Volume 57

2018

How admitting migrants with any skills can help overcome a shortage of workers with particular skills

By ODED STARK and LUKASZ BYRA

Reprinted from

INTERNATIONAL REVIEW OF ECONOMICS AND FINANCE

International Review of Economics and Finance 57 (2018) 144–150

Contents lists available at ScienceDirect

International Review of Economics and Finance

journal homepage: www.elsevier.com/locate/iref

How admitting migrants with any skills can help overcome a shortage of workers with particular skills ☆

Oded Stark [a,b,*], Lukasz Byra [b]

[a] University of Bonn, Germany
[b] University of Warsaw, Poland

ARTICLE INFO

JEL classification:
D62
F22
J24

Keywords:
Skill heterogeneity
Production externalities
Market inefficiency
Shortage of particular skills
Social planner's choice
"Import" of skills
A migration admission fee
Skill acquisition subsidy

ABSTRACT

A country that experiences a shortage of workers with particular skills naturally considers two responses: import skills or produce them. Skill import may result in large-scale migration, which will not be to the liking of the natives. Skill production will require financial incentives, which will not be to the liking of the ministry of finance. In this paper we suggest a third response: impose a substantial migration admission fee, "import" fee-paying workers regardless of their skills, and use the revenue from the fee to subsidize the acquisition of the required skills by the natives. We calculate the minimal fee that will remedy the shortage of workers with particular skills with fewer migrants than under the skill "import" policy.

1. Introduction

When a country faces a shortage of workers with particular skills, it may consider an "import" of workers of the type needed, or it may seek to encourage (subsidize) the "production" of the needed skills domestically. Each of these responses has a downside: direct "import" may result in substantial migration, and that may not be liked by the natives; subsidies require financing, possibly by means of higher taxation. In this paper, we propose and study a third response, which works as follows: the country introduces an admission fee (at a level that will not curb migration); it accepts foreign workers with any skills as long as they pay the fee; and it uses the fee revenues to subsidize the acquisition of the necessary skills by natives.

We study the attractiveness of an admission fee policy in comparison with the direct "import" policy. To this end we construct a model in which individuals in country H (for "host") choose to acquire one of two skill types; as an illustrative example, we resort to skill types labeled "managers" and "scientists."[1] Working as a scientist confers prestige and generates

☆ We are indebted to two referees for thoughtful comments and enlightening advice.

* Mailing address: ZEF, University of Bonn, Walter-Flex-Strasse 3, D-53113 Bonn, Germany.
E-mail address: ostark@uni-bonn.de (O. Stark).

[1] We stress that the reference to scientists and managers is a "working terminology." We can replace scientists with Skill Type I, and managers with Skill Type II. We can use the differentiating characteristics of the two types as delineated in the text, and then provide examples such as technicians and supervisors, engineers and MBAs, and so on.

https://doi.org/10.1016/j.iref.2018.02.019
Received 12 November 2017; Received in revised form 19 February 2018; Accepted 26 February 2018
Available online 16 March 2018
1059-0560/

externalities that boost the productivity of H's entire workforce.[2] By prestige we mean social status. Working as a manager does not confer prestige nor does it generate production externalities. Individuals vary in the importance that they attach to prestige. We refer to this variation as a difference in the desire for prestige. We begin by calculating the market equilibrium in a setting in which migration is not allowed. In the equilibrium, managers earn more than scientists; this is a market "compensation" for not enjoying occupational prestige.[3] We show that from the perspective of H's social planner, the market equilibrium is inefficient: too few individuals take up science, and the share of scientists in the workforce is lower than socially optimal. We then let H open up to migration, where entry is made conditional on payment of a substantial fee. We assume that the wage gain from migration for managers is considerably greater than that for scientists. In the presence of a high admission fee, this wage gain differential results in the migration of only managers. We show that using a sufficiently high revenue from the admission fee to subsidize the acquisition of scientific skills by the natives can enable H to attain the socially optimal share of scientists in its workforce, as well as to obtain that objective with fewer migrants than under the direct "import" policy.

Our analysis contributes to the current policy debate in the US regarding alternative schemes to the H-1B visa quotas (Becker, 2011; Sparber, 2016; Stark, Byra, Casarico, & Uebelmesser, 2017).[4] A drawback of the ongoing policy discussion is a lack of theoretical models that compare and rank alternative policies. The analysis undertaken in this paper provides an example of how a theoretical perspective can influence policy formation.

In Section 2 we consider country H prior to migration. We model the choice of skill type, characterize the equilibrium skill type distribution, and compare this distribution with the distribution favored by the social planner. In Section 3 we trace the consequences of H opening up to migration under an admission fee, and calculate the minimal fee for which this policy is preferable to the direct "import" policy. In Section 4 we test for robustness which reveals that the results reported in Sections 2 and 3 hold under alternative formulations of the production function and of the distribution of the desire for prestige. A discussion and conclusions are in Section 5.

2. A model of production and skill acquisition in a country closed to migration

A developed country H is populated by a continuous set of individuals (workers) of measure one who derive utility from consumption and prestige. At the beginning of their single period of life, the individuals decide which skill type to acquire. There are two skill types to choose from: science, S, and management, M. The individuals differ in their desire for prestige. The utility function of individual j whose skill type is $t = S, M$ is

$$u_t^j = c_t + \kappa(t)\varepsilon^j, \tag{1}$$

where c_t denotes the consumption of an individual of type t, ε^j measures the individual's desire for prestige, and $\kappa(t)$ is a function such that $\kappa(S) = 1$ and $\kappa(M) = 0$ implying that science is socially prestigious but management is not. The desire for prestige, ε, is a random variable uniformly distributed on the interval [0,1] with density function $f(\varepsilon) = 1$ and cumulative distribution function $F(\varepsilon) = \varepsilon$ for $\varepsilon \in [0,1]$. The variation of ε across the individuals represents the idea that the desire for prestige depends on individual-specific characteristics such as personality, values, and family background. The consumption of an individual of type t is equal to his earnings which, in turn, are based on his wage rate, w_t, minus the cost of skill acquisition, k, namely $c_t = w_t - k$. (The cost of skill acquisition is the same for the two skill types.)

Of the two skill types, an individual chooses the one that confers higher utility. Recalling (1), that $\kappa(S) = 1$, and that $\kappa(M) = 0$, scientific skills will be preferred to managerial skills when $w_S - k + \varepsilon^j \geq w_M - k$ or, equivalently, when $\varepsilon^j \geq w_M - w_S$. If $\varepsilon^j < w_M - w_S$, then managerial skills will be preferred to scientific skills. Denoting by $\bar{\varepsilon} = w_M - w_S$ the threshold desire for prestige, the supply of scientists, L_S, and the supply of managers, L_M, are

$$L_S = \Pr(\varepsilon^j \geq \bar{\varepsilon}) = 1 - F(\bar{\varepsilon}) = 1 - \bar{\varepsilon} \quad \text{and} \quad L_M = \bar{\varepsilon}. \tag{2}$$

A large number of identical competitive firms employ scientists and managers to produce H's consumption good, which they sell at a unit price. The production of firm i, Y^i, is

$$Y^i = (a_S + \eta \bar{L}_S)L_S^i + (a_M + \eta \bar{L}_S)L_M^i, \tag{3}$$

where L_t^i is the size of the workforce of type t employed by firm i, and a_M, a_S, and η are constants such that $a_M > a_S > 0$ and $1 > a_M - a_S > \eta > 0$. The externalities generated by scientists, $\eta \bar{L}_S$, depend on the share of scientists in the workforce, $\bar{L}_S = \frac{L_S}{L_S + L_M}$, where $L_t = \sum_i L_t^i$ denotes the aggregate size of the workforce of type t.

[2] Empirical evidence that skills such as science generate high production externalities is in Peri, Shih, & Sparber (2014, 2015).

[3] According to data released by the US Department of Labor, Bureau of Labor Statistics (https://www.bls.gov/oes/current/oes_nat.htm), among the major occupational groups in the US in 2016, Management Occupations (classification 11) ranked top with an annual mean wage of $118,020. This is substantially higher than the mean wages in Computer and Mathematical Occupations (classification 15), $87,880, and in Life, Physical, and Social Science Occupations (classification 19), $72,930.

[4] The H-1B is a US visa that allows US employers to employ foreign workers in specialty occupations for a period of up to six years.

2.1. Market equilibrium

From the perspective of a single firm, the marginal product of a worker of type t is a constant $a_t + \eta \bar{L}_S$. In equilibrium, the marginal product of workers of type t is equal to their market wage, $a_t + \eta \bar{L}_S = w_t$.[5] Because the profit maximizing firm will employ any number of workers of type t as long as $a_t + \eta \bar{L}_S = w_t$, the distribution of the workforce between the two skill types is determined by the supply side. On inserting $w_M = a_M + \eta \bar{L}_S$ and $w_S = a_S + \eta \bar{L}_S$ in $\bar{\varepsilon} = w_M - w_S$, it follows that in equilibrium, the threshold desire for prestige is $\bar{\varepsilon}^* = a_M - a_S$, where an asterisk indicates the market equilibrium value of a variable. The equilibrium supply of scientists, L_S^*, and the equilibrium supply of managers, L_M^*, are

$$L_S^* = 1 - \bar{\varepsilon}^* \quad \text{and} \quad L_M^* = \bar{\varepsilon}^*, \tag{4}$$

and the equilibrium share of scientists in H's workforce is $\bar{L}_S^* = 1 - \bar{\varepsilon}^*$. By inserting this share into $w_t = a_t + \eta \bar{L}_S$, we get the equilibrium values of the wages of scientists and managers, respectively $w_S^* = a_S + \eta(1 - \bar{\varepsilon}^*)$ and $w_M^* = a_M + \eta(1 - \bar{\varepsilon}^*)$, where $w_M^* > w_S^*$.

2.2. The social planner's choice

Let there be a social planner whose objective is to obtain a distribution of H's workforce between the two skill types that will maximize the welfare of the natives. This welfare is measured by the utilitarian social welfare function

$$W = \int_0^{\bar{\varepsilon}} u_M^j f(\varepsilon^j) d\varepsilon^j + \int_{\bar{\varepsilon}}^1 u_S^j f(\varepsilon^j) d\varepsilon^j. \tag{5}$$

We denote by $\bar{\varepsilon}^{**} = a_M - a_S - \eta$ the value of $\bar{\varepsilon}$ that maximizes (5) (a derivation of $\bar{\varepsilon}^{**} = a_M - a_S - \eta$ is in the following proof of Claim 1), where two asterisks indicate an optimal value of a variable under the social planner's choice. We state and prove the following claim.

Claim 1. The social planner's optimal share of scientists in the workforce is higher than the corresponding market equilibrium share of scientists in the workforce, namely $\bar{L}_S^{**} > \bar{L}_S^*$.

Proof. Because $L_S + L_M = 1$, we have that $\bar{L}_S^{**} = L_S^{**} = 1 - \bar{\varepsilon}^{**}$ and that $\bar{L}_S^* = L_S^* = 1 - \bar{\varepsilon}^*$. Thus, for $\bar{L}_S^{**} > \bar{L}_S^*$ to hold, it suffices that $\bar{\varepsilon}^{**} < \bar{\varepsilon}^*$. Utilizing $u_S^j = w_S - k + \varepsilon^j$, $u_M^j = u_M = w_M - k$, $w_t = a_t + \eta \bar{L}_S$, and $\bar{L}_S = 1 - \bar{\varepsilon}$, we can rewrite the social welfare function in (5) as $W = a_M \bar{\varepsilon} + (a_S + \eta)(1 - \bar{\varepsilon}) + \int_{\bar{\varepsilon}}^1 \varepsilon^j f(\varepsilon^j) d\varepsilon^j - k$. The first-order condition for the maximization of (5) is given by $\frac{\partial W}{\partial \bar{\varepsilon}} = a_M - a_S - \eta - \bar{\varepsilon}^{**} = 0$ which, when solved for $\bar{\varepsilon}^{**}$, yields $a_M - a_S - \eta = \bar{\varepsilon}^{**} < \bar{\varepsilon}^* = a_M - a_S$. The second-order condition for a maximum at $\bar{\varepsilon} = \bar{\varepsilon}^{**}$ is met: $\frac{\partial^2 W}{\partial \bar{\varepsilon}^2} = -1 < 0$. Q.E.D.

Claim 1 implies that if the social planner has his way, he will see to it that the number of individuals taking up science will be greater than the number of individuals taking up science in the market equilibrium.

3. Correcting for the market inefficiency by introducing and utilizing an admission fee

Suppose that in order to alleviate the shortage of scientists, H opens up to migration from F (for "foreign") by workers of any skill type, conditional on payment of an admission fee. Just like the workforce in H, the workforce in F is assumed to consist of managers and scientists. We also assume that the wages paid to scientists and managers in F, which are exogenous to the model, are proportionately lower than the corresponding wages paid to scientists and managers in H, $w_t^F = \beta w_t^*$, $t = S, M$, $0 < \beta < 1$, that the prestige "premium" for working as a scientist is the same in F as it is in H, and that the admission fee is the only cost of migration.[6] Thus, recalling that $w_M^* > w_S^*$, it follows that the gain for managers from migration is larger than the gain for scientists from migration:

$$w_M^* - w_M^F > w_S^* - w_S^F. \tag{6}$$

H sets the admission fee, x, in order to draw on the receipts from the fee to subsidize the acquisition of scientific skills by natives.[7] To this end, it naturally prefers to introduce a high fee. It follows from (6) that when the admission fee is set at the highest feasible

[5] In equilibrium we cannot have that $a_t + \eta \bar{L}_S < w_t$ because then firms will not employ workers at all. And $a_t + \eta \bar{L}_S > w_t$ is not possible either because then the firms' zero-profit condition is violated.

[6] The idea that migration is motivated not only by a preference for higher earnings (consumption) but also by a desire to obtain gains in terms of social prestige is presented in Fan and Stark (2011).

[7] Alternatively, without changing any of our results, we could assume that the firms that employ migrant workers pay the admission fee, rather than the migrants. The firms will then pass on the fee to the migrants, offering wage $w_t^* - x$. The reason for that is that because for the firm to be indifferent between employing a native worker and a migrant worker – a condition that has to hold in equilibrium – the overall cost for a firm of employing a native worker has to be the same as the overall cost for a firm of employing a migrant worker.

level, namely when it is set slightly below the gain for a manager from migration, $w_M^* - w_M^F - \sigma$, $\sigma \to 0$, then only managers will find it desirable to migrate; scientists will be discouraged because for them the net gain from migration is negative. In the remainder of this paper we assume that H sets the fee at $x = w_M^* - w_M^F - \sigma \approx w_M^* - w_M^F$, which results in migration only by managers.[8]

When the acquisition of scientific skills is subsidized, the utility of scientist j is given not by $u_S^j = w_S - k + \varepsilon^j$ as before but, rather, by $u_S^j = w_S - k(1-s) + \varepsilon^j$, where s is the fraction of the cost of the acquisition of scientific skills paid for by the subsidy. For example, the subsidy can take the form of stipends and lower fees for the study of science subjects. The utility of a manager remains unchanged at $u_M = w_M - k$. When $w_S - k(1-s) + \varepsilon^j \geq w_M - k$ or, rearranged, when $\varepsilon^j \geq w_M - w_S - sk$, scientific skills will be preferred to managerial skills. Using superscript *ef* to indicate a variable under an admission (entrance) fee, and denoting the threshold desire for prestige by $\bar{\varepsilon}^{ef} = w_M - w_S - sk$, the supply of (native) scientists, L_S^{ef}, and the supply of (native and migrant) managers, $L_M^{ef} + Q_M$, are given by

$$L_S^{ef} = 1 - \bar{\varepsilon}^{ef} \quad \text{and} \quad L_M^{ef} + Q_M = \bar{\varepsilon}^{ef} + Q_M, \tag{7}$$

where Q_M is the number of migrant managers admitted by H.

As already mentioned, the firms do not have a preference between employing a native worker and a migrant worker and, as noted in Sub-section 2.1, the firms will be pleased to employ any number of workers of type t as long as $w_t = a_t + \eta \bar{L}_S^{ef}$, where $\bar{L}_S^{ef} = \frac{L_S^{ef}}{L_S^{ef} + L_M^{ef} + Q_M}$ is the share of scientists in H's workforce under the admission fee. We assume that H maintains a balanced budget, which requires that the subsidy bill is equal to the admission fee revenue, namely $xQ_M = skL_S^{ef}$. On substitution for L_S^{ef} from (7), the balanced budget requirement is

$$xQ_M = sk(1 - \bar{\varepsilon}^{ef}). \tag{8}$$

On rewriting (8) and recalling that $w_t = a_t + \eta \bar{L}_S$ and that $a_M - a_S = \bar{\varepsilon}^*$, the equilibrium condition for the distribution of the individuals between the skill types, $w_M - w_S - sk = \bar{\varepsilon}^{ef}$, becomes

$$\bar{\varepsilon}^* - \frac{xQ_M}{1 - \bar{\varepsilon}^{ef}} = \bar{\varepsilon}^{ef}. \tag{9}$$

Solving (9) for $\bar{\varepsilon}^{ef}$ yields[9]

$$\bar{\varepsilon}^{ef} = \frac{1 + \bar{\varepsilon}^*}{2} - \frac{1}{2}\sqrt{(1 - \bar{\varepsilon}^*)^2 + 4xQ_M}. \tag{10}$$

From (10) we see that $L_S^{ef} = 1 - \bar{\varepsilon}^{ef}$ increases with x and with Q_M: obviously, the higher the admission fee that can be levied on migrant managers, and the larger the number of managers who enter H, the higher the fee revenue available to support natives taking up science.

Suppose that of the two policies, "importing" managers under an admission fee and directly "importing" scientists, H prefers the policy that requires fewer migrants. To this end, we have to calculate the number of migrants needed to attain the same share of scientists in H's workforce under the two policies. We denote by Q_S the number of migrant scientists admitted under direct "import," and by $\bar{L}_S^q = \frac{L_S^q + Q_S}{L_S^q + L_M^q + Q_S}$ the share of scientists in H's workforce under direct "import," where superscript q indicates a variable under a direct "import" policy. We state and prove the following claim.

Claim 2. If $x > Q_S + 1 - \bar{\varepsilon}^*$, then the share of scientists in H's workforce obtained by the "import" of Q_S scientists under direct "import" can also be attained by the "import" of $Q_M < Q_S$ managers under an admission fee.

Proof. We first show that if $x > Q_S + 1 - \bar{\varepsilon}^*$, then $\bar{L}_S^{ef} > \bar{L}_S^q$ for $Q_M = Q_S$. Because $L_S^{ef} + L_M^{ef} = L_S^q + L_M^q = 1$, we have that $\bar{L}_S^{ef} = \frac{L_S^{ef}}{1 + Q_M}$ and that $\bar{L}_S^q = \frac{L_S^q + Q_S}{1 + Q_S}$. Assuming that $Q_M = Q_S$, then $\bar{L}_S^{ef} > \bar{L}_S^q$ holds as long as $L_S^{ef} > L_S^q + Q_M$. Because $L_S^{ef} = 1 - \bar{\varepsilon}^{ef}$, and because under direct "import" the relative attractiveness of the two skill types is the same as in the no-migration setting, namely because $L_S^q = L_S^* = 1 - \bar{\varepsilon}^*$, $L_S^{ef} > L_S^q + Q_M$ can be rewritten as

$$\bar{\varepsilon}^* - \bar{\varepsilon}^{ef} > Q_M. \tag{11}$$

Substituting (10) into the left-hand side of (11) yields

$$-\frac{1 - \bar{\varepsilon}^*}{2} + \frac{1}{2}\sqrt{(1 - \bar{\varepsilon}^*)^2 + 4xQ_M} > Q_M. \tag{12}$$

[8] Setting the admission fee at $x = w_M^* - w_M^F - \sigma$ is optimal for H: a fee $x < w_M^* - w_M^F$ will yield revenue that is lower than the revenue yielded by a fee $x = w_M^* - w_M^F$; and a fee $x \geq w_M^* - w_M^F$ will result in reluctance of F managers to migrate.

[9] Formally, there are two solutions to (9). The solution that is ignored is not feasible because it is outside the interval $\varepsilon \in [0,1]$. We note that because $\bar{\varepsilon}^{ef} \in [0,1]$, then for a high enough fee revenue, namely for $xQ_M \geq \bar{\varepsilon}^*$, the lower constraint on $\bar{\varepsilon}^{ef}$ will bind, namely $\bar{\varepsilon}^{ef} = 0$.

From (12), taking simple algebraic steps,[10] it follows that $x > Q_M + 1 - \bar{\varepsilon}^*$ or, because $Q_M = Q_S$, that

$$x > Q_S + 1 - \bar{\varepsilon}^*. \tag{13}$$

We now show that if $x > Q_S + 1 - \bar{\varepsilon}^*$, then $\bar{L}_S^{ef} = \bar{L}_S^q$ for some $Q_M < Q_S$. If $x > Q_S + 1 - \bar{\varepsilon}^*$, then because $\bar{L}_S^{ef} > \bar{L}_S^q$ for $Q_M = Q_S$, and because $\bar{L}_S^{ef} = \bar{L}_S^* < \bar{L}_S^q$ for $Q_M = 0$, it follows from the continuity of $\bar{L}_S^{ef}$ in Q_M that $\bar{L}_S^{ef} = \bar{L}_S^q$ for some $Q_M < Q_S$. Q.E.D.

Let the number of scientists admitted under direct "import" be set at a level that yields the optimal share of scientists in the workforce, $\bar{L}_S^{q*} = \bar{L}_S^{**}$. What is then the minimum level of admission fee that will make H prefer the policy of "importing" managers under an admission fee to the direct "import" of scientists? Because $\bar{L}_S^{q*} = \frac{L_S^{q*} + Q_S}{L_S^{q*} + L_M^{q*} + Q_S} = \frac{1 - \bar{\varepsilon}^* + Q_S}{1 + Q_S}$ and because $\bar{L}_S^{**} = 1 - \bar{\varepsilon}^{**}$, setting $\bar{L}_S^{q*} = \bar{L}_S^{**}$ requires that

$$\frac{1 - \bar{\varepsilon}^* + Q_S}{1 + Q_S} = 1 - \bar{\varepsilon}^{**}. \tag{14}$$

Recalling that $\bar{\varepsilon}^* = a_M - a_S$ and that $\bar{\varepsilon}^{**} = a_M - a_S - \eta$, solving (14) for Q_S yields

$$Q_S = \frac{\eta}{\bar{\varepsilon}^{**}}. \tag{15}$$

Thus, if $x > \frac{\eta}{\bar{\varepsilon}^{**}} + 1 - \bar{\varepsilon}^*$, then fewer migrants are needed to attain the optimal share of scientists in H's workforce under an admission fee than under direct "import," namely $\bar{L}_S^{ef*} = \bar{L}_S^{q*} = \bar{L}_S^{**}$ for some $Q_M < Q_S = \frac{\eta}{\bar{\varepsilon}^{**}}$.

4. Robustness of the preceding results to an alternative constellation of assumptions

In this section we show that the results reported in Sections 2 and 3 can be obtained under alternative assumptions. In the preceding sections we drew on a simple production function with no complementarity between skill types, and we assumed that the individuals' desire for prestige, ε, is distributed uniformly on the interval [0,1]. To demonstrate qualitative equivalence under an alternative modeling protocol, we now admit complementarity, resorting instead of (3) to a CRS Cobb–Douglas production function

$$Y^i = L_S{}^{\eta} L_S^i{}^{\alpha} L_M^i{}^{1-\alpha}, \tag{16}$$

where $L_S{}^{\eta}$ measures the externalities generated by scientists, $0 < \alpha < 1$ is a constant, and we assume that ε is defined over the interval $[0, E]$ with a general density function $f(\cdot)$ and a general cumulative function $F(\cdot)$, such that $F'(\varepsilon) = f(\varepsilon) > 0$; thus, the distribution is not necessarily uniform. For the special case $f(\varepsilon) = \frac{1}{E}$ and $E = 1$, the formulation of the desire for prestige is as in Section 2, implying that the present representation is more general.

Under these formulations, the first-order conditions for profit maximization are $w_S = \alpha L_S{}^{\eta}(L_M^i/L_S^i)^{1-\alpha}$ and $w_M = (1-\alpha)L_S{}^{\eta}(L_S^i/L_M^i)^{\alpha}$. Dividing w_M by w_S, we derive the relative demand for workers, $\frac{w_M}{w_S} = \frac{1-\alpha}{\alpha}\frac{L_S^i}{L_M^i}$. Because, as already noted, the firms are identical and employ scientists and managers at the same ratio, the market ratio is the same as the ratio of a single firm, $\frac{w_M}{w_S} = \frac{1-\alpha}{\alpha}\frac{L_S}{L_M}$. Thus, the market wages of scientists and of managers are given, respectively, by $w_S = \alpha L_S{}^{\eta}(L_M/L_S)^{1-\alpha}$ and $w_M = (1-\alpha)L_S{}^{\eta}(L_S/L_M)^{\alpha}$, and the difference between these wages is

$$w_M - w_S = L_S{}^{\alpha+\eta} L_M{}^{1-\alpha}\left(\frac{1-\alpha}{L_M} - \frac{\alpha}{L_S}\right). \tag{17}$$

As in Section 2, on the supply side, the equilibrium condition for the distribution of H's workforce between the two skill types is given by $\bar{\varepsilon} = w_M - w_S$ and, thus, the supply of scientists is $L_S = 1 - F(\bar{\varepsilon})$, and the supply of managers is $L_M = F(\bar{\varepsilon})$. Inserting these levels in (17), it follows that in equilibrium

$$\bar{\varepsilon}^* = (1 - F(\bar{\varepsilon}^*))^{\alpha+\eta} F(\bar{\varepsilon}^*)^{1-\alpha}\left(\frac{1-\alpha}{F(\bar{\varepsilon}^*)} - \frac{\alpha}{1 - F(\bar{\varepsilon}^*)}\right). \tag{18}$$

In the current setup, the social planner's objective is to choose $\bar{\varepsilon}$ so as to maximize

$$W = \int_0^{\bar{\varepsilon}} u_M^j f(\varepsilon^j) d\varepsilon^j + \int_{\bar{\varepsilon}}^{E} u_S^j f(\varepsilon^j) d\varepsilon^j$$

or equivalently, when we utilize $u_S^j = w_S - k + \varepsilon^j$, $u_M^j = u_M = w_M - k$, $w_S = \alpha L_S{}^{\eta}(L_M/L_S)^{1-\alpha}$, $w_M = (1-\alpha)L_S{}^{\eta}(L_S/L_M)^{\alpha}$, $L_S = 1 - F(\bar{\varepsilon})$, and $L_M = F(\bar{\varepsilon})$, the social planner's objective is to maximize

[10] Multiplying both sides of (12) by 2 and then adding to each side $1 - \bar{\varepsilon}^*$ transforms (12) to $\sqrt{(1-\bar{\varepsilon}^*)^2 + 4xQ_M} > 2Q_M + 1 - \bar{\varepsilon}^*$. On taking both sides to the power of 2, the latter inequality becomes $(1-\bar{\varepsilon}^*)^2 + 4xQ_M > 4Q_M^2 + 4Q_M(1-\bar{\varepsilon}^*) + (1-\bar{\varepsilon}^*)^2$. Subtracting $(1-\bar{\varepsilon}^*)^2$ from both sides and then dividing throughout by Q_M transforms the inequality to $x > Q_M + 1 - \bar{\varepsilon}^*$.

$$W = (1 - F(\bar{\varepsilon}))^{\alpha+\eta} F(\bar{\varepsilon})^{1-\alpha} + \int_{\bar{\varepsilon}}^{E} \varepsilon^j f(\varepsilon^j) d\varepsilon^j - k. \tag{19}$$

From the corresponding first-order condition for a maximum, $(1 - F(\bar{\varepsilon}^{**}))^{\alpha+\eta} F(\bar{\varepsilon}^{**})^{1-\alpha} \left(\frac{1-\alpha}{F(\bar{\varepsilon}^{**})} - \frac{\alpha+\eta}{1-F(\bar{\varepsilon}^{**})} \right) f(\bar{\varepsilon}^{**}) - \bar{\varepsilon}^{**} f(\bar{\varepsilon}^{**}) = 0$, we get[11]

$$\bar{\varepsilon}^{**} = (1 - F(\bar{\varepsilon}^{**}))^{\alpha+\eta} F(\bar{\varepsilon}^{**})^{1-\alpha} \left(\frac{1-\alpha}{F(\bar{\varepsilon}^{**})} - \frac{\alpha+\eta}{1 - F(\bar{\varepsilon}^{**})} \right). \tag{20}$$

We note that when $\bar{\varepsilon}^{**} = \bar{\varepsilon}^*$, where $\bar{\varepsilon}^*$ is now given by (18), the equality in (20) is violated: the left-hand side is then bigger than the right-hand side: $\bar{\varepsilon}^* > \bar{\varepsilon}^* - \eta(1 - F(\bar{\varepsilon}^*))^{\alpha+\eta-1} F(\bar{\varepsilon}^*)^{1-\alpha}$. This implies that $\bar{\varepsilon}^*$ is too large to satisfy (20), and that the social planner will optimally choose $\bar{\varepsilon}^{**} < \bar{\varepsilon}^*$. Thus, the socially desirable number of scientists in H is higher than the market equilibrium number, namely $L_S^{**} = 1 - F(\bar{\varepsilon}^{**}) > 1 - F(\bar{\varepsilon}^*) = L_S^*$, and so is the share of scientists in H's workforce, $\bar{L}_S^{**} = \frac{L_S^{**}}{L_S^{**} + L_M^{**}} = 1 - F(\bar{\varepsilon}^{**}) > 1 - F(\bar{\varepsilon}^*) = \bar{L}_S^*$.

Suppose now that in order to alleviate the shortage of scientists, H opens up to migration subject to the payment of an admission fee. We assume that (6) continues to hold; that H sets the fee at $x = w_M^* - w_M^F$ which results in only managers finding it worthwhile to migrate; and that in a manner like the one presented in Section 3, H uses the proceeds from the fee to subsidize the acquisition of scientific skills by natives. Under these assumptions, the distribution of the workforce of H between the two skill types is determined, as in Section 3, by $\bar{\varepsilon}^{ef} = w_M^{ef} - w_S^{ef} - sk$, where sk is the subsidy per scientist rendered by the balanced budget constraint, $xQ_M = skL_S^{ef}$. On inserting $\bar{\varepsilon}^{ef} = w_M^{ef} - w_S^{ef} - sk$, $xQ_M = skL_S^{ef}$, $L_S^{ef} = 1 - F(\bar{\varepsilon}^{ef})$, and $L_M^{ef} = F(\bar{\varepsilon}^{ef}) + Q_M$ in (17), the market equilibrium condition is

$$\bar{\varepsilon}^{ef*} + \frac{xQ_M}{1 - F(\bar{\varepsilon}^{ef*})} = (1 - F(\bar{\varepsilon}^{ef*}))^{\alpha+\eta} (F(\bar{\varepsilon}^{ef*}) + Q_M)^{1-\alpha} \left(\frac{1-\alpha}{F(\bar{\varepsilon}^{ef*}) + Q_M} - \frac{\alpha}{1 - F(\bar{\varepsilon}^{ef*})} \right). \tag{21}$$

Under direct "import," the equivalent market equilibrium condition is

$$\bar{\varepsilon}^{q*} = (1 - F(\bar{\varepsilon}^{q*}) + Q_S)^{\alpha+\eta} F(\bar{\varepsilon}^{q*})^{1-\alpha} \left(\frac{1-\alpha}{F(\bar{\varepsilon}^{q*})} - \frac{\alpha}{1 - F(\bar{\varepsilon}^{q*}) + Q_S} \right). \tag{22}$$

Although it is analytically impossible to express $\bar{\varepsilon}^{ef*}$ and $\bar{\varepsilon}^{q*}$ in closed forms, we can gain some insight into the conditions needed for the migration of managers under an admission fee to be preferred to the migration of scientists under direct "import," by limiting attention to migration that is fairly small in size. To this end, we calculate the response of $\bar{\varepsilon}^{ef*}$ to a marginal increase in Q_M, and the response of $\bar{\varepsilon}^{q*}$ to a marginal increase in Q_S. Referring to (21), we define

$$G(\bar{\varepsilon}^{ef*}, Q_M) \equiv \bar{\varepsilon}^{ef*} + \frac{xQ_M}{1 - F(\bar{\varepsilon}^{ef*})} - (1-\alpha)(1 - F(\bar{\varepsilon}^{ef*}))^{\alpha+\eta} (F(\bar{\varepsilon}^{ef*}) + Q_M)^{-\alpha} + \alpha(1 - F(\bar{\varepsilon}^{ef*}))^{\alpha+\eta-1} (F(\bar{\varepsilon}^{ef*}) + Q_M)^{1-\alpha}, \tag{23}$$

and referring to (22), we define

$$H(\bar{\varepsilon}^{q*}, Q_S) \equiv \bar{\varepsilon}^{q*} - (1-\alpha)(1 - F(\bar{\varepsilon}^{q*}) + Q_S)^{\alpha+\eta} F(\bar{\varepsilon}^{q*})^{-\alpha} + \alpha(1 - F(\bar{\varepsilon}^{q*}) + Q_S)^{\alpha+\eta-1} F(\bar{\varepsilon}^{q*})^{1-\alpha}. \tag{24}$$

Because in the market equilibrium we have that $G(\bar{\varepsilon}^{ef*}, Q_M) = 0$ and that $H(\bar{\varepsilon}^{q*}, Q_S) = 0$, we can apply to these functions the implicit function theorem. This yields, respectively, $\frac{d\bar{\varepsilon}^{ef*}}{dQ_M} = -\frac{\partial G/\partial Q_M}{\partial G/\partial \bar{\varepsilon}^{ef*}}$ and $\frac{d\bar{\varepsilon}^{q*}}{dQ_S} = -\frac{\partial G/\partial Q_S}{\partial G/\partial \bar{\varepsilon}^{q*}}$. Because

$$\frac{\partial G}{\partial Q_M} = \frac{x}{1 - F(\bar{\varepsilon}^{ef*})} + \alpha(1-\alpha)(1 + Q_M)(1 - F(\bar{\varepsilon}^{ef*}))^{\alpha+\eta-1} (F(\bar{\varepsilon}^{ef*}) + Q_M)^{-\alpha-1} > 0,$$

$$\frac{\partial G}{\partial \bar{\varepsilon}^{ef*}} = 1 + f(\bar{\varepsilon}^{ef*}) \frac{xQ_M}{(1 - F(\bar{\varepsilon}^{ef*}))^2} + f(\bar{\varepsilon}^{ef*})(1 - F(\bar{\varepsilon}^{ef*}))^{\alpha+\eta} (F(\bar{\varepsilon}^{ef*}) + Q_M)^{1-\alpha}$$
$$\times \left[\frac{\alpha(1-\alpha)}{(F(\bar{\varepsilon}^{ef*}) + Q_M)^2} + \frac{(1-\alpha)(2\alpha+\eta)}{(1 - F(\bar{\varepsilon}^{ef*}))(F(\bar{\varepsilon}^{ef*}) + Q_M)} + \frac{\alpha(1-\alpha-\eta)}{(1 - F(\bar{\varepsilon}^{ef*}))^2} \right] > 0,$$

$$\frac{\partial H}{\partial Q_S} = -(1 - F(\bar{\varepsilon}^{q*}) + Q_S)^{\alpha+\eta-2} F(\bar{\varepsilon}^{q*})^{-\alpha} \left[(1-\alpha)(\alpha+\eta)(1 - F(\bar{\varepsilon}^{q*}) + Q_S) + \alpha(1-\alpha-\eta) F(\bar{\varepsilon}^{q*}) \right] < 0,$$

and because

$$\frac{\partial H}{\partial \bar{\varepsilon}^{q*}} = 1 + f(\bar{\varepsilon}^{q*})(1 - F(\bar{\varepsilon}^{q*}) + Q_S)^{\alpha+\eta} F(\bar{\varepsilon}^{q*})^{1-\alpha} \left[\frac{\alpha(1-\alpha)}{F(\bar{\varepsilon}^{q*})^2} + \frac{(1-\alpha)(2\alpha+\eta)}{(1 - F(\bar{\varepsilon}^{q*}) + Q_S) F(\bar{\varepsilon}^{q*})} + \frac{\alpha(1-\alpha-\eta)}{(1 - F(\bar{\varepsilon}^{q*}) + Q_S)^2} \right] > 0,$$

we get that $\frac{d\bar{\varepsilon}^{ef*}}{dQ_M} < 0$, and that $\frac{d\bar{\varepsilon}^{q*}}{dQ_S} > 0$. Recalling that the shares of scientists in the workforce of H under an admission fee and under direct "import" are given, respectively, by $\bar{L}_S^{ef} = \frac{L_S^{ef}}{L_S^{ef} + L_M^{ef} + Q_M} = \frac{L_S^{ef}}{1 + Q_M}$ and by $\bar{L}_S^{q} = \frac{L_S^{q} + Q_S}{L_S^{q} + L_M^{q} + Q_S} = \frac{L_S^{q} + Q_S}{1 + Q_S}$, then, in the neighborhood of $Q_S = Q_M = 0$, the migration of managers under an admission fee will be preferable to the migration of scientists

[11] The second-order condition for a maximum, $-f(\bar{\varepsilon}^{**}) \left[(1 - F(\bar{\varepsilon}^{**}))^{\alpha+\eta} F(\bar{\varepsilon}^{**})^{1-\alpha} \left(\frac{(1-\alpha)\alpha}{F(\bar{\varepsilon}^{**})^2} + \frac{2(\alpha+\eta)(1-\alpha)}{F(\bar{\varepsilon}^{**})(1-F(\bar{\varepsilon}^{**}))} + \frac{(\alpha+\eta)(1-\alpha-\eta)}{(1-F(\bar{\varepsilon}^{**}))^2} \right) f(\bar{\varepsilon}^{**}) + 1 \right] < 0$, holds.

under direct "import" if $\frac{\partial \bar{L}_S^{ef*}}{\partial Q_M}\Big|_{Q_M=0} > \frac{\partial \bar{L}_S^{q*}}{\partial Q_S}\Big|_{Q_S=0}$. Because $\frac{\partial \bar{L}_S^{ef*}}{\partial Q_M} = \frac{\partial L_S^{ef*}}{\partial Q_M}\frac{1}{1+Q_M} - \frac{L_S^{ef*}}{(1+Q_M)^2}$, because $\frac{\partial \bar{L}_S^{q*}}{\partial Q_S} = \frac{\partial L_S^{q*}}{\partial Q_S}\frac{1}{1+Q_S} + \frac{1-L_S^{q*}}{(1+Q_S)^2}$, and because for $Q_S = Q_M = 0$ we have that $L_S^{ef*} = L_S^{q*} = L_S^*$, then $\frac{\partial \bar{L}_S^{ef*}}{\partial Q_M}\Big|_{Q_M=0} > \frac{\partial \bar{L}_S^{q*}}{\partial Q_S}\Big|_{Q_S=0}$ holds if $\frac{\partial L_S^{ef*}}{\partial Q_M}\Big|_{Q_M=0} > \frac{\partial L_S^{q*}}{\partial Q_S}\Big|_{Q_S=0} + 1$. In turn, because $\frac{\partial L_S^{ef*}}{\partial Q_M} = \frac{\partial(1-F(\bar{\varepsilon}^{ef*}))}{\partial Q_M} = -f(\bar{\varepsilon}^{ef*})\frac{\partial \bar{\varepsilon}^{ef*}}{\partial Q_M}$, and because $\frac{\partial L_S^{q*}}{\partial Q_S} = \frac{\partial(1-F(\bar{\varepsilon}^{q*}))}{\partial Q_S} = -f(\bar{\varepsilon}^{q*})\frac{\partial \bar{\varepsilon}^{q*}}{\partial Q_S}$, then $\frac{\partial L_S^{ef*}}{\partial Q_M}\Big|_{Q_M=0} > \frac{\partial L_S^{q*}}{\partial Q_S}\Big|_{Q_S=0} + 1$ holds if $-f(\bar{\varepsilon}^*)\Big(\frac{\partial \bar{\varepsilon}^{ef*}}{\partial Q_M}\Big|_{Q_M=0} - \frac{\partial \bar{\varepsilon}^{q*}}{\partial Q_S}\Big|_{Q_S=0}\Big) > 1$. Recalling that $\frac{d\bar{\varepsilon}^{ef*}}{dQ_M} < 0$ and that $\frac{d\bar{\varepsilon}^{q*}}{dQ_S} > 0$, we note that $-f(\bar{\varepsilon}^*)\Big(\frac{\partial \bar{\varepsilon}^{ef*}}{\partial Q_M}\Big|_{Q_M=0} - \frac{\partial \bar{\varepsilon}^{q*}}{\partial Q_S}\Big|_{Q_S=0}\Big) > 1$ holds if $\frac{\partial \bar{\varepsilon}^{ef*}}{\partial Q_M}\Big|_{Q_M=0}$ is large enough. Because $\frac{\partial L_S^{ef*}}{\partial x} = \frac{\partial(1-F(\bar{\varepsilon}^{ef*}))}{\partial x} = -f(\bar{\varepsilon}^{ef*})\frac{\partial \bar{\varepsilon}^{ef*}}{\partial x} > 0$, (where the sign of $\frac{\partial L_S^{ef*}}{\partial x}$ is due to $\frac{d\bar{\varepsilon}^{ef*}}{dx} = -\frac{\partial G/\partial x}{\partial G/\partial \bar{\varepsilon}^{ef*}} = -\frac{Q_M}{1-F(\bar{\varepsilon}^{ef*})}\frac{1}{\partial G/\partial \bar{\varepsilon}^{ef*}} < 0$), we infer that for a large enough admission fee, $\frac{\partial \bar{\varepsilon}^{ef*}}{\partial Q_M}\Big|_{Q_M=0}$ will be such that $-f(\bar{\varepsilon}^*)\Big(\frac{\partial \bar{\varepsilon}^{ef*}}{\partial Q_M}\Big|_{Q_M=0} - \frac{\partial \bar{\varepsilon}^{q*}}{\partial Q_S}\Big|_{Q_S=0}\Big) > 1$ will hold.

We see then that drawing on the assumption of complementarity between skill types, as done in the production function (16), does not change qualitatively our main result: there is a threshold level of the admission fee such that for higher fees the migration of managers under an admission fee is preferable to the migration of scientists under direct "import" in the sense that the former policy delivers the same share of scientists in H's workforce as the latter policy, yet requires for that purpose fewer migrants.

5. Discussion and conclusions

An intuitive response to the shortage of workers with particular skills is to "import" workers of the needed skill type. We have outlined an alternative policy: impose a high migration admission fee, allow migrants to self-select in response to the fee, and use the proceeds from the fee to support the domestic "production" of the needed skills. The fee policy will induce migration of workers for whom the increase in earnings upon migration (the returns from migration) are the highest; in our illustrative example, these are "managers." There is no need to import directly that which is scarce.

The models presented in the preceding sections are crisp in the sense that they guide a choice between two distinct policies: one relying on "import" of the needed workers, the other relying on (possibly adverse) self-selection of the migrants whose admission fee subsidizes the domestic production of the workers in short supply. The stark difference in the composition of migration by skill type yielded by our models may not, however, obtain in practice. In the real world, we might observe high-earning workers of more than one skill type responding to the fee. These workers can include workers of the skill type needed in H. The results reported for the case in which the migrants coming to H under an admission fee are not of the skill type needed in H will naturally carry through to a case in which some of the migrants are of the needed skill type.

For some skill types, skills acquired in F are less productive in H than in F. Workers with such skill types would require costly retraining on migration, which could discourage them from migrating. If the workers who require retraining were managers, then our proposed policy could seemingly appear less appealing. When H announces that it will admit managers, those who seek to migrate will most likely prepare themselves for the move. They will choose specialties and areas of expertise that will smoothly transfer to H, and minimize the need for retraining. For example, there are numerous MBA programs, many of them run in migrant-originating countries by institutions based in migrant-destination countries and, therefore, it is not difficult to pre-tailor and align managerial skills in order to ensure productive work on arrival. In addition, suppose that there is a spectrum of managers, ranging from those whose training and background can result in a swift transition into productive work at destination, and those who are at the opposite end of the spectrum. Bringing in the former is what we have in mind. Thus, there is no good reason to assume that migrant managers will require more intensive training than, say, migrant scientists.

Our modeling abstracts from several considerations related to dynamics. When a time dimension is brought to bear, a concern could be raised that whereas importing delivers an instant supply, endogenous skill acquisition is time-consuming. In the short run, with an admission fee, H could experience a decline in the share of scientists in its workforce following the arrival of migrant managers, given the lack of locally trained scientists who, while responding to the subsidy, have not as yet completed their acquisition of skills. The negative effect of domestic skill acquisition in the short run will, however, be small when the skill acquisition process is fairly short. And there is a possibility that for reasons such as social stigma, native managers will, in response to the arrival of migrant managers, seek to switch to science even in the absence of subsidies to do so (Bound, Khanna, & Morales, 2017). This effect too is a dynamic consideration from which our model abstracts.

References

Becker, G. S. (2011). *The challenge of immigration: A radical solution*. Occasional Paper 145. London: Institute of Economic Affairs.

Bound, J., Khanna, G., & Morales, N. (2017). Understanding the economic impact of the H-1B program on the U.S. Working Paper 23153. Cambridge, MA: National Bureau of Economic Research.

Fan, C. S., & Stark, O. (2011). A theory of migration as a response to occupational stigma. *International Economic Review*, *52*(2), 549–571.

Peri, G., Shih, K., & Sparber, C. (2014). Foreign STEM workers and native wages and employment in U.S. cities. Working Paper 20093. Cambridge, MA: National Bureau of Economic Research.

Peri, G., Shih, K., & Sparber, C. (2015). STEM workers, H-1B visas, and productivity in US cities. *Journal of Labor Economics*, *33*(S1), S225–S255.

Sparber, C. (2016). Choosing skilled foreign-born workers: evaluating alternative methods for allocating H-1B work permits. Working Paper 17178. Chicago, IL: Society of Labor Economists.

Stark, O., Byra, L., Casarico, A., & Uebelmesser, S. (2017). A critical comparison of migration policies: entry fee versus quota. *Regional Science and Urban Economics*, *66*, 91–107.