same scientist is going to be more productive in America than in a developing country because of better facilities and more resources, immigration may help overall innovation (some of the benefits of which may flow back to firms in poorer countries)".[5]

In this paper we explore how emigration from the South affects innovation activities in the home (sending) country. In particular, we investigate the existence of a channel through which the knowledge learned by emigrants after interacting with higher skills in the North can flow back to the South.[6] We refer to this channel as "intellectual diaspora", that is, the remote mobilization of intellectuals and professionals abroad and their connection to scientific, technological and cultural programs at home. We also examine the role of intellectual property rights (IPRs) protection in the South by exploring how IPRs interact with emigration in determining innovation performance. The key question we aim to answer is whether an appropriate level of IPRs protection could help transforming the brain drain caused by skilled emigration into a brain gain. In sum, we argue that although emigration may directly result into a brain drain, it also causes a brain gain affect, the extent of which depends on the strength of IPRs protection.

The role of IPRs protection in any study that involves innovation and the developing world is crucial. However, while the trade-off faced by an emerging economy between imitation and the provision of incentives for domestic innovation through IPRs are clear (Maskus, 2000), the interrelationships between skilled migration and IPRs policy in determining innovation remain to be explored. Our work fills this gap and contributes to the above mentioned strand of research by capturing the diaspora dimension of migration and discovering how IPRs protection in the sending country may influence the effect of skilled migration on in-

[5] The Economist, "Give me your scientists...", March 7, 2009.

[6] In this framework the capacity of innovation of the Southern innovators which remain in their origin countries is related to their access to valuable technological knowledge partially accumulated abroad (i.e. brain banks). On this issue, see Agrawal et al. (2011).

novation there.[7] On this basis, we shed light on the net impact of emigration on innovation and show whether a strong IPRs regime at home can eventually turn the initial brain drain into a brain gain.

Our theoretical framework is a standard occupational choice model in which emigration reduces effective innovation activities due to the loss of the most skilled (the *extensive margin*). Migration however also opens a diaspora channel, through which the knowledge acquired abroad can flow back into the innovation sector in the home economy and enhance the skills of the remaining workers there (the *intensive margin*). To investigate whether the beneficial effects of diaspora could outweigh the direct negative effects of the flow of skilled workers, we look at the size and the average skills of the innovation sector. While a strong level of IPRs protection directly increases the magnitude of gains from diaspora by raising the returns to skills and expanding the innovation sector (thus causing the diaspora effect to fall on a larger range of workers actively using their skills in the economy), it also endogenously increases the skill composition of the emigrants (thus leading to an increase in the quality of skills learned and transmitted back home). As a consequence, a strong level of IPRs protection in the sending country makes it more likely for diaspora gains to outweigh the negative effects of brain drain on innovation, thus facilitating a potential net brain gain.[8]

Using a sample of emerging and developing economies, we then perform an empirical analysis to investigate the joint impact of emigration and IPRs protection in the sending country on innovation there. The sample we use is a panel of 35 low-income countries ranging from 1995 to 2006. We measure innovation activities in the South through the number of resident patents with data taken from WIPO (World Intellectual Property Organization). We use this information together with extensive original data on migration flows and stocks obtained from national statistical offices and with the index of IPRs protection as measured by Park (2008). Our findings show the impact of emigration on innovation to be positive in

[7] Among the vast literature on intellectual property rights, Chen and Puttinan (2005) and Parello (2008) are perhaps most closely related to our work, as they specifically focus on domestic skill accumulation and innovation. While the former relates positively IPRs protection to innovation, the latter deems it to be ineffective for innovation in less developed countries.

[8] These results are in contrast to the theoretical conclusion obtained in McAusland and Kuhn (2011), who claim IPRs to be an obstacle to the international flow of brains. In short, they argue that if brains are emigrating, a country may as well lower its IPRs to free ride on brains that have moved elsewhere. While their study is to our knowledge the first contribution which explicily investigates the link between IPRs and brain circulation, it does not take into account any channels through which the skills acquired abroad can be transferred back into the country of origin.

the presence of strong IPRs protection. IPRs hence have a role in promoting the beneficial effects of the diaspora channel of knowledge, confirming the main conclusions of our theoretical model. By conducting an empirical investigation focused on emerging and developing countries, our work also contributes to the missing world of empirical analysis on innovation and development in the South.[9]

In order to validate that our main empirical findings are mainly driven by the phenomenon of intellectual diaspora rather than by other compatible explanations, we also apply a variant of the method proposed by Spilimbergo (2009). In particular, we construct a measure of emigration that makes it possible to relate an increase in resident patents granted in a sending country to "where" the emigrants go. The underlying intuition is that emigrants may better promote innovation in their home countries if their host countries have a higher potential for innovation. This approach allows us to confirm that it is the skills learned from abroad by emigrants and transferred back to their home country that increase successful innovation there under strong IPRs, thus corroborating our theoretical conclusions.

In the remainder of the paper, we introduce the theory in section 2, the empirical exercise in section 3, and conclude in section 4.

2 The Model

2.1 Basic Framework

Suppose there are two regions: a developing economy referred to as the South, and an alternative North with better economic opportunities and employment possibilities, where skills and wages are higher by assumption. As the focus of our study is the Southern market, we concentrate our analysis on goods invented, produced and consumed locally in the South.[10] Consumers have the following utility function:

$$U_i = C_i = \left[\int_0^N c_j^{\alpha} di \right]^{\frac{1}{\alpha}}, \tag{1}$$

[9] Indeed, while innovation has been deemed central to economic take-off, catch-up, and development in low-income countries, research on innovation tends to neglect developing countries, leaving a large gap in economic literature (Lorentzen and Mohamed, 2010).

[10] To single out the impact of migration from South to North on local innovation, we abstract from trade-related issues. For s study of the trade and migration in an occupational choice model see Iranzo and Peri (2009). While their study is not innovation-related, Davis and Naghavi (2010) explore the effects of trade and offshoring on innovation and growth in a similar but dynamic occupational choice setting.

where individual consumption C_i is divided between a continuum of N invented goods subscripted by $j \in (0, N)$, and $\alpha \in (0, 1)$ represents the inverse measure of product differentiation.

There are two sectors in the economy, a production and an innovation sector. Labor is the only factor of production and innovation, and is mobile between sectors. Workers are spread over a continuum of skills $z \in [0, \infty)$, distributed with density $g(z)$ and cumulative distribution $G(z)$. We normalize the mass of workers to one. While production does not require skills, a worker i with skills z_i in the innovation sector has productivity h_i such that

$$h_i(z) = z_i + Z, \tag{2}$$

where z_i represents own skill endowment and Z (defined below) is spillovers of knowledge learned by emigrants abroad through what we call the "diaspora" channel.

The timing of the model is as follows. Nature reveals the IPR regime exogenous to our model. Emigration takes place in period 0, activating the diaspora channel. Innovation is then carried out in the first period, and production occurs in the second.

The core of our analysis deals with the events that occur in period 0. We first study the implications of the IPR regime, which determines the size of the innovation sector and the skill composition of migration. We then look at the impact of emigration on innovation, measured by average skills to represent effective innovation activities in that sector, given the IPR regime in the South.

Emigration in period 0 is modelled as a movement of labor from the South to the North at a cost F, which allows only the highest skilled to move. Potential diaspora is then realized by means of skilled emigrants transferring their newly acquired knowledge back to the South. We define the positive externalities from diaspora networks as

$$Z = b\tilde{\zeta}, \tag{3}$$

where the average skills endowment of those who migrate to the North is $\tilde{\zeta} > 0$. Parameter $b \geq 0$ measures the intensity of diasporas, which is influenced by factors such as the level of academic and professional interactions and the amount of skills learned in the North, or the successful transmission of knowledge to and the absorptive capacity of the South. Note that $b = 0$ implies no international knowledge transfer, $b = 1$ the return of only original (pre-migration) skills of emigrants, and $b > 1$ the diffusion of their improved skills to the South.

In period 1, N goods are invented. Each good needs ρ units of skills. Total amount of human capital in the economy can be written as

$$H(z) = \int_{z_1}^{\infty} h_i g(z) dz, \tag{4}$$

where z_1 represents the skills of a threshold worker indifferent between working in the production or the innovation sector. The total number of goods available for consumption are

$$N = N(z) = H(z)/\rho. \tag{5}$$

In order to work in the innovation sector, each worker must go through training at a cost e, which is paid in the second period. Effective wage (wage per unit of skill) for the high-skilled in the innovation sector is equal to ω_H and is paid in period 2, giving each individual with skills z_i a wage equivalent to $z_i\omega_H$.

In period 2, the production sector absorbs all workers who have not worked in the innovation sector in the first period. The production function is CRS in labor and has productivity equal to one, so that there is a one to one relationship between output and labor, $n_j = l_j$. Individual wage is identical for all workers in this sector and equals ω_L.

2.2 Patents and Consumption

We use the basic framework in Saint-Paul (2003, 2004) as our benchmark, modelling IPR protection as the probability that an innovator can obtain monopoly power over his invention.[11] The probability of being granted a patent is q, which captures the degree of IPR protection.[12] The price of a non-patented good is equal to its marginal cost normalized to one, which also gives us wages in the production sector $p_L = \omega_L = 1$. Otherwise, if a patent is granted, a firm charges monopoly price $p_M = \mu$, which is a mark-up over marginal cost

$$\mu = 1/\alpha. \tag{6}$$

[11] Saint Paul (2004) uses this setting to explore the implications of IPR and redistribution on occupational choice and welfare.

[12] Grossman and Lai (2004) also model patent protection in a similar manner.

Next, consumption is divided between patented and non-patented goods, c_P and c_N respectively. Consumers allocate their income y (net of training costs) between the two types of goods by maximizing (1) or equivalently

$$\underset{c_N, c_P}{Max} \quad Nqc_P^{\alpha} + N(1-q)c_N^{\alpha}, \tag{7}$$

under the budget constraint

$$y = Nq\mu c_P + N(1-q)c_N. \tag{8}$$

The solution to the above maximization problem is:

$$c_N = \frac{y}{\psi}, c_P = \frac{y}{\psi}\mu^{\frac{1}{(\alpha-1)}}, \tag{9}$$

where

$$\psi = N(1-q) + Nq\mu^{\frac{\alpha}{(\alpha-1)}} \tag{10}$$

captures the love of variety effect as $\partial\psi/\partial N > 0$, and the disutility caused by monopoly pricing as $\partial\psi/\partial q < 0$.

Using (1), (7), (9) and (10), aggregate consumption index is therefore

$$C = \frac{y}{\psi^{\frac{(\alpha-1)}{\alpha}}} = \frac{y}{P},$$

where $P = \psi^{\frac{(\alpha-1)}{\alpha}}$ is the aggregate price index.

The value of a patent, which is equal to monopoly profit, is equal to

$$\pi = (\mu - 1)\frac{Y\mu^{\frac{1}{(\alpha-1)}}}{\psi}, \tag{11}$$

where Y is aggregate income (net of training cost). In the above expression, the first term on the RHS is the mark-up while the second is total demand for the patented good.

Under a competitive labor market, expected profit from inventing a new good must equal to its cost in terms of skills so that

$$q\pi = \rho\omega_H.$$

This gives

$$\omega_H = q(\mu - 1)Y\mu^{\frac{1}{(\alpha-1)}}/\psi\rho. \tag{12}$$

As we are interested in the direct effect of strengthening IPRs protection (which corresponds to an increase in q) on employment in the innovation sector, we partially differentiate (12) with respect to q to get

$$\frac{\delta\omega_H}{\delta q} = \frac{(\mu - 1)Y\mu^{\frac{1}{(\alpha-1)}} + \rho N(1 - \mu^{\frac{\alpha}{(\alpha-1)}})}{\psi^2\rho^2} > 0. \tag{13}$$

Recalling that $\mu > 1$ and $\alpha < 1$, the sign of the derivative in (13) reveals that stronger patent protection increases effective wages in the innovation sector. Notice that this has no effect on the skills of each individual worker and only changes average skills by increasing the returns to working in the innovation sector, hence expanding its size. While the size of the innovation sector is given by equation (4), the average level of skills in the South is denoted by

$$\tilde{z} = \frac{1}{1 - G(z_1)} \int_{z_1}^{\infty} z dg(z). \tag{14}$$

Differentiating (14) with respect to z_1 reflects the basic results from the occupational choice model of Roy (1951). Since $\frac{\delta\tilde{z}}{\delta z_1} < 0$, the entry of less skilled workers in the innovation sector reduces average skills there. This could also be interpreted as a negative direct effect of IPRs caused by a misallocation of the low-skilled to the innovation sector. This is in line with Glass and Saggi (1998) and Vandenbussche, et al. (2006), who argue that a shift of such workers away from less-skill intensive activities such as imitation could have adverse effects for countries far from the technological frontier. In our analysis below we show how this reallocation of workers following an improvement of IPRs can be beneficial due to diaspora gains.

2.3 Innovation and Migration

A worker with skill level z_i can either work in the innovation sector and earn $\omega_H z_i - e$ or become a production worker with wage $\omega_L = 1$, choosing the option that generates a higher income. Therefore, given $\omega_H > 1$, a worker chooses to work in the innovation sector if[13]

$$\omega_H z_i - e > 1 \Rightarrow z_1 = \frac{1+e}{\omega_H}. \tag{15}$$

Lemma 1 *The threshold skill level z_1, which determines the equilibrium allocation of workers between the production and the innovation sector, is decreasing in effective wages ω_H as $\frac{\delta z_1}{\delta \omega_H} = -\frac{1+e}{\omega_H} < 0$: higher effective skilled wages in the South shift workers from the production to the innovation sector.*

A worker migrates to the North if his gains from doing so net migration costs exceed what he would earn in the innovation sector at home:

$$\omega_M z_i - e - F > \omega_H z_2 - e \Rightarrow z_2 = \frac{F}{\omega_M - \omega_H}, \tag{16}$$

where we assume an exogenous effective wage in the innovation sector of the North higher than that in the South: $\omega_M > \omega_H$.

Lemma 2 *The threshold skill level z_2, which distinguishes emigrants from non-emigrants, is increasing in effective wages ω_H as $\frac{\delta z_2}{\delta \omega_H} = \frac{F}{(\omega_M - \omega_H)^2} > 0$: higher effective skilled wages in the South discourages emigration to the North.*

Observing (15) and (16) together reveals the size of the innovation sector. It is derived from the brain drain effect which relates to migration of the highly skilled population (lower z_2) and from the effect of the movement of workers from the production to the innovation sector as a result of stronger IPRs (lower z_1). Higher moving costs F deter emigration and preserve the size of the innovation sector; higher training costs to work in the innovation sector e decrease the size by preventing the low skilled from entering the innovation sector; higher prospective wages abroad ω_M encourage the flow of skills away from the country, while higher wages in the innovation sector at home ω_H attract workers from the production sector and reduce skilled emigration.

[13] Using z_i instead of h_i from (2) to find the threshold in (15) follows from the assumption that a worker does not take into account potential spillovers of knowledge learned by emigrants abroad, when choosing his occupation or deciding whether or not to migrate. This assumption avoids the anticipation of potential benefits from diaspora and free-riding on migration by others.

Finally, stronger IPR protection discourages emigration by the lower end of skilled workers. Defining

$$\tilde{\zeta} = \frac{1}{1 - G(z_2)} \int_{z_2}^{\infty} z dg(z) \tag{17}$$

as the average skill composition of migrants, stronger IPRs increase the *skill intensity* of migration by limiting the migrants to those with highest skills, as $\partial\tilde{\zeta}/\partial z_2 > 0$.[14]

Lemma 3 *Given Lemma 2 along with the definition of $\tilde{\zeta}$ in (17), $\partial\tilde{\zeta}/\partial z_2 > 0$ implies that a higher in z_2 increases the skill intensity of migration as long as the number of migrants is greater than zero, i.e. $z_2 < \infty \Rightarrow G(z_2) < 1$.*

2.4 Equilibrium

The economy is in equilibrium when the allocation of workers across sectors is compatible with the labor and product market clearing conditions. Recall that the total number of workers in the production sector in terms of the threshold skill level z_1 is

$$L = L(z_1) = \int_0^{z_1} g(z) dz = G(z_1), \tag{18}$$

and that total skills in the innovation sector in terms of z_1 and z_2 are expressed by

$$H(z) = H(z_1, z_2) = \int_{z_1}^{z_2} h_i g(z) dz. \tag{19}$$

Market clearing implies that total output net training cost Y is equal to total factor income:[15]

$$Y = \omega_H H(z_1, z_2) + L(z_1). \tag{20}$$

This equilibrium condition can equivalently be written through the labor market clearing condition

$$L(z_1) = [N(1-q)]\frac{Y}{\psi} + Nq\frac{Y\mu^{\frac{1}{(\alpha-1)}}}{\psi}, \tag{21}$$

[14] Total skills of emigrants increases as more workers move to the North, while their average skills fall since every new migrating worker is endowed with lower initial skills ($\partial\tilde{\zeta}/\partial z_2 > 0$).

[15] In what follows, we assume training costs e to be embedded in Y, which simplifies the notation but does not influence the results.

where the first and the second term on the RHS derive from total consumer demand for the non-patented and patented goods respectively.

[FIGURE 1 ABOUT HERE]

We can close the model by using equations (5), (10), (12), and (20) to solve for the equilibrium effective wage in terms of z_1 and z_2:

$$\omega_H = \omega_H(z_1, z_2) = \frac{q(\mu - 1)\mu^{\frac{1}{(\alpha-1)}} L(z_1)}{\rho + H(z_1, z_2)[1 - q(1 - \mu^{\frac{\alpha}{(\alpha-1)}})]}. \tag{22}$$

The following two-equations system allows us to calculate the dynamics of z_1 and z_2:

$$\begin{aligned} z_1\omega_H(z_1, z_2) &= 1 + e, \\ z_2\omega_H(z_1, z_2) &= \omega_M z_2 - F. \end{aligned} \tag{23}$$

Equilibrium effective wage $\omega_H(z_1, z_2)$ and the conditions in (23) can be interpreted as follows. We saw from (12) that an increase in the level of IPR protection raises the effective wage associated with one unit of skill. As the wage of the worker with skills z_1 in the innovation sector net of training cost is always equal to unity, an increase in q is always followed by a fall in z_1, as $\partial L(z_1)/\partial z_1 > 0$ in the numerator and $\partial H(z_1, z_2)/\partial z_1 < 0$ in the denominator work to keep the wage of the new (lower skilled) threshold worker net training cost equal to unity.

In addition, rewriting equilibrium conditions in (23) as

$$\begin{aligned} z_1 q(\mu - 1)\mu^{\frac{1}{(\alpha-1)}} L(z_1) &= (1 + e)\left\{\rho + H(z_1, z_2)[1 - q(1 - \mu^{\frac{\alpha}{(\alpha-1)}})]\right\}, \\ z_2 q(\mu - 1)\mu^{\frac{1}{(\alpha-1)}} L(z_1) &= (\omega_M z_2 - F)\ \left\{\rho + H(z_1, z_2)[1 - q(1 - \mu^{\frac{\alpha}{(\alpha-1)}})]\right\}, \end{aligned} \tag{24}$$

we can easily see that thresholds z_1 and z_2 must move in opposite directions, i.e. $\partial z_2/\partial z_1 < 0$. This is so because the LHS of (24) is strictly increasing in z_1, while the RHS is decreasing in z_1 through $H(z_1, z_2)$. Migration threshold z_2 must therefore increase to reestablish equilibrium as $\partial H(z_1, z_2)/\partial z_2 > 0$.[16]

Redefining averages skills from (14) after adding threshold z_1 to account for migration,

[16] See Appendix for a formal proof and the derivation of the total derivatives.

we have

$$\tilde{z} = \frac{1}{G(z_2) - G(z_1)} \int_{z_1}^{z_2} z dg(z). \qquad (25)$$

Differentiating (25) with respect to z_1 and z_2 gives $\frac{\delta \tilde{z}}{\delta z_1} < 0$ and $\frac{\delta \tilde{z}}{\delta z_2} > 0$.

Lemma 4 *Given (25) along with Lemmas 1-2, a rise in per unit wages of the skilled in the South lowers average skills* $\tilde{z}$ ($\frac{\delta \tilde{z}}{\delta \omega_H} < 0$) *if* $\left|\frac{\delta z_1}{\delta \omega_H}\right| > \left|\frac{\delta z_2}{\delta \omega_H}\right|$, *and increases it if the opposite holds.*

We can conclude that an increase in the IPR protection level q shifts workers from the production to the innovation sector, increasing the size of the latter and lowering average skills in the South. However, Lemma 4 shows that IPR protection does not only imply an expansion of the innovation sector by lowering z_1, but also via increasing z_2 as $\partial z_2/\partial z_1 < 0$. This reduced migration works against the negative impact of IPRs on average skills in the innovation sector, and at the same time increases the skill composition of the emigrants $\tilde{\zeta}$ from Lemma 3. The impact of IPR enforcement on the home economy is illustrated in Figure 1.

Proposition 5 *A stronger level of IPR protection in the South (higher* q*) increases the returns to working in the innovation sector* ω_H *and therefore (1) expands the size of the innovation sector from both ends of the spectrum* ($\frac{dz_2}{dz_1} < 0$) *by reducing* z_1 ($\frac{dz_1}{dq} < 0$) *and raising* z_2 ($\frac{dz_2}{dq} > 0$)*; (2) increases the skill intensity of migration by increasing* $\tilde{\zeta}$ *through a larger* z_2*.*

Proof. *See (13), (24), (17), and the Appendix.* ■

We now turn to analyze the conditions under which skilled emigration could promote innovation in the South. In particular, we study how emigration changes the level of skills in the South, and how the magnitude of this effect is determined by the IPRs regime. We then explore when the beneficial effects of cross-border diaspora are likely to outweigh the negative brain drain effect of emigration on innovation and transform it into brain gain.[17]

[17] The brain gain channel which we refer to has a different interpretation from that of the relevant literature. While the literature on brain gain and development highlights that the brain gain channel is realized through an increase in the incentives for human capital formation in the sending countries, in our framework the brain gain channel is realized through an increase in the size and average skill level of the innovation sector of the origin country. Both interpretations, however, lead to the same conclusion: under certain conditions, skilled emigration could be beneficial for growth in the sending countries.

2.5 Intellectual Property Rights and Diaspora

In order to measure the net effect of migration on innovation in the South, we must weight the magnitude of the negative brain drain effect against gains brought about by the diaspora channel. Brain drain can be summarized as the direct loss of skills embedded in workers who migrate abroad, i.e. *the extensive margin.* This is in other words the amount of skills initially available prior to migration minus the base skills of the remaining workers post-migration:

$$BD = \int_{z_1}^{\infty} zg(z)dz - \int_{z_1}^{z_2} zg(z)dz = \int_{z_2}^{\infty} zg(z)dz. \qquad (26)$$

[FIGURE 2 ABOUT HERE]

Next, we rewrite the aggregate supply of skills as

$$H(z_1, z_2) = \int_{z_1}^{z_2} (z + Z)g(z)dz = \int_{z_1}^{z_2} (z + b\tilde{\zeta})g(z)dz = \int_{z_1}^{z_2} zg(z)dz + b\int_{z_1}^{z_2} \tilde{\zeta}g(z)dz, \qquad (27)$$

The first term on the RHS represents the amount of skill workers in the innovation sector are originally endowed with, and the second term the aggregate diaspora effect on the same workers still residing in the South, i.e. *the intensive margin.*[18] Such potential gains from diaspora are illustrated in Figure 2. The second term on the RHS of (27) denotes the virtual return of upgraded skills through diaspora and can be rewritten to define brain gain as

$$BG = b\int_{z_1}^{z_2} \tilde{\zeta}g(z)dz = b\tilde{\zeta}\int_{z_1}^{z_2} g(z)dz = b\tilde{\zeta}[G(z_2) - G(z_1)] = b\frac{G(z_2) - G(z_1)}{1 - G(z_2)}\int_{z_2}^{\infty} zdg(z), \qquad (28)$$

where $[G(z_2) - G(z_1)]$ represents the size of the innovation sector, which is then multiplied by the diaspora term $b\tilde{\zeta}$ to account for the total effect of the latter on innovation in the home economy. Recall that an improvement of the IPR regime increases returns to skills (working in the innovation sector) by increasing effective wages ω_H. This results in an expansion of the innovation sector by reducing z_1 and increasing z_2. The RHS of equation (28) reveals that protecting IPRs increases the number of workers in the innovation sector that can benefit from diaspora by enlarging $[G(z_2) - G(z_1)]$. The diaspora mechanism is depicted in Figure 3. Emigration also increases brain gain by enhancing the level of skills $\tilde{\zeta}$

[18] Note that emigrants are excluded when summing up local skills in the South.

that can be transferred back to the home country. This secondary effect however disappears if we take into account the number of emigrants, which implies multiplying the RHS of (28) with $1 - G(z_2)$. As it will be clarified below, this effect is not necessary for our results and removing it simply limits the channels of gains from diaspora to the one associated with the size of the innovation sector.

[FIGURE 3 ABOUT HERE]

To see whether the brain gain effects caused by a diaspora channel could dominate the physical escape of skills caused by brain drain we must calculate the net effect of migration on total human capital in the sending country and test whether

$$\begin{aligned} BD - BG &\gtrless 0 \qquad (29) \\ \int_{z_2}^{\infty} zg(z)dz - b\frac{G(z_2) - G(z_1)}{1 - G(z_2)}\int_{z_2}^{\infty} zdg(z) &\gtrless 0 \\ b\frac{G(z_2) - G(z_1)}{1 - G(z_2)} &\equiv \Phi \gtrless 1. \end{aligned}$$

As seen above, the term $\Phi \equiv b\frac{G(z_2)-G(z_1)}{1-G(z_2)}$ can take a value greater or less than one. Brain gains through diaspora dominate when $\Phi > 1$, which is more likely for high levels of IPR protection because $\frac{\partial z_1}{\partial q} < 0 \Rightarrow G'(z_1) > 0 \Rightarrow \frac{\partial \Phi}{\partial z_1} < 0$ and $\frac{\partial z_2}{\partial q} > 0 \Rightarrow G'(z_2) > 0 \Rightarrow \frac{\partial \Phi}{\partial z_2} > 0$. As a result, IPRs indirectly promote brain gains by increasing the size of the innovation sector and the quality of diaspora, even if it could directly reduce average skills in the innovation sector (see Lemma 4).

Proposition 6 *Given proposition* 1 *and equation (29), gains from diaspora could outweigh the direct loss of skills caused by migration if the IPR regime in the South is sufficiently strong, so that* $b\frac{G(z_2)-G(z_1)}{1-G(z_2)} \equiv \Phi > 1$ *holds. This is so because 1. diasporas from the North reach out a larger number of workers who use their skills in the innovation sector:* $\frac{\partial[G(z_2)-G(z_1)]}{\partial q} > 0$*; 2. the average skills of migrants* $\tilde{\zeta}$ *and hence the quality of skills acquired abroad and transmitted back is higher:* $\frac{\partial[\frac{1}{1-G(z_2)}]}{\partial q} > 0$.

Proof. *See equation (29), Proposition 1, and Lemmas 3-4.* ■

2.6 Summary and Main Empirical Implications

In our theoretical model we investigate under what circumstances skilled emigration may be beneficial for development. We show that this occurs in the presence of a strong IPR regime, which may turn a brain drain into a brain gain.

In our framework a country's potential for innovation is influenced both by the size and average skill level of the innovation sector and by the average skill level of migrants. An increase in the size and average skill level of the innovation sector, as well as an increase in the average skill level of migrants, increase the absorptive capacity of the country where migration originates from, thus leading to stronger beneficial effects of cross-border diaspora networks. These beneficial effects are larger the bigger is the innovation sector, which occurs under strong patent protection.

The mechanism at work is as follows. Emigration has two effects. On the one hand, it decreases the average skills of the innovation sector $\tilde{z}$ since the implied loss of the most skilled induces a lower z_2 (*the extensive margin*). On the other hand, it increases the skills of the remaining workers in the innovation sector because of the diaspora channel (*the intensive margin*). This latter effect occurs through $\tilde{\zeta}$, which enhances the skills of all remaining individuals in the innovation sector as long as $b > 0$. The IPR regime also affects innovation in two ways. On the one hand, it affects the size of the innovation sector. On the other hand, it endogenously influences the skill composition of the emigrants. Indeed, an increase in IPRs protection enhances the attractiveness of working in the innovation sector, by thus increasing its size from both ends of the spectrum: it causes a move of the low skilled workers from the production to the innovation sector (i.e. z_1 falls) and it reduces emigration (i.e. z_2 rises). With a larger innovation sector, the potential for absorption of the newly acquired skills from the North ($b\tilde{\zeta}$) is higher, as the diaspora effect falls on a larger range of workers (i.e. a larger $H(z)$). At the same time, a reduction in the number of emigrants (i.e. a larger z_2) leads to a increase in their average skills $\tilde{\zeta}$, and hence to an increase in the quality of the skills that can be sent back to the original country.

This line of reasoning leads to the conclusion that the gains in human capital from diaspora are more likely to outweigh the direct drain of skills caused by emigration under a stronger IPRs regime. The main testable implications of our model are the following:

1. Abstracting from IPRs protection, skilled emigration is harmful for the origin country's

potential for development, leading only to brain drain.

2. In the presence of IPRs protection, skilled emigration could be beneficial for innovation. This occurs when the level of IPRs protection in the origin country is sufficiently strong. In such a case, the IPRs regime may help transform a brain drain in a net brain gain.

3 Empirical Analysis

3.1 Data and Specification

Our empirical analysis focuses on a sample composed by emerging and developing countries (EDC) as classified by IMF (2010). We make this choice because our theoretical model specifically concentrates on the determinants of innovation in developing countries. The dataset is an unbalanced panel including 35 countries and covering the time interval from 1995 to 2006.[19] The unit of analysis is a country-year.

The innovation measure we adopt is resident patent applications, i.e. the patent applications by residents of each country to the local national patent office. Additional tests will be done using patent grants.[20] Patent data are from the WIPO database. Our main migration measure is the gross flow of emigrants. An alternative migration measure is gross migrant stock, which we use in our robustness checks. The data on emigration flows and stocks are retrieved by aggregating original bilateral yearly data on immigrant flows and stocks by country of origin into 27 receiving OECD countries.[21] Intellectual property rights are measured through the Park (2008) index of IPRs protection. For all details about our data and sources, see Appendix.

To investigate whether in the presence of emigration brain gains are more likely to prevail under stronger IPR regimes, we explicitly focus on the interrelationships between migration and IPRs protection. To this end, we study the determinants of innovation with the help of an

[19] The list of countries in our sample is reported in Appendix.

[20] On the benefits of using patent statistics to measure innovation, see Griliches (1990). Along with input data such as R&D expenditures and the human capital employed in research, patents have become the most common measure of innovation output (Hall et al. 2001) and of knowledge spillovers (Mancusi 2008).

[21] Although for our analysis it would have been ideal to use data on skilled emigration, detailed statistics on the skill composition of emigrants by origin countries are available only for the two most recent census years (1990 and 2000) or, at maximum, every 5-years (from 1975 till 2000), but only with reference to the six major receiving OECD countries. For details about emigration data by skill levels, see Beine et al. (2010) and Defoort (2008).

empirical specification which introduces the following key variables: migration, intellectual property rights protection and the interaction between migration and IPRs protection.

The baseline specification we adopt is the following:

$$\begin{aligned} patents_{it} &= \beta_0 + \beta_1 emigr_{it-5} + \beta_2 IPR_{it-1} + \beta_3 emigr_{it-5} IPR_{t-1} + \\ &\quad + \gamma pop_{it} + \delta gdppc_{it-1} + \alpha_i + \eta_t + \varepsilon_{it} \end{aligned}$$

where i denotes the country and t the year. The dependent variable $patents_t$ is our measure of innovation. The variable $emigr_{t-5}$ represents emigration and is taken with a five-years lag, to take into account the time needed for the emigrants to acquire skills in the destination and interact to transfer the knowledge to their home countries.[22] IPR_{t-1} is the measure of IPRs protection and is taken with one lag, to avoid endogeneity issues. The variable $emigr_{t-5} IPR_{t-1}$ is the interaction term between emigration and IPRs protection. The cumulative effect of migration on innovation is then captured by β_1 and $\beta_3 IPR_{t-1}$ and varies with the level of IPRs protection. pop_t and $gdppc_{t-1}$ are population and GDP per capita, which are included to account for size effects, with a lag in case of GDP because of potential endogeneity issues. Finally, the α_i's are time-invariant country-specific effects, the η_t's are time dummies and ε_{it} is the error term.

Following the related literature, we complete our baseline specification by including a number of relevant controls. First of all, we add patent stock, which can be considered as a proxy for a country's absorptive capacity (Hall et al., 2001). Its potential effect on the amount of innovation activities is positive.[23] We also add R&D expenditure, which is considered a proxy for a country's potential for innovation and is expected to positively influence innovation. A further relevant control is education, an additional proxy for the ability to absorb new knowledge. The education measure we use is tertiary education, which we believe could best capture this ability. Government spending is next added to measure the degree of economic freedom. Finally, trade and FDI are included in the light of a rich literature on North-South trade and FDI as determinants of innovation in low-income

[22] In the case of patent grants, this also pertains to the time needed to create a patent.

[23] To derive the patent stock series we use the perpetual inventory method (Coe and Helpman, 2005). Patent stock (PS) of country i at time t is $PS_{i,t} = PS_{i,t-1}(1-d) + P_{i,t-1}$, where d is the depreciation rate and P is patent flow. The initial value of patent stock (i.e. at time t_0) is expressed by: $PS_{i,t_0} = P_{i,t_0}/(g+d)$, where g is the average growth rate of patent flow (Griliches, 1980). We assume a depretiation rate of 15% (Hall et al., 2001) and take g as the average growth rate of patents in the first decade of available and reliable data of the patent series, i.e. starting from year 1990. As specified in the Appendix, the patent series start from 1985. However, consistent and complete data are only available from the 1990s.

countries. In our empirical analysis all additional controls except education are taken with one lag to avoid potential endogeneity issues. For details on the sources of the control variables, see Appendix. Table 1 illustrates the summary statistics of the key variables of our analysis with reference to the sample under consideration.

[TABLE 1 ABOUT HERE]

3.2 Results

Table 2 presents our results using resident patent applications as dependent variable. The migration variable is gross emigration flows. All estimations are performed using fixed effects regression methods and include country and time dummies.[24] We initially consider our baseline specification with all the three main variables of interest (migration, IPRs protection and the interaction between emigration and IPRs) and the two key controls for size effects (population and GDP per capita).[25]

[TABLE 2 ABOUT HERE]

Column (1) in Table 2 shows that our three main variables of interest are highly significant. The negative and significant coefficient of emigration suggests that migration by itself could induce brain drain. At the same time, there is a negative and significant effect of IPRs on patents, suggesting that IPRs protection by itself does not increase domestic innovation in developing countries (Qin, 2007). This effect could also be due to the fact that a high degree of IPRs protection reduces the propensity to innovate by blocking essential technological spillovers that in developing countries are only possible through imitation (Madsen et al., 2010). Nevertheless, key to our analysis is the interaction term between migration and IPRs protection, which reveals to be highly significant and positive. This suggests that IPRs protection helps the diaspora channel of knowledge that originates from migration.

[24] Our estimation strategy takes into account the characteristics of the WIPO data and the specificity of patent data at country level. While Table 1 shows that in our sample there is no country with zero patents, it may also happen that very poor countries may not report this variable. As a consequence, a missing data could actually represent a zero. However, since WIPO estimates the data missing for a given office or period of time from the available data and includes them in aggregate totals, our missing data on patents at country level are actual missing data and should not represent zeros. Where data is missing for a given office or period of time, WIPO estimates the missing data from the available data.

[25] Since our sample begins in 1995, the first observation of the lagged migration variable dates back to 1990.

This also means that above a certain threshold level of IPRs protection migration induces brain gain, thus mirroring the conclusion we derive in our theoretical model.[26]

In column (1) of Table 2 our two size controls (population and GDP per capita) are positive and significant, as expected. Columns (2) to (7) in turn add to the baseline specification our additional controls: patent stock, R&D expenditure, education, government spending, trade and FDI. The results show that patent stock and R&D expenditure are positive and significant determinants of innovation. The positive sign of patent stock suggests that innovation is stronger in the presence of a higher level of absorptive capacity: this implicitly confirms that the diaspora channel of knowledge is effective when the ability to absorb new knowledge is high. The positive sign of R&D is intuitive and follows the main predictions of the relevant literature: the more efforts are devoted to R&D, the bigger is a country's potential for innovation. Tertiary education appears to be insignificant in this framework: its negative sign could be due to the fact that highly educated people in developing countries may prefer to apply for patents in more advanced economies.[27] In this specification, both trade and FDI are positive as expected, but not significant.[28] Finally, column (8) simultaneously adds all controls into the specification.[29] As the results show, the coefficients of our three main variables of interest remain significant and of the same sign as in the baseline specification: migration is negative and significant, IPRs protection is negative and significant and the interaction term between migration and IPRs protection is positive and significant.[30]

3.2.1 Robustness Tests

In Table 3 we perform two different robustness checks for our results. The dependent variable is again patent applications. To further investigate the issue of omitted variables, we

[26] In the following we will perform a specific test for this effect.

[27] Although tertiary education has here a non-significant coefficient, we also find that primary education affects positively and significantly the number of patents granted. The results are available upon request. We do not present the results with primary education as we believe tertiary education to be more relevant in a study of the determinants of innovation. Related to this, it is worth pointing out that even after controlling for the extent of human capital the effects of our three main variables of interest remain significant.

[28] This suggests that international technology transfer is not necessarily due to trade and FDI and at the same time reinforces our view that migration plays an important role in innovation.

[29] We here exclude R&D expenditure since there is a large number of missing data for this variable and consequently including R&D our sample reduces to a large extent (i.e. the initial sample looses 200 observations). The results with all controls including R&D are in line with the other results and are available upon request.

[30] To check whether the effect of emigration on innovation is due to capital independently from knowledge transfers, we also investigated the role of remittances. In our specifications, remittances are not significant.

first estimate our key specifications in first differences, thus choosing a different estimation methodology with respect to fixed effects. While the fixed effects (within) estimator is derived by subtracting the time-average model from the original model, the first difference estimator is obtained by subtracting the model lagged by one period from the original model. In other words, the first difference model removes the time-invariant individual components by first-differencing the data. The relative efficiency of the first difference estimator with respect to the fixed effect estimator depends on the properties of the error term. In particular, the first difference estimator requires weaker exogeneity assumptions and it is usually preferred if the errors are serially correlated. Indeed, while the fixed effects estimator assumes that the error terms are serially uncorrelated, the first difference estimator only assumes that the first differences in the errors are uncorrelated. The results of first difference estimates are displayed in the first two columns of Table 3. We here test the robustness of our results illustrating two of the key specifications we find most relevant: the specification with the significant controls, i.e. size (population and GDP per capita) and absorptive capacity (patent stock), in column 1, and our full specification, in column 2. The coefficient of the interaction term between IPRs protection and migration remains positive and significant, while that of IPRs protection remains negative and significant and migration looses significance.

[TABLE 3 ABOUT HERE]

The last two columns of Table 3 perform a different robustness check. We here adopt the same estimation methodology as before (i.e. fixed effects) but use an alternative measure of migration. Instead of using flows, we use gross emigration stocks, largely exploited in the reference literature. As we can see from the table, all results are in line with the previous findings: our three main variables of interest are significant and of the same sign as before.

3.2.2 A Measure of Successful Innovation

We here go a step further and investigate the effect of emigration and IPRs protection using a different measure of innovation: resident patent grants. A key difference between patent applications and patent grants is that while patent applications can be considered a general proxy for innovation activities, patent grants can be thought as a proxy for successful innovation. Patent grants hence represent a "stronger" measure of innovation. The results of our key specifications are reported in Table 4. In the first two columns we use emigration flows as migration measure, while in the last two columns we use emigration stocks. As we can see from the table, the results persist and thus reinforce our previous findings.

[TABLE 4 ABOUT HERE]

To investigate in detail whether and under what conditions migration induces a brain drain or a brain gain, we now explicitly consider the effect of emigration on innovation with variations in level of IPRs. Figure 4 illustrates the joint impact of emigration and IPRs protection on patent grants for the specification which includes all controls and emigration flows as the migration measure (i.e. column 2). The figure shows the marginal effect of emigration on resident patent grants for different levels of IPRs protection, together with its 95% confidence interval.

[FIGURE 4 ABOUT HERE]

As the figure suggests, while in correspondence to weak IPRs protection the effect of migration on resident patents is negative and significant, under strong IPRs protection migration has a positive and significant effect on innovation. In line with the predictions of our theoretical model (see condition (29)), this confirms that *emigration fosters innovation through diaspora, as long as the IPRs regime is strong.* It is important to point out that, even if we could interpret this result as the interaction between IPRs and diaspora, there could be other explanations of why IPRs foster innovation. For example, since skilled emigration increases the returns to skills, the country of origin may have a higher incentive to invest in education. The presence of a higher degree of IPRs protection could then make this incentive even stronger, thus generating a higher potential for innovation. This interpretation is in line with the traditional explanation of brain gain.

3.2.3 The Emigration Index

We now propose an alternative approach to evaluate the impact of emigration on innovation in less developed countries. As it is likely that the intensity of knowledge transferred back to the countries of origin depends on how technologically advanced is the destination country, a more precise measure of emigration should take into account the heterogeneity of the host countries.

In our empirical investigation we have so far considered the total gross emigration flows/stocks of each emerging country to 27 different OECD countries, thus not making any distinctions between the destinations. We now instead assign different weights to the emigration data according to the destination countries in order to take into account potential differences in the effectiveness of the cross-border transfer of skills. The weights are based on a proxy of the innovation potential in each destination country. The purpose is to explore whether and to what extent the number of resident patents at home changes according to "where" emigrants go.

The strategy we apply is a variant of the approach introduced by Spilimbergo (2009) to investigate the transfer of norms. While Spilimbergo argues that foreign-trained individuals promote democracy in their home countries if they study in democratic countries, we here argue that emigrants promote innovation in their home countries if their host countries have a high potential for innovation. In order to capture the heterogeneity among destination countries we construct an emigration index defined as the weighted average of emigration flows (or stocks) with weights depending on the level of development in each host country. The emigration index of the origin country i is defined as:

$$Emigration\ index_{it} = \sum_j \frac{m_{ijt}}{M_{it}} I_{jt}$$

where i is the origin country, j is destination country and t denotes time. m_{ij} is the bilateral emigration flow (or stock) from country i to country j, M_i is total emigration flow (or stock) from country i, and I_j is an index of technological progress of country j.[31] This emigration index lies between 0 and 1; the index is 1 if all emigrants go to the most advanced countries and 0 if all emigrants are in countries with the lowest potential for innovation. Since I is a proxy for the potential for innovation, it is reasonable to expect that emigrants who are in countries characterized by a high degree of development could benefit more in terms of skill accumulation with respect to the others. This line of reasoning could allow us to interpret this index as a measure of emigration that considers different levels of skills.

To construct the index, the development measure we adopt is the GDP per capita of each destination country.[32] The chosen measure of home innovation is resident patent grants,

[31] Bilateral migration flows and stocks are present in our original dataset on migration flows and stocks (see Appendix). The dataset is thus here fully exploited.

[32] Alternative measures of the potential for innovation are R&D expenditure and resident patents in the host country. We do not use R&D expenditure since the data on R&D are scarse and lead us to loose too

which are the actual output of successful innovation. Notice that this test is more sensible for patent grants as opposed to patent applications because patent granted are the output of successful innovation, which is the relevant measure when investigating the effect of the "quality" of skills learned from abroad.

Our findings are reported in Table 5. The dependent variable is resident patent grants per thousand of population, which is a measure of patent intensity. The first two columns refer to emigration flows, whereas the last two refer to emigration stocks.[33]

[TABLE 5 ABOUT HERE]

The findings show that our key variables are always significant and of the same sign as in the previous regressions. In particular, the interaction between "skill-corrected" emigration and IPRs protection is positive and highly significant across all different estimations. In column 2 and 4 government spending shows to be negative and significant. The negative sign of government spending could be explained by the fact that a low share of government spending appears to be positively related to the degree of economic freedom as measured by the country's reliance on personal choice and markets (Gwartney and Lawson, 2000). In column 2 FDI reveals to be negative and significant. This could be explained by the fact that inward FDI has a negative effect on the productivity of local domestic firms through the existence of negative externalities (Aitken and Harrison, 1999) and/or that foreign entrants often displace local firms to less-innovative market segments (see e.g. Cantwell, 1989).

In conclusion, also taking into account different degrees of effectiveness of skill transfers among destination countries, the results show that the brain gain impact of emigration on innovation in less developed countries increases with the degree of IPRs protection. This reinforces our theoretical hypothesis and validates that our results are mainly driven by the diaspora channel under study rather than by other compatible explanations.

3.2.4 Summing Up

To sum up, in the empirical specifications we consider the effects of our three main variables of interest on patents are the same and largely robust: migration is negative and significant,

many observations. We do not use resident patents since a great number of patents by OECD residents are supplied to the European Patent Office, thus making very difficult to impute to each country the appropriate number of resident patents.

[33] In our sample of 35 EDC countries, the emigration index lies between 0.375 and 0.798 if emigration flows are considered, while it lies between 0.327 and 0.8 if emigration stocks are considered.

IPRs protection is negative and significant and the interaction term between migration and IPR protection is positive and significant. In addition, the impact of migration on innovation reveals to be positive and significant in correspondence to higher levels of IPRs protection. These results shed light on the role of IPRs protection in promoting the beneficial effects of the diaspora channel of knowledge, thus confirming the main insights of our theoretical model. It is important to point out that although our results are derived in terms of total migration, it is possible to draw similar conclusions also in terms of skilled migration. Indeed, as shown before, all our main results hold when using our "skill-corrected" measure of migration. In addition, it is true that starting from the 1990s migration to the OECD area has been increasingly composed of high skilled immigrants who originate from developing countries (Docquier and Rappoport, 2010).

4 Conclusions

In this paper we have explored the link between cross-border diaspora networks and the capacity of innovation of a country where emigration originates from. The perspective we adopt is that of a developing country. We argue that although skilled emigration out of a developing country may directly result in the well-known concept of brain drain, it can also cause an indirect brain gain effect, the extent of which depends on the level of intellectual property rights protection in the origin country. The paper conducts a joint theoretical and empirical analysis of this issue.

The theoretical model relates a country's potential for innovation to the size and average skills of its innovation sector, as well as to the average skills of migrants. Our framework draws upon the realistic assumption that emigration may originate cross-border diaspora networks between skilled emigrants and natives. It turns out in the presence of a strong IPRs regime the gains in human capital deriving from the diaspora channel of knowledge are more likely to outweigh the direct drain of skills caused by emigration. As a consequence, when patents are sufficiently protected, informal networks of emigrants and people remaining at home are crucial in turning a brain drain into a brain gain. The main conclusions of our theoretical analysis are then tested in our empirical investigation. Using a sample of EDC economies, we show that the impact of emigration on innovation is positive in the presence of strong IPRs protection, thus confirming our main theoretical insights. Our key empirical findings are confirmed using a number of different robustness checks.

The results of the paper shed light on the joint role of institutions and migration in promoting growth, by thus contributing to the rich debate about the brain drain/brain gain effects of emigration. In particular, we explicitly model a process of transfer of knowledge from developed to developing countries which is independent of trade and FDI and which mainly relies on people's movement. In addition, the paper fills a gap in the rich literature on diaspora networks, by directly focussing on the potential relationship between knowledge absorbed by emigrants abroad and growth in their home countries.

A Appendix

A.1 Country List

Our sample consists of 35 emerging and developing countries (EDC). The countries are the following: Algeria, Argentina, Bangladesh, Brazil, Bulgaria, Chile, China, Colombia, Ecuador, Egypt, Guatemala, Honduras, Hungary, India, Iran, Jamaica, Jordan, Kenya, Lithuania, Madagascar, Malaysia, Mexico, Morocco, Pakistan, Peru, Philippines, Poland. Romania, Russia, Sri Lanka, Thailand, Turkey, Ukraine, Venezuela, Vietnam.

A.2 Data Description and Sources

Patents

We use two series of patent data: resident patent applications and resident patent grants. Resident patent applications are patent applications by residents of each country to the local national patent office. Resident patent grants are patents granted in each country to its residents by the local national patent office. The data are annual and start in 1985. The source is WIPO (2010). Patent stock series are calculated using the perpetual inventory method and a 15% depreciation rate. For details on this method, see the text.

Migration

We use two series of migration data: emigration flows out of each country and stocks of emigrants abroad. The data are annual. Emigration flows and stocks are derived by summing up available bilateral immigration flows and stocks by country of origin into 27 OECD countries. The original bilateral migration dataset has been kindly provided by

Mariola Pytlikova and collects information from different statistical offices of the world, supplemented by published OECD statistics from "Trends in International Migration" publications and Eurostat data. In total, the original dataset contains annual information on immigration flows and stocks in 27 OECD countries from 95 countries of the world for the period 1985-2006. For a more comprehensive description of earlier versions of the same dataset, see Pedersen et al. (2008) and Pedersen and Pytlikova (2008). To construct our data on emigration flows and stocks, the original data were purged of evident outliers and missing data for bilateral flows and stocks for which there was sufficient non-missing years were interpolated.

Intellectual Property Rights

The source is Park (2008). The data represent an index of the strength of patent protection for each of the countries of the dataset. The index is the unweighted sum of five separate scores for: coverage; membership in international treaties; duration of protection; enforcement mechanisms; and restrictions. Available data cover 123 countries for the period from 1960 till 2005, in five-year intervals. Given the focus of our study, we selected the sample of data starting in 1995. For the missing values in each of the five-year intervals, we impute the index of patent protection which is defined for the starting year of the corresponding time interval.

Additional Controls

All additional controls (GDP, population, R&D, education, government spending, trade and FDI) are from World Bank (2009) and United Nations. All data have an annual frequency. The education variable is measured by enrollment in tertiary education

A.3 Proof of Proposition 1

We have a system of 2 equations:

$$\begin{aligned} \omega_H z_1 - 1 - e &= 0 \qquad \text{(A)} \\ \overbrace{\frac{q(\mu-1)\mu^{\frac{1}{(\alpha-1)}} L(z_1)}{\rho + H(z_1,z_2)[1-q(1-\mu^{\frac{\alpha}{(\alpha-1)}})]}}^{\omega_H} z_1 - 1 - e &= 0 \end{aligned}$$

$$\begin{aligned}\omega_M z_2 - \omega_H z_2 - F &= 0 \qquad \text{(A)}\\ \omega_M z_2 - \overbrace{\frac{q(\mu-1)\mu^{\frac{1}{(\alpha-1)}}L(z_1)}{\rho + H(z_1,z_2)[1-q(1-\mu^{\frac{\alpha}{(\alpha-1)}})]}}^{\omega_H} z_2 - F &= 0\end{aligned}$$

given

$$\frac{\partial L(z_1)}{\partial z_1} > 0, \frac{\partial H(z_1,z_2)}{\partial z_1} < 0, \frac{\partial H(z_1,z_2)}{\partial z_2} > 0$$

which implies

$$\frac{\partial \omega_H}{\partial q} > 0, \frac{\partial \omega_H}{\partial z_1} > 0, \frac{\partial \omega_H}{\partial z_2} < 0. \qquad \text{(A)}$$

We would like to establish whether

$$\frac{dz_1}{dq} \gtrless 0, \frac{dz_2}{dq} \gtrless 0, \frac{dz_2}{dz_1} \gtrless 0.$$

Considering ω_H as a function of z_1, z_2, and q, we have the two conditions given by two functions $\Gamma_i(z_1, z_2, q) = 0$, for $i = 1, 2$:

$$\begin{cases}\Gamma_1(z_1,z_2,q) = -z_1\omega_H(z_1,z_2,q) + 1 + e = 0\\ \Gamma_2(z_1,z_2,q) = z_2\omega_H(z_1,z_2,q) + F - z_2\omega_M = 0\end{cases}.$$

Subsequently, we calculate the total differentials $d\Gamma_1$ and $d\Gamma_2$ and we equate them:

$$d\Gamma_1 = d\Gamma_2 \Longleftrightarrow \frac{\partial \Gamma_1}{\partial z_1}dz_1 + \frac{\partial \Gamma_1}{\partial z_2}dz_2 + \frac{\partial \Gamma_1}{\partial q}dq = \frac{\partial \Gamma_2}{\partial z_1}dz_1 + \frac{\partial \Gamma_2}{\partial z_2}dz_2 + \frac{\partial \Gamma_2}{\partial q}dq,$$

then we consider the plane $(z_1,\ q)$ to evaluate the slope of the function $z_1(q)$, so we impose $dz_2 = 0$, and after calculating the first order partial derivatives we obtain:

$$-\left(\omega_H(\cdot) + z_1\frac{\partial \omega_H}{\partial z_1}\right)dz_1 - z_1\frac{\partial \omega_H}{\partial q}dq = z_2\frac{\partial \omega_H}{\partial z_1}dz_1 + z_2\frac{\partial \omega_H}{\partial q}dq.$$

Subsequently, we collect terms and identify the ratio of differentials:

$$\frac{dz_1}{dq} = -\frac{(z_1+z_2)\frac{\partial \omega_H}{\partial q}}{\omega_H(\cdot) + (z_1+z_2)\frac{\partial \omega_H}{\partial z_1}}. \qquad (30)$$

From the investigation of (30) we can deduce that:

$$\frac{dz_1}{dq} < 0 \text{ as } \omega_H(\cdot) + (z_1 + z_2)\frac{\partial \omega_H}{\partial z_1} > 0.$$

We can repeat the same procedure by setting $dz_1 = 0$ in the relation $d\Gamma_1 = d\Gamma_2$ in order to accomplish a relation between the differentials dz_2 and dq:

$$-z_1\frac{\partial \omega_H}{\partial z_2}dz_2 - z_1\frac{\partial \omega_H}{\partial q}dq = \left(\omega_H(\cdot) + z_2\frac{\partial \omega_H}{\partial z_2}\right)dz_2 + z_2\frac{\partial \omega_H}{\partial q}dq - \omega_M dz_2.$$

The slope will amount to:

$$\frac{dz_2}{dq} = -\frac{(z_1 + z_2)\frac{\partial \omega_H}{\partial q}}{\omega_H(\cdot) - \omega_M + (z_2 + z_1)\frac{\partial \omega_H}{\partial z_2}} \tag{31}$$

(31) has a form which is analogous to (30), so that we can carry out a similar investigation:

$$\frac{dz_2}{dq} > 0 \text{ as } \omega_H - \omega_M + (z_2 - z_1)\frac{\partial \omega_H}{\partial z_2} < 0.$$

Finally, to derive the sign of $\frac{dz_2}{dz_1}$, we divide (31) by (30) to obtain

$$\begin{aligned} \frac{dz_2/dq}{dz_1/dq} &= \frac{dz_2}{dz_1} = \left(\frac{(z_1 + z_2)\frac{\partial \omega_H}{\partial q}}{\omega_H(\cdot) - \omega_M + (z_2 + z_1)\frac{\partial \omega_H}{\partial z_2}}\right)\left(\frac{\omega_H(\cdot) + (z_1 - z_2)\frac{\partial \omega_H}{\partial z_1}}{(z_1 + z_2)\frac{\partial \omega_H}{\partial q}}\right) \\ &= \frac{\omega_H(\cdot) + (z_1 + z_2)\frac{\partial \omega_H}{\partial z_1}}{\omega_H(\cdot) - \omega_M + (z_2 + z_1)\frac{\partial \omega_H}{\partial z_2}}. \end{aligned} \tag{32}$$

Using the same argument as for (30) and (31), we can deduce from (32) that

$$\frac{dz_2}{dz_1} < 0$$

because given (A), both the numerator of (32) is positive, while the denominator is negative.

We have therefore proved that

$$\frac{dz_1}{dq} < 0, \frac{dz_2}{dq} > 0, \frac{dz_2}{dz_1} < 0.$$

That is, stronger IPR protection expands the size of the innovation sector from both sides of the spectrum of skills by decreasing z_1 and increasing z_2. Furthermore, thresholds z_1 and z_2 always move in the opposite direction.

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FIGURES AND TABLES

Figure 1.
Stronger IPRs Enforcement

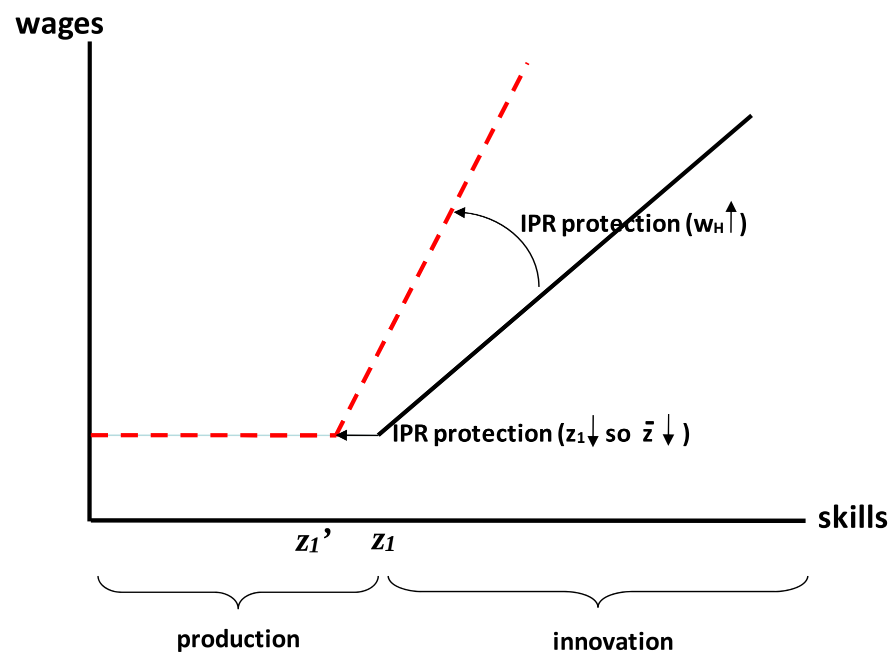

Figure 2.
Diaspora Gains

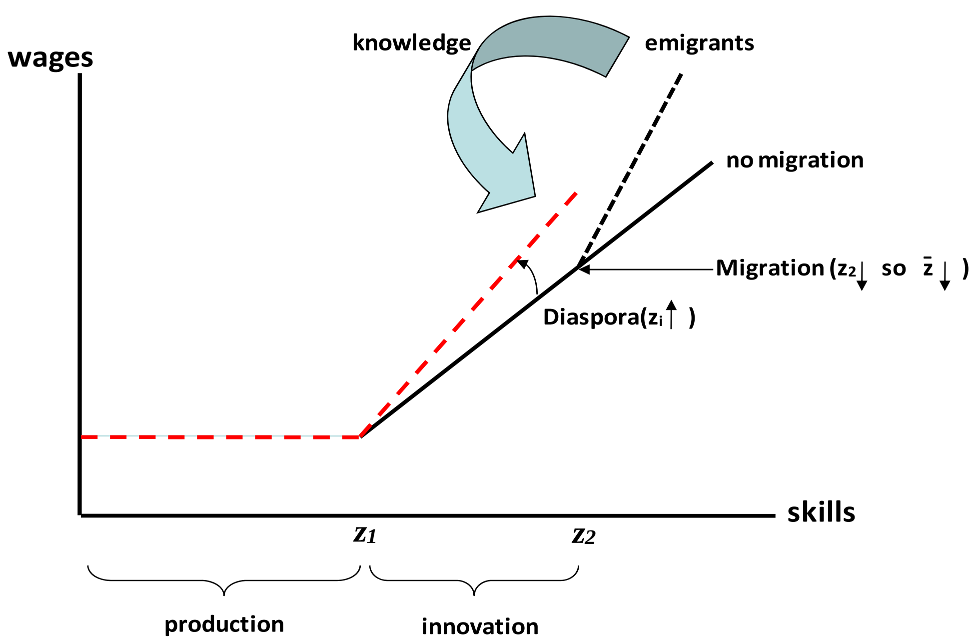

Figure 3.
The Impact of IPRs on Diaspora

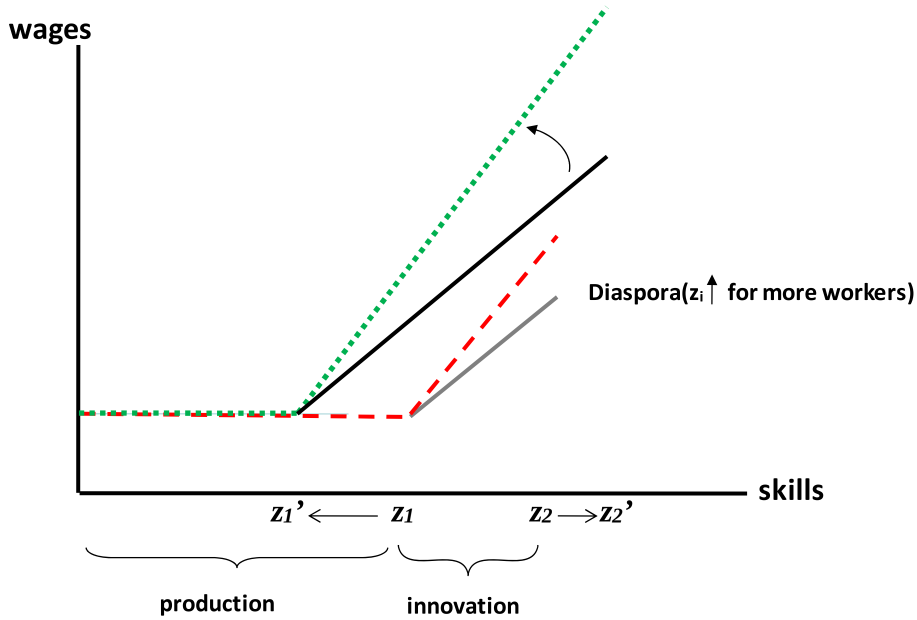

Figure 4.
The Joint Impact of Migration and IPRs on Innovation

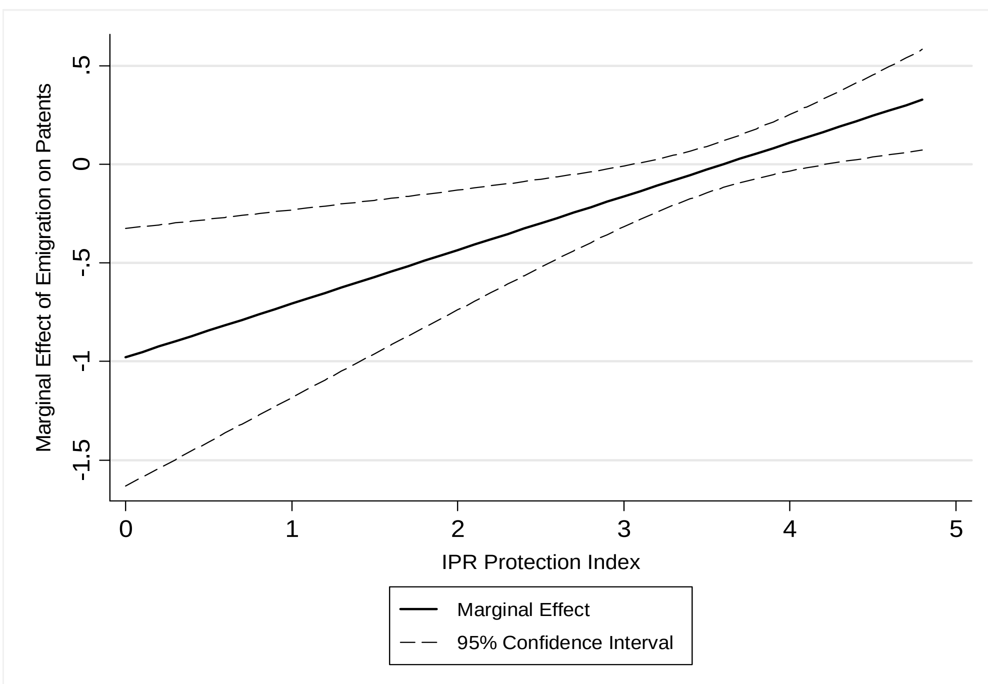

Table 1.
Summary Statistics

	Observations	Mean	Std. Dev.	Min.	Max.
Resident Patent Applications	351	2831.638	10528.06	2	122318
Resident Patent Grants	325	1351.92	4179.25	1	25644
Emigration Flow	420	53451.54	60715.85	293	351567
Emigration Stock	420	918893.4	1564047	3979	11600000
Emigration Flow Index	420	0.616	0.080	0.375	0.798
Emigration Stock Index	420	0.636	0.074	0.327	0.800
IPRs Protection	420	2.940	0.843	1.080	4.540
Population	420	17.397	1.357	14.724	20.994
GDP Per Capita	420	8.492	0.755	6.635	9.779
Resident Patent Stock (Applications)	363	12203.93	34456.52	4.709	266384.1
Resident Stock (Grants)	352	5728.098	17076.18	3.442	108220.1
R&D	248	0.502	0.318	0.035	1.417
Tertiary Education	330	0.260	0.179	0.020	0.760
Government Spending	415	0.756	0.165	0.029	0.993
Trade	411	0.715	0.395	0.149	2.204
FDI	419	0.030	0.029	0	0.237

Table 2.
The Impact of Emigration and IPRs Protection on Resident Patent Applications

	Fixed Effects (1)	Fixed Effects (2)	Fixed Effects (3)	Fixed Effects (4)	Fixed Effects (5)	Fixed Effects (6)	Fixed Effects (7)	Fixed Effects (8)
Emigration Flow$_{t-5}$	-0.421**	-0.489**	-0.924***	-0.400*	-0.599**	-0.398**	-0.421**	-0.538**
	(0.198)	(0.185)	(0.212)	(0.207)	(0.254)	(0.194)	(0.201)	(0.244)
IPRs Protection$_{t-1}$	-1.330**	-1.391**	-2.057***	-1.323**	-1.775**	-1.338**	-1.331**	-1.581*
	(0.603)	(0.620)	(0.670)	(0.639)	(0.731)	(0.601)	(0.618)	(0.785)
Emigr. Flow$_{t-5}$ x IPRs$_{t-1}$	0.123**	0.135**	0.207***	0.126**	0.169**	0.125**	0.123**	0.155**
	(0.056)	(0.053)	(0.062)	(0.058)	(0.071)	(0.056)	(0.057)	(0.067)
Population	4.873***	2.589**	4.077**	5.381***	4.834***	5.480***	4.878***	1.504
	(1.421)	(1.170)	(1.687)	(1.222)	(1.458)	(1.370)	(1.486)	(1.267)
GDP Per Capita$_{t-1}$	1.661**	1.279**	0.626	2.175***	1.550**	1.824**	1.663**	0.432
	(0.739)	(0.494)	(0.721)	(0.698)	(0.741)	(0.701)	(0.741)	(0.583)
Patent Stock (Appl.) $_{t-1}$		0.621***						0.877***
		(0.145)						(0.245)
R&D$_{t-1}$			1.212***					
			(0.374)					
Tertiary Education				-0.506				0.317
				(0.875)				(0.742)
Government Spending$_{t-1}$					-0.516			-0.388
					(0.330)			(0.379)
Trade$_{t-1}$						0.627		0.474
						(0.390)		(0.402)
FDI$_{t-1}$							0.030	-2.259
							(1.830)	(1.434)
Constant	-89.65***	-50.60**	-62.47*	-102.8***	-85.64***	-101.9***	-89.76***	-25.53
	(28.75)	(22.30)	(35.49)	(23.29)	(29.28)	(27.08)	(29.78)	(24.98)
Country Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Countries	35	32	32	35	35	35	35	31
Observations	348	321	200	280	316	343	348	224
R-Squared	0.354	0.484	0.534	0.378	0.365	0.382	0.354	0.560

Note: Robust standard errors in parentheses, clustered at country level. * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable is resident patent applications. Patent applications, patent stock, emigration flow, population and GDP per capita are in logarithms.

Table 3.
The Impact of Emigration and IPRs Protection on Resident Patent Applications
Robustness Checks

	First Differences	First Differences	Fixed Effects	Fixed Effects
	(1)	(2)	(3)	(4)
Emigration $Flow_{t-5}$	-0.257	-0.289		
	(0.156)	(0.188)		
IPRs $Protection_{t-1}$	-0.947*	-0.969*	-1.817***	-2.166***
	(0.502)	(0.563)	(0.551)	(0.530)
Emigr. $Flow_{t-5}$ x $IPRs_{t-1}$	0.083*	0.089*		
	(0.044)	(0.052)		
Emigration $Stock_{t-5}$			-0.539***	-0.636***
			(0.168)	(0.162)
Emigr. $Stock_{t-5}$ x $IPRs_{t-1}$			0.139***	0.167***
			(0.039)	(0.036)
Population	1.136	1.207	2.183*	0.896
	(1.206)	(1.247)	(1.275)	(1.286)
GDP Per $Capita_{t-1}$	0.795	0.484	1.268**	0.378
	(0.479)	(0.636)	(0.509)	(0.596)
Patent Stock (Appl.) $_{t-1}$	0.461***	0.607**	0.612***	0.912***
	(0.154)	(0.233)	(0.134)	(0.233)
Tertiary Education		-0.459		0.160
		(0.596)		(0.726)
Government $Spending_{t-1}$		0.107		-0.313
		(0.287)		(0.364)
$Trade_{t-1}$		0.736*		0.651
		(0.410)		(0.421)
FDI_{t-1}		-1.925		-2.209
		(1.341)		(1.313)
Constant			-41.25	-11.96
			(24.76)	(26.25)
Country Effects			Yes	Yes
Time Effects	Yes	Yes	Yes	Yes
Number of Countries	32	30	32	31
Observations	270	166	321	224
R-Squared	0.087	0.148	0.491	0.579

Note: Robust standard errors in parentheses, clustered at country level. * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable is resident patent applications. Patent applications, patent stock, emigration flow and stock, population and GDP per capita are in logarithms.

Table 4.
The Impact of Emigration and IPRs Protection on Resident Patent Grants

	Fixed Effects (1)	Fixed Effects (2)	Fixed Effects (3)	Fixed Effects (4)
Emigration Flow$_{t-5}$	-0.510***	-0.979***		
	(0.177)	(0.333)		
IPRs Protection$_{t-1}$	-1.585**	-2.987***	-2.076***	-3.376***
	(0.622)	(0.943)	(0.637)	(0.881)
Emigr. Flow$_{t-5}$ x IPRs$_{t-1}$	0.137**	0.272***		
	(0.051)	(0.093)		
Emigration Stock$_{t-5}$			-0.639***	-0.911***
			(0.181)	(0.264)
Emigr. Stock$_{t-5}$ x IPRs$_{t-1}$			0.146***	0.250***
			(0.042)	(0.068)
Population	4.928***	5.390***	4.195**	4.800***
	(1.682)	(1.898)	(1.547)	(1.482)
GDP Per Capita$_{t-1}$	2.103***	1.826*	2.005***	1.941**
	(0.693)	(0.943)	(0.646)	(0.811)
Patent Stock (Grants)$_{t-1}$	0.659***	0.475*	0.702***	0.489*
	(0.196)	(0.241)	(0.195)	(0.243)
Tertiary Education		0.588		0.278
		(1.786)		(1.722)
Government Spending$_{t-1}$		-0.963		-0.889
		(0.855)		(0.902)
Trade$_{t-1}$		0.981		1.081
		(0.887)		(0.859)
FDI$_{t-1}$		-3.322		-3.096
		(2.114)		(1.979)
Constant	-99.04***	-98.49***	-82.42**	-87.57***
	(32.19)	(32.59)	(30.37)	(26.52)
Country Effects	Yes	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes
Number of Countries	32	30	32	30
Observations	297	210	297	210
R-Squared	0.288	0.323	0.297	0.333

Note: Robust standard errors in parentheses, clustered at country level. * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable is resident patent grants. Patent grants, patent stock, emigration flow and stock, population and GDP per capita are in logarithms.

Table 5.
The Emigration Index, IPRs Protection and Resident Patent Grants

	Fixed Effects (1)	Fixed Effects (2)	Fixed Effects (3)	Fixed Effects (4)
Emigration Flow Index$_{t-5}$	-0.146**	-0.151		
	(0.065)	(0.104)		
IPRs Protection$_{t-1}$	-0.043**	-0.044**	-0.039**	-0.060**
	(0.018)	(0.021)	(0.018)	(0.028)
Emigr. Flow Ind.$_{t-5}$ x IPRs$_{t-1}$	0.055**	0.054**		
	(0.025)	(0.026)		
Emigration Stock Index$_{t-5}$			-0.120	-0.175
			(0.102)	(0.122)
Emigr. Stock Ind.$_{t-5}$ x IPRs$_{t-1}$			0.049*	0.077**
			(0.024)	(0.035)
GDP Per Capita$_{t-1}$	0.005	-0.002	-0.000	-0.005
	(0.017)	(0.019)	(0.017)	(0.019)
Patent Stock (Grants)$_{t-1}$	-0.013	-0.010	-0.016	-0.021
	(0.023)	(0.012)	(0.028)	(0.015)
Tertiary Education		-0.017		-0.030
		(0.016)		(0.019)
Government Spending$_{t-1}$		-0.056*		-0.052*
		(0.032)		(0.029)
Trade$_{t-1}$		0.052		0.055
		(0.038)		(0.040)
FDI$_{t-1}$		-0.085**		-0.043
		(0.033)		(0.036)
Constant	0.091	0.164	0.121	0.206
	(0.137)	(0.204)	(0.140)	(0.208)
Country Effects	Yes	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes
Number of Countries	32	30	32	30
Observations	297	210	297	210
R-Squared	0.0787	0.188	0.0704	0.207

Note: Robust standard errors in parentheses, clustered at country level. * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable is resident patent grants rate (resident patent grants per thousand of population). The emigration indexes are calculated as described in the text.

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