Intellectual Property Rights and Diaspora Knowledge Networks: Can Patent Protection Generate Brain Gain from Skilled Migration?*

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Abstract. This paper studies the mechanism through which intellectual property rights (IPR) protection can influence the impact of skilled migration on innovation activities in developing countries. We argue that knowledge acquired by emigrants abroad can flow back to their country of origin through diaspora networks. IPR protection in the sending country facilitates this channel by increasing returns to skills and encouraging workers to move into the innovation sector. An expansion of the innovation sector allows diaspora knowledge to be absorbed by a larger range of workers. Strong IPR enforcement therefore makes it more likely for brain drain to be transformed into brain gain.

JEL classification: O30, F22, J24

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*We are grateful to Andrés Carvajal and two anonymous referees for their valuable comments and insights which greatly helped us to improve the paper. We would also like to thank Olena Ivus, Peter Kuhn, Elisabetta Lodigiani, Arsen Palestini, Hillel Rapoport, Gilles Saint-Paul, as well as the seminar participants at University of Lille 1, the University of Bologna, EEA 2011 Oslo, GLOBELICS 2010 Kuala Lumpur, GLOBELICS 2011 Buenos Aires, International Workshop on Economics of Global Interactions 2011 Bari, ITSG 2011 Milan, PRIN Workshop 2013 Bologna, RES 2012 Cambridge, and the WIPO Experts' Meeting on Intellectual Property, the International Mobility of Knowledge Workers and the Brain Drain 2013 Geneva for very helpful remarks. We would like to acknowledge the European Commission for financial support through the 7th Framework Programme Project INGINEUS. Financial support from Fondazione Cassa Risparmio di Modena and from MIUR through the PRIN project "Institutions, Social Dynamics, and Economic Development" is also acknowledged.

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). Skilled migration is a third factor that has been gaining importance due to its remarkable growth along with trade and FDI since the 1990's (Docquier and Rapoport 2012). The resulting surge in the outward transfer of the human capital 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 needs not harm the South and may even increase its potential for development through a brain gain.

The so-called brain gain effect derives from an incentive channel that works through increased expected returns to education brought about by migration prospects (Mountford 1997; Stark, Helmenstein and Prskawetz 1997; Beine, Docquier and Rapoport 2001, 2008; BDR).[2] An additional channel is return migration, which can induce innovation through the knowledge possessed by migrants returning from more advanced economies (Domingues Dos Santos and Postel-Vinay 2003; Mayr and Peri 2009; Dustmann, Fadlon and Weiss 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 to the sending countries (Agrawal, Kapur and McHale 2011; AKM; Kerr 2008). Student/scholarly networks, local associations of skilled expatriates, short-term consultancies by high-skilled expatriates in their country of origins, and other unestablished intellectual/scientific diaspora networks are a few examples of such networks (Meyer and Brown 1999).[3] Sociological studies, such as Meyer (2001), suggest that such informal networks are crucial in turning brain drain into a brain gain. Nevertheless, AKM (2011) did not find a strong case for the Indian diaspora of inventors in the US and the transfer of their knowledge back to their homeland. Breschi, Lissoni and Miguelez (2015; BLM) add that while inventors in India do not benefit from their expatriates abroad, other countries such as China and Russia seem to experience substantial advantages that stem from their diasporas. They argue that these different findings across sending countries may have a lot to do with their absorptive capacity.

This research contributes to the literature by exploring the channel through which the knowledge acquired by emigrants after interacting with superior skills in developed countries (North) can flow back to the South. We refer to this channel as an "intellectual diaspora", that is, the remote mobilization of intellectuals and professionals abroad and their connection to scientific, technological and cultural programs at home.[4] This can be thought of as a scientist from the South being more productive in the North due to better facilities and more resources, with some of the benefits of his innovation flowing back to his home country. We provide a framework to show how the beneficial effect of diaspora networks through the cross-border sharing of ideas is heterogeneous, and that it depends on the absorptive capacity of the sending country. The paper aims to assess the role of intellectual property rights (IPR) protection in the South in determining its absorptive capacity, and in turn, the impact of emigration on innovation activities in the home (sending) country. In a companion study, Naghavi and Strozzi (2015), we show evidence that knowledge acquired by emigrants abroad could be exploited in their home countries under sound IPR institutions. Motivated by these findings, we build a model to propose a mechanism through which an appropriate level of IPR protection could help reverse the brain drain caused by skilled emigration. In sum, we argue

[1] Seminal works include 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 (2011).

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

[3] 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, BDR (2011) show the influence of diasporas on the evolution of migration flows and their composition in terms of skills.

[4] In this framework, the capacity of innovation of Southern innovators, who remain in their origin countries, is related to their access to valuable technological knowledge that is partially accumulated abroad (i.e., brain banks). For more on this issue, see AKM (2011).

that although emigration may directly result in a brain drain, it also generates a flow of ideas and inventions back to the sending country, the extent of which depends on the strength of IPR protection. The results complement the findings of BLM (2015) in that the diaspora channel is only operational when the source region is in possession of a sufficient level of absorptive capacity to enable interaction opportunities between inventors abroad and those residing in their home countries.

While the trade-off faced by an emerging economy between imitation and the provision of incentives for domestic innovation through IPRs are well-understood (Maskus 2000), the interrelationship between skilled migration and IPR policy in determining innovation remains unexplored. Our work fills this gap and contributes to the above-mentioned strand of research by capturing the diaspora dimension of migration and revealing how IPR protection in the sending country may influence the effect of skilled migration on innovation there.[5] On this basis, we shed light on the net impact of emigration on innovation and determine whether a strong IPR regime at home can eventually turn the initial brain drain into a brain gain. Our theoretical framework is a variant of the Yeaple (2005) and Ohnsorge and Trefler (2007) models of heterogeneous workers, in which we introduce an innovation sector, migration, and IPR protection. 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 to the home economy and enhance skills of the remaining workers in the innovation sector (the *intensive margin*). To investigate whether the beneficial effect of diasporas could outweigh the direct negative effect of the outflow of skilled workers, we look at the absorptive capacity of the sending country. A strong level of IPR protection increases absorptive capacity by raising returns to skills, encouraging workers to shift from production to innovation activities. An enlarged innovation sector allows diaspora gains to reach out to a larger range of workers actively using their skills in the economy. As a consequence, a strong level of IPR protection in the sending country increases the magnitude of potential benefits from diasporas, making it more likely for the gains to outweigh the negative effects of brain drain on innovation, and thus facilitating a potential net brain gain.[6]

2. The model

2.1. The 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 assumed to be higher. Because the focus of our study is the southern market, we concentrate our analysis on goods invented, produced and consumed locally in the South.[7]

Following a Dixit and Stiglitz (1977) monopolistic competition framework with CES (constant elasticity of substitution) preferences, consumers have the following utility function:

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

where individual aggregate consumption index C_i is divided between a continuum of N invented

[5] 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 positively relates IPR protection to innovation, the latter deems it to be ineffective for innovation in less-developed countries.

[6] These results are in contrast to the theoretical conclusion obtained by 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 that explicitly 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.

[7] Using a reduced form model that abstracts from trade and FDI related issues allows us to single out the impact of South-North migration, but clearly does not provide definitive answers to how IPRs and diasporas interact. See Iranzo and Peri (2009) for a study of trade and migration and Davis and Naghavi (2011) for the effects of trade and offshoring on innovation within the same occupational choice setting. These papers however do not deal with the issue of IPRs.

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. In the spirit of Roy (1951) occupational choice model with heterogeneous labor, 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. Define z_1 as the skills of a threshold worker indifferent between working in the production or the innovation sector and z_2 as the threshold above which workers choose to migrate.

While production does not require skills, a worker i with skills z_i in the innovation sector has productivity h_i such that

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

where z_i represents own skill endowment and Z (defined below) is the international spillover of knowledge learned by emigrants abroad through what we call the diaspora channel. We are interested in observing the initial skill endowment of each individual (their innate ability) used in the innovation sector and how the assumed superior knowledge from the North can flow back to upgrade workers' productivity.

The timing of the model is as follows. Given the IPR regime, which is assumed to be 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.

Emigration in period 0 is modeled 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

$$Z = b\zeta(z_2), \tag{3}$$

where the skills endowment of those who migrate to the North is

$$\zeta(z_2) = \int_{z_2}^{\infty} z g(z) dz. \tag{4}$$

Parameter $b \geq 0$ measures the intensity of diaspora gains, 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 the South. This measure can also be thought of as to how much innovations undertaken by emigrants abroad are still suitable to serve the southern economy, a concept referred to as a negative "expatriate brains" effect in McAusland and Kuhn (2011). 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. The total amount of human capital in the economy can be written as

$$H(z_1, z_2) = \int_{z_1}^{z_2} h_i g(z) dz. \tag{5}$$

The total number of inventions available for consumption are in turn

$$N = H(z_1, z_2)/\rho. \tag{6}$$

To work in the innovation sector, each worker must obtain education at a cost e, which is paid in the second period. The wage per unit of skill for the high-skilled in the innovation sector is ω_H and is paid in period 2, giving each individual with skills z_i a wage equivalent to $h_i \omega_H$.

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 a productivity equal to 1 so that there is a one-to-one relationship between output and labor. Individual wage is identical for all workers in this sector and equals ω_L.

2.2. Patents and consumption

We use the basic framework presented in Saint-Paul (2003, 2004) as our benchmark, modeling IPR protection as the probability that an innovator can obtain monopoly power over his invention.[8] The probability of being granted a patent is q, which captures the degree of IPR protection.[9] We assume a numéraire sector producing generic goods whose patents have expired with a price normalized to 1, which also determines wages in the production sector, $\omega_L = 1$.[10] A non-patented good can be imitated driving its price (p_N) down to the marginal cost of production.

If a patent is granted, a firm charges monopoly price (p_P) which given preferences includes a mark-up over marginal cost. The extent of the mark-up depends on the level of product differentiation among the varieties available in the market (α). Prices p_N and p_P are given by

$$p_N = \omega_L = 1,$$
$$p_P = \omega_L \mu = \mu = 1/\alpha.$$

A higher degree of product differentiation (lower α) implies more monopoly power and therefore a higher price. When IPRs are fully protected, the model falls under a standard monopolistic competition model. Similarly, no IPR protection represents the case of perfect competition.

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

$$\underset{c_N, c_P}{Max} \quad N_P c_P^{\alpha} + N_N c_N^{\alpha}, \tag{7}$$

under the budget constraint

$$y = \mu N_P c_P + N_N c_N, \tag{8}$$

where $N_P + N_N = N$, and $N_P = Nq$ and $N_N = N(1-q)$ are the total number of patented and non-patented goods respectively, determined by the IPR regime. 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

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

captures the love of variety effect as $\partial\psi/\partial N > 0$ and the disutility caused by monopoly pricing as $\partial\psi/\partial q < 0$. Consumers do not care whether the commodities they buy are patent-protected, but are inclined to consume more non-patented goods because they are cheaper.

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

$$C = \frac{y}{P},$$

where P is the aggregate price index,

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

that originates from the standard Dixit-Stiglitz index of all varieties' prices, $P = \left(N_P p_P^{\frac{\alpha}{(\alpha-1)}} + N_N p_N^{\frac{\alpha}{(\alpha-1)}}\right)^{\frac{(\alpha-1)}{\alpha}}$.

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

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

[10] For clarity of exposition, here we implicitly consider a homogeneous numéraire good that takes the form of $j = 0$, as in Melitz and Redding (2014). The results remain identical using a separable utility function with an additive numéraireire good, a, as demonstrated in Appendix A.6.

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

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

where Y is aggregate income (net of education cost). In the above expression, the first term on the right-hand side (RHS) is the mark-up over marginal cost $(p_P - \omega_L)$, whereas the second is total demand for the patented good.

Under a competitive innovation sector, expected operating profit from inventing a new good must equal to its cost of creation in terms of skills such that

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

Using (11), this gives

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

Replacing for ψ from (10) and recalling that $\mu > 1$, stronger patent protection (higher q) increases wages in the innovation sector ω_H as

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

for a given level of aggregate income. More stringent IPR enforcement protects inventors against imitation making it more attractive to work in the innovation sector.

2.3. Migration

To determine the migration threshold skill level z_2, suppose a worker migrates to the North if his gains from doing so, net of migration costs, exceed what he would earn in the innovation sector at home:

$$\omega_M z_i - e - F > \omega_H h_i - e \Rightarrow \omega_M z_2 - F = \omega_H z_2 + \omega_H Z \Rightarrow z_2 = \frac{F + \omega_H Z}{\omega_M - \omega_H}, \tag{14}$$

where we consider an exogenous wage in the innovation sector of the North higher than that in the South: $\omega_M > \omega_H$. Note that this assumption allows the paper to focus on South-North skilled migration, where returns to skills are assumed to be determined by the protection of the output of skills, i.e. patents, and therefore higher in the North.[11]

Suppose a positive level of migration is triggered by a reduction in F. We can state

LEMMA1. *A reduction in the fixed cost of migration encourages emigration of skills to the North* $\left(\frac{\partial z_2}{\partial F} > 0\right)$, *but opens a channel for potential diaspora gains* $\left(\frac{\partial\zeta(z_2)}{\partial z_2} < 0\right)$.

Proof. Follows directly from (4) and (14).

It follows from Lemmas 1 that a reduction in migration costs F spurs the brain drain syndrome, decreasing the size of the innovation sector by a movement of workers from the upper tail of the distribution of skills out of the country. At the same time migration creates an opportunity for new knowledge to flow into the country through an increased number of skilled migrants abroad, $\zeta(z_2)$.[12]

[11] There are other cases not dealt with in this model, where for example the least-skilled migrate because returns to education are assumed to be higher in the South due to the scarcity of skills (Borjas 1987). Including heterogeneous migration costs that are decreasing in skills to this framework generates a further possibility of non-monotonic migration patterns and self-selection into migration by those with an intermediate level of schooling (Chiquiar and Hanson 2005).

[12] In addition, higher prospective wages abroad ω_M encourage the flow of skills away from the country, whereas higher wages in the innovation sector at home ω_H reduce skilled emigration. Higher potential gains from diaspora Z similarly discourage migration as individuals are aware that they can partially enjoy the knowledge acquired by others who emigrate without bearing the costs of migration themselves.

2.4. *Intellectual property rights protection*

To pin down the threshold skill level z_1 above which individuals choose to obtain education and work in the innovation sector, consider a worker with productivity h_i, who can either work in the innovation sector and earn $\omega_H h_i - e$, where $\omega_H > 1$, or become a production worker with wage $\omega_L = 1$. Choosing the option that generates a higher income, a worker self-selects to work in the innovation sector if

$$\omega_H h_i - e > 1 \Rightarrow \omega_H z_i + \omega_H Z - e > 1 \Rightarrow z_1 = \frac{1 + e - \omega_H Z}{\omega_H}. \quad (15)$$

LEMMA 2. *IPR protection increases returns to skills in the South* $\left(\frac{\partial \omega_H}{\partial q} > 0\right)$ *by blocking imitation, shifting workers from the production to the innovation sector* $\left(\frac{\partial z_1}{\partial \omega_H} < 0\right)$.

Proof. Follows directly from (13) and (15).

It follows from Lemmas 2 that better IPR enforcement q attracts production workers to the innovation sector by reducing imitation, thereby increasing the returns to working in that sector (ω_H).[13] The impact of IPR enforcement on the southern labor market in the absence of migration is illustrated in Figure 1.

[FIGURE 1 ABOUT HERE]

We concentrate the analysis on the interior equilibria, so that $z_1 > 0$. At the limit when $z_1 = 0$, the economy ceases to produce the invented varieties regardless of a fully operational innovation sector. Likewise, to assure the existence of a home innovation sector, $z_2 > z_1$ must be true. Formally, looking at (14) and (15), this holds when $\frac{F + \omega_H Z}{\omega_M - \omega_H} > \frac{1 + e - \omega_H Z}{\omega_H}$. Using the most demanding scenario for the inequality to be satisfied (i.e. setting Z and ω_H to their minimum level of 0 and 1 respectively), the condition reduces to $F/(1+e) > (\omega_M - 1)$. This means that for an innovator sector to exist, the relative fixed cost of migration with respect to education should be greater than the gains from migration (where a lower F increases z_2 and a higher e increases z_1).[14] Under this condition, the lower skilled population cannot afford to cover migration costs. Therefore, there does not exist a level of z_i which makes a worker indifferent between migrating and working in the production sector. Instead, we can be certain that an innovation sector exists, in which a worker with skills z_2 is indifferent about staying or migrating. At the limit when $z_1 = z_2$, there is no longer an innovation sector in the South, as all those who obtain education migrate.[15]

Next we look at the effect of IPR protection on the migration decision of innovation workers. A look back at (14) shows that the threshold skill level z_2 increases in wages ω_H as $\frac{\partial z_2}{\partial \omega_H} > 0$, that is, higher skilled wages in the South discourage emigration to the North. It follows:

LEMMA 3. *Higher returns to skills obtained through IPR protection retain skilled workers in the home innovation sector* $\left(\frac{\partial z_2}{\partial \omega_H} > 0\right)$ *and reduce the size of diasporas* $\left(\frac{\partial \zeta(z_2)}{\partial z_2} < 0\right)$.

Proof. Follows directly from (4), (13) and (14).

Lemma 3 suggests that IPR protection works as a force against brain drain by preserving skills in the South. An improvement in the IPR protection level q partially prevents migration by recognizing the rights of inventors and discouraging imitation. A change in z_2 also changes the composition of

[13] In addition, higher training costs e prevent entry by the low-skilled, whereas higher wages in the innovation sector at home ω_H and higher potential diaspora gains Z increase returns to working in the innovation sector, thereby shifting workers there.

[14] See Appendix A.1 for the feasibility of the assumption.

[15] In case $z_1 > z_2$, thresholds z_1 and z_2 simply do not exist. In such a scenario, there is again no innovation sector in the South. The unique relevant threshold becomes a new z_3, which is derived by comparing earnings from migration with earnings from working in the production sector: using $\omega_M z_i - e - F = 1$, $z_3 = (1 + e + f)/\omega_M$. Workers with skills lower than z_3 stay in the production sector while workers with skills higher than z_3 obtain education and migrate. Note that z_3 only depends on the exogenous parameters of the model and is therefore independent from IPR protection.

international spillovers that affect workers' productivity. Namely, reduced migration induced by IPRs limits potential gains from diaspora by encouraging more skilled workers to remain in the home economy.

2.5. General equilibrium

The economy is in equilibrium when the allocation of workers across sectors is compatible with the labor and product market clearing conditions. In this section, we will see that wages adjust endogenously together with z_1 and z_2 to reach equilibrium, thereby determining also the amount of human capital being utilized in the economy $H(z_1, z_2)$, the number of inventions N, and the aggregate price index P.

The total number of workers in the production sector in terms of the threshold skill level z_1 is

$$L(z_1) = \int_0^{z_1} g(z)dz = G(z_1), \tag{16}$$

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

$$H(z_1, z_2) = \int_{z_1}^{z_2} h_i g(z)dz. \tag{17}$$

Market clearing implies that total output Y is equal to total factor income:[16]

$$Y = \omega_H H(z_1, z_2) + L(z_1). \tag{18}$$

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

$$L(z_1) = [N(1-q)]\frac{Y}{\psi} + Nq\frac{Y\mu^{\frac{1}{(\alpha-1)}}}{\psi}, \tag{19}$$

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

We can close the model by using equations (6), (10), (12), (18), and (19) to solve for the equilibrium wage in terms of z_1 and z_2:

$$\omega_H = \omega_H(z_1, z_2) = \frac{q(\mu-1)\mu^{\frac{1}{(\alpha-1)}} L(z_1)}{H(z_1, z_2)[1 - q(1 - \mu^{\frac{1}{(\alpha-1)}})]}. \tag{20}$$

An increase in q on the RHS of (20) is always compensated 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) and an upward shift in z_2 (as $\partial H(z_1, z_2)/\partial z_2 > 0$) to maintain equilibrium. Using (20) together with (15), (14), we obtain the following two-equation system:

$$\begin{aligned} \omega_H(z_1, z_2)(z_1 + Z) &= 1 + e, \\ \omega_H(z_1, z_2)(z_2 + Z) &= \omega_M z_2 - F. \end{aligned} \tag{21}$$

Using (20) to rewrite the equilibrium condition (21) and dividing each side of the two equations, it is easy to see that thresholds z_1 and z_2 must move in opposite directions:

$$\frac{\omega_M z_2 - F}{z_2 + Z} = \frac{1 + e}{z_1 + Z} \tag{22}$$

The RHS of (22) is clearly decreasing in z_1 and increasing in z_2 as $\partial Z/\partial z_2 < 0$. The LHS is also

[16] We assume education cost e to be embedded in Y, which simplifies the notation but does not influence the results.

strictly increasing in z_2 as

$$\frac{dLHS}{dz_2} = \frac{\omega_M Z + F + \frac{\partial Z}{\partial z_2}(F - \omega_M z_2)}{(z_2 + Z)^2} > 0, \tag{23}$$

where $\frac{\partial Z}{\partial z_2} < 0$ and $F - \omega_M z_2 < 0$ from (14). Thresholds z_1 and z_2 must therefore move in opposite directions to maintain equilibrium. We can state that in general equilibrium, the reallocation of workers in the economy caused by migration or IPR protection either reduces or increases the size of the innovation sector from both sides of the distribution. It will be seen below how this general equilibrium effect reinforces our key results. We can now calculate the dynamics of z_1 and z_2 with respect to changes in the IPR regime, q, and subsequently analyze how skilled emigration could promote innovation in the South. We then explore the conditions under which the beneficial effects of cross-border diaspora are likely to outweigh the negative brain drain effect of emigration and transform it into brain gain.

3. Diasporas and innovation

This section studies the combined effect of IPRs and migration on innovation in the sending country through the diaspora channel, i.e. the spillover of superior knowledge learned by migrants back to their country of origin. Such potential gains from skilled migration are denoted by Z in equation (3) and illustrated in Figure 2. The aim is to show that although a reduction in migration costs F hurts innovation in the South via brain drain by inducing the marginal emigrant to leave (Lemma 1), it also helps the southern inframarginal innovators via diaspora feedbacks. The extent to which such feedbacks create gains for the sending country depends on the size of the innovation sector, itself determined by the level of IPR enforcement.

[FIGURE 2 ABOUT HERE]

To start, observing Lemmas 2-3 reveals that IPR protection increases the size of the innovation sector by attracting less skilled workers into the innovation sector and discouraging more skilled workers from migration:

Proposition 1. *IPRs fosters potential gains from diaspora by expanding the size of the innovation sector from both sides of the spectrum ($\frac{dz_1}{dq} < 0$, $\frac{dz_2}{dq} > 0$), thereby increasing the absorptive capacity of the home economy.*

Proof. Follows directly from Lemmas 2-3 with the formal proof in the Appendix A.2.

Proposition 1 states that for any given F that yields a positive level of migration, more stringent IPR protection allows potential gains from diaspora, Z, to fall on a larger range of workers active in the innovation sector. It will be seen below that this effect of IPRs can create net gains from diasporas despite of reducing the number of migrants, as long as the intensity of international knowledge flows is sufficiently high (large b). The change in the magnitude of the diaspora mechanism caused by stronger IPRs is depicted in Figure 3.

[FIGURE 3 ABOUT HERE]

We can also directly derive the consequences of strengthening IPR enforcement on innovation in the South by calculating the effect of a change in the IPR regime on the number of inventions, N.

Corollary 1. *IPR protection increases the number of innovations by driving more workers into the home innovation sector, but also decreases it by limiting migration and hence reducing the amount of diaspora knowledge spillovers. The total effect is therefore ambiguous* $\left(\frac{dN(z_1,z_2,q)}{dq} \lessgtr 0\right)$.

Proof. See Appendix A.3.

We are now in the position to make some conclusions about how IPR protection influences the effect of migration on innovation activities in the sending country. Recall from (6) that the number of innovations in the South is proportional to $H(z_1, z_2)$, which according to Equations (2) and (5) depends both on the size of the innovation sector and the potential gains from diaspora. To measure the net effect of migration on innovation in the South, we must weigh the magnitude of the negative brain drain effect against gains brought about by the diaspora channel. To make the point, let us first consider a shift from a no-migration scenario to one with a positive level of migration. 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 basic skills of the remaining workers post-migration:

$$BD = \int_{z_1}^{\infty} zg(z)dz - \int_{z_1}^{z_2} zg(z)dz = \int_{z_2}^{\infty} zg(z)dz. \tag{24}$$

Next, we rewrite the aggregate supply of skills as

$$H(z_1, z_2) = \int_{z_1}^{z_2} (z + Z)g(z)dz = \int_{z_1}^{z_2} zg(z)dz + b\zeta(z_2)\int_{z_1}^{z_2} g(z)dz. \tag{25}$$

The first term on the RHS represents the amount of skills that workers in the innovation sector are originally endowed with, and the second term represents the aggregate diaspora effect on the same workers still residing in the South, i.e., *the intensive margin.*[17] The second term on the RHS of (25) denotes the virtual return of upgraded skills through diasporas and can be rewritten to define brain gain as

$$BG = b\zeta(z_2)\int_{z_1}^{z_2} g(z)dz = b[G(z_2) - G(z_1)]\int_{z_2}^{\infty} zg(z)dz, \tag{26}$$

The term in the brackets $[G(z_2) - G(z_1)]$ represents the size of the innovation sector, which multiplied by the diaspora term $b\zeta(z_2)$ accounts for the total effect of the latter on innovation in the home economy. Recall that an improvement in the IPR regime increases returns to skills (working in the innovation sector) by increasing wages ω_H. This results in an expansion of the innovation sector by reducing z_1 and increasing z_2. The RHS of Equation (26) reveals that protecting IPRs increases the number of workers in the innovation sector who can benefit from diaspora by enlarging $[G(z_2) - G(z_1)]$. However, it also reduces the size of diasporas (number of migrants) and hence the amount of potential knowledge they can send back.

To determine whether the brain gain effects caused by a diaspora channel could dominate the flight 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

$$\begin{gathered} BD - BG \gtrless 0 \\ \int_{z_2}^{\infty} zg(z)dz - b[G(z_2) - G(z_1)]\int_{z_2}^{\infty} zg(z)dz \gtrless 0 \\ b[G(z_2) - G(z_1)] \equiv \Phi \gtrless 1. \end{gathered} \tag{27}$$

As seen above, the term $\Phi \equiv b[G(z_2) - G(z_1)]$ 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, in line with the positive interaction effect between IPR protection and emigration in the empirical findings of Naghavi and Strozzi (2015), IPRs makes it more likely for skilled migration to generate brain gains by increasing the size of the innovation sector and absorptive capacity in the South. Also the intensity of international spillovers (b) must be large enough to compensate for the negative diaspora

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

effect of IPRs through the reduced stock of knowledge that can potentially be sent back, $\zeta(z_2)$.

PROPOSITION 2. *Gains from diaspora could outweigh the direct loss of skills caused by migration if the IPR level in the South and intensity of knowledge spillovers are sufficiently high such that* $b[G(z_2) - G(z_1)] \equiv \Phi > 1$. *IPRs furnish the conditions for knowledge from diasporas to reach out to a larger number of workers in the innovation sector* $\left(\frac{d[G(z_2)-G(z_1)]}{dq} > 0\right)$.

Proof. Derives from Lemma 1 and Proposition 1 together with (27).

An alternative approach to measure diaspora spillovers would be to consider the average skill level of migrants abroad, $\tilde{\zeta} = \frac{1}{1-G(z_2)} \int_{z_2}^{\infty} z dg(z)$, as opposed to the absolute sum in equation (3). This can be attractive because the quality of knowledge transmitted home through diasporas would be falling with increased migration as every additional skilled migrant has lower skills than the previous one and therefore reduces the average contribution to the home economy through a reduction in $G(z_2)$. As a result, what would matter is the composition of the emigrants, and not the scale. Nevertheless, for any given any level of migration, better IPR protection allows the diaspora spillovers to fall over a larger range of innovation workers at home increasing their skills on the intensive margin. Using this approach only results in an additional term, $\frac{1}{1-G(z_2)}$, on the RHS of (26), which in fact strengthens our original argument.

Looking at the problem from a broader perspective, we can also calculate the effect of an exogenous reduction in migration costs F on the number of innovations in the South and how the sign of the change depends on the IPR regime.

COROLLARY 2. *Migration induced by a lower* F *results in a drain of existing skills utilizable in the innovation sector, but increases the possibility for superior knowledge to be learned and sent back from diasporas. Stronger IPR protection in the South makes it more likely for the latter positive effect to dominate so that* $\left(\frac{dN(z_1,z_2,q)}{dF} < 0\right)$.

Proof. See Appendix A.4.

Interestingly, the results produced by the model are compatible with the alternative explanations provided in BDR (2001) and Mayr and Peri (2009) on human capital development and return migration respectively. To compare, IPRs work as an intermediary channel to extract (brain) gains from skilled migration by encouraging education in the home country. Similarly, IPRs induce return migration of workers with enhanced skills back into the innovation workers. We can therefore conclude that when skilled migration generates positive knowledge flows, IPR protection creates the conditions for the southern innovation sector to absorb benefits from diasporas by stimulating human capital development, return migration, or intellectual diaspora networks.

4. Extension: local spillovers

In our model, the size of the innovation sector is proportional to the number of inventions, N, which is itself directly determined by the amount of human capital in the innovation sector, $H(z_1, z_2)$. This allows us to focus the analysis on the initial skill endowment of each individual (their innate ability) used in the innovation sector and how the assumed superior knowledge from the North can flow back to upgrade workers' productivity in proportion to their skills. Using such framework, however, abstracts from local spillovers caused by interaction among Southern co-workers in the innovation sector.

In an alternative framework, average skills in the innovation sector can also play a role in the productivity of innovation workers, h_i. This concept is for example used in the production function of Helpman, Itskhoki and Redding (2009, 2010, 2013) to show how the productivity of a worker may depend on the average productivity of his team. Introducing this feature creates a secondary (direct) negative effect of IPR enforcement on innovation because average skills and hence research productivity is reduced as less talented workers become researchers. This view is also is in line with Glass and Saggi (1998) and Vandenbussche, Aghion and Meghir (2006), who argue that a shift of less skilled workers away from less skill-intensive activities could have adverse effects for countries far from the technological frontier.

We now study the impact of IPR protection, directly and through emigration, and the combination of the two by means of diaspora knowledge networks on local externalities that occur within the southern innovation sector.

Define local spillovers as a direct product of average level of skills in the innovation sector, or the amount of effective innovation activities that lead to the creation of new patents:

$$\tilde{z} = \frac{1}{1 - G(z_1)} \int_{z_1}^{\infty} z dg(z). \tag{28}$$

We first use the amount of skills workers are endowed with to study the direct effect of IPRs and migration on innovation ($\tilde{z}$) keeping Z fixed. We then investigate how the productivity of each worker (h_i) increases in the intensive margin through diasporas in proportion to their initial level of skills.

As in the main analysis, better IPR enforcement q changes average skill level and therefore effective innovation activities by increasing the returns to working in the innovation sector. IPR protection increases ω_H as demonstrated in (13), encouraging less skilled workers to move into the innovation sector. As a consequence, local spillovers measured by the average level of skills in (28) fall due to an expansion of that sector towards the less skilled mass of workers, i.e. $\frac{d\tilde{z}}{dz_1} > 0$.[18] Differentiating (28) with respect to z_1 reflects the basic results from the occupational choice model of Roy (1951). Because $\frac{d\tilde{z}}{dz_1} > 0$, the entry of less-skilled workers in the innovation sector reduces average skills. We interpret this as a direct negative effect of IPRs on innovation caused by a misallocation of the low-skilled to the innovation sector.

To account for migration, lets redefine average skills in (28) as

$$\tilde{z} = \frac{1}{G(z_2) - G(z_1)} \int_{z_1}^{z_2} z dg(z). \tag{29}$$

Here, we see that a higher ω_H also discourages the most skilled from emigrating, thereby increasing the local spillovers presented in (29), i.e. $\frac{d\tilde{z}}{dz_2} > 0$.[19] Addition of workers with higher skills than those in the innovation sector increases average skills. We can conclude that an increase in the IPR protection also has a positive effect on local spillovers by preserving workers from the upper tail of the distribution of skills in the South. The total effect of IPR on $\tilde{z}$ hence depends on the distribution of skills in the country: when the distribution is skewed towards the low-skilled the negative effect of IPR dominates (more likely for developing countries), whereas the positive effect through migration would prevail for societies with a skill distribution skewed towards the high end.

The results in the previous sections can be replicated by bringing together IPR protection and migration to study their combined effect on innovation in the sending country through diaspora externalities, Z in equation (3). This final effect of IPRs via migration is independent of local spillovers and directly depends on the size of the innovation sector, which increases from both spectrums. This allows potential gains from diaspora to fall on a larger range of workers active in the innovation sector to work against the negative impact of IPRs on local spillovers. Therefore, our main argument that IPRs creates the conditions for new knowledge from diasporas to benefit a larger number of innovation workers in the intensive margin remains valid. This is an important point because in Naghavi and Strozzi (2015) we also show that in emerging and developing countries IPR protection by itself has a negative impact on domestic innovation, whereas it works as a moderating factor to exploit gains from international migration by enhancing the absorptive capacity of the home country.

In sum, the IPR regime affects innovation in two ways. On the one hand, it affects the size

[18] See Appendix A.5 for the proof.

[19] See the Appendix A.5 for proof.

of the innovation sector. On the other hand, it endogenously influences the skill composition in the innovation sector. Both are caused by a flow of low-skilled workers from the production to the innovation sector (i.e., z_1 falls) and reduced emigration (i.e., z_2 rises). Although the presence of the low skilled in the innovation sector may directly reduce local spillovers ($\tilde{z}$), the potential for absorption of the newly acquired skills from the North ($b\zeta$) is higher regardless because the diaspora effect influences a larger range of workers.

5. Conclusion

In this paper, we have explored the link between cross-border diaspora networks and innovation capacity in migrants' countries of origin. 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 country of origin. 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 of the innovation sector. Both interpretations, however, lead to the same conclusion: under certain conditions, skilled emigration could be beneficial for growth in the sending countries.

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. IPR protection influences a country's potential for innovation by changing the size of the innovation sector. This could increase the absorptive capacity of the emigrants' country of origin, thus leading to more beneficial effects from cross-border diaspora networks.

The mechanism at work is as follows. Emigration has two effects. On the one hand, it decreases the amount of skills in the innovation sector by losing the most skilled through a lower z_2 (the extensive margin). On the other hand, it can increase the skills of the remaining workers in the innovation sector through the positive externalities of the diaspora channel Z (the intensive margin). The IPR regime in turn influences innovation by changing the size of the innovation sector. An increase in IPR protection enhances the attractiveness of working in the innovation sector, thus increasing its size from both ends of the spectrum: this causes a flow of low-skilled workers from the production to the innovation sector (i.e., z_1 falls) and reduces emigration (i.e., z_2 rises). Although IPRs reduce the size of the diaspora by limiting migration, the potential for absorption of the newly acquired skills from the North is higher because the diaspora effect influences a larger range of workers.

Our theory draws upon the realistic assumption that emigration may give origin to cross-border diaspora networks between skilled emigrants and natives. It turns out that in the presence of a strong IPR 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 simple setting introduced is a first step to highlight the joint role of institutions and migration in promoting growth and aims to encourage further research on the issue. It can be extended to incorporate a wider range of topics into the framework such as trade, FDI, and imitation (versus innovation) in developing countries.

A. Appendix

A.1. Feasibility of the assumption on thresholds

Inequality $z_1 < z_2$ must hold so that not everyone in the innovation sector migrates. This requires

$$\begin{aligned} \frac{1+e-\omega_H Z}{\omega_H} &< \frac{F+\omega_H Z}{\omega_M-\omega_H} \\ &\Rightarrow F > \frac{(\omega_M-\omega_H)(1+e-\omega_H Z)}{\omega_H} - \omega_H Z. \end{aligned}$$

For a $z_2 < \infty$ to exist so that someone would find it optimal to migrate, we must have a worker with skills $z_i < \infty$ such that

$$\begin{aligned} \omega_M z_i - e - F &> \omega_H z_i + \omega_H Z - e \\ &\Rightarrow F < (\omega_M-\omega_H) z_i - \omega_H Z. \end{aligned}$$

Putting the two inequalities together, we prove the existence of a feasible range of F along which both conditions are valid. That is, $z_1 < z_2 < \infty$ is viable if and only if

$$\begin{aligned} (\omega_M-\omega_H) z_i - \omega_H Z &> \frac{(\omega_M-\omega_H)(1+e-\omega_H Z)}{\omega_H} - \omega_H Z \\ \frac{(\omega_M-\omega_H)(1+e-\omega_H Z)}{\omega_H} &< (\omega_M-\omega_H) z_i \\ \frac{1+e-\omega_H Z}{\omega_H} &< z_i \\ 1+e &< \omega_H(z_i+Z), \end{aligned}$$

which is true for all $z_i > z_1$ (see (15)).We can therefore conclude that the two conditions can contemporaneously be satisfied for the entire range of skill distribution.

A.2. Derivations of the equilibrium

We have a system of two equations:

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

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

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

$$\frac{\partial \omega_H}{\partial q} > 0, \frac{\partial \omega_H}{\partial z_1} > 0, \frac{\partial \omega_H}{\partial z_2} < 0.$$

We would like to establish whether

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

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 $i = 1, 2$:

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

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

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

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

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

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

$$\frac{dz_1}{dq} = -\frac{(z_1 + z_2 + 2Z)\frac{\partial \omega_H}{\partial q}}{\omega_H(\cdot) + (z_1 + z_2 + 2Z)\frac{\partial \omega_H}{\partial z_1}}. \tag{A1}$$

From the investigation of (A1) we can deduce that

$$\frac{dz_1}{dq} < 0 \text{ as } \frac{\partial \omega_H}{\partial z_1} > 0 \text{ and } \frac{\partial \omega_H}{\partial q} > 0. \tag{A2}$$

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

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

The slope will amount to the following:

$$\frac{dz_2}{dq} = -\frac{(z_1 + z_2 + 2Z)\frac{\partial \omega_H}{\partial q}}{\omega_H(\cdot) - \omega_M + (z_1 + z_2 + 2Z)\frac{\partial \omega_H}{\partial z_2} + 2\omega_H\frac{\partial Z}{\partial z_2}} \tag{A3}$$

(A3) has a form that is analogous to (A1), so we can carry out a similar investigation:

$$\frac{dz_2}{dq} > 0 \text{ as } \omega_H - \omega_M < 0,\ \frac{\partial \omega_H}{\partial z_2} < 0,\ \frac{\partial Z}{\partial z_2} < 0, \text{ and } \frac{\partial \omega_H}{\partial q} > 0.$$

We have therefore proved that

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

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.

Finally, to account for the general equilibrium effect, we must also derive the sign of $\frac{dz_2}{dz_1}$. Dividing (A3) by (A1) we obtain

$$\frac{dz_2/dq}{dz_1/dq} = \frac{dz_2}{dz_1} = \frac{\omega_H(\cdot) + (z_1 + z_2 + 2Z)\frac{\partial \omega_H}{\partial z_1}}{\omega_H(\cdot) - \omega_M + (z_2 + z_1 + 2Z)\frac{\partial \omega_H}{\partial z_2} + 2\omega_H \frac{\partial Z}{\partial z_2}} \tag{A4}$$

Using the same argument as that for (A1) and (A3), we can deduce from (A4) that

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

This is because, given (A2), the numerator of (A4) is positive while the denominator is negative.

We have therefore proved that 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 opposite directions.

A.3. Proof of Corollary 1

According to (6), the sign of a change in $N(z_1, z_2, q)$ is equivalent to that in $H(z_1, z_2, q)$. We therefore proceed by taking the total derivative of $H(z_1, z_2, q)$ with respect to q.

$$\frac{dH(z_1,z_2,q)}{dq} = \frac{d\int_{z_1}^{z_2} h_i g(z)dz}{dq} = \frac{d\int_{z_1}^{z_2} [z_i + b\zeta(z_2)]g(z)dz}{dq} = \frac{d\int_{z_1}^{z_2} [z_i + b\int_{z_2}^{\infty} zg(z)dz]g(z)dz}{dq}$$

$$= \frac{d\int_{z_1}^{z_2} z_i g(z)dz}{dq} + \frac{d\int_{z_1}^{z_2} [b\int_{z_2}^{\infty} zdg(z)dz]g(z)dz}{dq} = \frac{d\int_{z_1}^{z_2} z_i g(z)dz}{dq} + \frac{d\left(b[G(z_2) - G(z_1)]\int_{z_2}^{\infty} zdg(z)dz\right)}{dq}$$

$$= \overbrace{\underbrace{\overbrace{z_2 G'(z_2)\overbrace{\frac{dz_2}{dq}}^{+}}^{+} - \overbrace{z_1 G'(z_1)\overbrace{\frac{dz_1}{dq}}^{-}}^{-}}_{\text{more skills enter innovation sector}}}^{+} - \overbrace{\underbrace{\overbrace{bz_2 G'(z_2)[G(z_2) - G(z_1)]\overbrace{\frac{dz_2}{dq}}^{+}}^{+}}_{\substack{\text{change in spillover amount on current workers} \\ \text{(-) as IPRs reduce diaspora}}}}^{-}$$

$$+ \overbrace{\underbrace{\overbrace{G'(z_2)b\zeta(z_2)\overbrace{\frac{dz_2}{dq}}^{+}}^{+} - \overbrace{G'(z_1)b\zeta(z_2)\overbrace{\frac{dz_1}{dq}}^{-}}^{-}}_{\text{benefits from diaspora for new innovation workers}}}^{+}$$

$$= G'(z_2)\frac{dz_2}{dq}[z_2 + b\zeta(z_2)] - G'(z_1)\frac{dz_1}{dq}[z_1 + b\zeta(z_2)] - bz_2 G'(z_2)[G(z_2) - G(z_1)]\frac{dz_2}{dq}$$

$$= G'(z_2)\frac{dz_2}{dq}h(z_2) - G'(z_1)\frac{dz_1}{dq}h(z_1) - G'(z_2)\frac{dz_2}{dq}z_2 b[G(z_2) - G(z_1)]$$

The first two terms represent the positive effect of IPRs due to entry of more workers into the innovation sector and the last term is the negative diaspora effect caused by reduced migration.

A.4. Proof of Corollary 2

According to (6), the sign of a change in $N(z_1, z_2, q)$ is equivalent to that in $H(z_1, z_2, q)$. We therefore proceed by taking the total derivative of $H(z_1, z_2, q)$ with respect to F.

$$\frac{dH(z_1,z_2,q)}{dF} = \frac{d\int_{z_1}^{z_2} h_i g(z)dz}{dF} = \frac{d\int_{z_1}^{z_2}[z_i + b\zeta(z_2)]g(z)dz}{dF} = \frac{d\int_{z_1}^{z_2}[z_i + b\int_{z_2}^{\infty} zg(z)dz]g(z)dz}{dF}$$

$$= \frac{d\int_{z_1}^{z_2} z_i g(z)dz}{dF} + \frac{d\int_{z_1}^{z_2}[b\int_{z_2}^{\infty} zg(z)dz]g(z)dz}{dF} = \frac{d\int_{z_1}^{z_2} z_i g(z)dz}{dF} + \frac{d\left(b[G(z_2)-G(z_1)]\int_{z_2}^{\infty} zg(z)dz\right)}{dF}$$

$$= \overbrace{\underbrace{\overbrace{z_2G'(z_2)\overbrace{\frac{dz_2}{dF}}^{+}}^{+}}_{\text{brain drain: skills leaving}}}^{+} \overbrace{- \underbrace{\overbrace{bz_2G'(z_2)[G(z_2)-G(z_1)]\overbrace{\frac{dz_2}{dF}}^{+}}^{+}}_{\substack{\text{change in spillover amount on current workers} \\ \text{(-) as migration generates more diasporas}}}}^{-} \overbrace{+ \underbrace{\overbrace{G'(z_2)b\zeta(z_2)\overbrace{\frac{dz_2}{dF}}^{+}}^{+}}_{\text{brain drain: diasporas benefits no longer used}}}^{+}$$

$$= G'(z_2)\frac{dz_2}{dF}\left\{z_2(1 - b[G(z_2) - G(z_1)]) + b\zeta(z_2)\right\}$$

We obtain $\frac{dH(z_1,z_2,q)}{dF} < 0$ if and only if $z_2 b[G(z_2) - G(z_1)] > z_2 + b\zeta(z_2)$, which can be simplified to $z_2\Phi > h(z_2)$. Note the extra term on the RHS with respect to Proposition 1 that appears here as we are calculating the number of inventions as opposed to a pure brain drain. That is, when talking in terms of total productivity per workers, those who leave take with them not only their innate abilities but also what they learn from diasporas. Rewriting the new condition as

$$\Phi > 1 + \frac{b\zeta(z_2)}{z_2},$$

it is more likely to be satisfied under strong IPR enforcement as an increase in q increases the RHS through a higher z_2 and a lower z_1 (expanding the innovation sector), and decreases the LHS through a higher z_2 (less brain drain and more remaining workers to benefit from diasporas). Setting the initial (pre-existing) level of diaspora knowledge flow equal to zero, the condition simplifies to that obtained in Proposition 1.

A.5. Proof of the results in Section 4

To find out the direct effect of IPR protection on local spillovers we have to calculate $d\tilde{z}/dz_1 > 0$. To prove the effect of variations in z_1 on average skills we derive

$$\frac{d\left[\frac{1}{1-G(z_1)}\int_{z_1}^{\infty} zdG(z)\right]}{dz_1} = \frac{-\frac{d\left[\int_{\infty}^{z_1} zG'(z_1)dz\right]}{dz_1}[1 - G(z_1)] - [-G'(z_1)]\int_{z_1}^{\infty} zdG(z)}{[1 - G(z_1)]^2}$$

$$= \frac{G'(z_1)[\tilde{z} - z_1]}{[1 - G(z_1)]} > 0$$

This implies that if z_1 goes down as a consequence of a rise in IPR protection q, then $\tilde{z}$ also falls due to the Roy effect, and the misallocation of workers, i.e. less skilled labor moving into the innovation sector.

To calculate the effect of IPRs on local spillovers through migration we have to calculate $d\tilde{z}/dz_2$. To prove the effect of variations in z_2 on average skills we derive

$$\frac{d\left[\frac{1}{G(z_2)-G(z_1)}\int_{z_1}^{z_2} zdG(z)\right]}{dz_2} = \frac{\frac{d\left[\int_{z_1}^{z_2} zG'(z_2)dz\right]}{dz_2}[G(z_2)-G(z_1)] - [G'(z_2)]\int_{z_1}^{z_2} zdG(z)}{[G(z_2)-G(z_1)]^2}$$
$$= \frac{G'(z_2)[z_2-\widetilde{z}]}{[G(z_2)-G(z_1)]} > 0$$

This implies that if z_2 goes increases as a consequence of reduced migration (due to better IPRs), then $\tilde{z}$ also increases due to the Roy effect, and by keeping the most skilled in the home innovation sector.

A.6. Introducing a separable numéraire good

Consider utility

$$U_i = C_i = \left[\int_0^N c_j^{\alpha} dj\right]^{\frac{1}{\alpha}} + a,$$

where individual aggregate consumption index C_i is divided between a continuum of N invented goods subscripted by $j \in (0, N)$, plus a numéraire homogenous good labeled a, with $\alpha \in (0,1)$ representing the inverse measure of product differentiation.

Using a monotonic transformation to utility function U_i^{α}, which would yield the same optimization solution, consumers maximize

$$\underset{c_N, c_P}{Max} \quad N_P c_P^{\alpha} + N_N c_N^{\alpha} + a^{\alpha},$$

under the budget constraint

$$y = p_P N_P c_P + p_N N_N c_N + a,$$

Normalizing the price of the numéraire to one also determines wages in the production sector, $\omega_L = 1$. A non-patented good can be imitated driving its price down to the marginal cost of production, $p_N = 1$. Consequently, given $p_P = \mu$, $N_P + N_N = N$, $N_P = Nq$ and $N_N = N(1-q)$, the solution to the above maximization problem is:

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

where

$$\psi = Nq\mu^{\frac{\alpha}{(\alpha-1)}} + N(1-q) + 1, \tag{A5}$$

leading to an aggregate price index of

$$P = \left(N_P p_P^{\frac{\alpha}{(\alpha-1)}} + N_N p_N^{\frac{\alpha}{(\alpha-1)}} + 1\right)^{\frac{(\alpha-1)}{\alpha}}.$$

The labor market clearing condition turns to

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

which together with (6), (12), (18), and now (A5) give the equilibrium wage in the innovation sector:

$$\omega_H = \omega_H(z_1, z_2) = \frac{q(\mu - 1)\mu^{\frac{1}{(\alpha-1)}} L(z_1)}{\rho + H(z_1, z_2)[1 - q(1 - \mu^{\frac{1}{(\alpha-1)}})]}. \tag{A6}$$

It is easy to see that the rest of the analysis and the results obtained in the paper remain identical using (A6).

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Figure 1.
Stronger IPRs Enforcement

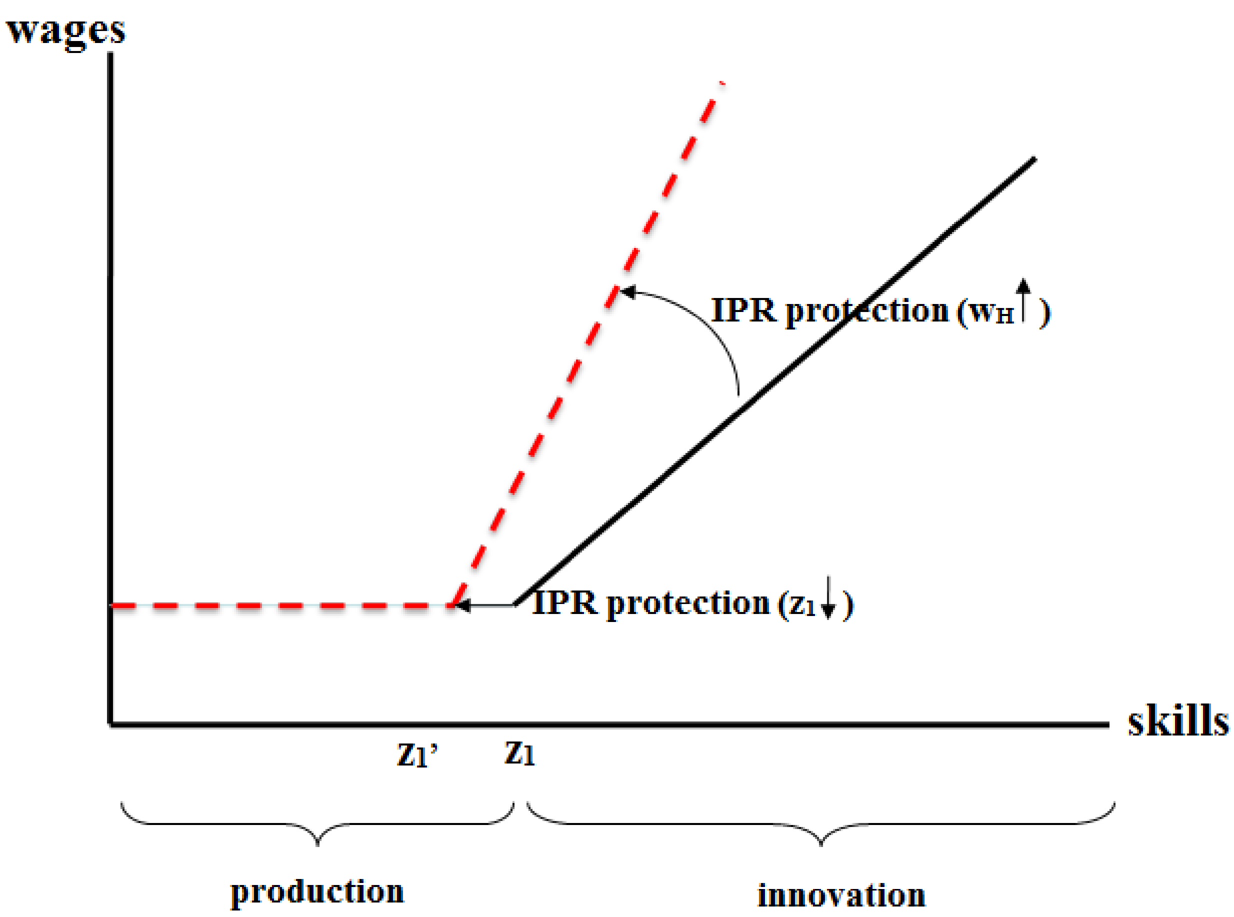

Figure 2.
Diaspora Gains

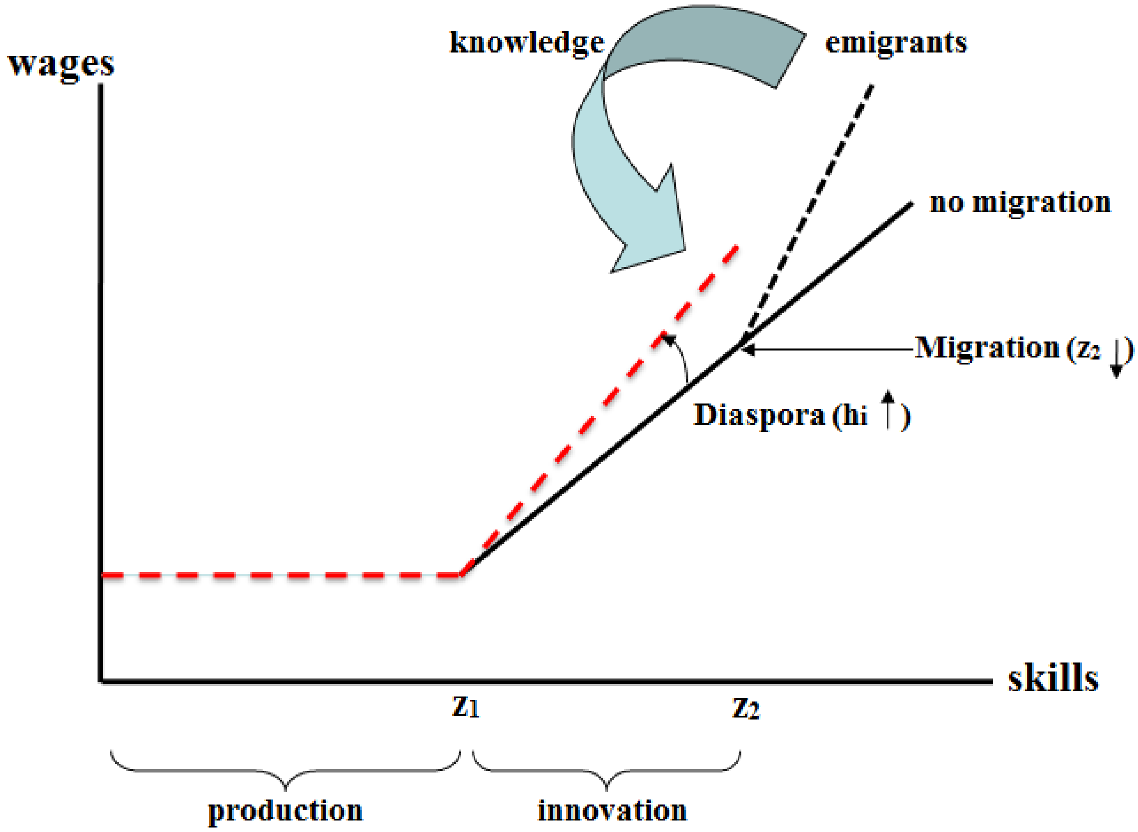

Figure 3.
The Impact of IPRs on Diaspora