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Abstract

We develop a model to explain two-way migration of high-skilled individuals between countries that are similar in their economic characteristics. High-skilled migration results from the combination of workers whose abilities are private knowledge, and a production technology that gives incentives to firms for hiring workers of similar ability. In the presence of migration cost, high-skilled workers self-select into the group of migrants. The laissez-faire equilibrium features too much migration, explained by a negative migration externality. We also show that for sufficiently low levels of migration cost the optimal level of migration, while smaller than in the laissez-faire equilibrium, is strictly positive. Finally, we extend our model into different directions to capture stylized facts in the data and show that our baseline results also hold in these more complex modelling environments.

JEL-Codes: D820, F220.

Keywords: international migration, skilled workers, positive assortative matching.

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1 Introduction

In this paper we develop a simple model to explain two-way migration of high-skilled individuals between developed countries. While the phenomenon of two-way migration has received little attention in the theoretical literature, it is quantitatively important, in particular for high-skilled individuals migrating between high-income countries. Table 1, which is based on data from Docquier, Lowell, and Marfouk (2008), shows for country pairs within the EU15 and the OECD, respectively, the share of bilateral migration that can be characterised as two-way. The share is measured by the Index of Bilateral Balance in Migration (Biswas and McHardy, 2005), which for each country pair (i, j) is given by $B_{ij} \equiv 2\min(\mathrm{Em}_{ij}, \mathrm{Em}_{ji})/(\mathrm{Em}_{ij} + \mathrm{Em}_{ji})$, with Em_{ij} as the stock of emigrants from country i residing in country j.[1] The numbers in Table 1 are the average values of the index for the respective country group, in a given year and skill group. The data show that the share of two-way migration is highest for high-skill individuals, that it has grown over time, and that it is higher within the homogeneous group of EU15 countries than in the more heterogeneous group of OECD countries.

		high skill	med. skill	low skill	total
EU15	1990	0.61	0.53	0.20	0.35
	2000	0.64	0.51	0.28	0.48
OECD	1990	0.23	0.22	0.14	0.19
	2000	0.28	0.26	0.13	0.22

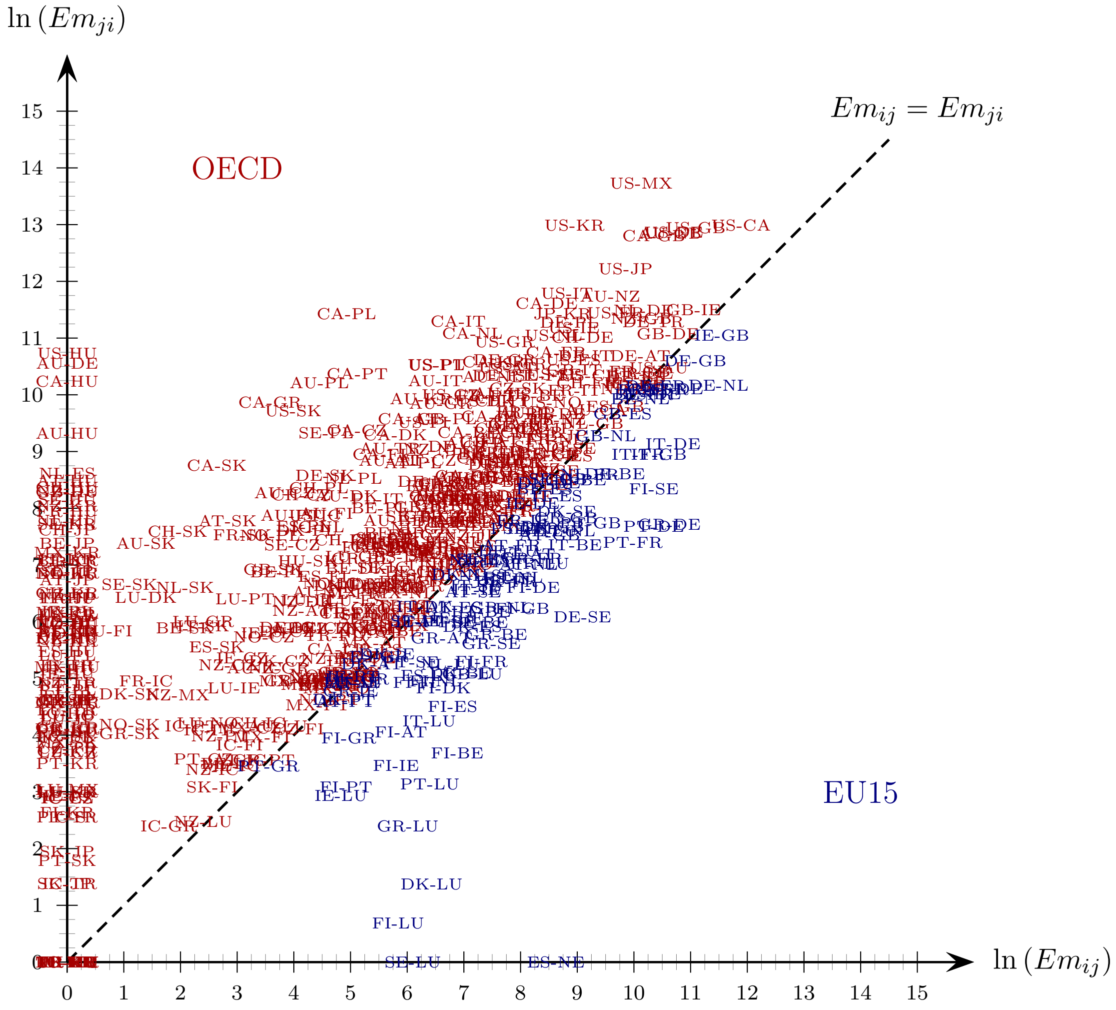
Table 1: *Index of Bilateral Balance in Migration for EU15 and OECD countries*

Focussing on high-skilled (tertiary educated) individuals, Figure 1 gives a more disaggregated view at the level of country pairs for the EU15 (below the diagonal) and the OECD (above the

[1]The construction of the index is directly analogous to the well-known Grubel-Lloyd index measuring intra-industry trade, i.e. two-way trade in goods within the same industry.

diagonal).[2] The figure confirms that a lot of high-skilled migration between EU15 countries is two-way in nature, while this is true to a lesser extent for the larger and more heterogeneous group of OECD countries.

Figure 1: *Two-way migration among EU15 and among OECD countries*



[2]The figure plots $(15 \times 14)/2 = 105$ country pairs from the set of EU15 countries and $(30 \times 29)/2 = 435$ country pairs from the sample of OECD countries. Chile, Estonia, Israel and Slovenia are omitted, as data on two-way migration is not available for these countries in Docquier, Lowell, and Marfouk (2008). Note that country pairs are order such that for the set of EU15 countries (blue) the net-emigration country appears first, while for the set of OECD countries (red) the net-immigration country is named first. Hence, the strict separation in above and below the 45 degree line.

Despite this regularity there is, of course, incidence of substantial two-way migration for specific country pairs that are part of the OECD but not part of the EU15. Taking Canada and the US as another prominent example of rather similar countries, we observe substantial high-skilled migration in both directions, with the share of two-way migration being 0.5 for the year 2000.[3]

The key challenge in explaining two-way migration of similar (highly skilled) individuals within a group of similar (high-income) countries – rather than one-way migration from low-income to high-income countries – lies in the fact that country differences cannot be expected to play a central role. The model we develop in the main part of this paper therefore uses the assumption that countries are identical in all respects (this assumption is relaxed later on). In both countries there is a continuum of workers with differing abilities, which are private knowledge. The production technology, borrowed from Kremer (1993), exhibits complementarities between the skill levels of individual workers, and profit maximising firms therefore aim for hiring workers of identical skill. Migration is costly, and the cost is the same for all individuals. High-skilled individuals from both countries self-select into emigration in order to separate themselves from low-skilled co-workers at home. Firms can distinguish natives and immigrants, which allows them to form more efficient matches, leading to larger gross wage premia for skilled workers.

The welfare effects of migration in our model are stark: In the laissez-faire equilibrium all individuals are worse off than in autarky. We show that this result is due to a negative migration externality which leads to too much migration in equilibrium. We also show that for sufficiently low migration cost the level of migration chosen by an omniscient social planner is strictly positive (but of course lower than in the laissez-faire equilibrium), since the existence of migrants as a distinct group of individuals enables firms to match workers of more similar expected skill. While aggregate gains from migration exist in the social planner equilibrium, the distributional effects are strong: All migrants gain relative to autarky, while all natives are worse off. These distributional effects are mitigated if the social optimum is implemented via a migration tax, since in this case the possibility of redistributing part of the gains to non-migrants

[3] See Schmitt and Soubeyran (2006) and the references cited therein for additional anecdotal evidence on the balance in migration flows between Canada and the US.

exists.

The framework we develop in the main section of our paper is deliberately stylised in order to bring out the basic mechanism driving two-way migration in our model and its welfare implications in the most transparent way possible. Due to its simplicity, the basic version of the model has some extreme implications, and we introduce multiple extensions with the aim for the model to better replicate various stylised facts of international migration. In a first extension, we consider a situation where skills are imperfectly observable, rather than unobservable as in our benchmark model. The most important effect of this change is to give rise to instances where firms co-hire migrants and natives, thereby mitigating the complete segregation between migrants and natives across firms that is implied by our basic framework (cf. Hellerstein and Neumark, 2008; Andersson, García-Pérez, Haltiwanger, McCue, and Sanders, 2014). Our second extension analyses two-way migration in a world where skills are only imperfectly transferable across countries (cf. Mattoo, Neagu, and Özden, 2008; Chiswick and Miller, 2009). In this extension the skill distributions of migrants and natives overlap, giving rise to a scenario in which migrants can find themselves in the middle (instead of on the top) of the destination country's skill distribution. Acknowledging that migration in our framework effectively acts as a signalling device, we then show that migration is still observed as an equilibrium phenomenon in our model if we add alternative signals, as for example education (cf. Spence, 1973).

In a fourth extension of our model we add capital as an internationally immobile factor that is an essential input in the production of all firms (cf. Kremer, 1993). This extension introduces into our framework interactions between migrants and domestic factors of production, which are well known in principle from many existing models of international migration (see, e.g., the complementarity between labour and capital underlying the "immigration surplus" first documented in Berry and Soligo (1969) and more recently reviewed by Borjas (1999), or the imperfect substitutability between natives and migrants recently highlighted in Ottaviano and Peri (2012)). We show that migration is potentially more benign in this case than in our basic model, since it allows for the more efficient allocation of capital between domestic firms, with firms hiring migrants having a higher capital intensity due to a capital-skill complementary that is well known from many models of migration. Lastly, we allow for small differences in countries' technologies. By gaining access to a better technology, workers from the low-tech country then have an additional incentive to migrate, while the opposite holds true for workers from the high-tech economy. Incorporating this modified incentive structure, we still find two-way migration, which now is, however, biased towards the technologically superior country: The high-tech country experiences net immigration while the low-tech country faces net emigration.

The vast majority of theoretical models on high-skilled migration are in the tradition of the "brain drain" literature, focussing on high-skilled migration from developing to more advanced economies. Early contributions to this literature focused on the economic losses for source countries.[4] However, more recently the possibility of a net "brain gain" as the prospect of emigration raises education incentives has been emphasised by Mountford (1997), Stark, Helmenstein, and Prskawetz (1997) and Beine, Docquier, and Rapoport (2001).[5] Embedding high-skilled migration between asymmetric countries into a general equilibrium model of inter- and intra-industry trade Iranzo and Peri (2009) show that source countries gain, if high-skilled migration and trade are complements and gains from trade through a larger set of varieties accrue globally. Similarly, Bougheas and Nelson (2012) find that the majority of workers in source and sending countries benefit from high-skilled emigration as Ricardian-type comparative advantages and the gains from trade associated with it are reinforced.[6] Hendricks (2001) use the same basic migration mechanism as we do and models costly emigration as a signalling device, which is used by the most able individuals to reveal their high but otherwise unobservable skills.[7] Unlike our paper, which analyses two-way migration between similar countries, Hendricks (2001) thereby focuses on one-way migration and the subsequent assimilation of migrants into the more advanced destination economy.

[4] Grubel and Scott (1966) point to the loss of positive externalities as professionals emigrate. Bhagwati and Hamada (1974) stress the fiscal loss associated with the emigration of high-income earners, while Wong and Yip (1999) show that a brain drain has negative growth effects as human capital accumulation is deteriorated.

[5] For a detailed review of the brain drain/gain literature see Hanson (2010) or Docquier and Rapoport (2012).

[6] For a discussion of the complementarity between international migration and international trade see for example Felbermayr, Grossmann, and Kohler (2015).

[7] See also Giannetti (2001), who also models migration as a signalling device to explain inter-regional migration patterns in Italy.

What all these models have in common are directed flows of high-skilled migrants from less to more advanced economies triggered by exogenous country asymmetries. To the best of our knowledge, we are the first to develop a model that can explain two-way international migration of high-skilled workers between identical countries. Schmitt and Soubeyran (2006) address the interesting but distinct question of two-way migration by individuals that have the same occupation, rather than the same skill level. In their model, individuals have either high skills or low skills, and they choose to be either entrepreneurs or workers, as in Lucas (1978). The career choice of individuals depends not only on their own skill level, but also on the skill distribution within each country. The equilibrium may feature two-way migration of both entrepreneurs and workers, but high-skill individuals only migrate to the country where skills are relatively scarce. If the countries are identical, as assumed in the main part of our model, no migration occurs.

The paper proceeds as follows: Section 2 derives the baseline model of two-way, high-skilled migration between identical countries. The welfare effects are derived in Section 3. Section 4 extends the basic model allowing for imperfect observability as well as imperfect transferability of skills, alternative signalling devices, non-mobile factors of production and country asymmetries. Section 5 concludes.

2 The Model

Consider a world with two perfectly symmetric countries, each populated by a heterogeneous mass of workers, which we normalise to one without loss of generality.[8] Workers in each country differ with respect to their skills s which are uniformly distributed over the interval $[0, 1]$, and which are assumed to be private information. Moreover, workers are risk neutral, such that utility $u(x) = x$ can be expressed as a linear function of consumption x. Each country is a single sector economy producing a homogeneous *numéraire* good y under perfect competition, which is costlessly traded.

We follow Kremer (1993) in assuming a production technology which requires the processing

[8]Since countries are assumed to be symmetric, we suppress all country indices.

of $l = 1, 2$ tasks, each to be performed by a single worker. Firm-level output is given by

$$y = f(s_1, s_2) = 2As_1s_2, \tag{1}$$

where $A > 0$ is a technology parameter and s_l denotes the skill level of a worker performing task $l = 1, 2$. Note that $\partial f(s_1, s_2)/\partial s_l > 0 \ \forall \ l = 1, 2$. Moreover we have $\partial^2 f(s_1, s_2)/\partial s_l \partial s_{\hat{l}} > 0$ for all $l, \hat{l} = 1, 2$ and $l \neq \hat{l}$, such that (1) is supermodular and workers enter production as complements.

In an equilibrium that features migration, firms can identify an individual worker as a member of either the group of natives or the group of immigrants. This is the only information they can base their hiring decision on, and this information is valuable since, as we show below, the average skill of the two groups is different. Firms maximise their expected profits by choosing the optimal skill mix of their employees:

$$\max_{\bar{s}_1, \bar{s}_2} \pi(\bar{s}_1, \bar{s}_2) = 2A\bar{s}_1\bar{s}_2 - w(\bar{s}_1) - w(\bar{s}_2), \tag{2}$$

with $\bar{s}_l$, $l = 1, 2$, denoting the average skill of the group from which the worker for task l is hired, and $w(\bar{s}_l)$ being the expected wage paid to this worker. Lemma 1 gives the solution to this optimisation problem.

Lemma 1 *Firms maximise expected profits by hiring workers of the same expected skill.*

Proof See the appendix.

Wages cannot be based on individual ability, since this is private information. Consequently, each worker is paid half the firm's output independent of her actual contribution. Using this remuneration rule, the expected wage rate of an individual worker with skill s equals

$$w(\bar{s}_\ell, s) = A\bar{s}_\ell s, \tag{3}$$

where $\bar{s}_\ell$ with $\ell \in \{L, H\}$ is the average skill of the group to which the individual belongs. We assume that migration is costly, and the cost is equal to c. Although workers cannot observe the individual skill of their potential co-workers, the distribution of skills in both countries is known, such that expectations can be formed with regard to a potential co-worker's average skill $\bar{s}_\ell$. It is now straightforward to show that our model leads to self-selection of the most able individuals into emigration.

To see this, consider some arbitrary cutoff ability $\tilde{s}$ that separates high-skill and low-skill individuals. The average skills in the two groups, L and H, are $\bar{s}_L = \tilde{s}/2$ and $\bar{s}_H = (1+\tilde{s})/2$ due to our assumption of a uniform distribution, and the resulting difference between the averages of both groups $\bar{s}_H - \bar{s}_L$ is equal to $1/2$ for all values of $\tilde{s}$. The expected wage gain for an individual worker of being paired with a co-worker from group H is now given by $A(\bar{s}_H - \bar{s}_L)s = As/2$, and it follows immediately that this gain is increasing in an individual's skill s. With identical migration cost for each individual, and assuming an interior solution, i.e. $0 < \tilde{s} < 1$, it follows that high-skilled individuals self-select into migrating abroad, while low-skilled individuals are deterred from migration by the cost attached to it. For the indifferent worker with skill, $\tilde{s}$, the condition $A\tilde{s}/2 = c$ holds, which immediately gives the migration cutoff in the *laissez-faire* equilibrium as

$$\tilde{s}^{\mathrm{lf}} = \frac{2c}{A}. \tag{4}$$

Self-selection into migration, $\tilde{s}^{\mathrm{lf}} \in (0,1)$, then obviously requires $c \in (0, A/2)$. Proposition 1 summarises:

Proposition 1 *With strictly positive but not prohibitively high migration cost, all workers with skill $s > \tilde{s}^{lf} = 2c/A$ emigrate, while all workers with skill $s \leq \tilde{s}^{lf} = 2c/A$ stay in their home country. Migration flows increase for a higher level of technology A, and for lower migration cost c.*

Proof See the appendix.

Taking stock, our model is able to explain two-way, high-skilled migration flows between two ex ante and ex post symmetric countries, which are driven by the desire of high-skilled workers to get separated from their low-skilled counterparts. In the resulting equilibrium costly migration acts as a signalling device, allowing high-skilled workers to (partly) reveal their true skill levels as in Spence (1973).

Lemma 1 and Proposition 1 together imply that firms hire only migrants or only natives. While this extreme implication of our model is counterfactual of course, Hellerstein and Neumark (2008), Andersson, García-Pérez, Haltiwanger, McCue, and Sanders (2014), Aslund and Skans (2010), Dustmann, Glitz, Schönberg, and Brücker (2015) and Glitz (2014) find that there is indeed considerable segregation of natives and migrants across workplaces in the US, Sweden and Germany.[9] Interestingly, Hellerstein and Neumark (2008), Andersson, García-Pérez, Haltiwanger, McCue, and Sanders (2014) and Aslund and Skans (2010) also find that the high degree of workplace segregation between natives and migrants in the US and Sweden is only weakly related to the workers' general education. Picking up on this, we show in Section 4.1 below that a simple extension of our model, in which the abilities of some individuals are observable, is compatible with the empirical observation of imperfect workplace segregation between (high-skilled) natives and migrants.

As another straightforward implication of Proposition 1 we find the extreme result that within each country migrants are at the top, while natives are at the bottom of the skill distribution with no overlap in both groups' skill ranges. Modelling imperfectly transferable skills in line with the empirical findings by Mattoo, Neagu, and Özden (2008) and Chiswick and Miller (2009) we show in Section 4.2 that our model can account for an overlap in the skill range of migrants and natives. Alternatively we show in Section 4.3 that a similar result can be obtained if workers can choose between migration and education as signalling devices. Since the key mechanisms driving migration in our model are unaffected by these extensions, we stick to our more parsimonious formulation with unobservable but perfectly transferable skills and migration as the only signalling device for the time being, in order to save on notation and terminology.

[9] Hellerstein and Neumark (2008) find that 39.4% of Hispanics in the US have a co-worker who is also Hispanic, while only 4.5% of the white workers have Hispanic co-workers. Comparing this to a probability of 6.9% for having a Hispanic co-worker under random matching reveals a substantial workplace segregation by ethnicity. Figure 1 in Andersson, García-Pérez, Haltiwanger, McCue, and Sanders (2014) plots the cumulative distribution of the immigrant co-worker share for natives and migrants, respectively, which significantly differ from the distribution that would result under random assignment.

3 Welfare

In order to analyse the welfare effects of migration, the natural comparison is the scenario of prohibitive migration cost $c \geq A/2$, which leads to $\tilde{s}^{\text{lf}} = 1$ (the "autarky case"). The value of aggregate production equals total wage income, which for an arbitrary cutoff $\tilde{s}$ is given by

$$Y(\tilde{s}) = A\left[\int_0^{\tilde{s}} \left(\frac{\tilde{s}}{2}\right)^2 \mathrm{d}s + \int_{\tilde{s}}^1 \left(\frac{1+\tilde{s}}{2}\right)^2 \mathrm{d}s\right] = \frac{A\left[1+\tilde{s}(1-\tilde{s})\right]}{4}. \tag{5}$$

Total output is therefore minimised under autarky ($\tilde{s} = 1$), and maximised if exactly half the individuals become migrants ($\tilde{s} = 1/2$). Aggregate output rises, since firms that recruit their workers from a labour market with a more diverse labour supply are able to discriminate between the groups of natives and migrants. Since workers of the same nationality are more similar with respect to their (unobservable) skills, we find, that firms in a more fractionalised labour market realise productivity gains (cf. Trax, Brunow, and Suedekum, 2015) from the more efficient matching of workers according to Lemma 1.

Aggregate welfare equals the difference between total output and total migration cost:

$$W(\tilde{s}, c) = \frac{A[1+\tilde{s}(1-\tilde{s})]}{4} - c(1-\tilde{s}). \tag{6}$$

We can now use the link between $\tilde{s}^{\text{lf}}$ and c provided by (4) to express aggregate welfare in the laissez-faire equilibrium as a function of $\tilde{s^{\text{lf}}}$ alone:

$$W(\tilde{s}^{\text{lf}}) = \frac{A\left[1-\tilde{s}^{\text{lf}}(1-\tilde{s}^{\text{lf}})\right]}{4}. \tag{7}$$

Thus, the effect of migration on aggregate welfare is diametrically opposed to its effect on total output: Aggregate welfare is maximised under autarky ($\tilde{s}^{\text{lf}} = 1$), and minimised if exactly half the individuals become migrants ($\tilde{s}^{\text{lf}} = 1/2$).

We now look at individual welfare, which is identical to an individual's expected wage rate, net of migration cost, if applicable. Non-migrants' and migrants' welfare is given by

$$w_L(\tilde{s}^{\text{lf}}, s) = \frac{A\tilde{s}^{\text{lf}}s}{2} \qquad \text{and} \qquad w_H(\tilde{s}^{\text{lf}}, s) - c = \frac{A[s-\tilde{s}^{\text{lf}}(1-s)]}{2},$$

respectively. We see that all individuals are worse off than in the autarky equilibrium, where the expected wage rate of an individual with skill s is equal to $As/2$.[10] For non-migrants, this simply happens because the pool of co-workers available for matching now has a lower average skill. For migrants, this is explained by a negative external effect induced by migration that can best be seen by a thought experiment, in which individual migration occurs sequentially, in the order of decreasing ability of migrants: Every migrant, apart from the most skilled one, in this case reduces the average skill of individuals in the migrant pool, thereby inflicting losses on infra-marginal migrants' wages. This effect is rationally ignored by individual migrants.

Figure 2: *Laissez-faire equilibrium*

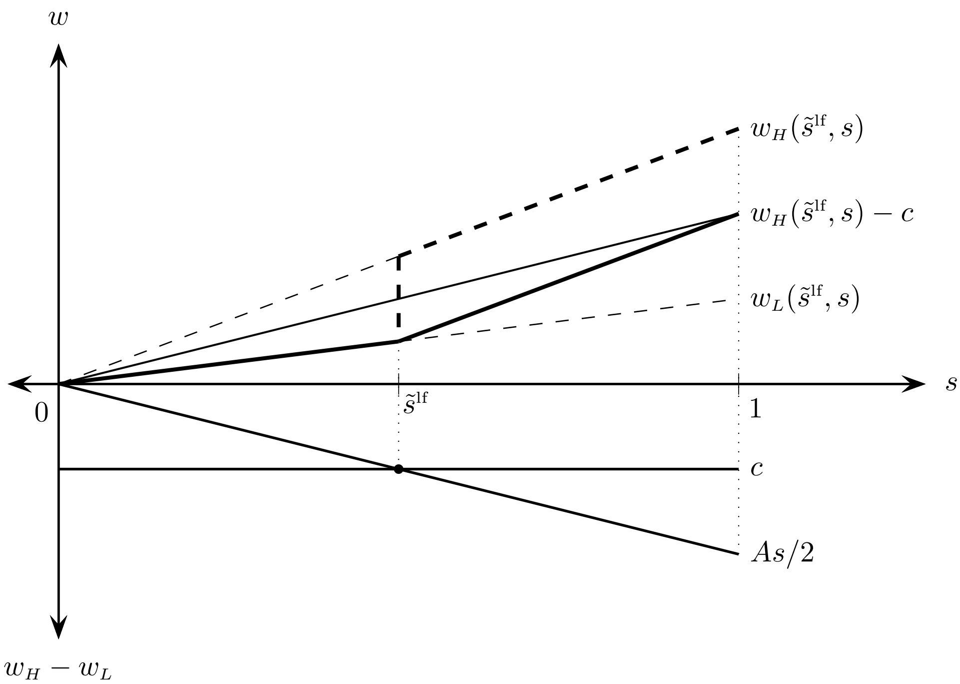


Figure 2 illustrates the results. The bottom quadrant shows how the migration cutoff is determined by the equality of migration cost and expected migration gain for the marginal migrant. The top quadrant shows in bold the resulting wage profile in the open economy as a function of individual ability s where for migrants a distinction is made between the gross wage

[10]Of course this result depends on the assumed skill distribution. As we show in a supplement, which is available from the authors upon request, an equilibrium in which every worker is worse off results for all skill distributions, which feature a convex cumulative density function, while for skill distributions with concave cumulative density functions there are net gains from migration for the most able migrants.

(bold dashed) and the net wage, which subtracts migration cost (bold solid). The wage profile in autarky is given by the thin solid line for comparison. Aggregate welfare is measured by the area under the autarky wage profile and open economy wage profile, respectively.

The main welfare implications of high-skilled migration are summarised as follows:

Proposition 2 *International migration leads to aggregate production gains, and to losses in aggregate welfare. Furthermore, all individuals are worse off in the laissez-faire migration equilibrium than in the autarky equilibrium.*

Following the approach of Benhabib and Jovanovic (2012) we now look at the social planner equilibrium. The social planner can freely choose the migration cutoff $\tilde{s}$ taking as given migration cost c, but disregarding individuals' migration incentives, which link $\tilde{s}^{\mathrm{lf}}$ to c in the *laissez-faire* equilibrium. Maximising (6) with respect to $\tilde{s}$ gives the optimal migration cutoff, $\tilde{s}^{\mathrm{sp}}$, and hence the socially optimal extent of migration as a function of c:

$$\tilde{s}^{\mathrm{sp}} = \frac{1}{2} + \frac{2c}{A}. \tag{8}$$

Hence, while there is "too much" migration in the laissez-faire equilibrium due to the negative migration externality, the optimal level of migration is strictly positive if migration costs are sufficiently low. Note also that $\tilde{s}^{\mathrm{sp}} > 1/2$ and therefore it is never socially optimal to have more than half the population emigrating. It furthermore follows from (8) that zero migration is enforced by the social planner ($\tilde{s}^{\mathrm{sp}} = 1$) whenever $c \geq A/4$.

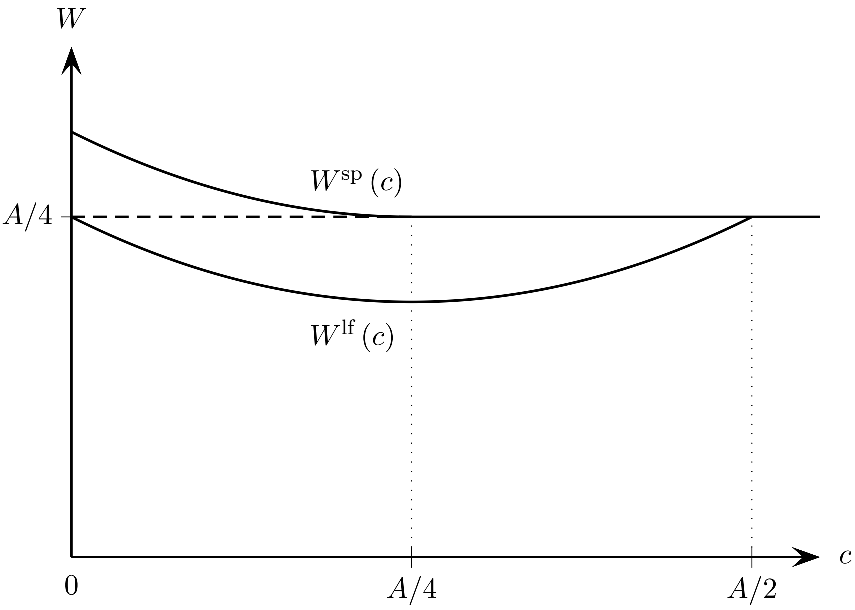
We can compare welfare in the laissez-faire and social planner scenarios by substituting the respective migration cutoffs from (4) and (8) into (6), thereby expressing aggregate welfare in each scenario as a function of migration cost:

$$W^{\mathrm{lf}}(c) = \frac{A}{4} - c\left(\frac{1}{2} - \frac{c}{A}\right), \tag{9}$$

$$W^{\mathrm{sp}}(c) = \frac{5A}{16} - c\left(\frac{1}{2} - \frac{c}{A}\right), \tag{10}$$

and it is easily checked that $W^{\mathrm{sp}}(c)$ is strictly larger than autarky welfare $A/4$ for all non-prohibitive levels of c. The relationship between aggregate welfare and migration cost in the laissez-faire equilibrium and the social-planner equilibrium is illustrated in Figure 3.

Figure 3: *Aggregate Welfare*

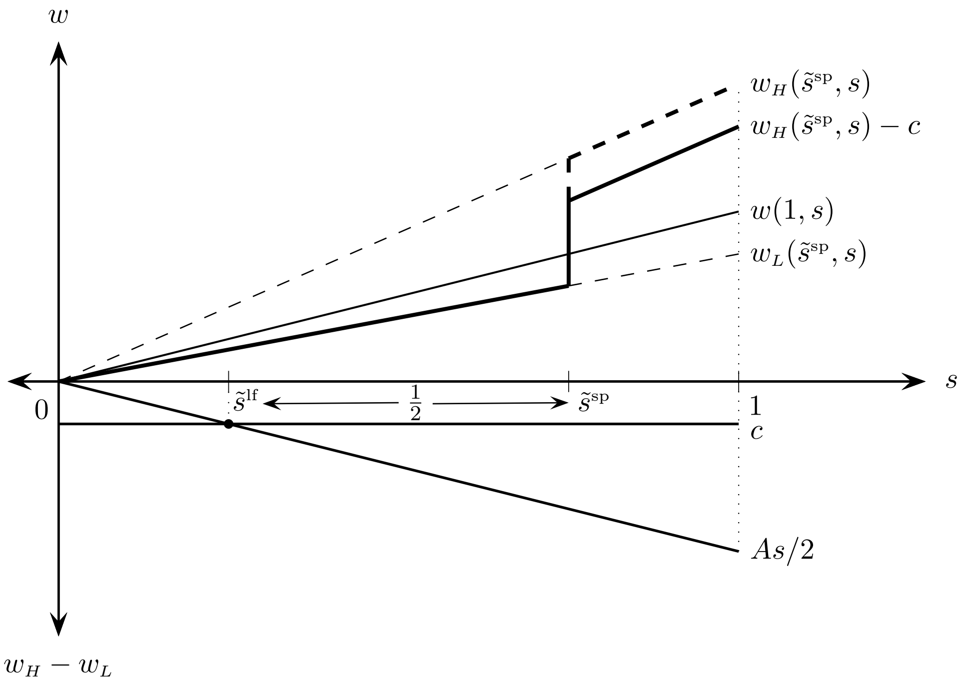


We now look at the effect that a socially optimal level of international migration has on individual wages. Clearly, non-migrants are worse off with any level of high-skill emigration, since the expected quality of their co-workers falls. Hence, we can restrict our attention to comparing the expected net wage of migrants in the social optimum with the respective wage in autarky. The net wage of migrants is given by

$$w_H(\tilde{s}^{\mathrm{sp}}, s) - c = \frac{A(1+\tilde{s}^{\mathrm{sp}})s}{2} - c,$$

and, substituting for $\tilde{s}^{\mathrm{sp}}$, it is immediate that there is a wage gain relative to autarky for migrants with skill, $s > 4c/(4c+A)$. Simple algebra shows that this threshold value is strictly smaller than $\tilde{s}^{\mathrm{sp}}$ as derived in (8), and therefore in the social optimum all migrants are better off than under autarky. Figure 4, which is directly analogous to Figure 2 (but for expositional purposes considers a smaller migration cost c) illustrates this. In constructing Figure 4, we use the fact that from our results (4) and (8) we know that $\tilde{s}^{\mathrm{sp}} = \tilde{s}^{\mathrm{lf}} + 1/2$. Furthermore, the size of the jump in the wage profile in the upper quadrant at $\tilde{s}^{\mathrm{sp}}$ is determined by the the wage gain for the marginal migrant, which is determined in the lower quadrant. Proposition 3 summarises the results:

Figure 4: *Social planner equilibrium*



Proposition 3 *The socially optimal level of migration is strictly lower than in the laissez-faire equilibrium, if the latter features positive migration levels. For $c < A/4$ the socially optimal level of migration is strictly positive. In the social optimum, all migrants are better off than under autarky, while all non-migrants are worse off.*

The social optimum can alternatively be implemented by a tax on migration by both countries. In this case, individual incentives to migrate are again relevant, of course. We assume that a country's tax revenue is distributed equally to all nationals, independent of their residence, and hence does not affect the migration decision. Note that what countries care about in our setup is emigration, not immigration: Immigrants do not interact with natives, and hence have no effect on their wage rate, while emigration reduces the quality of matches available for those left behind. Hence, a government in our framework would set an emigration tax, not an immigration tax. Condition (4) now holds in a modified form, with effective (tax-inclusive) migration cost $c + t$ replacing c:

$$\tilde{s} = \frac{2(c+t)}{A}.$$

Substituting for $\tilde{s}$, using $\tilde{s}^{\text{sp}}$ from Eq. (8), implies $t^{\text{sp}} = A/4$. Notably, the optimal emigration tax rate does not depend on whether it is set cooperatively between countries, or non-cooperatively. This is due to the fact, mentioned above, that a country's welfare is independent of the extent of immigration (which is the only variable affected by the other country's emigration tax).

Figure 5: *Equilibrium with optimal emigration tax*

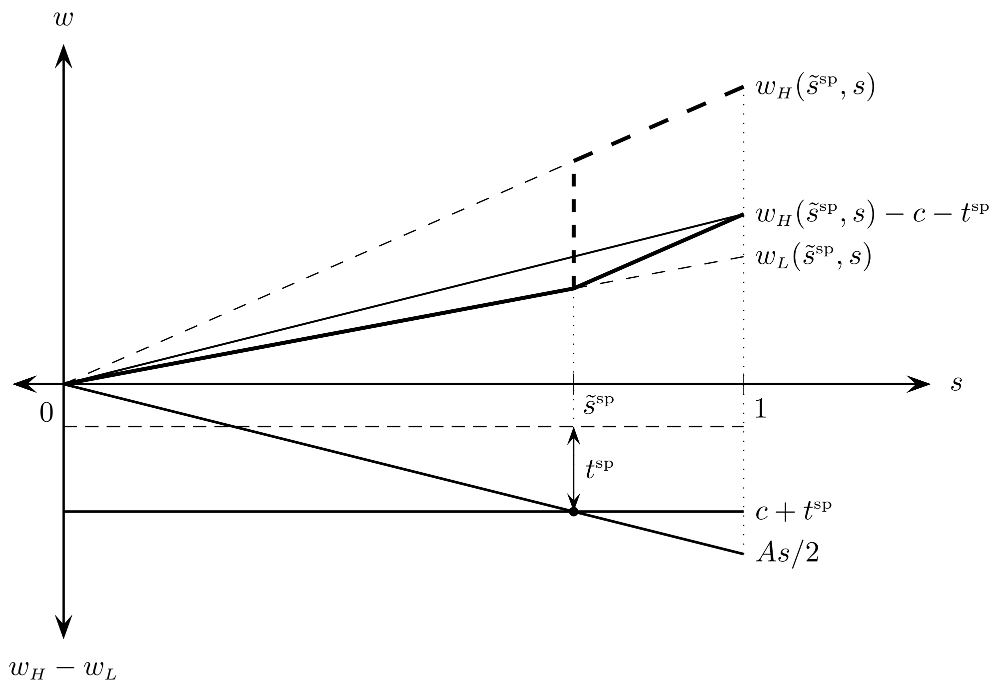


Figure 5 shows the resulting distribution of wages, where as before the bold dashed line gives the distribution of gross wages, and the bold solid line gives the distribution of net wages, subtracting effective migration cost $c + t^{\text{sp}}$. While in principle Figure 5 resembles Figure 2 from the laissez-faire equilibrium, with $c + t^{\text{sp}}$ substituted for c, there is one crucial difference: The migration equilibrium now yields tax revenue, which is equally redistributed among natives. The resulting transfer-inclusive wage is not shown in Figure 5 in order to avoid clutter, but it is clear that the transfer leads to a parallel upward shift in the net-wage profile. Consequently, individuals with the highest abilities and individuals with the lowest abilities are better off than in autarky: For both groups the absolute pre-transfer losses relative to autarky are small, as shown above, and therefore their transfer-inclusive incomes are higher than in autarky. It can be shown analytically that this simple tax-transfer scheme does not make everyone better off than in autarky, and hence individuals with intermediate abilities (the most high-skilled non-migrants and the least skilled migrants) see their transfer-inclusive net wages fall.[11]

4 Extensions

Five important assumptions of the model presented in Sections 2 and 3 are that *(i)* individual ability of all workers is unobservable, *(ii)* migrants' skills are perfectly transferable across countries, *(iii)* migration is the only available signalling device, *(iv)* internationally mobile labour is the only factor of production, and *(v)* countries are ex ante identical in all respects. We now consider extensions of our model, where we relax these five assumptions one at a time. In doing so, we focus on the most interesting implications of the respective extension. In Section 4.1 we consider the case where the ability of individuals becomes observable with a positive probability. In Section 4.2 we allow for imperfect transferability of migrants' skills. In Section 4.3 we introduce education as an alternative signalling device. In Section 4.4 we add an internationally immobile factor of production to the model. In Section 4.5 we consider country asymmetries.

4.1 Imperfect Observability of Skill

As discussed earlier, one key stylised fact that our benchmark model does not capture well is the imperfect segregation between high-skilled migrants and non-migrants in the workplace, as documented by Hellerstein and Neumark (2008), Andersson, García-Pérez, Haltiwanger, McCue, and Sanders (2014), Aslund and Skans (2010). In our benchmark model the probability of a given migrant being matched with another migrant is equal to one, while the empirical studies find matching rates in excess of those that would be found under random matching, but significantly smaller than one. We now demonstrate that imperfect observability of skill leads to exactly the same outcome in our model.[12]

For the sake of continued tractability we model the imperfect observability of abilities in a parsimonious and stylised way. Consider the following sequence of events. Before individuals

[11] The proof is shown in a supplement available from the authors upon request.

[12] Hendricks (2001) introduces the possibility of cross-matching between migrants and natives by assuming that an exogenous fraction of migrants is indistinguishable from natives.

decide about migration their abilities are revealed with probability $p \in (0, 1)$. Then, as in our baseline model, individuals decide whether to migrate, incurring migration cost $c > 0$, or to stay put. This decision is based on a comparison of expected incomes. Once migration has taken place, with probability $q \in (0, 1)$ the abilities of those whose skills have been private knowledge so far, are revealed. Finally, firms hire workers and production takes place.

Before considering a worker's migration decision in this changed environment, we have to derive the wage schedule for workers with observable skills. The firm's profit maximisation problem can analogously to (2) be written as

$$\max_{s_1, s_2} \pi (s_1, s_2) = 2As_1 s_2 - w (s_1) - w (s_2), \tag{11}$$

in which s_l, $l = 1, 2$, refers to the skill of a worker performing task $l = 1, 2$, while $w (s_l)$ denotes the wage paid to this workers. The solution to the profit maximisation problem is given by the following lemma:

Lemma 2 *If workers' skills are perfectly observable, firms maximise their profits by hiring only workers with exactly the same skill level.*

Proof Positive assortative matching of workers within firms follows immediately from the supermodularity of (1), see Kremer (1993). ■

Using the zero profit condition as well as the result on positive assortative matching in (11), the wage rate of a worker with observable skill level s is given by

$$w (s) = As^2. \tag{12}$$

Now it is easy to see that individuals with ex ante observable skills have no incentive to migrate, irrespective of their skill level: They are positively assortatively matched in any case, leaving them with a wage rate as given by (12), and by staying put they can save migration cost c. For workers whose skill is unobservable ex ante, an analogous logic to Section 2 applies: They know that with probability $1 - q$ their skill level remains unobservable ex post, in which case a switch from low-skill group L, with $\bar{s}_L = \tilde{s}/2$, to high-skill group H, with $\bar{s}_H = (1 + \tilde{s})/2$, yields a wage gain of $As/2$. However, with probability q their skill level is revealed ex post and the worker earns the same wage at home and abroad. Hence, the expected wage gain of switching from group L to H amounts to $(1-q)As/2$. For the indifferent worker with skill $\tilde{s}$ condition $(1-q)A\tilde{s}/2 = c$ must hold, giving a migration cutoff

$$\tilde{s}^{\mathrm{lf}} = \frac{2c}{(1-q)A}. \tag{13}$$

Comparison to (4) from the benchmark model shows that a positive probability q of a migrant's skill being revealed ex post increases the migration cutoff, i.e. reduces the incidence of migration among those with ex ante undisclosed skill levels.

We now illustrate the degree of workplace segregation predicted by our model. Consider first the probability that a randomly picked migrant would have another migrant as a co-worker under random matching. This would happen with a probability equal to the migrants' population share, which is $(1-p)\,(1-\tilde{s}^{\mathrm{lf}})$. Now consider the same probability predicted by the model. With probability $(1-q)$ the migrant's skill is private knowledge, in which case he is matched with another migrant with probability one. With probability q his skill is revealed ex post, and he is matched with a co-worker of identical skill. Within the relevant group of individuals whose skill has been revealed, the share of migrants is $(1-p)q/[(1-p)q+p]$, where $(1-p)q$ is the share of migrants of known skill in the overall population at this skill level, and p is the share of natives in the overall population at this skill level.

Hence, in our extended model the probability for a random migrant to be matched with another migrant is equal to

$$\mathrm{Prob}(p,q) = 1-q+q\left[\frac{(1-p)q}{(1-p)q+p}\right],$$

and it is easily shown that $\mathrm{Prob}(p,0) = 1$, $\mathrm{Prob}(p,1) = 1-p$, and $\partial\mathrm{Prob}/\partial q < 0$. Hence, the probability for a random migrant to be matched with another migrant is higher than under random matching. Interestingly, for a given migrant the probability of being matched with another migrant does not depend on his skill level s. This is also compatible with the results from Hellerstein and Neumark (2008), Andersson, García-Pérez, Haltiwanger, McCue, and Sanders (2014), and Aslund and Skans (2010), who find that workplace segregation is at most weakly related to skill levels. Summing up, we have the following result:

Proposition 4 *The probability of migrants to have a co-worker who is also a migrant does not depend on their skill level, and it is furthermore smaller than one, but larger than under random assignment of workers into workplaces.*

4.2 Imperfect Transferability of Skills

As discussed in Section 2, our baseline model implies zero overlap in the skill range of migrants and natives: Migrants are always at the top of the destination country's wage distribution, while natives are at the bottom. This outcome is a consequence of the assumption in the benchmark version of our model that skills are perfectly transferable between countries. In accordance with results from Mattoo, Neagu, and Özden (2008) and Chiswick and Miller (2009), who show that immigrants in the US are more likely to suffer from occupational "underplacement" than natives, we now allow for a less than perfect transferability of workers' pre-migration skills. In particular, we assume that migrants can transfer only a fraction θ of their skills, while the fraction $1-\theta$ of skills is country specific and therefore becomes obsolete when going abroad. The migration arbitrage condition then reads

$$\frac{A\tilde{s}}{2}\left[(1+\tilde{s})\theta^2-\tilde{s}\right]=c, \tag{14}$$

where we have substituted $\bar{s}_L=\tilde{s}/2$ and $\bar{s}_H=\theta\left(1+\tilde{s}\right)/2$. Solving for the *laissez-faire* migration cutoff $\tilde{s}^{\mathrm{lf}}$ yields

$$\tilde{s}^{\mathrm{lf}}=\frac{A\theta^2-\sqrt{A^2\theta^4-8\left(1-\theta^2\right)c}}{2A\left(1-\theta^2\right)}, \tag{15}$$

where $\tilde{s}^{\mathrm{lf}}\in(0,1)\ \forall\ c\in\left(0,A\left(2\theta^2-1\right)/2\right)$, which implies that an economically meaningful solution requires $\theta\in(\sqrt{1/2},1]$. Differentiating (15), we find that given our parameter constraint for θ, we have $\partial\tilde{s}^{\mathrm{lf}}/\partial\theta<0$. Thus, as one would reasonably expect, lower skill transferability θ weakens the incentive to migrate. There is now an overlap of the skill distributions by migrants and natives, respectively, since the lowest-skill immigrant has skill level $\theta\tilde{s}^{\mathrm{lf}}$, while the highest-skill native has skill level $\tilde{s}^{\mathrm{lf}}$. Proposition 5 sums up.

Proposition 5 *If skills are imperfectly transferable internationally, the skill distributions of migrants and natives overlap.*

4.3 Migration vs. Education as Signalling Devices

While in our baseline model the only way for individuals to signal their true skill is by costly migration, in reality there is of course a wide range of possible signals, with education being probably the best known example, as already outlined by Spence (1973). We now analyse whether the presence of costly education as an alternative signalling device limits the importance of our signalling story in explaining the phenomenon of two-way migration.

Similar to migration, education involves a fixed cost, $c_e > 0$, and workers can now choose whether to emigrate, to get an education, or to do neither. Focussing on the signalling aspect of education, it is assumed that education does not alter workers' skills. Firms observe both signals and use this information to form more efficient matches at the workplace. The equilibrium is derived in the same way as in the baseline model. The results are summarised in the following proposition.

Proposition 6 *With costly migration and costly education as two alternative ways for workers to signal their skill, and provided the cost of neither signal is prohibitive,*

(i) high-skilled workers select into the costlier signal, while medium-skilled workers select into the less costly signal, whenever costs for the two signals are sufficiently different,

(ii) high-skilled workers select into the costlier signal, and the other signal is not chosen, whenever costs for the two signals are sufficiently similar.

Proof See the appendix.

The intuition for Proposition 6 is the following. If the costs of the two signals are sufficiently different, high-skilled workers use the costlier signal to get separated from co-workers with lower skills. Medium-skilled workers are deterred from the costlier signal, but they have an incentive to get separated from low-skilled workers, which is achieved by selecting into the signal with the lower cost. Now consider the case where the costs of the two signals become more similar, by holding the cost of the cheaper signal constant, while the cost of the more expensive signal gradually declines. As the costlier signal is easier to afford, the group of individuals choosing the cheaper signal shrinks at both ends: The most high-skilled in this group now select the expensive signal. This in turn makes it less attractive for everybody else to be in this group, causing workers to drop out at the lower end as well. With converging costs of the two signals, this mechanism eventually leads to the disappearance of the group choosing the cheaper signal.

Figure 6: *Possible equilibria with two alternative signals*

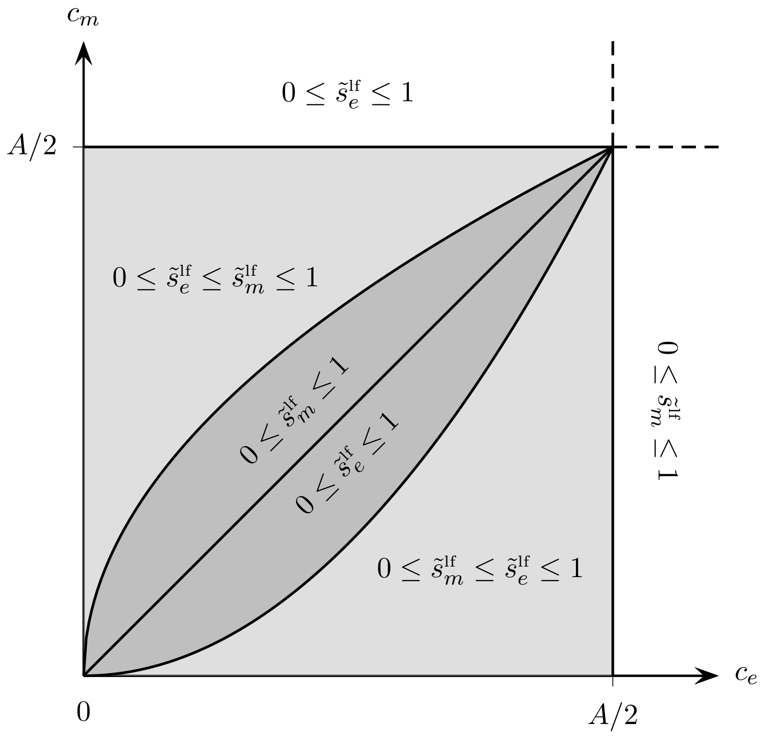


Figure 6 illustrates this result. The two curves enclosing the dark lens are given by $c_m = 2c_e^2/A$ and $c_e = 2c_m^2/A$, respectively. All parameter constellations within this lens represent cases in which the costs for the two signals are similar, and in these cases only the costlier signal is used. For combinations of c_m and c_e outside the lens, but inside the light, grey square both signals coexist with the high-skilled (medium-skilled) workers using the expensive (cheap) signal. If one of the signals is prohibitively expensive, i.e. $c_m \geq A/2$ or $c_e \geq A/2$, only the cheaper one is used. If both are too costly, none is used.

To sum up, in general, adding education as an alternative signalling device does not rule out the use of migration as a signal. In fact for the largest part of the relevant parameter space both signals coexist. In particular it is shown in the appendix that, if $0 < c_e < c_m < A/2$, the resulting migration cutoff $\tilde{s}_m$ is the same as in Eq. (4). Only for parameter combinations leading to $0 < 2c_e^2/A < c_m < c_e < A/2$ education completely replaces migration as a signalling device.[13]

4.4 Internationally Immobile Factors of Production

In this subsection, we add internationally immobile capital to our model. Capital is modelled as an essential input in all firms, and hence we introduce an interaction between migrants and domestic factors of production that is standard in most migration models (cf. Berry and Soligo, 1969; Borjas, 1999), but has not been a feature of our basic model. The production technology is unchanged with respect to labour, i.e. there are two tasks, which have to be performed by exactly one worker each, and following Kremer (1993) we assume that capital is combined with labour in a Cobb-Douglas fashion. The resulting production function is given by

$$y = f(s_1, s_2, k) = 2As_1s_2k^\alpha, \tag{16}$$

with $\alpha \in [0, 1]$ denoting the partial production elasticity of capital and k being the per capita capital stock used in production. With firms knowing only the average skill within the groups, L and H, Lemma 1 implies positive assortative matching of group members. The profit maximising level of capital depends on whether the firm employs individuals from group H or L, and we show in the appendix that the amount of capital used by either type of firm is given by:

$$k_L = \left[\tilde{s} + (1-\tilde{s})\left(\frac{1+\tilde{s}}{\tilde{s}}\right)^{\frac{2}{1-\alpha}}\right]^{-1}\bar{k}, \tag{17}$$

$$k_H = \left[(1-\tilde{s}) + \tilde{s}\left(\frac{\tilde{s}}{1+\tilde{s}}\right)^{\frac{2}{1-\alpha}}\right]^{-1}\bar{k}, \tag{18}$$

where $\bar{k}$ is the average capital stock in the economy. It is easily checked that $k_H \geq \bar{k} \geq k_L$. Hence, firms employing workers of a higher expected ability, which in equilibrium will be firms employing migrants, have a higher capital intensity.

[13] If the cost of education declines in a worker's skill, such that the effective cost of eduction for an individual with skill s equals c_e/s instead of c_e, it can be shown that the equilibrium is of the type $0 < \tilde{s}_m^{\mathrm{lf}} < \tilde{s}_e^{\mathrm{lf}} < 1$ for all $0 < c_m < c_e < A/2$.

In analogy to Section 2, wages are determined by splitting available revenue (now the difference between total firm revenue and payments to capital) equally between the two workers. Capital returns are distributed equally among the nationals of a country, and hence capital ownership does not distort the decision to migrate. In analogy to the baseline model, the laissez-faire migration equilibrium is then determined by the condition that the wage gain for the marginal migrant is equal to the migration cost. We get

$$\tilde{s}^{\mathrm{lf}} = \frac{2c}{A(1-\alpha)\bar{k}^{\alpha}} \left(\Phi\right)^{-1}, \tag{19}$$

with

$$\Phi \equiv (1+\tilde{s}^{\mathrm{lf}}) \left(\frac{k_H}{\bar{k}}\right)^{\alpha} - \tilde{s}^{\mathrm{lf}} \left(\frac{k_L}{\bar{k}}\right)^{\alpha} \geq 1,$$

where the inequality is strict whenever $\alpha > 0$. Comparison with (4) shows that the relative size of the laissez-faire migration cutoffs in the two models depends on two effects. A larger value for $(1-\alpha)\bar{k}^{\alpha}$ increases migration flows since the migration cost falls in relation to average income. The second effect is given by Φ^{-1}, and it shows that an additional incentive to migrate exists in the extended model, which stems from the reallocation of domestic capital towards firms employing (more productive) migrants.

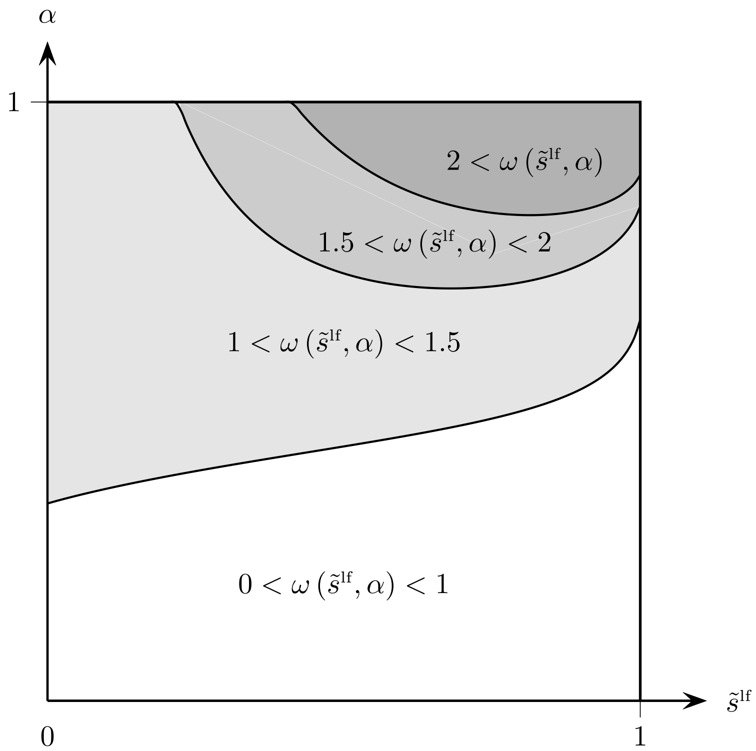
We now turn to the welfare implications that migration has in the framework with capital just described. Going through the same steps as in the baseline model, we find that aggregate welfare in the laissez-faire migration equilibrium is given by

$$W(\tilde{s}^{\mathrm{lf}}, \alpha) = \frac{A\left\{k_H^{\alpha} - \left[2\Phi(1-\alpha)\bar{k}^{\alpha} - k_H^{\alpha}\right]\tilde{s}^{\mathrm{lf}}(1-\tilde{s}^{\mathrm{lf}}) - \left(k_H^{\alpha} - k_L^{\alpha}\right)\left(\tilde{s}^{\mathrm{lf}}\right)^3\right\}}{4}, \tag{20}$$

and it is easily checked that autarky welfare is equal to $W(1,\alpha) = A\bar{k}^{\alpha}/4$. We can now compute the relative welfare levels in the migration equilibrium and in autarky, $\omega\left(\tilde{s}^{\mathrm{lf}}, \alpha\right) \equiv W\left(\tilde{s}^{\mathrm{lf}}, \alpha\right)/W\left(1, \alpha\right)$, where aggregate migration gains exist whenever $\omega(\tilde{s}^{\mathrm{lf}}, \alpha) > 1$.

Figure 7 provides a contour plot of $\omega\left(\tilde{s}^{\mathrm{lf}}, \alpha\right)$ for all combinations of $\tilde{s}^{\mathrm{lf}}$ and α, where combinations that lead to $\omega\left(\tilde{s}^{\mathrm{lf}}, \alpha\right) > 1$ are highlighted in different shades of grey. All other combinations lead to aggregate welfare losses from migration. We find that in contrast to our baseline model that abstracts from complementarities in production between internationally mobile and immobile factors, there exists now a non-trivial parameter space where welfare losses from the

Figure 7: *Aggregate welfare in a model with capital*



negative migration externality are overcompensated by the efficiency gains resulting from the reallocation of capital towards migrant-employing firms. The results are summarised as follows:

Proposition 7 *For high (low) values of α the model features aggregate welfare gains (losses) from international migration.*

Turning to the social planner's solution, one can show that the socially optimal level of migration will be lower than the one in the *laissez-faire* equilibrium given by Eq. (19).[14] It is easy to see why: Adding capital to the model opens up a new channel for gains from migration, but does not add a new distortion. Hence, the migration externality remains the only distortion in the model. As an immediate consequence migration levels in the *laissez-faire* equilibrium will in general be too high.

[14] The proof is deferred to a supplement available from the authors upon request.

4.5 Country Asymmetries

We now extend our baseline model by assuming $A_D \neq A_F$, where A_D denotes the technology level of the domestic economy while A_F refers to the corresponding technology parameter in the foreign economy. Recalling Eq. (3), the two country-specific indifference conditions for the marginal migrant can be written as

$$\frac{A_i \tilde{s}_i}{2}\left[\frac{A_j}{A_i}(1+\tilde{s}_i)-\tilde{s}_i\right]=c \quad \forall \quad i,j \in \{D,F\} \quad \text{with} \quad i \neq j, \tag{21}$$

where we have used $\bar{s}_{Li} = \tilde{s}_i/2$ and $\bar{s}_{Hi} = (1+\tilde{s}_i)/2$. Solving for $\tilde{s}_i^{\text{lf}}$ yields

$$\tilde{s}_i^{\text{lf}} = \frac{A_j - \sqrt{A_j^2 + 8\,(A_j - A_i)\,c}}{2\,(A_i - A_j)} \quad \forall \quad i,j \in \{D,F\} \quad \text{with} \quad i \neq j. \tag{22}$$

It is now easy to check that the technologically superior country experiences net immigration, i.e. for $A_j > A_i$ we have $\tilde{s}_j^{\text{lf}} > \tilde{s}_i^{\text{lf}}$. Moreover, it follows from differentiating (21) that $\partial \tilde{s}_i^{\text{lf}}/\partial A_i > 0 > \partial \tilde{s}_i^{\text{lf}}/\partial A_j$ if countries are not too dissimilar, i.e. if $2/3 < A_D/A_F < 3/2$. This is the case we focus on henceforth. Thus, emigration increases if the technology in the destination country gets better, while it falls if the same occurs in the source country. The prohibitive level of migration cost is now also country-specific: Setting $\tilde{s}_i^{\text{lf}} = 1$ in (22), we find that emigration occurs from country i whenever $c < (2A_j - A_i)/2$.

Turning to the welfare implications of migration, aggregate welfare of nationals from country $i \in \{D,F\}$ can be expressed analogously to Eq. (6) as

$$W_i(\tilde{s}_i, c) = \frac{(A_i - A_j)(\tilde{s}_i)^3}{4} + \frac{A_j[1+\tilde{s}_i(1-\tilde{s}_i)]}{4} - (1-\tilde{s}_i)c, \tag{23}$$

for all $i,j \in \{D,F\}$ with $i \neq j$. In analogy to the baseline model we can use the link between migration cost and the laissez-faire migration cutoff in (22) to express aggregate welfare as a function of $\tilde{s}_i^{\text{lf}}$ alone:

$$W_i^{\text{lf}}(\tilde{s}_i^{\text{lf}}) = \frac{A_i(\tilde{s}_i^{\text{lf}})^2(2-\tilde{s}_i^{\text{lf}})}{4} + \frac{A_j[1-(\tilde{s}_i^{\text{lf}})^2](1-\tilde{s}_i^{\text{lf}})}{4}. \tag{24}$$

Migration leads to aggregate welfare gains for the nationals of country i, whenever $W_i(\tilde{s}_i^{\text{lf}}) > W_i\,(1) = A_i/4$ for $\tilde{s}_i^{\text{lf}} \in (0,1)$, where (22) can be used to derive the necessary condition on the cost of migration. We find the following:

Proposition 8 *Aggregate welfare is lower in a migration equilibrium than under autarky for nationals of the country with the better technology. For nationals of the technologically inferior country, aggregate welfare gains from migration exist if migration costs are sufficiently low.*

Proof See the appendix.

Relative to the baseline model, in which all individuals lose from trade in the laissez-faire equilibrium, country asymmetries result in an additional welfare effect that is positive for migrants from the technologically inferior country (since they use a more efficient technology in the destination country) and negative for migrants from the other country. It is therefore intuitively plausible that only nationals from the technologically inferior country may gain in the aggregate from migration.[15]

With the asymmetric version of our model at hand we can now return to Figure 1, which compares two-way migration within the EU15 and the OECD. Using (22) and focussing (without loss of generality) on the case $A_j \geq A_i$, it is now possible to compute the familiar index of bilateral balance in migration:

$$B_{ij}(\tilde{s}_i^{\text{lf}}, \tilde{s}_j^{\text{lf}}) = \frac{2 \min (\text{Em}_{ij}, \text{Em}_{ji})}{\text{Em}_{ij} + \text{Em}_{ji}} = \frac{2(1 - \tilde{s}_j^{\text{lf}})}{2 - \tilde{s}_j^{\text{lf}} - \tilde{s}_i^{\text{lf}}}. \tag{25}$$

Note that, if countries are identical, i.e. $A_j = A_i = A$, we have $\tilde{s}_j^{\text{lf}} = \tilde{s}_j^{\text{lf}} = \tilde{s}^{\text{lf}}$ and $B_{ij}(\tilde{s}_i^{\text{lf}}, \tilde{s}_j^{\text{lf}})$ in (25) takes a value of one. Moreover, it is straightforward to show that $B_{ij}(\tilde{s}_i^{\text{lf}}, \tilde{s}_j^{\text{lf}})$ declines monotonically as $A_j - A_i$ increases: As countries become more dissimilar migration becomes less balanced. This is in accordance with the results in Table 1, which show that migration of tertiary educated individuals between EU15 country pairs is more balanced than between country pairs in the more heterogeneous group of OECD countries.

[15] Notably, the negative migration externality discussed in Section 3 is also present here. In particular we can show that the migration cutoffs $\tilde{s}_i^{\text{sp}} \ \forall \ i = D, F$ that an omniscient social planner would choose are strictly higher than the ones from Eq. (22). The mathematical proof is deferred to a supplement available from the authors upon request.

5 Conclusion

In this paper we have developed a model that can explain two-way migration of high-skilled individuals between countries at the same level of economic development. In our model high-skilled individuals use costly migration as a way to signal their true skill level. Support for our theory can be found in the pattern of high-skilled migration among rather similar countries (like the EU15, or Canada and the US), which, as we have shown, is characterised by a substantial degree of "two-way-ness".

Our baseline model is extremely simple, but for this very reason it is transparent as well, and it furthermore lends itself to a comprehensive welfare analysis. We identify a negative externality from migration, resulting from the fact that the marginal migrant ignores the negative effect her migration decision has on expected wages of both natives and migrants. As a consequence, there is too much migration in the laissez-faire equilibrium with positive migration cost, and aggregate welfare is lower than in autarky. This does not mean, however, that *all* migration in our model is socially harmful. We show that, if migration cost is sufficiently low, a social planner would choose strictly positive migration levels. The negative migration externality in this case has to be traded off against the better quality of matches within firms that can be achieved due to the existence of a well-defined high-skill group, comprising the migrants.

The negative migration externality is a fundamental feature of our framework, which survives in more general versions of our model. The persistence of the negative externality notwithstanding, aggregate gains from migration re-emerge as a possible feature of the laissez-faire equilibrium once our baseline framework is amended by standard features known from other migration models. In particular, once we introduce a second factor that is internationally immobile and a complement to labour in production, aggregate gains from migration exist, provided the income share of this factor is sufficiently high and migration cost is sufficiently low. The welfare gains in this case result from a more efficient domestic allocation of internationally immobile factors of production, notably in the absence of any country asymmetries that would normally be responsible for positive welfare effects of migration.

6 Appendix

6.1 Proof of Lemma 1

In order to prove Lemma 1 it suffices to show that given production function (1) firms optimally decide to match only workers of the same expected skill, such that $\bar{s}_l = \bar{s}_\ell$ with $l = 1, 2$ and $\ell \in \{L, H\}$. The simple proof presented here is taken from Basu (1997). For a more general proof of positive assortative matching see Becker (1991) or Sattinger (1975).

Consider two different arbitrary average skill levels, $\bar{s}_L$ and $\bar{s}_H$, with $\bar{s}_H > \bar{s}_L$. A firm facing optimisation problem (2) now has three different possibilities of pairing workers:

$$\pi(\bar{s}_H, \bar{s}_H) = 2A\bar{s}_H^2 - 2w(\bar{s}_H), \tag{A.1}$$

$$\pi(\bar{s}_L, \bar{s}_L) = 2A\bar{s}_L^2 - 2w(\bar{s}_L), \tag{A.2}$$

$$\pi(\bar{s}_H, \bar{s}_L) = 2A\bar{s}_H\bar{s}_L - w(\bar{s}_H) - w(\bar{s}_L). \tag{A.3}$$

Let us first suppose $\pi(\bar{s}_H, \bar{s}_L) \geq \pi(\bar{s}_H, \bar{s}_H)$ which results in the following chain of inequalities

$$2A\bar{s}_H\bar{s}_L - w(\bar{s}_H) - w(\bar{s}_L) \geq 2A\bar{s}_H^2 - 2w(\bar{s}_H), \tag{A.4}$$

$$2A\bar{s}_H(\bar{s}_H - \bar{s}_L) \leq w(\bar{s}_H) - w(\bar{s}_L), \tag{A.5}$$

$$2A\bar{s}_L(\bar{s}_H - \bar{s}_L) < w(\bar{s}_H) - w(\bar{s}_L), \tag{A.6}$$

$$2A\bar{s}_H\bar{s}_L - w(\bar{s}_H) - w(\bar{s}_L) < 2A\bar{s}_L^2 - 2w(\bar{s}_L), \tag{A.7}$$

where $\bar{s}_H > \bar{s}_L$ has been utilised to derive inequality (A.6) from (A.5). Note that inequality (A.7) implies $\pi(\bar{s}_L, \bar{s}_L) \geq \pi(\bar{s}_H, \bar{s}_L)$. Now imagine $\pi(\bar{s}_L, \bar{s}_H) \geq \pi(\bar{s}_L, \bar{s}_L)$ giving rise to

$$2A\bar{s}_H\bar{s}_L - w(\bar{s}_H) - w(\bar{s}_L) \geq 2A(\bar{s}_L)^2 - 2w(\bar{s}_L), \tag{A.8}$$

$$2A\bar{s}_L(\bar{s}_H - \bar{s}_L) \geq w(\bar{s}_H) - w(\bar{s}_L), \tag{A.9}$$

$$2A\bar{s}_H(\bar{s}_H - \bar{s}_L) > w(\bar{s}_H) - w(\bar{s}_L), \tag{A.10}$$

$$2A(\bar{s}_H)^2 - 2w(\bar{s}_H) > 2A\bar{s}_H\bar{s}_L - w(\bar{s}_H) - w(\bar{s}_L), \tag{A.11}$$

where again $\bar{s}_H > \bar{s}_L$ has been utilised to derive inequality (A.10) from (A.9). Inequality (A.11) implies $\pi(\bar{s}_H, \bar{s}_H) \geq \pi(\bar{s}_H, \bar{s}_L)$. Taking stock, profits from positive assortative matching always surpass profits from cross matching, such that firms always decide to pair workers of identical skill, i.e. $\bar{s}_l = \bar{s}_\ell$. ■

6.2 Proof of Proposition 1

The proof proceeds in two steps. At first we prove the existence and uniqueness of an equilibrium with positive selection into migration, i.e. $\tilde{s} \in (0,1)$ for $c \in (0, A/2)$. Then it is shown that the equilibrium with no migration is unique provided that $c \geq A/2$.

For the equilibrium with $c \in (0, A/2)$ to exist, it must hold that at least one worker has an incentive to deviate, when being in an equilibrium without migration, while no worker wants to deviate, when being in an equilibrium with migration. More formally, focussing on the worker with the maximum skill, $s = 1$, it can be shown that $w(\bar{s}, 1) = A/2 < w(1,1) - c = A - c \ \forall \ c \in (0, A/2)$. Conversely, it follows for all workers, $s \in [\tilde{s}, 1]$, that $w(\bar{s}_L, s) \leq w(\bar{s}_H, s) - c \ \forall \ c = \tilde{s}A/2 \in (0, A/2)$. To see this, note that the above inequality simplifies to $\tilde{s} \leq s$, once $c = \tilde{s}A/2$ as well as $\bar{s}_L = \tilde{s}/2$ and $\bar{s}_L = (1 + \tilde{s})/2$ are replaced. Uniqueness can be proven by considering a simple counter example which readily extents to more general cases. Imagine two (or more) cutoffs, $0 < \tilde{s}_1 < \tilde{s}_2 < 1$, exist. Moreover assume all workers with $s \in [0, \tilde{s}_1) \ \wedge \ s \in [\tilde{s}_2, 1]$ and average skill, $\bar{s}_1$, stay in Home, while all workers with $s \in [\tilde{s}_1, \tilde{s}_2)$ and average skill, $\bar{s}_2$, select into migration. For the workers with critical abilities, $\tilde{s}_1$ and $\tilde{s}_2$, then must hold that $w(\bar{s}_1, \tilde{s}_1) = w(\bar{s}_2, \tilde{s}_1) - c$ and $w(\bar{s}_1, \tilde{s}_2,) = w(\bar{s}_2, \tilde{s}_2) - c$, respectively. Since $w(\bar{s}_\ell, s) \ \forall \ \ell = 1, 2$ increases monotonically in s, the above two conditions can only be fulfilled simultaneously, if $\tilde{s}_1 = \tilde{s}_2 = \tilde{s}$, which rules out multiplicity of equilibria.

The equilibrium without migration is stable for $c \geq A/2$, if no individual with skill, $s \in [0,1]$, has an incentive to deviate, i.e. even if deviation allows to match with the most high-skilled co-worker with $s = 1$, the condition, $w(\bar{s}, s) \geq w(1, s) - c$, should hold. Replacing $c \geq A/2$ this condition simplifies to $1 \geq s$, which is fulfilled for all $s \in [0,1]$. $\blacksquare$

6.3 Proof of Proposition 6

Without loss of generality let us focus on $c_e > c_m$, the opposite case, $c_m > c_e$, then follows by symmetry. Equilibrium may feature up to three groups of workers: migrants, educated workers, and those who do not signal at all. The corresponding subindices are $\hat{\ell} \in \{m, e, n\}$. As in the baseline model the wage rate of a worker with skill $s_{\hat{\ell}}$ is given by Eq. (3), i.e. $w\left(\bar{s}_{\hat{\ell}}, s_{\hat{\ell}}\right) = A\bar{s}_{\hat{\ell}} s_{\hat{\ell}}$ with $\bar{s}_{\hat{\ell}}$ being the average skill in group $\hat{\ell} \in \{m, e, n\}$. At prohibitive cost, $c_m \geq A/2$ and /or

$c_e \geq A/2$, no worker with $s \in [0,1]$ has an incentive to deviate from an equilibrium without migration. To see this, note that $w(\bar{s}, s) \geq w(s, s) - c_m$, in which $\bar{s} = 1/2$, can be rewritten as $1 \geq s \ \forall \ s \in [0,1]$, once we take into account that $c_m \geq A/2$. An analogous logic applies to education, if $c_e \geq A/2$.

For scenario *(i)* to arise the sorting $0 \leq \tilde{s}_m < \tilde{s}_e \leq 1$ has to apply. Note that all workers with $s \in [0, \tilde{s}_m)$ choose not to signal, all workers with $s \in [\tilde{s}_m, \tilde{s}_e)$ select into migration and all workers with $s \in [\tilde{s}_e, 1]$ select into education. The resulting average skills in the three groups are then given by $\bar{s}_n = \tilde{s}_m/2$, $\bar{s}_m = (\tilde{s}_m + \tilde{s}_e)/2$ and $\bar{s}_e = (\tilde{s}_e + 1)/2$. Intuitively, $\bar{s}_e > \bar{s}_m > \bar{s}_n$. For the marginal workers, $\tilde{s}_m$ and $\tilde{s}_e$ the following two arbitrage conditions apply

$$w(\bar{s}_n, \tilde{s}_m) = w(\bar{s}_m, \tilde{s}_m) - c_m, \tag{A.12}$$

$$w(\bar{s}_m, \tilde{s}_e) - c_m = w(\bar{s}_e, \tilde{s}_e) - c_e. \tag{A.13}$$

Solving both equations yields $\tilde{s}_e = 2c_e/A$ and $\tilde{s}_m = c_m/c_e$ for all $c_m < 2c_e^2/A < A/2$. Note that the first inequality sign in this condition follows from $\tilde{s}_m < \tilde{s}_e$, while the second inequality sign follows from $\tilde{s}_e < 1$.

Scenario *(ii)* is derived in a stepwise fashion by eliminating all possible equilibrium sortings, except for $0 \leq \tilde{s}_e \leq \tilde{s}_m = 1$. Intuitively, $0 \leq \tilde{s}_m < \tilde{s}_e \leq 1$ cannot be an equilibrium, since for $2c_e^2/A < c_m < c_e < A/2$, this sorting is incompatible with the incentive constraints (A.12) and (A.13). Assuming $0 \leq \tilde{s}_e < \tilde{s}_m \leq 1$ would imply that $\bar{s}_m > \bar{s}_e$. Recalling that $c_e > c_m$, this cannot be a stable outcome, as workers with $s \in [\tilde{s}_e, \tilde{s}_m)$, who select into education, bear larger cost, $c_e \geq c_m$, and have smaller gains, $w(s, \bar{s}_m) > w(s, \bar{s}_e)$, than those who select into migration. Clearly, for any worker with $s \in [\tilde{s}_e, \tilde{s}_m)$ using migration instead of education as a signalling device would be optimal. Since we already have shown that the equilibrium without migration does not exist for $c_m < c_e < A/2$, the only remaining equilibrium constellations are $0 \leq \tilde{s}_m \leq \tilde{s}_e = 1$ and $0 \leq \tilde{s}_e \leq \tilde{s}_m = 1$. Intuitively, individual incentives are such that each worker who is inclined to signal, prefers to be in the same group as the workers with the maximum skill, $s = 1$. On the contrary, the workers with $s = 1$ are indifferent between both signals, since in both equilibria welfare equals $w(\bar{s}_m, 1) - c_m = w(\bar{s}_e, 1) - c_e = A/2$. Extending this comparison to all workers with $s \in [\bar{s}_e, 1]$, it can be easily shown that $w(\bar{s}_m, s) - c_m \leq w(\bar{s}_e, s) - c_e$. Thus, all workers with $s \in [\tilde{s}_e, 1]$ weakly prefer $0 \leq \tilde{s}_e \leq \tilde{s}_m = 1$ over $0 \leq \tilde{s}_m \leq \tilde{s}_e = 1$, such that $0 \leq \tilde{s}_e \leq \tilde{s}_m = 1$ is the only equilibrium for $2c_e^2/A < c_m < c_e < A/2$. ∎

6.4 Derivation of Eqs. (17) and (18)

Facing the production function from (16), and knowing only the average skill within the two groups, L and H, firms optimally match together only workers from the same subgroup, L or H. We can therefore separately write down the reduced form profit maximization problem for the resulting two types of firms:

$$\max_{k_\ell} \;\; \pi_\ell(k_\ell) = 2A\bar{s}_\ell^2 k_\ell^\alpha - 2w(\bar{s}_\ell) - rk_\ell \;\; \forall \;\; \ell \in \{L, H\}\,. \tag{A.14}$$

The profit maximising level of capital depends on whether the firm employs individuals from group H or L. It follows from

$$\frac{\partial \pi_\ell(k_\ell)}{\partial k_\ell} = 2A\alpha\bar{s}_\ell^2 k_\ell^{\alpha-1} - r \stackrel{!}{=} 0 \;\; \forall \;\; \ell \in \{L, H\}\,, \tag{A.15}$$

and we get the standard result that the rate of return to capital, r, equals its value marginal product. Using the above equation in combination with the full employment condition:

$$\bar{k} = \tilde{s}k_L + (1-\tilde{s})\,k_H, \tag{A.16}$$

as well as $\bar{s}_L = \tilde{s}/2$ and $\bar{s}_H = (1+\tilde{s})/2$ allows us to solve for the amount of capital used by firms solely employing natives or migrants, respectively:

$$k_L = \left[\tilde{s} + (1-\tilde{s})\left(\frac{1+\tilde{s}}{\tilde{s}}\right)^{\frac{2}{1-\alpha}}\right]^{-1}\bar{k}, \tag{A.17}$$

$$k_H = \left[(1-\tilde{s}) + \tilde{s}\left(\frac{\tilde{s}}{1+\tilde{s}}\right)^{\frac{2}{1-\alpha}}\right]^{-1}\bar{k}, \tag{A.18}$$

with $k_H \geq \bar{k} \geq k_L$. ∎

6.5 Proof of Proposition 8

We start by proving that $W_i(\tilde{s}_i^{\mathrm{lf}}) \leq W_i(1) = A_i/4 \;\; \forall \;\; A_i \geq A_j$. Note that for $\tilde{s}_i^{\mathrm{lf}} = 1$ we obtain $W_i(1) = A_i/4$ from Eq. (24). Using this together with $W_i(\tilde{s}_i^{\mathrm{lf}})$ from Eq. (24) we obtain

$$\begin{aligned} W_i(\tilde{s}_i^{\mathrm{lf}}) - W_i(1) &= (A_j - A_i)\left[1 + (\tilde{s}_i^{\mathrm{lf}})^3\right] - A_i(1+\tilde{s}_i^{\mathrm{lf}})\,\tilde{s}_i^{\mathrm{lf}} + A_i 2\,(\tilde{s}_i^{\mathrm{lf}})^2 \\ &\leq (A_j - A_i)\left[1 + (\tilde{s}_i^{\mathrm{lf}})^3 - 2\,(\tilde{s}_i^{\mathrm{lf}})^2\right], \end{aligned} \tag{A.19}$$

where the last line is non-positive whenever $1 + (\tilde{s}_i^{\mathrm{lf}})^3 - 2(\tilde{s}_i^{\mathrm{lf}})^2 \geq 0$ and $A_i \geq A_j$. Since $1 + (\tilde{s}_i^{\mathrm{lf}})^3 - 2(\tilde{s}_i^{\mathrm{lf}})^2$ has a local maximum at $\tilde{s}_i^{\mathrm{lf}} = 0$ and intersects the abscissa at $\tilde{s}_i^{\mathrm{lf}} = 1$ and $\tilde{s}_i^{\mathrm{lf}} = 1/2 \pm \sqrt{5/4}$, we have $1 + (\tilde{s}_i^{\mathrm{lf}})^3 - 2(\tilde{s}_i^{\mathrm{lf}})^2 \geq 0 \;\forall\; \tilde{s}_i^{\mathrm{lf}} \in [0, 1]$ and, hence, $W_i(\tilde{s}_i^{\mathrm{lf}}) \leq W_i(1) \;\; \forall\; A_i \geq A_j$. In order to complete the proof of Proposition 8 it remains to show that for $A_j > A_i$ we have $W_i^{\mathrm{lf}}(c) \geq A_i/4 \;\forall\; 0 \leq c \leq \frac{1}{4}\left(2A_j - 3A_i + \sqrt{4A_j^2 - 8A_iA_j + 5A_i^2}\right)$, while $W_i^{\mathrm{lf}}(c) < A_i/4 \;\forall\; \frac{1}{4}\left(2A_j - 3A_i + \sqrt{4A_j^2 - 8A_iA_j + 5A_i^2}\right) < c < \frac{1}{2}(2A_j - A_i)$. Using (22) to substitute for $\tilde{s}_i^{\mathrm{lf}}$ in (24), it can be shown that $W_i^{\mathrm{lf}}(c) - A_i/4 = 0$ has three solutions, which are

$$c_1 = \frac{1}{2}(2A_j - A_i), \tag{A.20}$$

$$c_2 = \frac{1}{4}\left(2A_j - 3A_i + \sqrt{4A_j^2 - 8A_iA_j + 5A_i^2}\right), \tag{A.21}$$

$$c_3 = \frac{1}{4}\left(2A_j - 3A_i - \sqrt{4A_j^2 - 8A_iA_j + 5A_i^2}\right). \tag{A.22}$$

Note that since $2/3 < A_D/A_F < 3/2$, solution (A.22) is negative and therefore economically irrelevant. Solution (A.20) equals the prohibitive migration cost at which $\tilde{s}_i^{\mathrm{lf}} = 1$. Finally, it is easily checked that $0 < \frac{1}{4}\left(2A_j - 3A_i + \sqrt{4A_j^2 - 8A_iA_j + 5A_i^2}\right) < \frac{1}{2}(2A_j - A_i)$. Since Eq. (24) implies $W_i^{\mathrm{lf}}(0) = A_j/4 > A_i/4$ we can immediately infer that for low migration cost, i.e. $0 \leq c \leq \frac{1}{4}\left(2A_j - 3A_i + \sqrt{4A_j^2 - 8A_iA_j + 5A_i^2}\right)$ aggregate welfare gains exist, while for high migration cost, $\frac{1}{4}\left(2A_j - 3A_i + \sqrt{4A_j^2 - 8A_iA_j + 5A_i^2}\right) < c < \frac{1}{2}(2A_j - A_i)$, aggregate losses result. ■

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