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A simple model of brain circulation

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Abstract

This paper analyzes the allocation of two types of individuals differentiated by talent between two countries where they choose to be workers or entrepreneurs. An equilibrium with international migration exists when countries' talent endowments are sufficiently different. It is consistent with one-way or two-way migration whether individuals are entrepreneurs or workers. Although allowing migration increases domestic welfare in one country and decreases it in the other, it is always supported by majority voting in both countries.

Keywords: Migration; Skilled workers; Entrepreneurs; Brain drain

JEL classification: F2; F22; J61; J24; J31

1. Introduction

The paper investigates a two-country model with one- or two-way international migration of individuals differentiated by talent and working in a single industry. During the last 20 years, migration flows of skilled labor have increased significantly (OECD,

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2001) and they are starting to influence the size and the structure of industries. This widespread phenomenon is often described as 'brain circulation' (Johnson and Regets, 1998). For instance, between 1997 and 2002, an average of about 29,000 individuals migrated yearly from the US to Canada while about 73,000 individuals moved in the other direction.[2] These flows are small with respect to population but evidence suggests that these migrants are highly skilled (Gera et al., 2004). They are mostly concentrated in professions like managers, executives, engineers, scientists and entrepreneurs, and work predominantly in knowledge-based industries such as services and information technology.[3] Zucker and Darby (1995, 1999) document the flows of star scientists across borders and how these talented individuals shaped the biotechnology industry in its early stages.[4] Efforts to attract foreign software specialists in Germany, return migration to India and to China are other examples of the growing importance of talent for many industries. Clearly, economists should investigate brain circulation.

To address this issue, we consider a model with two key components. First, individuals are differentiated according to talent (skill or ability), which for our purpose is treated as exogenous. Second, all individuals choose to be workers or entrepreneurs. This decision determines the wage and the number of firms (i.e., entrepreneurs). Because individuals differ in talent levels, the model exhibits increasing returns to entrepreneurs' ability. Accordingly, firms may be differentiated in terms of size and profitability. International migration modifies the industry structure by influencing who is an entrepreneur and who is a worker among migrants and non-migrants. With this model, we can then analyze whether a country wishes to open migration to talented individuals.

Restricting the analysis to two types of talent, the paper makes four points. First, for migration to occur, the countries must be sufficiently different. Second, the equilibrium can exhibit two-way or one-way international migration by talent types. Because migration involves both workers and entrepreneurs, the flows can also be identified with respect to activities. Third, migration impacts the number, the size and the distribution of firms. Finally, although countries with different talent endowments have generally conflicting incentives about migration policy when based on a welfare criterion, they both choose to allow international migration by majority voting. This is true whether migration policy is about immigrants, emigrants or both.

The literature on international mobility of skilled individuals traditionally investigates the impact of the loss of human capital and of the loss of returns to public investments in training. We ignore these issues reviewed in Bhagwati and Wilson (1989). Treating talent as exogenous, we also ignore how migration can affect human capital formation (Stark, 2004). Our paper is related to Rauch (1991) who uses Lucas's (1978) model of agent's choice of activity. However, Rauch sets the choice of activity in a Heckscher–Ohlin–

[2] See Gera et al. (2004) and Harris (2004). A significant proportion of these flows are professionals under temporary NAFTA-TN visas.

[3] OECD (2002) reports that 'a quarter of Silicon Valley firms in 1998 were headed by immigrants from China and India and collectively created 52,300 jobs and generated almost USD17 billion in sales'.

[4] For example, during the 1990s, they identified 417 star bioscientists worldwide; the US attracted 26 of them and lost 20 while Canada, Switzerland and the UK had a net total loss of 19, despite attracting 9 (Zucker and Darby, 1999).

Samuelson model to investigate the links between patterns of trade and migration. To concentrate on migration patterns and on industry structure, our model has only one sector. Several articles also study the role of talent and entrepreneurs in international trade. Among them, Manasse and Turrini (2001) looks at trade in products differentiated by quality where quality depends on entrepreneurs' skills. Grossman (1984) investigates how opening a country to trade or to FDI affects the choice of becoming entrepreneur when entrepreneurship involves risk. These papers however do not consider international migration.

The paper is organized as follows. In the next Section, the basic structure of the model is laid out and the equilibrium without migration is derived. Different patterns of migration are analyzed in Section 3. In Section 4, we consider welfare and whether these countries open to international migration. Section 5 concludes.

2. The model and equilibrium without migration

The model is based on Lucas (1978) and Murphy et al. (1991). Consider two countries, A and B, which trade freely one homogeneous good and there is no international migration. There are two types of talent in the population of each country, $\{\theta_1,\theta_2\}$ with $\theta_1<\theta_2$. The number of individuals with talent θ_1 (θ_2) in country i is $\varphi_1^i\geq 0$ (respectively, $\varphi_2^i\geq 0$). The population is fully employed and each individual can always choose to be either a worker or an entrepreneur. A firm is defined as an entrepreneur with talent θ_j ($j=1,2$) and employs workers at wage w^i. Talent measures how an entrepreneur exploits the existing technology while a worker supplies one unit of labor.[5] The entrepreneur's earning is equal to firm profit and thus to,

$$\pi^i(\theta_j) = \theta_j f(l) - w^i l, \tag{1}$$

where $f(l)$ is the production function for l workers employed by the firm. We assume that technology is the same in both countries and that $f(l)$ exhibits decreasing marginal product of labor. The labor and the output markets are competitive in both countries. With free trade, the output price is given and identical in both countries. Without loss of generality, we have set the output price to one and we assume that $f(l)=l^{1/2}$.

Maximizing (1) with respect to l, the number of workers hired by θ_j-entrepreneur is

$$l^i(\theta_j) = \left(\frac{\theta_j}{2w^i}\right)^2 \tag{2}$$

and the corresponding profit is

$$\pi^i(\theta_j) = \frac{\theta_j^2}{4w^i}. \tag{3}$$

[5] The fact that talent matters only for entrepreneurs is without consequence; what is important is that the returns to talent increase relative to alternative occupations.

Hence, the firm size, measured by employment, and profit decrease with higher wages and increase with talent because revenue increases with talent and cost does not. Increasing returns to talent induce individuals to become entrepreneurs on two counts: they earn higher profit for a given firm size and they spread their talent over a larger firm scale.

The individual's decision to be a worker or an entrepreneur is based on the higher return from the two activities. Since profit increases with θ_j, there are three possible talent allocations: some (but not all) θ_1-individuals are entrepreneurs; all θ_1-individuals are workers and all θ_2-individuals are entrepreneurs (specialization by talent); and some (but not all) θ_2-individuals are entrepreneurs.

Each of these cases is valid under different parameter values. Since θ_1-individuals are entrepreneurs or workers in the first case, they must be indifferent between the two activities and profit must equal wage. From (3), $\hat{\pi}^i(\theta_1)=\hat{w}^i=\theta_1/2$ and it follows that $\hat{\pi}^i(\theta_2)=\frac{\theta_2}{2}\frac{\theta_2}{\theta_1}$. Thus there are two groups of firms in terms of size and profitability. The larger and more profitable firms are headed by θ_2-entrepreneurs and the others, by θ_1-entrepreneurs. The proportion of θ_1-individuals who are entrepreneurs in country i (λ_1^i) is determined by the equilibrium in the labor market. Since workers are only found among θ_1-individuals, the supply of workers is $L_S^i=(1-\lambda_1^i)\varphi_1^i$. Using (2) and given the two groups of firms, the demand for workers is $L_D^i=\lambda_1^i\varphi_1^i\left[\frac{\theta_1}{2w^i}\right]^2+\varphi_2^i\left[\frac{\theta_2}{2w^i}\right]^2$ so that $\lambda_1^i=\frac{1}{2}\left[1-\frac{\varphi_2^i}{\varphi_1^i}\left(\frac{\theta_2}{\theta_1}\right)^2\right]$. Since $0<\lambda_1^i<1$, this case arises when $0<\frac{\varphi_2^i}{\varphi_1^i}<\left(\frac{\theta_1}{\theta_2}\right)^2<1$, implying there are relatively few θ_2-individuals. We call it the 'talent-scarce case'.

In the second case where there is specialization by talent, all θ_1-individuals are workers and all θ_2-individuals are entrepreneurs. Hence, the labor supply is equal to φ_1^i and the labor demand is $L_D^i=\theta_2^i\left[\frac{\theta_2}{2w^i}\right]^2$, resulting in an equilibrium wage $\hat{w}^i=\frac{\theta_2}{2}\left(\frac{\varphi_2^i}{\varphi_1^i}\right)^{1/2}$. Given (3), profit becomes $\hat{\pi}^i(\theta_2)=\frac{\theta_2}{2}\left(\frac{\varphi_1^i}{\varphi_2^i}\right)^{1/2}$. Thus, all firms have the same size and profitability but wage and profit now directly depend on the θ_1- and θ_2-population. This is an equilibrium provided that no individual wants to switch activities and this case requires $\left(\frac{\theta_1}{\theta_2}\right)^2<\frac{\varphi_2^i}{\varphi_1^i}<1$. There are now relatively more θ_2-individuals than in the first case and we call it the 'intermediate case'.

In the third case, θ_2-individuals are entrepreneurs or workers and must be indifferent between the two activities ($\hat{w}^i=\hat{\pi}^i(\theta_2)$). All workers (be they θ_1 or θ_2) have the same wage $\hat{w}^i=\theta_2/2$ and all the firms are identical in size and profitability. The proportion of entrepreneurs in the θ_2-population (λ_2^i) is determined by the labor market equilibrium and is equal to $\lambda_2^i=\frac{1}{2}\left[\frac{\varphi_1^i}{\varphi_2^i}+1\right]$. This case requires a relatively large number of θ_2-individuals $\left(\frac{\varphi_2^i}{\varphi_1^i}>1\right)$ and we call it the 'talent-abundant case'.

Defining earnings by type of individuals (i.e., $G_0^i(\theta_1)$, $G_0^i(\theta_2)$), relative earnings for each of the three cases (talent-scarce, intermediate and talent-abundant) are respectively,

$$\begin{aligned}
&G_0^i(\theta_1)=\frac{\theta_1}{2}<G_0^i(\theta_2)=\frac{\theta_2}{2}\frac{\theta_2}{\theta_1} && \text{if } 0\leq\frac{\varphi_2^i}{\varphi_1^i}<\left(\frac{\theta_1}{\theta_2}\right)^2;\\
&G_0^i(\theta_1)=\frac{\theta_2}{2}\left(\frac{\varphi_2^i}{\varphi_1^i}\right)^{\frac{1}{2}}<G_0^i(\theta_2)=\frac{\theta_2}{2}=\left(\frac{\varphi_1^i}{\varphi_2^i}\right)^{\frac{1}{2}} && \text{if } \left(\frac{\theta_1}{\theta_2}\right)^2<\frac{\varphi_2^i}{\varphi_1^i}<1;\\
&G_0^i(\theta_1)=G_0^i(\theta_2)=\frac{\theta_2}{2} && \text{if } \frac{\varphi_2^i}{\varphi_1^i}>1.
\end{aligned}\tag{4}$$

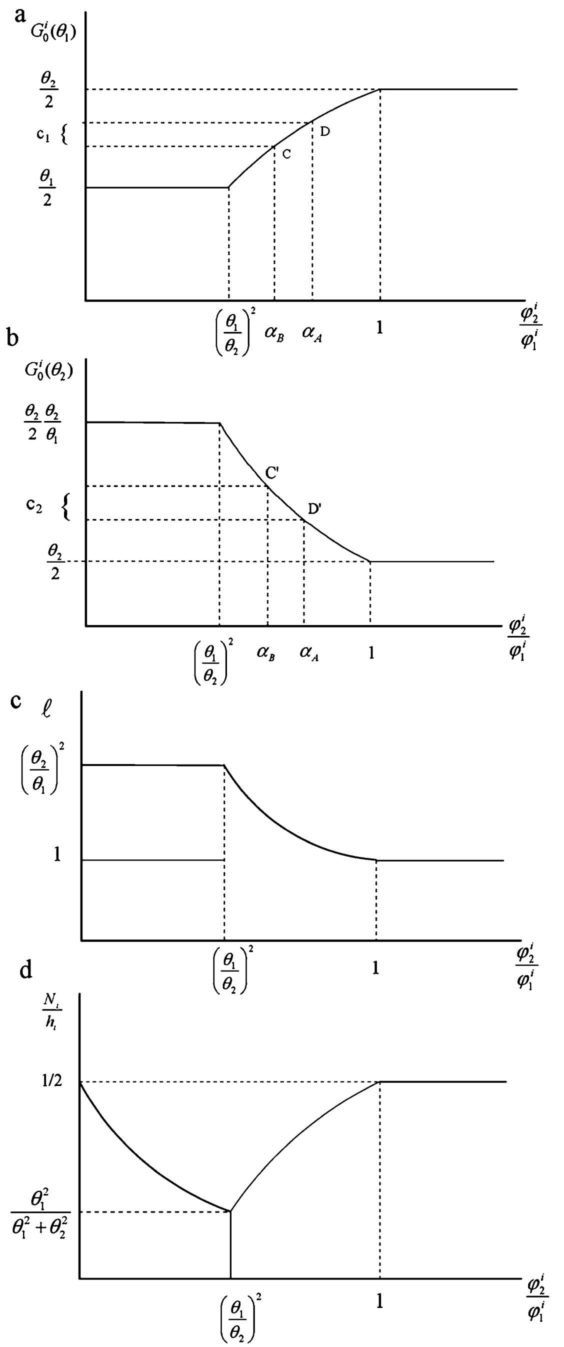

Fig. 1. (a) Type 1-earnings. (b) Type 2-earnings. (c) Firm size. (d) Relative number of firms.

Except for the intermediate case, the equilibrium earnings are independent of the relative number of φ_j-individuals. Keeping in mind that, although θ_1-individual's earnings could be firm's profit (as in the talent-scarce case), $G_0^i(\theta_1)$ always represents wage since there are always workers among θ_1-individuals. Similarly, although θ_2-individual's earnings could be wage, $G_0^i(\theta_2)$ always represents profit. Fig. 1a and b illustrate (4) where $G_0^i(\theta_1)$ could thus be interpreted as wage and $G_0^i(\theta_2)$ as profit.

In the talent-scarce case, since θ_1-individuals are relatively numerous, the wage is low relative to profit. When there are relatively more θ_2-individuals (the intermediate case), the smaller and less profitable θ_1-firms disappear and all entrepreneurs are θ_2-type. As the relative size of the θ_2-population rises, the number of firms increases, the demand for labor rises and so does the equilibrium wage. With costs rising, firm's profitability and size shrink. In the talent-abundant case, wage and profit are equal, and the demand for labor is sufficiently high for some θ_2-individuals to be workers. As a result, wage is the highest and profit is the lowest of the three cases.

Fig. 1c shows employment per firm and Fig. 1d, the proportion of entrepreneurs (or firms) in the total population h^i. In the talent-scarce case, the number of firms falls when φ_2^i/φ_1^i increases. This is because, although the number of firms with θ_2-entrepreneurs rises, the number of firms with θ_1-entrepreneurs falls even more. However, the supply of and demand for labor remain constant and so does the wage. Hence, on average, firms become bigger with φ_2^i/φ_1^i rising. As soon as all the less efficient firms have disappeared, the wage starts increasing as the number of θ_2-firms keeps rising. As a result, employment per firm falls. When φ_2^i/φ_1^i, the proportion of entrepreneurs in the population remains constant and so do wages and profits.[6] Since the average employment per firm is now the lowest of the three cases, there is a relatively large number of small firms.

Even though quite simple, the model generates three distinct cases where profit, wage, firm size and the number of firms are different. We now set the model in a two-country environment with international mobility to investigate the patterns of migration and their effects on activity choices.

3. Equilibria with international migration

In this model, a difference in talent endowments is not sufficient to generate international migration. For example, the two countries can be different, still belong to the talent-scarce case and no migration occurs. This happens because earnings are the same for both types of individuals across the two countries. To generate migration, the two countries should be *sufficiently different* (i.e., belong to different cases or be both in the intermediate case). From now on, we assume that A is a talent-abundant country ($\alpha_0^A=\varphi_2^A/\varphi_1^A>1$) and B is a talent-scarce country ($\alpha_0^B=\varphi_2^B/\varphi_1^B<(\theta_1/\theta_2)^2<1$). Then, Fig. 1a and b show that θ_1-individuals, relatively abundant in B, may have an incentive to migrate to A

[6] In the talent-scarce case, the number of firms N^i is $\lambda_1^i\varphi_1^i+\varphi_2^i$. Given λ_1^i and $h^i=\varphi_1^i+\varphi_2^i$, it is easy to check that the relative number of firms, N^i/h^i, falls at a decreasing rate when φ_2^i/φ_1^i increases. In the intermediate case, the relative number of firms, $\varphi_2^i/(\varphi_1^i+\varphi_2^i)$, increases at a decreasing rate number when φ_2^i/φ_1^i increases. In the talent-abundant case, $N^i=\lambda_2^i\varphi_2^i$ implying $N^i/h^i=1/2$.

because of earnings differential. Conversely, θ_2-individuals, relatively abundant in A, may have an incentive to migrate to B. While this pattern of migration is standard, it is interesting that two-way migration can be evaluated not only for types of individuals but also for activities. This is so because, in talent-scarce country B, θ_1-individuals have an incentive to migrate and, as shown in Section 2, they are both workers and entrepreneurs. Similarly for country A with respect to θ_2-individuals. Hence, the model can generate two-way migration among workers and entrepreneurs and two questions require further analysis. First, what are the circumstances under which one-way or two-way migration between A and B occur? Second, how do the two countries compare in the migration equilibrium and what are the possible outcomes?

Assume that c_1 (respectively, c_2) is the migration cost of a θ_1-(θ_2-) individual. Clearly, migration occurs only when, in the equilibrium without migration, earnings net of migration costs is higher in the destination country than earnings in the country of origin. Given the migration pattern described above, we denote by $x \geq 0$ the number of θ_1-individuals (workers and entrepreneurs) who migrate from B to A and by $y \geq 0$, the number of θ_2-individuals who migrate from A to B. These individuals have an incentive to move ($x>0$, $y>0$) when net earnings in the no-migration equilibrium (NG_0) are

$$\mathrm{NG}_0(\theta_1) = \left[G_0^{\mathrm{A}}(\theta_1) - c_1\right] - G_0^{\mathrm{B}}(\theta_1) > 0; \tag{5}$$

$$\mathrm{NG}_0(\theta_2) = \left[G_0^{\mathrm{B}}(\theta_2) - c_2\right] - G_0^{\mathrm{A}}(\theta_2) > 0. \tag{6}$$

Suppose both conditions hold, the equilibrium with two-way migration determining x and y requires that

$$\mathrm{NG}(\theta_1) = \left[G^{\mathrm{A}}(\theta_1) - c_1\right] - G^{\mathrm{B}}(\theta_1) = 0; \tag{7}$$

$$\mathrm{NG}(\theta_2) = \left[G^{B}(\theta_2) - c_2\right] - G^{A}(\theta_2) = 0, \tag{8}$$

since individuals must be indifferent between net earnings in the destination country and earnings in the country of origin.

Another possible outcome is one-way migration. If it is from B to A ($x>0$; $y=0$), (5) and (7) still hold but (6) and (8) must be negative or equal to zero and conversely for one-way migration from A to B ($x=0$; $y>0$ when (6) and (8) hold and (5) and (7) ≤ 0). Conditions (5) and (6) indicate that two-way migration depends upon low migration costs relative to the talent (or productivity) differential (i.e., $c_1<[\theta_2-\theta_1]/2$ and $c_2<[\theta_2/\theta_1][\theta_2-\theta_1]/2$) and, that one-way migration requires only one of these costs to be relatively high. These conditions are necessary but not sufficient (since we have ignored (7) and (8)). We now characterize the migration equilibria more precisely, especially the two-way migration equilibrium.

Migration flows change country A's relative talent endowment such that $\alpha^{\mathrm{A}} = \frac{\varphi_2^{\mathrm{A}}-y}{\varphi_1^{\mathrm{A}}+x} < \alpha_0^{\mathrm{A}}$ and country B's such that $\alpha^{\mathrm{B}} = \frac{\varphi_2^{\mathrm{B}}+y}{\varphi_1^{\mathrm{B}}-x} < \alpha_0^{\mathrm{B}}$. Suppose first migration flows make A and B more alike by bringing both countries in the intermediate-case range ($\alpha_0^{\mathrm{B}}<(\theta_1/\theta_2)^2<\alpha^{\mathrm{B}}<1$ and $(\theta_1/\theta_2)^2<\alpha^{\mathrm{A}}<1<\alpha_0^{\mathrm{A}}$). Then, earnings in the migration equilibrium are $G^{\mathrm{A}}(\theta_1) = \frac{\theta_2}{2}\sqrt{\alpha^{\mathrm{A}}}$, $G^{\mathrm{A}}(\theta_2) = \frac{\theta_2}{2}\left(1/\sqrt{\alpha^{\mathrm{A}}}\right)$; $G^{\mathrm{B}}(\theta_1) = \frac{\theta_2}{2}\sqrt{\alpha^{\mathrm{B}}}$ and $G^{\mathrm{B}}(\theta_2) = \frac{\theta_2}{2}\left(1/\sqrt{\alpha^{\mathrm{B}}}\right)$ (see (4)).

Proposition 1. *Two-way migration flows ($x>0$, $y>0$), such that countries A and B fall in the intermediate range, require $c_1\theta_2/(\theta_2-2c_1)<c_2<c_1\theta_2^2/(\theta_1^2+2c_1\theta_1)$. In this equilibrium, the migration cost for θ_1-individuals is lower than for θ_2-individuals and the two countries are never identical ($\alpha^B<\alpha^A$).*

Proof. Observe from (4) that $G^i(\theta_1)G^i(\theta_2)=[\theta_2/2]^2$ (i=A, B), so that (8) can be rewritten as $c_1\theta_2^2/4c_2=G^{\mathrm{A}}(\theta_1)G^{\mathrm{B}}(\theta_1)$. In the intermediate case with migration, this last equality and (7) become respectively $\sqrt{\alpha^{\mathrm{A}}}\sqrt{\alpha^{\mathrm{B}}}=n_1/n_2$ and $\sqrt{\alpha^{\mathrm{A}}}-\sqrt{\alpha^{\mathrm{B}}}=n_1$ where $n_1=2c_1/\theta_2$ and $n_2=2c_2/\theta_2$. Solving these two equations,

$$\sqrt{\alpha^{\mathrm{A}}}=(1/2n_2)\left[n_1n_2+\sqrt{(n_1n_2)^2+4n_1n_2}\right]; \tag{9}$$

$$\sqrt{\alpha^{\mathrm{B}}}=(1/2n_2)\left[-n_1n_2+\sqrt{(n_1n_2)^2+4n_1n_2}\right]. \tag{10}$$

Hence, $\alpha^A<\alpha^B$. Since $0<\alpha^{\mathrm{A}}<1, 0<\sqrt{\alpha^{\mathrm{A}}}\sqrt{\alpha^{\mathrm{B}}}=n_1/n_2<1$ and $c_2>c_1>0$. Moreover, in the intermediate case, $(\theta_1/\theta_2)^2<\alpha_B<\alpha_A<1$ which gives rise to two conditions: $\theta_1/\theta_2<\sqrt{\alpha_{\mathrm{B}}}$ and $\sqrt{\alpha_{\mathrm{A}}}<1$. With (9) and (10), the first inequality leads to $n_2>n_1/(1-n_1)$ and the second to $(\theta_1/\theta_2)^2+n_1(\theta_1/\theta_2)<n_1/n_2$. Together they define the sufficient range of c_2 over which two-way migration occurs when A and B fall in the intermediate case. □

In addition to be low relative to the talent differential, the two migration costs must be relatively similar but they cannot be identical. To understand why c_1 and c_2 are *different*, consider Fig. 1a, b. In equilibrium, the vertical difference between C' and D' (equal to c_2) is greater than the vertical difference between C and D (equal to c_1). This comes from the property that, in the intermediate case, $G(\theta_2)$ is more sensitive than $G(\theta_1)$ to a change in φ_2^i/φ_1^i.[7] This arises because a difference in wage between A and B must translate into a more than proportional difference in profits since a higher wage lowers profit directly through costs and indirectly through a smaller firm size. Therefore, the two countries cannot become identical with two-way migration.

The migration flows can now be characterized. Since $\alpha^{\mathrm{A}}=\frac{\varphi_2^{\mathrm{A}}-y}{\varphi_1^{\mathrm{A}}+x}$ and $\alpha^{\mathrm{B}}=\frac{\varphi_2^{\mathrm{B}}+y}{\varphi_1^{\mathrm{B}}-x}$, (9) and (10) define two equations with two unknowns, the flows x and y. Defining $\mu^{\mathrm{A}}=\left[(1/2n_2)\left(n_1n_2+\sqrt{(n_1n_2)^2+4n_1n_2}\right)\right]^2$ and $\mu^{\mathrm{B}}=\left[(1/2n_2)\left(-n_1n_2+\sqrt{(n_1n_2)^2+4n_1n_2}\right)\right]^2$, the migration flows of θ_1- and θ_2-individuals when the two economies are in the intermediate range are respectively

$$x=\frac{\varphi_2^{\mathrm{A}}+\varphi_2^{\mathrm{B}}-\left(\mu^{\mathrm{A}}\varphi_1^{\mathrm{A}}+\mu^{\mathrm{B}}\varphi_1^{\mathrm{B}}\right)}{\mu^{\mathrm{A}}-\mu^{\mathrm{B}}},\ \text{and}\ y=\frac{\mu^{\mathrm{A}}\mu^{\mathrm{B}}\left(\varphi_1^{\mathrm{A}}+\varphi_1^{\mathrm{B}}\right)-\left(\mu^{\mathrm{A}}\varphi_2^{\mathrm{B}}+\mu^{\mathrm{B}}\varphi_2^{\mathrm{A}}\right)}{\mu^{\mathrm{A}}-\mu^{\mathrm{B}}}.$$

Since among θ_1-individuals in B (θ_2-individuals in A), workers and entrepreneurs have the same incentive to migrate, x (y) includes both types. Hence, this equilibrium is consistent with two-way migration of both entrepreneurs and workers. Observe however that some migrants switch activities. Since, in the equilibrium with migration, all θ_1-individuals are workers and all θ_2-individuals are entrepreneurs, some migrating θ_1-

[7] Specifically, $|\partial G(\theta_1)/\partial(\varphi_2/\varphi_1)|<|\partial G(\theta_2)/\partial(\varphi_2/\varphi_1)|$ when $\varphi_2/\varphi_1<1$.

individuals who were entrepreneurs in country B are now workers in country A and some migrating θ_2-individuals who where workers in A are now entrepreneurs in country B. Overall, allowing migration increases the number of entrepreneurs (or firms) in the two countries provided that $\varphi_2^A + \varphi_2^B(\theta_2/\theta_1)^2 - (\varphi_1^A + \varphi_1^B) > 0$ and thus provided that the overall population of θ_1-individuals is not too large compared to that of θ_2-individuals.[8]

When the parameters of the model are outside the range given in Proposition 1, there cannot be two-way migration. This implies that one-way migration involves neither too low, nor too similar migration costs. The following proposition summarizes the results.

Proposition 2. *One-way migration of θ_1-individuals ($x > 0$; $y = 0$) is consistent with the equilibrium where the two countries belong to the intermediate case provided that $c_1 < [\theta_2 - \theta_1]/2$ and $c_2 \geq [\theta_2/\theta_1][\theta_2 - \theta_1]/2$. One-way migration of θ_2-individuals ($x = 0$; $y > 0$) is consistent with the equilibrium where the two countries belong to the intermediate case provided that $c_1 \geq [\theta_2 - \theta_1]/2$ and $c_2 < [\theta_2/\theta_1][\theta_2 - \theta_1]/2$. The first case requires $c_2 > c_1$ and the second case is consistent with $c_1 = c_2 > 0$.*

Proof. See the Appendix.

Since $c_2 > c_1$ is necessary for two-way migration, it is a fortiori the case when only θ_1-individuals migrate. Similarly, migration cost c_1 must be relatively high to discourage θ_1-individuals from migrating ($x = 0$). It follows that $c_1 = c_2$ is also consistent with this equilibrium. However, since migration costs are positive when equal, the two countries cannot become identical even in this case.

Other equilibria with migration are possible. For instance, with higher migration costs, there could still be migration equilibria where the two countries are less different than in the initial equilibrium but more different than when both countries fall in the intermediate case. Proposition 3 summarizes the possibilities.

Proposition 3. *Given the equilibrium without migration in which A is a talent-abundant country and B is a talent-scarce country, allowing migration of θ_1- and θ_2-individuals leads to two additional equilibria: (i) A is still a talent-abundant country and B falls in the intermediate case, and (ii) A falls in the intermediate case and B is still a talent-scarce country. These cases involve one-way migration of θ_1- or θ_2-individuals.*

Proof. See the Appendix.

All other combinations are inconsistent with an equilibrium with migration.[9] Note that even if a country maintains its relative talent intensity after migration, some changes do occur. For instance, from Section 2, A has a proportion of $\lambda_2^A = \frac{1}{2}\left[\frac{1}{\varphi_2^A/\varphi_1^A} + 1\right]$ entrepreneurs among θ_2-individuals so that $\frac{\partial \lambda_2}{\partial(\varphi_2/\varphi_1)} < 0$. Since φ_2^A/φ_1^A falls with migration, the proportion of entrepreneurs among θ_2-individuals rises even if A remains a talent-

[8] The effect of allowing migration on the total number of firms is equal to the difference between the number of entrepreneurs with migration ($\varphi_2^A + \varphi_2^B$) and without migration ($\lambda_2\varphi_2^A + \lambda_1\varphi_1^B + \varphi_2^B$).

[9] They are inconsistent with conditions (5)–(8). For instance, there is no migration when A (B) has still many (few) θ_2-individuals. Similarly, migration cannot make one or both countries become the other country's initial type.

abundant country. Similarly, when country B remains a talent-scarce country with migration, the proportion of entrepreneurs among θ_1-individuals must fall with respect to the initial equilibrium since $\lambda_1^B = \frac{1}{2}\left[1 - \frac{\varphi_2^B}{\varphi_1^B}\left(\frac{\theta_2}{\theta_1}\right)^2\right]$ and $\frac{\varphi_2^B}{\varphi_1^B}$ always increase in B.

Hence, given the initial no-migration equilibrium in A and B, migration always involves both workers and entrepreneurs and makes both countries more similar but never identical. In addition, an equilibrium with migration requires that at least one country falls in the intermediate case and, that both do for two-way migration. In all cases, the industry structure in both countries is affected not only by migration but also by non-migrants' changes in activities. In the next section, we consider the implications of these results for migration policy choices.

4. Welfare, voting and migration policies

To understand some of the policy implications of migration, we first analyze how welfare per capita changes with talent endowment. For country i, the welfare index is measured by total earnings, that is profit and wage divided by population. The proportion of θ_2-individuals in the economy is $z_2^i = \varphi_2^i / h^i$, where h^i is total population. Average welfare per capita is then,

$$\frac{W^i}{h^i} = \begin{cases} \frac{\theta_1}{2}\left[1 + z_2^i\left(\left(\frac{\theta_2}{\theta_1}\right)^2 - 1\right)\right] & \text{if } 0 < z_2^i < \frac{\theta_1^2}{\theta_1^2 + \theta_2^2}; \\ \theta_2\left[\left(1 - z_2^i\right) z_2^i\right]^{1/2} & \text{if } \frac{\theta_1^2}{\theta_1^2 + \theta_2^2} < z_2^i < \frac{1}{2}; \\ \frac{\theta_2}{2} & \text{if } z_2^i > \frac{1}{2}, \end{cases} \tag{11}$$

for the talent-scarce, intermediate and talent-abundant cases respectively. It is easy to check that average welfare per capita increases with z_2^i up to the talent-abundant case where it becomes constant. This is because total welfare is a positive convex combination of earnings. In the talent-scarce case, most individuals have low earnings. In the talent-abundant case, all the firms are run by the most able entrepreneurs and all the workers earn as much as the entrepreneurs and more than in the talent-scarce case.[10] Since half the population is entrepreneurs, this case is characterized by many small firms; despite increasing returns to talent, 'small is beautiful'. Clearly, if country i could select the proportion of θ_2-individuals in the economy (z_2^i), it would always choose to be a talent-abundant country.

But this analysis is not instructive about how domestic welfare changes with migration since the population of each country changes. To do so, we evaluate welfare of the *initial* population in each country. In B, total welfare in the pre-migration equilibrium is $W_0^B = \varphi_1^B G_0^B(\theta_1) + \varphi_2^B G_0^B(\theta_2)$, while in the post-migration equilibrium, it is $W^B = (\varphi_1^B - x)G^B(\theta_1) + x(G^A(\theta_1) - c_1) + \varphi_2^B G^B(\theta_2)$. Since, $c_1 = G^A(\theta_1) - G^B(\theta_1)$ in equilibrium,

[10] Hence, there is also an equal distribution of earnings. However, θ_2-enterpreneurs have higher earnings in the talent-scarce and in the intermediate cases.

$W^B - W_0^B = \varphi_1^B[G^B(\theta_1) - G_0^B(\theta_1)] + \varphi_2^B[G^B(\theta_2) - G_0^B(\theta_2)]$. It is then easy to show that, when B is a talent-scarce country which allows migration, the total welfare of its initial population *decreases* provided the talent intensity falls in the intermediate range.[11] Using the same reasoning, the change in welfare of A's initial population is determined by $W^A - W_0^A = \varphi_1^A[G^A(\theta_1) - G_0^A(\theta_1)] + \varphi_2^A[G^A(\theta_2) - G_0^A(\theta_2)]$ which is *positive* when A is a talent-abundant country and when migration brings A in the intermediate range.[12]

The fact that one country loses and the other gains from migration is standard. What is interesting here is the link between the welfare effects of migration and the migration patterns. Specifically, whenever migration is strong enough to move a country in the intermediate range, the welfare of its pre-migration population decreases if the country gains θ_2-individuals (and/or loses θ_1-individuals) and it increases if the country loses θ_2-individuals (and/or gains θ_1-individuals). This outcome is due to the fact that earnings and activity choices are endogenous. But also important is the fact that θ_2-earnings are relatively more sensitive to a change in the population mix than θ_1-earnings.

This welfare analysis does not explicitly take into account heterogeneity among individuals and it is interesting to consider migration decisions based on majority voting, i.e., determined solely by self interest.[13] Recall that, when both countries belong to the intermediate case in the migration equilibrium, earnings change such that $G_0^A(\theta_1) > G^A(\theta_1)$, $G_0^A(\theta_2) < G^A(\theta_2)$, $G_0^B(\theta_1) < G^B(\theta_1)$ and $G_0^B(\theta_2) > G^B(\theta_2)$. Hence, in A, θ_2-individuals prefer migration to no migration and, since it is a talent-abundant country ($\alpha_0^A = \varphi_2^A / \varphi_1^A > 1$), their choice reflects the majority decision. Similarly, in B, θ_1-individuals prefer migration to no migration and, since $\alpha_0^B = \varphi_2^B / \varphi_1^B < 1$, their choice also reflects the majority vote. Whether there is one-way or two-way migration, the above earnings inequalities do not change and therefore, the initial population in both countries always chooses to allow migration by majority voting.[14] Hence, both countries support migration policies be they about immigrants, emigrants or both. This strong result also arises because activity choices are endogenous and earnings are linked whether individuals are workers, entrepreneurs, θ_1-type or θ_2-type.

5. Conclusions

The paper has developed a simple two-country, one-sector model where individuals are differentiated according to two types of talent. The countries have different endowments of

[11] Specifically, the sign of $W^B - W_0^B$ corresponds to the sign of $\alpha^B - \left(\frac{\theta_1}{\theta_2} + \frac{\theta_2}{\theta_1}\right)(\alpha^B)^{1/2} + \alpha_0^B$ which is negative when $\alpha_0^B < (\theta_1/\theta_2)^2 < \alpha^B < 1$.

[12] In this case, the sign of $W^A - W_0^A$ corresponds to the sign of $\alpha^A - (1 - \alpha_0^A)(\alpha^A)^{1/2} + \alpha_0^A$ which is positive when $(\theta_1/\theta_2)^2 < \alpha^A < 1 < \alpha_0^A$. Note also that whenever migration does not bring a country in the intermediate range, the initial population's welfare of that country remains constant.

[13] See Benhabib (1996), and Bilal et al. (2003) on median voter decisions with migration issues.

[14] This conclusion also holds when one country remains in its initial range with migration. Since the other country necessarily falls in the intermediate case, the individuals benefiting from migration win the decision. Both countries choose to allow migration but in one, individuals are indifferent between migration and no migration.

talent and all individuals choose to be workers or entrepreneurs. Allowing migration generates incentives for the relatively abundant type of individuals to move to the other country. Migrants can be workers and entrepreneurs and, depending on the parameters of the model, there may be one-way or two-way migration. Because the choice of activity is endogenous, some individuals switch activities when crossing the border and these movements induce some non-migrants to switch activities as well. As a result the industry structure is sensitive to the migration of talented individuals. Finally, the endogenous choice of activities and the interdependence among individuals' earnings imply that if a country allows migration by majority voting, it does not matter whether migration policy is about immigrants, emigrants or both.

The model is admittedly simple but it captures some important stylized facts associated with current patterns of migration and in particular with brain circulation. It is also sufficiently simple to be used to address more complex issues associated with contemporary migration questions. For instance, the model could be expanded to investigate the relationship between trade and migration flows by linking individuals' types to differentiated products (Manasse and Turrini, 2001; Yeaple, 2003). One could also increase the number of destination countries to understand better why some countries, like the US, seem more successful at attracting talented individuals than others. Finally, talent could become endogenous with the introduction of human capital formation. These are only some of the issues that need to be analyzed to understand the positive and normative aspects of brain circulation, a phenomenon the importance of which is likely to keep growing.

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Appendix

1. Proof of Proposition 2.

i) $x>0$; $y=0$: Since A and B fall in the intermediate case, $(\theta_1/\theta_2)^2<\alpha^A=\varphi_2^A/(\varphi_1^A+x)<1<\alpha_0^A$ and $0<\alpha_0^B<(\theta_1/\theta_2)^2<\alpha^B=\varphi_2^B/(\varphi_1^B-x)<1$. In equilibrium, x is determined by (7), which can be written as $\sqrt{\alpha^A}-\sqrt{\alpha^B}=2c_1/\theta_2$. Hence, $\alpha^A\geq\alpha^B$ when $c_1\geq 0$. This case also requires $G_0^A(\theta_1)-G_0^B(\theta_1)>c_1$; $G_0^B(\theta_2)-G_0^A(\theta_2)\leq c_2$ and $G^B(\theta_2)-G^A(\theta_2)\leq c_2$. It is easy to check that $G^B(\theta_2)-G^A(\theta_2)<G_0^B(\theta_2)-G_0^A(\theta_2)\leq c_2$ so that the relevant parameters are determined only by $G_0^B(\theta_2)-G_0^A(\theta_2)=(\theta_2-\theta_1)(\theta_2/2\theta_1)\leq c_2$ and $G_0^A(\theta_1)-G_0^B(\theta_1)=(\theta_2-\theta_1)/2>c_1$. It follows that $c_2(c_1)$ must be relatively high (low). Since $G_0^A(\theta_1)G_0^A(\theta_2)=[\theta_2/2]^2$ and $G_0^B(\theta_1)G_0^A(\theta_1)=\theta_1\theta_2/4$, $G_0^B(\theta_2)-G_0^A(\theta_2)=[\theta_2/2]^2\ [1/G_0^B(\theta_1)-1/G_0^B(\theta_1)]=[\theta_2/2]^2[1/G_0^B(\theta_1)G_0^A(\theta_1)][G_0^A(\theta_1)-G_0^B(\theta_1)]=(\theta_2/\theta_1)[G_0^A(\theta_1)-G_0^B(\theta_1)]$. Hence, $G_0^A(\theta_1)-G_0^B(\theta_1)>c_1$ implies $\boldsymbol{c}_2\geq G_0^B(\theta_2)-G_0^A(\theta_2)>c_1(\theta_2/\theta_1)$ and thus $c_2>c_1\geq 0$.

ii) $x=0$; $y>0$: Since A and B fall in the intermediate case, $(\theta_1/\theta_2)^2<\alpha^A=(\varphi_2^A-y)/\varphi_1^A<1<\alpha_0^A$ and $0<\alpha_0^B<(\theta_1/\theta_2)^2<\alpha^B=(\varphi_2^B+y)/\varphi_1^B<1$. In equilibrium, y is determined by (8), which can be written as $1/\sqrt{\alpha^B}-1/\sqrt{\alpha^A}=2c_2/\theta_2$. Hence, $\alpha^A\geq\alpha^B$ when $c_2\geq 0$ This case also requires $G_0^A(\theta_1)-G_0^B(\theta_1)\leq c_1$; $G_0^B(\theta_2)-G_0^A(\theta_2)>c_2$; $G^A(\theta_1)-G^B(\theta_2)\leq c_1$ and the relevant parameters are determined only by $G_0^A(\theta_1)-G_0^B(\theta_1)\leq c_1$ and $G_0^B(\theta_2)-G_0^A(\theta_2)>c_2$. Hence, c_1 (c_2) must be relatively low (high) but positive. As above, $G_0^B(\theta_2)-G_0^A(\theta_2)=(\theta_2/\theta_1)[G_0^A(\theta_1)-G_0^B(\theta_1)]$ so that $c_2<G_0^B(\theta_2)-G_0^A(\theta_2)\leq(\theta_2/\theta_1)c_1$ which implies $c_2<(\theta_2/\theta_1)c_1$ Thus, $c_1=c_2$ is consistent with these inequalities as long as they are positive. □

2. Proof of Proposition 3. Suppose A has still many θ_2-individuals and B falls in the intermediate case with migration. This case implies $0<\alpha_0^B<(\theta_1/\theta_2)^2<\alpha^B=(\varphi_2^B+y)/(\varphi_1^B-x)<1<\alpha^A=(\varphi_2^A-y)/(\varphi_1^A+x)<\alpha_0^A$ with $G_0^A(\theta_1)=G^A(\theta_1)=G_0^A(\theta_2)=G^A(\theta_2)=\theta_2/2$, $G_0^B(\theta_1)=\theta_1/2$, $G_0^B(\theta_2)=(\theta_2/2)(\theta_2/\theta_1)$, $G^B(\theta_1)=(\theta_2/2)\sqrt{\alpha^B}$ and $G^B(\theta_2)=(\theta_2/2)\left(1/\sqrt{\alpha^B}\right)$. When $x>0$ and $y>0$, (7) and (8) can be written as $1-\sqrt{\alpha^B}=n_1$ and $\sqrt{\alpha^B}=c_1/c_2$, which implies that $c_2=\theta_2 c_1/(\theta_2-2c_1)$. This case almost never arises since this is the only possible parameter combination. When $x>0$ and $y=0, 1-\sqrt{\alpha^B}=n_1$ determines x. Among the three inequalities that must also hold, only $G_0^A(\theta_1)-G_0^B(\theta_1)>c_1$ and $G_0^B(\theta_2)-G_0^A(\theta_2)\leq c_2$ matter. They are $c_2>(\theta_2/2\theta_1)(\theta_2-\theta_1)$ and $(1/2)(\theta_2-\theta_1)>c_1$ implying that $c_2>c_1$. When $x=0$ and $y>0$, $1/\sqrt{\alpha^B}-1=n_2$ determines y uniquely. Among the three inequalities that must hold in equilibrium, only $G_0^A(\theta_1)-G_0^B(\theta_1)\leq c_1$ and $G_0^B(\theta_2)-G_0^A(\theta_2)>c_2$ matter so that $c_1=c_2$ is consistent with the equilibrium. The proof for the case in which A falls in the intermediate case and B has still few θ_2-individuals is similar. □

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