International Mobility of the Highly-Skilled, Endogenous R&D, and Public Infrastructure Investment*

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Abstract

This paper theoretically and empirically analyzes the interaction of migration of highly skilled labor and relative income between source and destination economies of expatriates. In a model with endogenous education and R&D investment decisions we show that international integration of the market for skilled labor aggravates between-country income inequality by harming those which are source economies to begin with while benefiting host economies. The result is robust to allowing governments to optimally adjust productivity-enhancing investments which could potentially attenuate brain drain. Optimal public investment even decreases in response to higher emigration. Consistent with our main hypothesis, we provide empirical support from 159 countries that increasing emigration causes log income differences between source and destination countries to widen.

Key words: Brain drain; Cross-country evidence; Educational choice; Public infrastructure investment; R&D investment.

JEL classification: F22; O30; H40.

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1 Introduction

In the year 2000, 20.4 million tertiary educated immigrants lived OECD countries, up from about 12.5 million in the year 1990 (Docquier and Marfouk, 2006). Half of the skilled migrants resided in the US and about a quarter in other Anglo-Saxon countries. Although in high-income countries the "emigration rate" of skilled workers (share of tertiary educated emigrants as a fraction of the sum of tertiary educated residents and emigrants) was a remarkable 3.5 percent, it was about twice as high in less developed countries. Brain drain is particularly high from poorly developed regions such as the Caribbean (with an emigration rate of 42.8 percent), Central America (16.9 percent) and Sub-Saharan Africa (13.1 percent). The outflow of skilled individuals from developing countries may further increase in the near future, as liberalization of international labor markets, particularly for high-skilled workers, is still ongoing. For instance, in view of the so far relatively little success of many EU countries to attract high-skilled labor from abroad, the European Commission proposed in October 2007 the so-called "blue card" scheme to significantly reduce immigration barriers for high-qualified workers.

This paper examines the implications of increasing mobility of the highly skilled for migration patterns and income differences between source and destination economies of expatriates. In a neoclassical framework, if anything, increased migration of high-skilled labor raises the wage rate per unit of skilled labor in the source economy and decreases it in the destination. As income differences are the main determinant of migration patterns in the first place (e.g. Lucas, 2005; Grogger and Hanson, 2008), this suggests that further integration of labor markets for the highly qualified would reduce between-country income inequality. However, we show this does not hold in a framework with increasing returns and endogenous technical change. To the contrary, due to scale effects which typically arise in models with endogenous R&D investment, migration flows of skilled workers aggravate global income differences. Our analysis demonstrates this point by developing a model where firms choose employment of researchers and professionals who conduct in-house R&D and individuals choose whether or not to acquire education. We show that a reduction in mobility costs raises income in economies which attracted skilled immigrants in the first place and harms economies already facing a brain drain.

<Figure 1>

Figure 1 presents first evidence consistent with this result. It plots the change between 1990 and 2000 in the total number of skilled emigrants (aged 25+) to OECD countries as fraction of skilled residents in 1990 ($MigChange$) against the change in the gap between log income per capita in a country to the OECD average ($GDPChange$).[1] The figure suggests that increasing brain drain is associated with widening income differences. We test this hypothesis more extensively in a sample of 159 countries by examining the impact of an increase in emigration between pairs of source and OECD destination countries to (log) per capita income differences between country pairs.

In order to provide a more comprehensive analysis of the interaction between global income differences and brain drain, we also allow for national public policy responses to increasing labor market integration. Prima facie, in view of the fact that income differences trigger migration flows, one may suspect that countries experiencing additional brain drain should compensate for the adverse effects by spending more on publicly financed productivity-enhancing measures. An increase in public investment would raise income of high-skilled labor, therefore attenuating brain drain. However, our analysis shows that it is optimal to reduce public investment expenditure when declining mobility costs lead to increased outflows of high-skilled labor.[2] Conversely, it is optimal to raise public investment levels if the economy is more prone to immigration. This suggests that the positive association between (net) emigration and (log) income differences still holds when allowing governments to adjust infrastructure expenditure. Figure 2 provides some evidence for the prediction that increases in migration outflows of skilled labor are positively associated with increasing differences in public infrastructure investment levels between source and host economies. It shows a positive relationship of $MigChange$ to the change between 1990 and 2000 in the gap of government acquisition of fixed assets

[1] Per capita income of those countries above the zero-line on the y-axis in Figure 1 thus diverged from the OECD average between 1990 and 2000.

[2] The result is not due to a decrease in the tax base stemming from additional outflows. It would still hold if individuals were forced to pay taxes in their country of birth, irrespective of their residency.

as fraction of GDP to the OECD average ($PubInvestChange$).[3]

<Figure 2>

The remainder of this paper is organized as follows. Section 2 discusses related literature. Section 3 presents the model. Section 4 analyzes the relationship between migration flows and income gaps without and with optimal adjustment of public investment. Section 5 confronts the main theoretical hypothesis with empirical evidence. The last section provides concluding remarks.

2 Related Literature

To the best of our knowledge, our paper is the first one which explicitly analyzes brain drain in a framework of endogenous technical change, thereby featuring endogenous scale effects on wage income implied by endogenous migration flows. In line with seminal papers on brain drain like Bhagwati and Hamada (1974), we emphasize adverse effects of outward migration for the source economy. More recently, scholars pointed to potential brain gain effects for the sending country (e.g., Mountford, 1997; Stark, Helmenstein and Prskawetz, 1997, 1998; Beine, Docquier and Rapoport, 2001). They show that if emigration prospects of skilled workers in developing countries are uncertain due to immigration quotas in advanced countries, a higher quota (better emigration prospect) fosters incentives to acquire education. The drain effect from higher outflows may then be dominated by an increase in the domestic skilled labor force. While not denying this possibility, our theoretical analysis does not emphasize such a mechanism.[4] We also abstract from potential gains for source economies from remittances since we are

[3] We experimented with other measures of public investment and obtained similar results. Countries above the zero-line on the y-axis in Figure 2 diverged in their public investment levels from the OECD average between 1990 and 2000.

[4] In our model higher emigration rates are associated with a higher fraction of skilled natives, too. However, an increase in the fraction of educated labor does not compensate the skill losses due to emigration. This is because there is no explicit immigration quota, albeit there exist migration costs. The migration possibilities are thus known ex ante to individuals in our framework and taken into account in the education decision. In fact, the empirical relevance of a potential brain gain mechanism seems to be confined to poor countries with rather low levels of human capital and low emigration rates of the skilled (Beine, Docquier and Rapoport, 2001, 2008). In these poorest countries, also R&D activity of firms which we endogenize in our framework plays little role.

interested in first-order effects of migration flows of high-skilled workers on the global distribution of income earned at source.

Another strand of literature has focussed on the implications of brain drain for the tax system (e.g. Bhagwati and Wilson, 1989; Wildasin, 2000; Andersson and Konrad, 2003) and education subsidies (Poutvaara and Kanniainen, 2000; Andersen, 2005). Instead, we analyze the implications of increasing mobility of high-skilled labor on public infrastructure expenditure for a given tax system. Our focus is also different but complementary to the literature on the implications of brain drain for public education finance (see e.g. Justman and Thisse, 1997, 2000; Egger, Falkinger and Grossmann, 2007). We assume that education is private but the government may incur productivity-enhancing investments apart from educational expenditures.

The theoretical part of our paper may be most closely related to Miyagiwa (1991) and Mountford and Rapoport (2007). Miyagiwa (1991) aims to explain why countries like the US can pay high wages to skilled professionals and therefore attract the best immigrants from abroad. He assumes that there are increasing returns to education, which implies that the wage level of educated workers rises with the amount of skilled labor. In our model, such scale effects are endogenously derived and we provide empirical evidence for them. Mountford and Rapoport (2007) analyze the interaction between migration flows, human capital formation in the presence of human capital externalities, and fertility. In their model, due to fertility responses, population size increases in poor countries which suffer from brain drain. Consequently, world inequality is predicted to rise in the longer run for a very different reason than in our model.

Regarding empirical evidence, our analysis complements two recent papers. First, Grogger and Hanson (2008) examine the impact of higher wage differences for skilled workers between source and destination as well as the impact of higher differences in skill premia on bilateral migration patterns of skilled labor. Second, Beine, Docquier and Ozden (2008) show that, in addition, the total stock of emigrants already living in a source country is an important determinant for subsequent emigration flows for skilled and unskilled labor. This suggests the presence of mobility-cost reducing networks effects from communities of people from the same nation and from friends and relatives already living abroad (see also Massey et al., 1993). In contrast to these contributions, we investigate the other direction of the relationship between income differences and emigration flows, namely the role of bilateral migration patterns for income differences between source and destination countries. In instrumental variable regressions we use, motivated by the research of Beine, Docquier and Ozden (2008), the total stock of emigrants as instrument for changes in emigration of skilled workers over time.

3 The Model

Consider a small economy which is populated by a unit mass of individuals, endowed with one unit of time. Each individual decides whether to become high-skilled, which requires $\bar{e} \in (0, 1)$ units of time,[5] or to remain low-skilled. High-skilled individuals may emigrate at some cost which may differ among individuals. In order to focus on migration patterns of high-skilled workers, we assume that low-skilled labor is immobile.[6] Time not used for education is inelastically supplied to a perfect labor market.

An individual i living at home cares exclusively about consumption level $c(i)$ of a homogenous final good. If the individual works abroad, utility is given by a discounted consumption level, $c(i)/(1 + \theta(i))$; see Stark, Helmenstein and Prskawetz (1997), and Egger, Falkinger and Grossmann (2007), among others. Parameter $\theta(i)$ captures, for instance, individual costs of living in a foreign social environment and the treatment of foreigners by administrative bodies. It is distributed according to a continuous p.d.f. $\varphi(\theta)$, with support Θ, $\theta \geq 0$. The c.d.f. of θ is denoted by $\Phi(\theta)$. When deciding whether or not to become skilled, individuals take both migration incentives and costs into account. The net wage rate of skilled labor, affecting migration incentives as will become apparent, is exogenously given by $\bar{w}_{net}$.

The final good is chosen as numeraire. It is produced under perfect competition,

[5] For simplicity, individuals are homogenous with respect to required education time. In supplementary material available on the authors' website, we allow for heterogeneity with respect to the ability of individuals to acquire education and show that the main results are robust to this extension.

[6] This can be motivated by the fact that migration costs are higher for people with lower education as they are more likely to have difficulties in finding a job, learning a foreign language and integrating in the foreign society. Furthermore, institutional barriers in potential host economies may prevent migration of low-skilled workers.

according to the technology

$$Y = X^{\alpha} Z^{1-\alpha}, \qquad 0 < \alpha < 1, \tag{1}$$

where X is a composite input consisting of n intermediate goods and input Z combines skilled and unskilled labor, H_Z and L_Z, respectively, according to

$$Z = B(H_Z)^{\beta}(L_Z)^{1-\beta}, \qquad 0 < \beta < 1, \; B > 0. \tag{2}$$

We assume that composite input X is given by the CES-index

$$X = \left[\int_0^n A(j)^{1-\alpha} x(j)^{\alpha} dj \right]^{\frac{1}{\alpha}}, \tag{3}$$

where $x(j)$ denotes the quantity of the intermediate input produced in sector $j \in [0, n]$ and $A(j)$ is the productivity parameter associated with that input.[7]

There is one firm in each intermediate goods sector. Intermediate goods producers can transform one unit of the final good into one unit of output. There is a large number of potential sectors in each economy. Entry is free but requires $f > 0$ units of skilled labor for setting up a firm.[8] Intermediate goods producers can improve productivity by employing high-skilled, non-production ("R&D") labor like scientists, engineers or managers. In line with the IO literature on innovation activities (e.g., Sutton, 1998), R&D investment costs are (endogenous) sunk costs for firms. Productivity $A(j)$ of intermediate good producer j which employs $h(j)$ units of R&D labor is given by

$$A(j) = a(h(j)), \tag{4}$$

where $a(\cdot)$ is an increasing and strictly concave function; moreover, let $\lim_{h \to 0} a'(h) \to \infty$ and $\lim_{h \to \infty} a'(h) = 0$.

According to (2), B measures the total factor productivity in the production of

[7] According to (1)-(3), there are constant-returns to scale in final goods production.

[8] Assuming instead that the set up requirement is partly or exclusively in terms of low-skilled labor is inconsequential for the main results.

intermediate good Z, referred to as "productivity" in what follows. It may be affected by public infrastructure investment, G, measured in terms of the final good. We assume $B = b(G)$, where $b(\cdot)$ is an increasing and strictly concave function with $b(0) > 0$; moreover, we assume $\lim_{G\to 0} b'(G) \to \infty$ and $\lim_{G\to\infty} b'(G) = 0$. Public infrastructure investment G is financed by proportional wage income taxation. The tax rate is denoted by $\tau \in (0, 1)$. It applies to all workers employed in the domestic economy (natives and immigrants, but not emigrants).[9]

We shall remark that all results would *exactly* remain the same if (2) and (4) were replaced by $Z = (H_Z)^\beta (L_Z)^{1-\beta}$ and $A(j) = Ba(h(j))$, respectively; that is, instead of raising productivity in $Z-$production, an increase in G would improve productivity of the R&D process. Thus, G may be interpreted as public infrastructure spending in a broad sense. One important question we wish to address is how (benevolent) national governments react to declining labor mobility costs, and possibly larger migration flows, if they have an instrument at hand which improves the economy's productivity.

4 Equilibrium Analysis

In this section we first analyze the equilibrium for given public investment, G, and then under optimal adjustment of public investment policy to migration.

4.1 R&D decision

We start with the decision of intermediate good firms. In view of the technology for final goods production, the inverse demand function for the latest version of intermediate input j is given by

$$p(j) = \alpha \left(\frac{A(j)Z}{x(j)} \right)^{1-\alpha} \left[= \frac{\partial Y}{\partial x(j)} \right], \tag{5}$$

[9] The assumption is made for concreteness. Results would be unchanged if immigrants were not be obliged to pay taxes or if emigrants still have to pay taxes at home, as will become apparent.

according to (1) and (3). Recalling that each firm has marginal cost of unity, "operating profits" (sales revenue minus production costs) of firm j are given by

$$\pi(j) = \max_{p(j),x(j)} \; [p(j) - 1]\, x(j) \;\; \text{s.t.} \;\; (5).$$

It is easy to show that prices are set according to $p(j) = 1/\alpha$ and intermediate good output levels are given by $x(j) = \alpha^{\frac{2}{1-\alpha}} A(j)Z$. Thus, resulting operating profits of a firm j read $\pi(j) = \delta A(j)Z$, where $\delta \equiv (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}$. Observing sunk costs and the R&D technology (4) prior to product market competition a firm j thus solves

$$\max_{h(j)} \delta Z a(h(j)) - wh(j) - wf, \tag{6}$$

where w denotes the wage rate for skilled labor. As firms are small, they take intermediate production level Z as given. The first-order condition associated with optimization problem (6) implies that R&D labor is the same for each firm j, i.e., $h(j) = h$. It is given by

$$\delta Z a'(h) = w. \tag{7}$$

Free entry implies that firms enter as long as operating profits ($\pi = \delta Z a(h)$) exceed sunk costs, $w(h+f)$; thus, in equilibrium,

$$\delta Z a(h) = w(h+f). \tag{8}$$

From (7), (8) and the properties of function $a(h)$ we find that there exists a unique R&D labor input per firm, h, which is implicitly given by

$$a(h) - a'(h)(h+f) = 0. \tag{9}$$

h only depends on the R&D technology and set up requirement f. In particular, it does neither depend on migration flows nor on public infrastructure expenditure.

4.2 Educational choice and equilibrium wages

Let q denote the domestic wage rate for unskilled labor. If not all skilled workers are migrating, in equilibrium, $w(1-\bar{e})=q$ must hold.[10] Denote the total number of (the endogenously determined) skilled and unskilled natives by H and L, respectively, i.e., $H+L=1$, and the mass of skilled emigrants by m. In equilibrium with labor market clearing, we have $L_Z=L$ and $H_Z+n(h+f)=(1-\bar{e})(H-m)$.[11] Thus, $H=1-L$ implies

$$(1-\bar{e})L+H_Z+n(h+f)=(1-\bar{e})(1-m). \tag{10}$$

We next derive the equilibrium wage rate for skilled labor, w, and the fraction of natives choosing education, H, for a given amount of emigrants, m. For this, we use (7), (9), (10), $w(1-\bar{e})=q$, $H+L=1$ together with the facts that price p_Z for the intermediate input Z equals marginal productivity of the final goods sector for this input, $\partial Y/\partial Z$, and that wage rates for skilled and unskilled labor are equal the respective marginal productivity in that sector, $w=p_Z\partial Z/\partial H_Z$ and $q=p_Z\partial Z/\partial L_Z$. We thus end up with seven equations, for the seven unknowns w, q, p_Z, H_Z, H, L, and n, where R&D input h is given by (9). Solving the system we obtain:

Lemma 1. *In equilibrium for a given amount of emigrants, m, the wage rate for skilled labor is given by*

$$w=\xi Ba'(h)(1-m), \tag{11}$$

where $\xi\equiv\delta\beta^{\beta}(1-\beta)^{1-\beta}\frac{(1-\bar{e})^{\beta}}{1+\alpha}$ is an unessential constant, and the fraction of skilled natives reads

$$H=\frac{\alpha+\beta+(1-\beta)m}{1+\alpha}. \tag{12}$$

All proofs are relegated to the Appendix. One can also show that per capita output of the final good, $y\equiv\frac{Y}{1-m}$, is given by $y=\tilde{\xi}Ba'(h)(1-m)$, where $\tilde{\xi}\equiv\frac{(1-\bar{e})\xi}{(1-\alpha)(1+\alpha)}$. Thus, y and wage rates are proportional to each other and positively depend on the "scale" of the domestic labor force, $1-m$; y and w therefore decline in the number of emigrants

[10] Recall that individuals have identical time costs, $\bar{e}$, to become skilled.

[11] Recall that skilled individuals work only a fraction $(1-\bar{e})$ of their time.

m. Such a scale effect is in line with almost all models of endogenous technical change.[12]

Three further remarks are in order. First, according to (9), there is no scale effect regarding R&D labor input per firm and thus no scale effect regarding average productivity of intermediate goods firms. This is because larger scale, and thus larger market size, means that more firms enter the economy, in a proportional way.[13] This feature of the model is consistent with recent empirical evidence provided by Laincz and Peretto (2006) in the context of vertical innovation models.[14] Second, note that raising productivity B has a lower effect on the wage rate w, the higher the number of emigrants (m) is. This insight plays an important role for the policy analysis in subsection 4.4. Third, note from (12) that the number of high-skilled individuals (H) is positively associated with the number of migrants, m. This is due to the complementarity of skilled and unskilled labor in the production of the intermediate input Z. Higher brain drain means that a lower amount of skilled labor is employed at home, which in turn raises the marginal productivity of skilled relative to unskilled labor and therefore fosters education incentives. However, we have $H_m < 1$, which implies that an increase in H is lower than the loss because of brain drain.[15] Moreover, $H > m$ whenever $m < 1$, i.e., both skilled and unskilled natives work in the considered economy.

4.3 Migration

We turn next to the migration decision of individuals. Let $w_{net} \equiv (1-\tau)w$ be the net wage rate a skilled worker earns at home (whereas $\bar{w}_{net}$ is earned abroad). As consumption equals after-tax wage income and is discounted by $\theta(i)$ when moving abroad, an individual i emigrates if $\bar{w}_{net} \geq (1+\theta(i))w_{net}$. This condition can be rewritten as $\theta(i) \leq \chi - 1$, where $\chi \equiv \bar{w}_{net}/w_{net}$ is the relative after-tax wage abroad. Thus, if $\chi \geq 1$,

[12] See Grossmann (2009) for an exception. For a comprehensive survey, see Jones (2005). As shown in supplementary material available on the authors' website, in a neoclassical model with endogenous educational choice, to the contrary, gross wage rates do not depend on the number of migrants. If the education structure is exogenous, w is *in*creasing in m.

[13] See the proof of Lemma 1 in Appendix.

[14] In vertical innovation models, R&D is targeted to productivity-improvements, like in this paper. Proportionality of firm size to the size of the domestic labor force is a key feature in this class of models.

[15] This is different to recent models with uncertain individual prospects to migrate, like Mountford (1997) or Stark, Helmenstein and Prskawetz (1997, 1998). In our model, individuals know in advance their migration prospects.

then the number of emigrants is given by $m = \int_0^{\chi-1} \varphi(\theta)d\theta = \Phi(\chi - 1)$. Suppose that in the case where $\chi < 1$, there will be immigration of $I(\chi)$ workers, i.e., $m = -I(\chi)$. We assume that $I(\chi)$ is a decreasing function (i.e. immigration rises if the relative wage χ abroad declines) and $I(1) = 0$. In sum, the number of migrants is given by

$$m = \begin{cases} \Phi(\chi - 1) \text{ if } \chi \geq 1, \\ -I(\chi) \text{ otherwise.} \end{cases} \tag{13}$$

Note that m increases if the relative after-tax wage abroad, χ, increases. Moreover, if $\chi = 1$, then $m = 0$.

The government budget constraint for financing public infrastructure, given tax rate τ, reads $G = \tau[qL + w(1 - \bar{e})(H - m)]$. Using equilibrium condition $q = w(1 - \bar{e})$ and $H + L = 1$, we have $\tau w = \frac{G}{(1-\bar{e})(1-m)}$. Employing the latter expression together with (11), it follows that the after-tax wage of skilled labor is given by

$$w_{net} = \xi B a'(h)(1 - m) - \frac{G}{(1 - \bar{e})(1 - m)} \equiv W(m, B, G). \tag{14}$$

Not surprisingly, higher productivity, $B = b(G)$, makes an economy less prone to brain drain ($W_B > 0$), all other things being equal. This holds because equilibrium wages are increasing in productivity. However, raising $B = b(G)$ by enhancing public infrastructure investment, G, comes at the cost of higher tax payments. This lowers net wages ($W_G < 0$) and through this effect fosters emigration. Outward migration of skilled workers has two negative effects on net wage rate w_{net} in the domestic economy, all other things equal: first, the gross wage declines due to the scale effect described in subsection 4.2 and, second, the tax base shrinks which in turn lowers after-tax income for a given public spending level; formally $W_m < 0$.[16]

Let us define $\tilde{W}(m, G) \equiv W(m, b(G), G)$. According to (14) and $b''(G) < 0$, for a given number of migrants, m, net wages are strictly concave as a function of public infrastructure investment, G, i.e., $\tilde{W}_{GG} < 0$. (This property is important when we turn

[16] If emigrants would be obliged to pay taxes in the source country, only the first effect was present. As still $W_m < 0$ in this case, results would remain qualitatively unchanged.

to optimal policy setting below.) Moreover, we can write the relative after-tax wage income abroad, $\chi = \bar{w}_{net}/w_{net}$, as

$$\chi = \frac{\bar{w}_{net}}{\tilde{W}(m,G)} \equiv \tilde{\chi}\left(m, G, \bar{w}_{net}\right). \tag{15}$$

As emigration has a negative effect on the net wage at home ($W_m < 0$), the relative wage rate abroad rises with m ($\tilde{\chi}_m > 0$). Thus, there exists a unique threshold level, $\underline{m}$, such that $\tilde{\chi}\left(\underline{m}, G, \bar{w}_{net}\right) = 1$. We have $\underline{m} < 0$ if and only if $\tilde{\chi}\left(0, G, \bar{w}_{net}\right) > 1$, i.e., $\underline{m} < 0$ is associated with a premium on net wages abroad in the case where there is no migration ($m = 0$). Similarly, $\underline{m} > (=)0$ if and only if $\tilde{\chi}\left(0, G, \bar{w}_{net}\right) < (=)1$. Combining (13) and (15), we obtain:

Lemma 2. *(i) In an equilibrium with $m \geq \underline{m}$, the number of emigrants, m, is implicitly given by*

$$m = \Phi(\tilde{\chi}\left(m, G, \bar{w}_{net}\right) - 1) \equiv M(m, G, \bar{w}_{net}), \tag{16}$$

where M is increasing in m; if φ is non-decreasing, M is also strictly convex as a function of m. (ii) In an equilibrium with $m < \underline{m}$, there is immigration ($m < 0$), where m is implicitly given by $m = -I(\tilde{\chi}\left(m, G, \bar{w}_{net}\right))$.

Let $\hat{m}(G, \bar{w}^{net})$ denote the equilibrium number of migrants (emigrants if $\hat{m} > \underline{m}$ and immigrants if $\hat{m} < \underline{m}$). An equilibrium $\hat{m}(G, \bar{w}^{net})$ with emigration is implicitly defined by $m = M(m, G, \bar{w}_{net})$. For $m > \underline{m}$, the three panels in Figure 3 graph possible curves of $M(m, G, \bar{w}_{net})$ as a function of m, called $M-$curves.[17] Graphically, $\hat{m}$ is determined by the intersection of the $M-$curve with the 45-degree line. Panel (a) of Figure 3 shows a situation where $\underline{m} = 0$ such that there is an equilibrium without any migration, $\hat{m}(G, \bar{w}^{net}) = 0$. Moreover, there is a second equilibrium with positive migration. The potential multiplicity of equilibrium arises from the fact that higher emigration lowers net wages at home (recall $W_m < 0$) and thus makes emigration even more attractive.

[17]Note from (16) that the shape of the $M-$curve critically depends on the c.d.f. of mobility costs, Φ, which is exogenously given.

Panel (b) depicts a case where $\underline{m} < 0$, the $M-$curve is $\mathcal{S}$-shaped, and for the solid line there are three equilibria with emigration.[18] Panel (c) depicts a case where $\underline{m} > 0$ and there are two equilibria with emigration. For $m < \underline{m}$, we have three additional equilibria with immigration.

<Figure 3>

Throughout, we focus our comparative-static analysis on equilibria which are stable according to the standard notion: Consider an equilibrium with emigration, $\hat{m} > 0$. Suppose that in the case where emigration would slightly decrease to $\tilde{m} < \hat{m}$, the relative net wage abroad (χ) adjusts such that $M(\tilde{m}, G, \bar{w}_{net}) > \tilde{m}$. Similarly, if emigration increased to $\tilde{m} > \hat{m}$, then the resulting number of migrants would fall below $\tilde{m}$. The equilibrium with $\hat{m} > 0$ is thus "stable" in the sense that small perturbations lead to a tendency of equilibrium to return to its initial level. Figure 3 reveals that this is the case if $M_m(\hat{m}, G, \bar{w}_{net}) < 1$. Otherwise, if $M_m(\hat{m}, G, \bar{w}_{net}) > 1$, the equilibrium is called "unstable", as slightly decreasing emigration to $\tilde{m} < \hat{m}$ would lead to less migration, $M(\tilde{m}, G, \bar{w}_{net}) < \tilde{m}$, and slightly increasing emigration to $\tilde{m} > \hat{m}$ would lead to higher emigration. In the case of immigration, we apply an analogous notion of stability. An equilibrium with immigration is thus stable if $-I'(\tilde{\chi})\tilde{\chi}_m < 1$ holds in equilibrium.

In panel (a) of Figure 3, there is only one stable equilibrium, which is the one where $\hat{m}(G, \bar{w}^{net}) = \underline{m} = 0$. The equilibrium with positive emigration is unstable. If the $M-$curve is like the solid line depicted in panel (b) of Figure 3, the equilibria with $\hat{m}_1$ and $\hat{m}_3$ are both stable whereas the equilibrium in the middle, $\hat{m}_2$, is unstable. In panel (c), there is only one stable equilibrium with emigration, but two stable equilibria with immigration.

We next examine the effects of an increase in the foreign wage, $\bar{w}_{net}$, and of a decrease in mobility costs, for given public infrastructure investment. A decrease in mobility costs is defined as a shift in the c.d.f. of θ, from $\Phi(\theta)$ to $\tilde{\Phi}(\theta)$, such that $\tilde{\Phi}(\theta) > \Phi(\theta)$ for all θ in the interior of support Θ (i.e., $\Phi(\theta)$ first-order stochastically dominates $\tilde{\Phi}(\theta)$). In words:

[18] According to Lemma 2, $M_{mm} \leq 0$ requires that the p.d.f. of mobility costs must be strictly decreasing, i.e., $\varphi' < 0$, in the relevant range; otherwise, the $M-$curve is strictly convex, as in panel (a).

for any given θ, the share of individuals with mobility costs higher than θ increases and the share of individuals with costs lower than θ declines. Moreover, we say that the economy becomes more prone to immigration if there is a shift from $I(\chi)$ to $\tilde{I}(\chi)$ such that $I(\chi) > \tilde{I}(\chi)$ for all $\chi \in (0,1)$. The following comparative-static results hold.

Proposition 1. *Assume that at least one stable equilibrium exists.*[19] *Then for a given public investment level G the following holds:*

(i) Suppose $\hat{m} = \underline{m} = 0$ initially. If mobility costs decline, then still $\hat{m} = 0$. If $\bar{w}_{net}$ increases, then emigration becomes positive ($\hat{m} > 0$).

(ii) Let $\hat{m}^{high}$ be the number of emigrants in a stable equilibrium $\hat{m}(G, \bar{w}_{net}) > 0$ where emigration is highest. If mobility cost decline or if $\bar{w}_{net}$ increases, then $\hat{m}^{high}$ increases (higher emigration) and the corresponding equilibrium net wage rate for skilled labor, $W(\hat{m}^{high}, B, G)$, declines.

(iii) Let $\hat{m}^{low}$ be the number of immigrants in a stable equilibrium $\hat{m}(G, \bar{w}_{net}) < 0$ where immigration is highest. If the economy becomes more prone to immigration or if $\bar{w}_{net}$ declines, then $\hat{m}^{low}$ decreases (higher immigration) and $W(\hat{m}^{low}, B, G)$ increases.

Higher labor mobility means that for any relative wage abroad, $\chi > 1$, more workers are willing to migrate. Thus, as depicted for the dotted line in panel (a) as well as for both the dotted and dashed lines in panel (b) in Figure 3, the $M-$curve from shifts upward. As $\underline{m}$ is unchanged by definition (recall $\tilde{\chi}(\underline{m}, G, \bar{w}_{net}) = 1$), the stable equilibrium without emigration in panel (a) is unchanged. In contrast, if the net wage rate abroad ($\bar{w}_{net}$) rises, χ increases and thus the $M-$curve shifts upward also for $m = 0$; in addition, $\underline{m}$ falls below zero. Consequently, in the new (stable) equilibrium, a positive amount of workers emigrate. This explains part (i) of Proposition 1. Now consider part (ii). For both the solid and the dotted $M-$curve in panel (b) of Figure 3 there are two stable equilibria. After a decrease in mobility cost (dotted curve) both the lower one and the higher one are associated with higher emigration than $\hat{m}_1$ and $\hat{m}_3$, respectively. For a larger reduction in mobility costs, leading to the dashed $M-$curve, the stable low-

[19] It may be the case that a stable equilibrium exists for some c.d.f. Φ and foreign net wage $\bar{w}_{net}$, but fails to exist after a decrease in mobility cost or an increase in the foreign net wage rate. To avoid only mildly interesting case distinctions, we do not consider such a scenario in what follows.

emigration equilibrium vanishes (as does the unstable equilibrium). In any case, the highest emigration level in a stable equilibrium ($\hat{m}^{high}$) rises. Moreover, as emigration has a negative effect on wages (recall $W_m < 0$), moving from one stable equilibrium to another one which is associated with a higher number of emigrants triggers a fall in the equilibrium wage rate for both skilled and unskilled labor (recall $q = (1 - \bar{e})w$). An increase in the net foreign wage, $\bar{w}_{net}$, again shifts the $M-$curve upwards and lowers $\underline{m}$. It therefore triggers higher emigration (provided the equilibrium is stable), in turn depressing wage rates at home. The opposite results hold when the economy becomes more prone to immigration which means that function $I(\chi)$ shifts. In panel (c), this is indicated by a downward shift from the solid to the dotted curve for the range $m < \underline{m}$, resulting in an increase of the (highest) number of immigrants (decrease of $\hat{m}^{low}$). This explains part (iii) of Proposition 1.

Proposition 1 suggests that, for given public expenditure G, both migration flows and wage differences among economies are accentuated if mobility costs decline. Interesting questions which arise from this result are: Should a (benevolent) government raise the level of public investment (G) to increase productivity B in response to lower mobility costs, for instance, in order to possibly compensate non-migrating workers for the wage decline following higher brain drain? Moreover, how does the optimal policy response depend on the direction of the accentuated migration flow? These questions are analyzed next.

4.4 Optimal Public Investment Policy

If there is more than one stable equilibrium, then which one materializes depends on the beliefs of skilled workers about the migration pattern. In equilibrium, beliefs must be identical. We assume that the government anticipates these beliefs when choosing public investment policy G.

To analyze policy setting behavior, we first have to formulate a government objective. We assume that governments exclusively care about utility of native individuals living in the domestic economy (non-migrants), given by consumption level $c(i)$. This may be the case, for instance, because non-migrants represent the median voter in the economy. Since consumption equals domestic after-tax wage income (which is the same for skilled and unskilled workers, as individuals are identical ex ante), the government aims to maximize

$$w_{net} = \tilde{W}(\hat{m}(G, \bar{w}_{net}), G) \equiv \hat{W}(G, \bar{w}_{net}). \tag{17}$$

We denote the government's optimal expenditure by $\hat{G}(\bar{w}_{net})[\equiv \arg\max_{G \geq 0} \hat{W}(G, \bar{w}_{net})]$ and show the following.

Proposition 2. *Assume that at least one stable equilibrium exists. The optimal public expenditure level, $\hat{G}$, minimizes emigration from a source economy or maximizes immigration to a host economy; that is, $\hat{m}_G(\hat{G}, \bar{w}_{net}) = 0$ and $\hat{m}_{GG}(\hat{G}, \bar{w}_{net}) > 0$ hold.*

Proposition 2 highlights the adverse effects of brain drain for a source economy, or the beneficial effects of immigration for a host economy, for income and welfare of non-migrants in the model. It shows that welfare maximization through public infrastructure investment policy is, in a source country, equivalent to minimizing brain drain. In a host economy, it is equivalent to maximizing the inflow of skilled workers. We next show in which direction the optimal infrastructure investment changes if mobility costs decline and, therefore, migration flows accentuate.

Proposition 3. *Assume that at least one stable equilibrium exists.*

(i) Suppose that initially there is no migration, $\hat{m}(\hat{G}, \bar{w}_{net}) = \underline{m} = 0$. If mobility costs decline, then optimal public investment level, $\hat{G}$, remains unchanged. If $\bar{w}_{net}$ increases, then $\hat{G}$ declines.

(ii) Let $\hat{m}^{high}$ be the number of emigrants in a stable equilibrium $\hat{m}(\hat{G}, \bar{w}_{net}) > 0$ where emigration is highest, given the optimal policy choice, $\hat{G}$. If mobility cost decline or if $\bar{w}_{net}$ increases, then $\hat{G}$ decreases and the corresponding equilibrium net wage rate for skilled labor, $\tilde{W}(\hat{m}^{high}, \hat{G})$, declines.

(iii) Let $\hat{m}^{low}$ be the number of immigrants in a stable equilibrium $\hat{m}(\hat{G}, \bar{w}_{net}) < 0$ where immigration is highest, given $\hat{G}$. If the economy becomes more prone to immigration or if $\bar{w}_{net}$ declines, then $\hat{G}$ increases and $\tilde{W}(\hat{m}^{high}, \hat{G})$ increases.

Proposition 3 suggests that declining mobility costs not only accentuate migration flows and income differences among economies (Proposition 1), but also accentuate differences in public investment spending levels: Economies which experience further brain drain optimally choose to lower public investment $\hat{G}$ whereas economies which experience further immigration of skilled labor increase $\hat{G}$. The intuition for this result can be seen from Figure 4, which depicts welfare $\tilde{W}(m, G) = W(m, b(G), G)$ for two levels of m.

< **Figure 4**>

If the number of emigrants increases from m_1 to $m_2 > m_1$ (or the number of immigrants decreases), not only net wages fall (recall $\tilde{W}_m = W_m < 0$) but also the marginal gain in net wages from an increase in public investment G declines ($\tilde{W}_{Gm} < 0$). The latter property stems from a combination of two effects which go in the same direction: first, the marginal income gain from raising productivity B declines if there is higher emigration (or less immigration);[20] second, the necessary increase in the income tax rate when raising public infrastructure investment G rises (so to balance the public budget).[21] Graphically, as shown in Figure 4, a higher migration outflow shifts welfare as a function of G (which is strictly concave as we have already seen that $\tilde{W}_{GG} < 0$) not only downward but also to the left.

For instance, if $\hat{m} > 0$ is a stable equilibrium, then brain drain is accentuated if mobility cost decline or the net wage abroad, $\bar{w}_{net}$, rises (part (ii) of Proposition 1). As a result, welfare as a function of G shifts as shown in Fig. 4 and the optimal infrastructure investment, $\hat{G}$, declines (part (ii) of Proposition 3). The other parts of Proposition 3 follow analogously.

[20] Formally, $W_{Bm} < 0$, according to (14). This property, which critically drives Proposition 3, does not hold in a neoclassical framework (see supplementary material).

[21] The latter property, $W_{Gm} < 0$, would modify to $W_{Gm} = 0$ if migrants would still have to pay taxes at home (for instance, because they commute for work abroad but live in the economy where they are born and residence-based taxation applies). Consequently, $\tilde{W}_{Gm} < 0$ would still hold in this case. Also the agglomeration effects which give rise to the possibility of multiple equilibria are only partly driven by the assumption that individuals are taxed where they work. All results would qualitatively remain the same if we relaxed that assumption. The crucial feature of the model are scale effects in wage levels, not tax effects.

We shall stress that we do not literally believe in the benevolent government for positive analysis. However, the changing trade-off between public investment provision and net wages after a change in the number of migrants may induce governments to reduce public spending even in more sophisticated political economy models.

In sum, allowing for government responses implies that accentuation of migration flows, triggered by declining mobility costs, goes along with increasing differences in public investment levels. The evidence presented in Figure 2 is consistent with this prediction of the model. Moreover, the result suggested by Proposition 1 that increasing mobility of high-skilled labor aggravates cross-country income differences is robust to endogenous government responses regarding public investment policy.

5 Empirical Evidence

Our theoretical analysis has highlighted the interaction between emigration of highly skilled labor and an economy's income gap to potential host economies of expatriates. This interaction is reflected by Proposition 1, which applies to a given public infrastructure investment, and in Proposition 3, which accounts for endogenous adjustment of G. To recall, on the one hand, the emigration incentive is an increasing function of relative income χ to potential destination economies; formally, the number of emigrants in the model is $m = \Phi(\chi - 1)$, where Φ is the c.d.f. of mobility costs in the population. On the other hand, higher emigration of skilled labor induces scale effects (associated with the R&D process in our theoretical model) which lead to an increasing income gap to destination economies (increases in χ).

The first direction, from income differences to migration outflows, has been examined empirically elsewhere. Two recent papers are notable. First, Grogger and Hanson (2008) provide convincing evidence for the critical role of wage differences between country pairs on emigration patterns of tertiary educated workers.[22] Second, Beine, Docquier and

[22] In the working paper version of this article (Grossmann and Stadelmann, 2008), we provided related evidence which is consistent with property $m = \Phi(\chi - 1)$. Contrary to Grogger and Hanson (2008), however, we looked at the impact of a higher aggregate emigration stock of a country on its per capita income. That is, we did not consider bilateral relationships. We also presented evidence for the interaction between emigration flows and income changes using a structural equation model.

Ozden (2008) show that, in addition to wage differences, network effects are important for the migration decision for both high-skilled and low-skilled workers. That is, the stock of emigrants already living in the source country positively affects migration flows in a causal way.

Our empirical analysis will focus on the second direction, from emigration to relative income. It thereby aims to complement previous literature by investigating the main novel hypothesis of our paper on the scale effect in the context of mobility of skilled labor, suggesting that increasing migration of high-qualified workers from source to host countries raises (log) income differences between country pairs.

5.1 Data and Estimation Strategy

The first main variable of interest is the emigration rate of high-skilled individuals. Docquier and Marfouk (2006) have established a dataset of emigration stocks and rates by educational attainment for the years 1990 and 2000. The authors count as emigrants all foreign-born individuals aged at least 25 who live in an OECD country and class them by educational attainment and country of origin. Thus, only emigration into OECD countries is captured, approximately 90 percent of educated migrants in the world.[23] As we are interested in the bilateral migration pattern of high-skilled individuals, we focus on emigration of the high educational category provided by Docquier, Marfouk and Lowell (2007). We construct the high-skilled emigration rate from country i to j in period t, denoted by $Mig_{ij,t}$, as the stock of skilled emigrants from country i living in (OECD) country j (M_{ij}) divided by the stock of skilled residents, S_i, in (source) country i, i.e. $Mig_{ij,t} := M_{ij}/S_i$. Denoting by $y_{i,t}$ the GDP per capita in country i in year t we first estimate, for a country pair (i, j):

$$\log\left(\frac{y_{j,t}}{y_{i,t}}\right) = \alpha_0 + \alpha_1 Mig_{ij,t} + \mathbf{x}'_{ij,t-1}\boldsymbol{\alpha}_z + u_{ij,t}. \tag{18}$$

Equation (18) is theoretically motivated by the positive impact of higher emigration

[23] See Docquier and Makfouk (2006) for a detailed discussion concerning data collection and construction issues.

(m) on relative (wage) income (χ), $\chi = \tilde{\chi}(m, \cdot)$ as given by (15) in the theoretical, increasing returns framework with endogenous scale effects as also reflected by wage equation (11) in Lemma 1.[24] The theoretical model predicts $\alpha_1 > 0$. $\mathbf{x}_{ij}$ is a vector of other controls potentially affecting log income differences between i and j (like relative school enrolment rates, relative investment rates, relative urban population shares, and region dummies for the source country to capture institutional differences to OECD destination countries). These controls are lagged to reduce endogeneity bias. We focus on (the log of) relative income in the year 2000 as dependent variable and take the lag to be 10 years. t and $t-1$ thus represent the year 2000 and 1990, respectively. u_{ij} is an error term.

As a first attempt to deal with potential endogeneity bias regarding the relationship of interest, we replace the high-skilled emigration rate in 2000 by the lagged one in 1990. More importantly, in addition to OLS regressions, we instrument the high-skilled emigration rate for the year 2000. First, we use the lagged (log of) the total stock of expatriates who emigrated from country i to j, $TotalMig_{ij,t-1}$, as instrument for $Mig_{ij,t}$. This is motivated by the notion that a larger community of people from the same nation already living abroad create mobility-cost reducing network effects (e.g. Massey et al., 1993; Beine, Docquier and Ozden, 2008). Moreover, we employ indicators for geographical factors and linguistic proximity typically used in the literature on migration. Our instruments are supposed to capture mobility costs, an important determinant of high-skilled migration in our theoretical model. The data sources and summary statistics of the employed variables are presented in Table 1.

< Table 1 >

As an implication of (15), our theory suggests that rising emigration flows, triggered by reductions in mobility costs, aggravate cross-country income differences (Proposition 1 and 3). To test this hypothesis, we regress the change in log of relative income per

[24]Recall that, according to the theoretical model, gross wage income for skilled and unskilled workers (w, q) and per capita GDP (y) are proportional to each other. We prefer the use of per capita GDP to wage data, as the latter seems more imprecise for many source countries; more precisely, we take relative GDP per capita as proxy for relative net wage income of the skilled.

capita of country pairs on a measure of the bilateral emigration flow: the change in the stock of the skilled population which migrated from country i to country j between 1990 and 2000 adjusted for the size of the skilled resident population of (souce) country i in 1990. Defining $DeltaGDP_{ij} := \log\left(\frac{y_{j,t}}{y_{i,t}}\right) - \log\left(\frac{y_{j,t-1}}{y_{i,t-1}}\right)$ and $DeltaMig_{ij} := \frac{M_{ij,t}-M_{ij,t-1}}{S_{i,t-1}}$, we estimate

$$DeltaGDP_{ij} = \beta_0 + \beta_1 DeltaMig_{ij} + \mathbf{z}'_{ij,t-1}\boldsymbol{\alpha}_z + \eta_{ij}. \tag{19}$$

According to the theoretical model, we expect $\beta_1 > 0$. $\mathbf{z}_{ij}$ is a vector of other controls potentially affecting the rate of change of relative income between i and j over time. Motivated by growth regressions which deal with potential income convergence across countries, we include the initial value of variables (in 1990) which affect income growth between 1990 and 2000 (again, the relative primary and tertiary school enrolment rate between host and source country, the relative investment rate, the relative urban population share, and region dummies).[25] η_{ij} is an error term.

Due to the apparent endogeneity problem, we focus on IV-estimates of (19). The change in emigration ($DeltaMig_{ij}$) is instrumented similarly to the emigration rate Mig_{ij} in the level regressions reflected by (18).

5.2 Results

Reported standard errors from all estimates account for destination clusters, following Grogger and Hanson (2008), among others.[26]

< Table 2>

Table 2 presents OLS estimates of the level-regressions (18). The coefficient of interest, α_1, is always positive and significantly different from zero at the one or five percent level. In column (1), the control variables include regional dummies and a dummy variable which indicates whether also the source country belongs to the OECD. Columns

[25] We do not control for public investment levels, which are endogenously determined by governments in response to migration incentives, according to the theoretical model (Proposition 3).

[26] We use the Huber-White method to adjust the variance-covariance matrix from our least squares results, to correct for heteroscedasticity and for correlated observations from cluster samples.

(2)-(4), in addition, control for differences in school enrolment (primary and tertiary), private capital investment, and the urban population share, respectively, whereas column (5) controls for all of these variables at once. The control variables have the expected signs and typically are significantly different from zero at the one percent level. Column (6) leaves out the dummies for regions and OECD and instead allows for source country fixed effects. Using source fixed effects substantially improves the fit and still implies that α_1 is different from zero, at the one percent level. Column (7)-(8) use the lagged high-skilled emigration rate in 1990. Results are similar to the use of the high-skilled emigration rate in 2000.

The size of α_1 is similar across specifications. It suggests quantitatively a rather large effect of an increase in the emigration rate on differences of the log of per capita income. For instance, with $\alpha_1 = 0.15$ (the average of coefficients for the source fixed effects specifications (6) and (8)), an increase in Mig_{ij} by one standard deviation implies that relative income rises by $(0.15 \times 0.2 =)$ 3 percent.

< **Table 3**>

Table 3 deals with the potential reverse causality problem by providing IV-estimations of (18) and (19). Columns (1)-(4) again present results for the level-regressions. These regressions control for lagged relative values of school enrolment, private investment and urbanization. The first two columns use the stock of total emigrants from country i in j in 1990 ($TotalMig_{ij,t-1}$) as instrument for the high-skilled emigration rate in 2000 ($Mig_{ij,t}$). According to column (1), α_1 is again positive and significantly different from zero at the one percent level. The regression includes a dummy for the region and OECD membership of the source country. With country fixed effects used instead, as for columns (2)-(4), significance of the coefficient drops. However, the main hypothesis is still supported. The magnitude of α_1 in column (2) is back to the OLS estimates in Table 2. According to column (3), using bilateral geographical distance between i and j ($Dist_{ij}$), an indicator for a common border ($Contig_{ij}$), and an indicator for common language of source and destination country ($ComLang_{ij}$) as instruments for Mig_{ij} raises the estimate of α_1. If in addition to the geographical variables the total stock of emigrants is employed in the first stage regression which instruments Mig_{ij}, the size of the coefficient again drops, however, to a size which is similar to the OLS estimates (column (4)). A F-test for the first stage results shows that the instruments are significantly related to the emigration rate.

Columns (5)-(8) estimate equation (19). The change in the emigration flow of tertiary educated workers from i to j (adjusted for the number of skilled residents in the source country), $DeltaMig_{ij}$, is instrumented. All reported regressions include source country fixed effects. Columns (5) and (6) employ only the total stock of emigrants ($TotalMig_{ij}$) in 1990 as an instrument for subsequent changes in emigration patterns of skilled workers. Beine, Docquier and Ozden (2008) argue that the initial stock of emigrants in truly exogenous to emigration flows. At the second stage, according to column (5), the coefficient of interest, β_1, is positive as predicted by the theory and significant at the five percent level, when no controls in addition to fixed effects are included. Accounting also for initial conditions as suggested by standard growth regressions does not change significance of β_1 but raises the size of the coefficient substantially, as shown in column (6). The F-test for the first stage suggests that $TotalMig_{ij}$ is highly related to $DeltaMig_{ij}$. The F-statistic drops, according to column (7), when analogously to column (3) of Table 3 only indicators for geography and linguistic proximity are employed as instruments. At the same time, β_1 is not anymore significantly different from zero, although the size of the coefficient is similar to that of column (6). When including the stock of emigrants in addition to the instruments in column (7), the coefficient is significant at the 15 percent level (column (8)).

The J-statistics in Table 3, which deal with the overidentifying restrictions, do not point to problems with the instruments. Overall, the IV-results confirm that that network effects drive emigration flows, as suggested by Beine, Docquier and Ozden (2008). More importantly, employing this result for IV-regressions of the impact of changes in the emigration pattern of skilled workers on changes in log income differences between source and destination countries supports the main hypothesis developed in this paper.

6 Concluding Remarks

This paper analyzed the relationship between migration of high-skilled individuals, relative income between source and destination economies of expatriates, and the optimal change in public infrastructure investment in response to endogenously changing migration flows. We showed that a decline in mobility costs increases emigration pressure for economies already suffering from brain drain, while benefiting those which were host economies to begin with. This holds true with and without optimal adjustment of public investment, suggesting that integration of labor markets for the highly skilled accentuates between-country income inequality. Higher outward migration is also associated with downward adjustment of public infrastructure investment.

We also provide empirical support which is consistent with the main predictions of the proposed theory. As a caveat, we are well aware of the need to analyze data on net rather than gross emigration rates. Unfortunately, such a dataset is yet not available. Moreover, the 10 year period we are able to focus on in the empirical analysis may be too short to capture all relevant changes. One cannot rule out, for instance, that Eastern European countries which have seen a large outflow of skilled workers after 1990 may benefit in the longer run from return migration, remittances, or increased education levels.

Appendix

Proof of Lemma 1. First, note that the inverse demand function of the final goods sector for input Z is given by $p_Z = (1-\alpha)Y/Z\, [\equiv \partial Y/\partial Z]$. Substituting $p_Z = (1-\alpha)Y/Z$ into $w = p_Z \partial Z/\partial H_Z$ and using (2), we have $w = \beta(1-\alpha)Y/H_Z$. According to (1), (3) and $x(j) = \alpha^{\frac{2}{1-\alpha}} a(h)Z$ we find $Y = \alpha^{\frac{2\alpha}{1-\alpha}} Zna(h)$ for final output and thus

$$w = \beta(1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}} \frac{na(h)Z}{H_Z}. \tag{20}$$

Combining (7) and (20) and recalling $\delta = (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}$ leads to

$$n = \frac{\alpha}{\beta}\frac{a'(h)}{a(h)}H_Z. \tag{21}$$

Combining $w = p_Z \partial Z/\partial H_Z$ and $q = p_Z \partial Z/\partial L_Z$, the relative wage rate of skilled labor is given by $\frac{w}{q} = \frac{\beta}{1-\beta}\frac{L_Z}{H_Z}$, according to (2). Combining this with $w(1-\bar{e}) = q$, we find that

$$L_Z = L = \frac{1-\beta}{\beta(1-\bar{e})}H_Z. \tag{22}$$

Substituting (21) and (22) into (10) and using that $(h+f)a'(h)/a(h) = 1$, we can solve for H_Z:

$$H_Z = \frac{\beta(1-\bar{e})}{1+\alpha}(1-m). \tag{23}$$

Now substitute (22) into (2) and use (23) to find

$$Z = B\left(\frac{1-\beta}{\beta(1-\bar{e})}\right)^{1-\beta}\frac{\beta(1-\bar{e})}{1+\alpha}(1-m). \tag{24}$$

Substituting (24) into (7), $w = \delta Z a'(h)$, confirms (11). To derive (12), substitute (23) into (22) and use $H = 1 - L$. ■

Proof of Lemma 2. We start with part (i). If $m \geq \underline{m}$ and therefore $\chi \geq 1$, then $m = \Phi(\chi - 1)$, according to (13). Thus, according to (16) and $\Phi'(\chi-1) = \varphi(\chi-1)$,

$$M_m(m, G, \bar{w}_{net}) = \varphi(\tilde{\chi}(m, G, \bar{w}_{net}) - 1)\tilde{\chi}_m(m, G, \bar{w}_{net}). \tag{25}$$

Since $\tilde{\chi}_m = -\bar{w}_{net}W_m/W^2 > 0$, according to (15), we find $M_m > 0$. Moreover, (25) implies $M_{mm} = \varphi'(\tilde{\chi}-1)(\tilde{\chi}_m)^2 + \varphi(\chi-1)\tilde{\chi}_{mm}$, where $\tilde{\chi}_{mm} = [2(W_m)^2 - W_{mm}W]\,\bar{w}_{net}/W^3$. It is easy to see from (14) that $W_{mm} < 0$; thus, $\tilde{\chi}_{mm} > 0$. Together with $\tilde{\chi}_m > 0$, this confirms that $M_{mm} > 0$ if $\varphi'(\tilde{\chi}(m, G, \bar{w}_{net}) - 1) \geq 0$, concluding the proof of part (i). Part (ii) follows from using (15) and $m = -I(\chi)$ if $\chi < 1$, according to (13). ■

Proof of Proposition 1. Follows immediately from the discussion in the main text. ■

Proof of Proposition 2. The first-order condition to the maximization of $\hat{W}(G, \bar{w}_{net}) = \tilde{W}(\hat{m}(G, \bar{w}_{net}), G)$ reads

$$\left[\hat{W}_G(G, \bar{w}_{net}) =\right] \tilde{W}_m(\hat{m}(G, \bar{w}_{net}), G)\hat{m}_G(G, \bar{w}_{net}) + \tilde{W}_G(\hat{m}(G, \bar{w}_{net}), G) = 0. \quad (26)$$

If $\hat{m} \geq 0$, by applying the implicit function theorem to (16), we obtain:

$$\hat{m}_G(G, \bar{w}_{net}) = \frac{\varphi(\tilde{\chi}\left(\hat{m}, G, \bar{w}_{net}\right) - 1)\tilde{\chi}_G\left(\hat{m}, G, \bar{w}_{net}\right)}{1 - M_m(\hat{m}, G, \bar{w}_{net})}. \quad (27)$$

Note that the denominator is positive in stable equilibrium, i.e., $M_m(\hat{m}, G, \bar{w}_{net}) < 1$. If $\hat{m} < 0$, by applying the implicit function theorem to $m + I(\tilde{\chi}\left(m, G, \bar{w}_{net}\right)) = 0$ (use part (ii) of Lemma 2), we find

$$\hat{m}_G(G, \bar{w}_{net}) = -\frac{I'(\tilde{\chi}(\hat{m}, G, \bar{w}_{net}))\tilde{\chi}_G\left(\hat{m}, G, \bar{w}_{net}\right)}{1 + I'(\tilde{\chi}(\hat{m}, G, \bar{w}_{net}))\tilde{\chi}_m(\hat{m}, G, \bar{w}_{net})}. \quad (28)$$

Again, in stable equilibrium, the denominator is positive. Moreover, using $\tilde{\chi}\left(\hat{m}, G, \bar{w}^{net}\right) = \bar{w}^{net}/\tilde{W}(\hat{m}, G)$ from (15), we find

$$\tilde{\chi}_G\left(\hat{m}, G, \bar{w}^{net}\right) = -\frac{\bar{w}^{net}}{\tilde{W}(\hat{m}, G)^2}\tilde{W}_G(\hat{m}, G). \quad (29)$$

Suppose that $\hat{G}$ is given by first-order condition (26). (At the end of the proof we show that the second-order condition indeed holds.) Substituting (27) into (26) and using (29), we find that whenever the optimal public investment level, $\hat{G}$, is associated with emigration, then $\hat{G}$ is given by

$$\left(1 - \frac{\tilde{W}_m(\hat{m}, \hat{G})\varphi(\tilde{\chi}\left(\hat{m}, G, \bar{w}_{net}\right) - 1)\bar{w}_{net}}{\left[1 - M_m(\hat{m}, G, \bar{w}_{net})\right]\tilde{W}(\hat{m}, G)^2}\right)\tilde{W}_G(\hat{m}, \hat{G}) = 0. \quad (30)$$

As the term in large brackets is positive in stable equilibrium (use $M_m < 1$ and $\tilde{W}_m < 0$), $\hat{G}$ is given by $\tilde{W}_G(\hat{m}, \hat{G}) = 0$, which holds if and only if $\hat{m}_G(\hat{G}, \bar{w}_{net}) = 0$, according to (27) and (29).

Similarly, using (28) and (29), the first-order condition (26) can be rewritten to

$$\left(1+\frac{\tilde{W}_m(\hat{m},\hat{G})I'(\tilde{\chi}(\hat{m},G,\bar{w}_{net}))\bar{w}_{net}}{[1+I'(\tilde{\chi}(\hat{m},G,\bar{w}_{net}))\tilde{\chi}_m(\hat{m},G,\bar{w}_{net})]\,\tilde{W}(\hat{m},G)^2}\right)\tilde{W}_G(\hat{m},\hat{G})=0. \tag{31}$$

Again, the term in large brackets is positive in stable equilibrium (use $I'<0$, $\tilde{W}_m<0$ and $1+I'(\tilde{\chi})\tilde{\chi}_m>0$). Thus, again, $\hat{G}$ is given by $\tilde{W}_G(\hat{m},\hat{G})=0$, which holds if and only if $\hat{m}_G(\hat{G},\bar{w}_{net})=0$, according to (28) and (29).

We next show that the second-order condition holds, i.e., $\hat{W}_{GG}(\hat{G},\bar{w}_{net})<0$. To see this, note that we just established that $\hat{W}_G(\hat{G},\bar{w}_{net})=\tilde{W}_G(\hat{m}(\hat{G},\bar{w}_{net}),\hat{G})=0$ when $\hat{G}$ is given by first-order condition (26). Hence,

$$\hat{W}_{GG}(\hat{G},\bar{w}_{net})=\tilde{W}_{Gm}(\hat{m}(\hat{G},\bar{w}_{net}),\hat{G})\hat{m}_G(\hat{G},\bar{w}_{net})+\tilde{W}_{GG}(\hat{m}(\hat{G},\bar{w}_{net}),\hat{G}). \tag{32}$$

Using $\hat{m}_G(\hat{G},\bar{w}_{net})=0$, we thus have $\hat{W}_{GG}(\hat{G},\bar{w}_{net})=\tilde{W}_{GG}\Big|_{G=\hat{G}}$.[27] Recalling that $\tilde{W}_{GG}<0$ confirms that the second-order condition holds.

Finally, we have to show that $\hat{m}_{GG}(\hat{G},\bar{w}_{net})>0$ holds, which means that emigration from a source economy ($\hat{m}>0$) is minimized and immigration to a host economy ($I=-\hat{m}$) is maximized. From (29) and $\tilde{W}_G\Big|_{G=\hat{G}}=0$ we have $\tilde{\chi}_G|_{G=\hat{G}}=0$ and $\tilde{\chi}_{GG}|_{G=\hat{G}}=\left[-\bar{w}_{net}\tilde{W}_{GG}/\tilde{W}\right]\Big|_{G=\hat{G}}>0$. $\tilde{W}_{GG}<0$ implies $\tilde{\chi}_{GG}|_{G=\hat{G}}>0$. This property will now be used. We start with emigration, $\hat{m}(\hat{G},\bar{w}_{net})\geq 0$. According to (27) and $\tilde{\chi}_G|_{G=\hat{G}}=0$, we obtain

$$\hat{m}_{GG}(\hat{G},\bar{w}_{net})=\left[\frac{\varphi(\tilde{\chi}-1)\tilde{\chi}_{GG}}{1-M_m}\right]\Bigg|_{G=\hat{G}}>0 \tag{33}$$

by using $\tilde{\chi}_{GG}|_{G=\hat{G}}>0$ and the fact that the denominator is positive in stable equilibrium. Similarly, when $\hat{m}(\hat{G},\bar{w}_{net})<0$, then (28) and $\tilde{\chi}_G|_{G=\hat{G}}=0$ imply

$$\hat{m}_{GG}(\hat{G},\bar{w}_{net})=\left[\frac{-I(\tilde{\chi})\tilde{\chi}_{GG}}{1+I'(\tilde{\chi})\tilde{\chi}_m}\right]\Bigg|_{G=\hat{G}}>0 \tag{34}$$

by using $I'<0$, $\tilde{\chi}_{GG}|_{G=\hat{G}}>0$ and the fact that the denominator is positive. This

[27] With respect to a function $F(m,G,\cdot)$, we employ the short-cut notation $F|_{G=\hat{G}}$ to indicate $F(\hat{m}(\hat{G},\bar{w}_{net}),\hat{G},\cdot)$ in what follows.

concludes the proof. ■

Proof of Proposition 3. Note that $\tilde{W}_{Gm} = W_{Bm}b' + W_{Gm}$. From (14), we have $W_{Bm} < 0$ and $W_{Gm} < 0$, which implies $\tilde{W}_{Gm} < 0$. The result follows from the discussion in the main text. ■

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Supplementary Material

(not intended for publication)

1. Heterogeneity

We now allow for the possibility that individuals differ in the time e which is required to become skilled. Suppose, for simplicity, that e is independently distributed of mobility costs θ and follows the uniform distribution with support $[0, 1]$.

There exists a marginal entrant into education who does not migrate and is indifferent whether or not to acquire education. This individual is characterized by time requirement $\hat{e}$, which is given by $w(1-\hat{e}) = q$. All individuals with $e \leq \hat{e}$ acquire education and its total mass is $H = \hat{e}$. If m skilled individuals emigrate, total supply (S) of skilled workers at home is $S = (1-\bar{e})(H-m)$, where the skilled spent on average $\bar{e} = 0.5\hat{e}$ units of time in education. Thus, using $H = \hat{e}$, we obtain

$$S = 0.5H(H-m). \tag{35}$$

The labor market clearing condition for skilled workers reads

$$H_Z + n(h+f) = S. \tag{36}$$

Substituting

$$n = \frac{\alpha}{\beta}\frac{a'(h)}{a(h)}H_Z \tag{37}$$

from (21) into (36) and using the fact that $a'(h)(h+f)/a(h) = 1$, according to (9), implies

$$H_Z = \frac{\beta S}{\alpha+\beta}. \tag{38}$$

Next, note that the relative wage rate for unskilled labor (relative to the skilled) is given by the relative marginal productivity:

$$\frac{q}{w} = \frac{(1-\beta)H_Z}{\beta L_Z}\left[= \frac{\partial Z/\partial L_Z}{\partial Z/\partial H_Z}\right] \tag{39}$$

(use (2)). From the equilibrium condition for educational choice, we also have $q/w = 1 - H$. Combining this with (39) and using both $L_z = L$ and (38) implies

$$L = \frac{(1-\beta)S}{(\alpha+\beta)(1-H)}. \tag{40}$$

Substituting (40) into $L + H = 1$ and rearranging terms, we also find

$$S = \frac{(\alpha+\beta)(1-H)^2}{1-\beta}. \tag{41}$$

Combining (35) and (41) implies that the fraction of skilled natives, H, is implicitly defined as an increasing function of the number of emigrants by

$$0.5H(H-m) - \frac{(\alpha+\beta)(1-H)^2}{1-\beta} = 0. \tag{42}$$

We write $H = \tilde{H}(m)$.

Next, substitute the expression for H_Z given in (38) and the expression for $L_Z = L$ given in (40) into (2) to obtain

$$Z = \frac{B\beta^{\beta}(1-\beta)^{1-\beta}S}{(\alpha+\beta)(1-H)^{1-\beta}}. \tag{43}$$

Substituting (43) into (7), $w = \delta Z a'(h)$, gives us, by using (41) and $H = \tilde{H}(m)$, the pre-tax wage rate per unit of skilled labor:

$$w = \delta a'(h) \left(\frac{\beta}{1-\beta}\right)^{\beta} B \left[1 - \tilde{H}(m)\right]^{1+\beta}. \tag{44}$$

The net wage rate for skilled labor is calculated next. A balanced government budget requires $G = \tau(wS + qL)$. Using equilibrium condition $w(1-H) = q$ and substituting (40) implies $G = \tau w S \frac{1+\alpha}{\alpha+\beta}$. Substituting (41) into this equation, using $H = \tilde{H}(m)$, and rearranging terms leads to

$$\tau w = \frac{1-\beta}{1+\alpha} \frac{G}{(1-\tilde{H}(m))^2}. \tag{45}$$

Thus, the net wage rate $w_{net} = (1-\tau)w$ is given by

$$w_{net} = \delta a'(h)\left(\frac{\beta}{1-\beta}\right)^{\beta} B\left[1-\tilde{H}(m)\right]^{1+\beta} - \frac{1-\beta}{1+\alpha}\frac{G}{(1-\tilde{H}(m))^2} \equiv W(m, B, G). \quad (46)$$

This confirms that the basic properties which lead to Proposition 1-3 are still valid when the model is extended for heterogeneity in ability; similar to the basic model, for instance, we have $W_m < 0$, $W_{Bm} < 0$, $W_{Gm} < 0$.

Moreover, we can derive an additional result: higher brain drain, triggered by a decrease in mobility costs, raises the wage premium for being skilled (i.e., raises wage inequality). To see this, use $q/w = 1 - H$ and $H = \tilde{H}(m)$ to find

$$\frac{w}{q} = \frac{1}{1-\tilde{H}(m)}. \quad (47)$$

This confirms that skill premium w/q is increasing in m.

2. Comparison to Neoclassical Framework

To highlight the importance of the properties of the wage function implied by the proposed increasing-returns framework with endogenous R&D, we compare our model to a standard (one-sector) neoclassical framework which allows for migration of skilled labor.

Again assume for production of the final good that $Y = X^{\alpha}Z^{1-\alpha}$, where input Z is given by some linearly homogenous function Γ of skilled and unskilled labor (H_Z and L_Z, respectively):

$$Z = B\Gamma(H_Z, L_Z) \equiv BL_Z\gamma(\kappa), \quad (48)$$

where $\kappa \equiv H_Z/L_Z$ is the skill intensity and $\gamma(\kappa) \equiv \Gamma(\kappa, 1)$, with $\gamma' > 0$, $\gamma'' < 0$. (B is again a productivity parameter.) Input X may be interpreted as physical capital, which can be borrowed at the (exogenous) world market price (interest rate) p. In a perfect market, inverse demand is given by $p = \alpha X^{\alpha-1}Z^{1-\alpha}$, i.e.,

$$\frac{X}{Z} = \left(\frac{\alpha}{p}\right)^{\frac{1}{1-\alpha}}. \quad (49)$$

The relative wage rate for unskilled labor (relative to the skilled) is given by the relative marginal productivity:

$$\frac{q}{w} = \frac{\gamma(\kappa) - \kappa\gamma'(\kappa)}{\gamma'(\kappa)} \equiv \Theta(\kappa), \tag{50}$$

where Θ is an increasing function. Moreover, in equilibrium, as workers are ex ante identical and face education costs $\bar{e}$, in equilibrium we again have $w(1-\bar{e}) = q$. Thus, $q/w = 1-\bar{e}$ and therefore skill intensity reads $\kappa = \Theta^{-1}(1-\bar{e})$. Next, note that the wage rate for skilled labor (w) is given by its marginal product ($\partial Y/\partial H_Z$), which according to (1) and (48) is given by

$$w = (1-\alpha)\left(\frac{X}{Z}\right)^{\alpha} B\gamma'(\kappa). \tag{51}$$

Using (49) and $\kappa = \Theta^{-1}(1-\bar{e})$ we find

$$w = (1-\alpha)\left(\frac{\alpha}{p}\right)^{\frac{\alpha}{1-\alpha}} B\gamma'(\Theta^{-1}(1-\bar{e})). \tag{52}$$

Thus, the wage rate w is independent of the number of migrants, m. This is different to the proposed increasing-returns framework of this paper, where w is decreasing in m, according to (11) in Lemma 1.

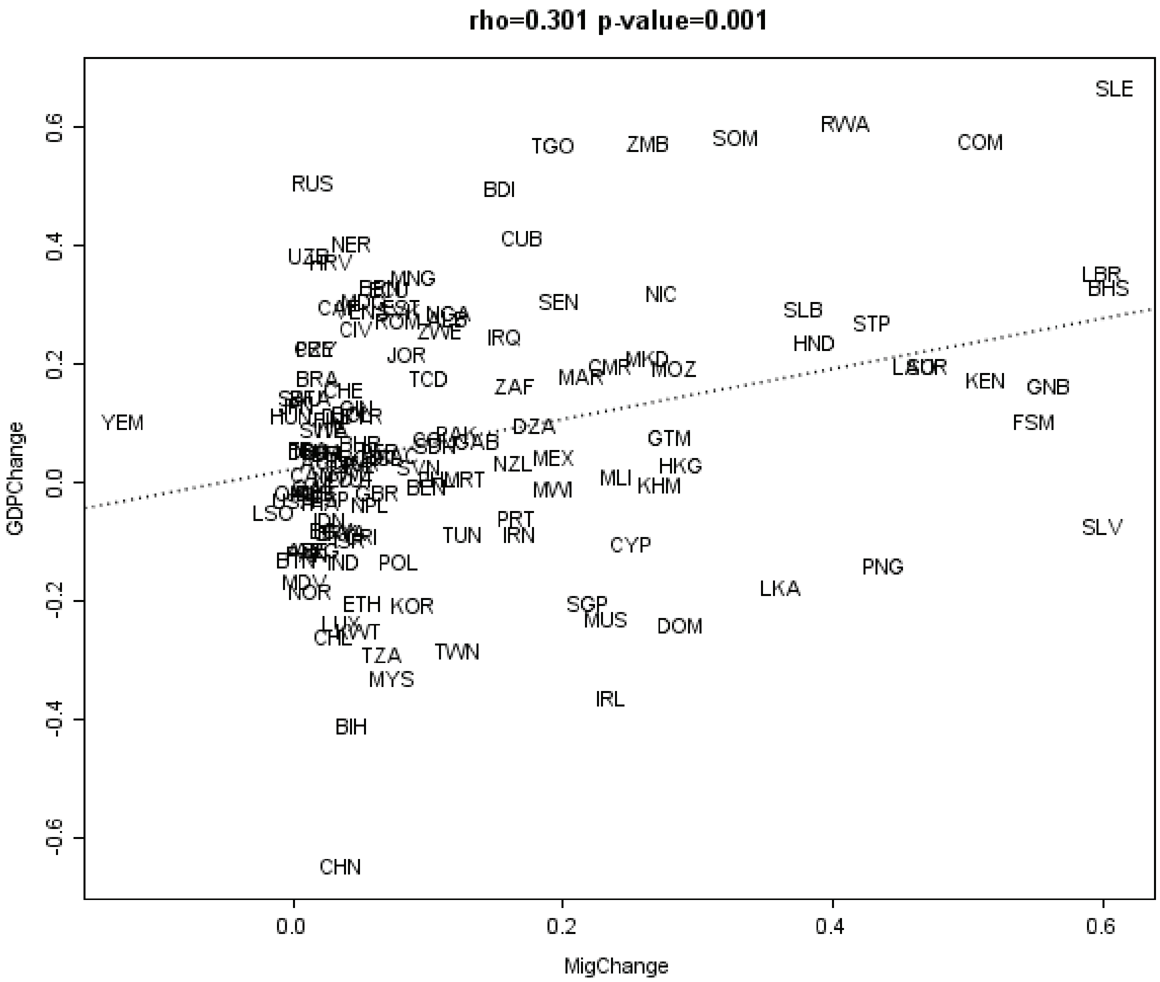
If we abstract from educational choice in the neoclassical framework, w is even increasing in m, due to the property of declining marginal productivity. To see this, suppose there is an exogenous mass of L unskilled and H skilled natives. Thus, if m skilled workers emigrate and the skilled again have education time costs $\bar{e}$, the skill intensity is $\kappa = (1-\bar{e})(H-m)/L$. In this case, (52) modifies to

$$w = (1-\alpha)\left(\frac{\alpha}{p}\right)^{\frac{\alpha}{1-\alpha}} B\gamma'\left(\frac{(1-\bar{e})(H-m)}{L}\right). \tag{53}$$

Property $\gamma'' < 0$ implies that an increase in m raises w. As a result, an increase in productivity $B = b(G)$, triggered by higher public investment G, has a higher effect on w the higher emigration is (i.e., $\partial^2 w/\partial B\partial m > 0$), in contrast to the proposed increasing-returns framework (where $\partial^2 w/\partial B\partial m < 0$, according to Lemma 1). This implies that lower mobility costs, triggering higher emigration of a source economy, tends to increase rather than to decrease the optimal public investment level in a neoclassical framework, in contrast to Proposition 3 (part (ii)).

Figure 1

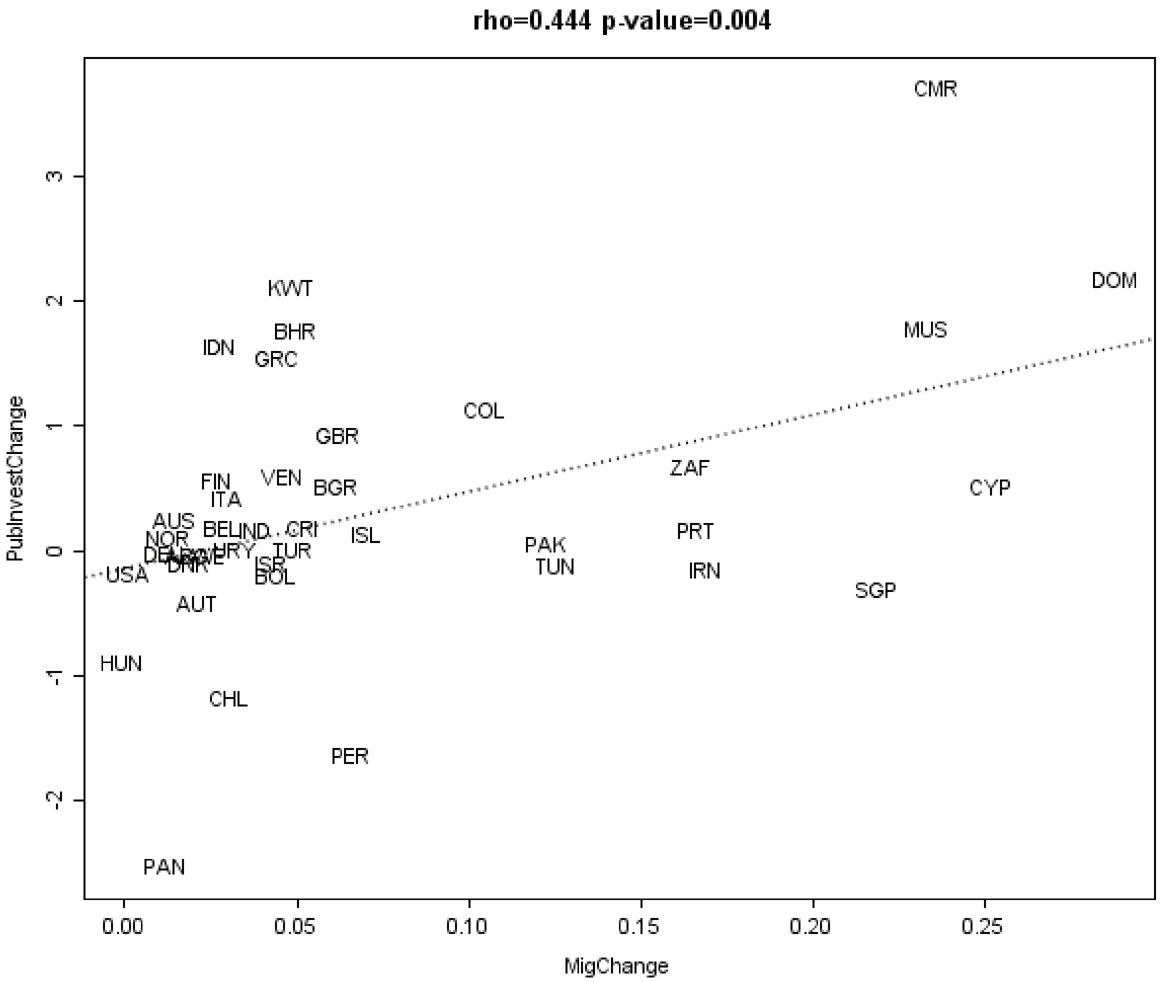
Correlation between changes in log GDP gaps and changes in aggregated high skilled emigration rates



Notes: rho represents the correlation coefficient. The p-value results from a test of the significance of the correlation. The plot is based on 138 observations (data excluding outliers). MigChange represents a country's total high skilled emigration stock in 2000 minus its total high skilled emigration stock in 1990 relative to its total high skilled residents in 1990 (i.e. increase in high skilled emigration rate over time). GDPChange represents the difference of log(mean GDP of OECD countries) minus log(GDP of country) between 2000 and 1990 (i.e. increase in income gaps over time).

Figure 2

Correlation between changes in public investment levels (as fraction of GDP) and changes in aggregated high skilled emigration rates



Notes: rho represents the correlation coefficient. The p-value results from a test of the significance of the correlation. The plot is based on 40 observations. MigChange represents a country's total high skilled emigration stock in 2000 minus its total high skilled emigration stock in 1990 relative to its total high skilled population in 1990 (i.e. increase in high skilled emigration rate over time). PubInvestChange represents the difference of mean public investment shares in OECD countries minus public investment share of the country between 2000 and 1990 (i.e. increase in public investment gaps over time). Public investment data (measure "Government Acquisition of Fixed Assets over GDP") is available from the IMF Government Financial Statistics from 1990 to 1992 and 1999 to 2001 (missing data matched with nearest year).

Figure 3
Migration in equilibrium for given public investment

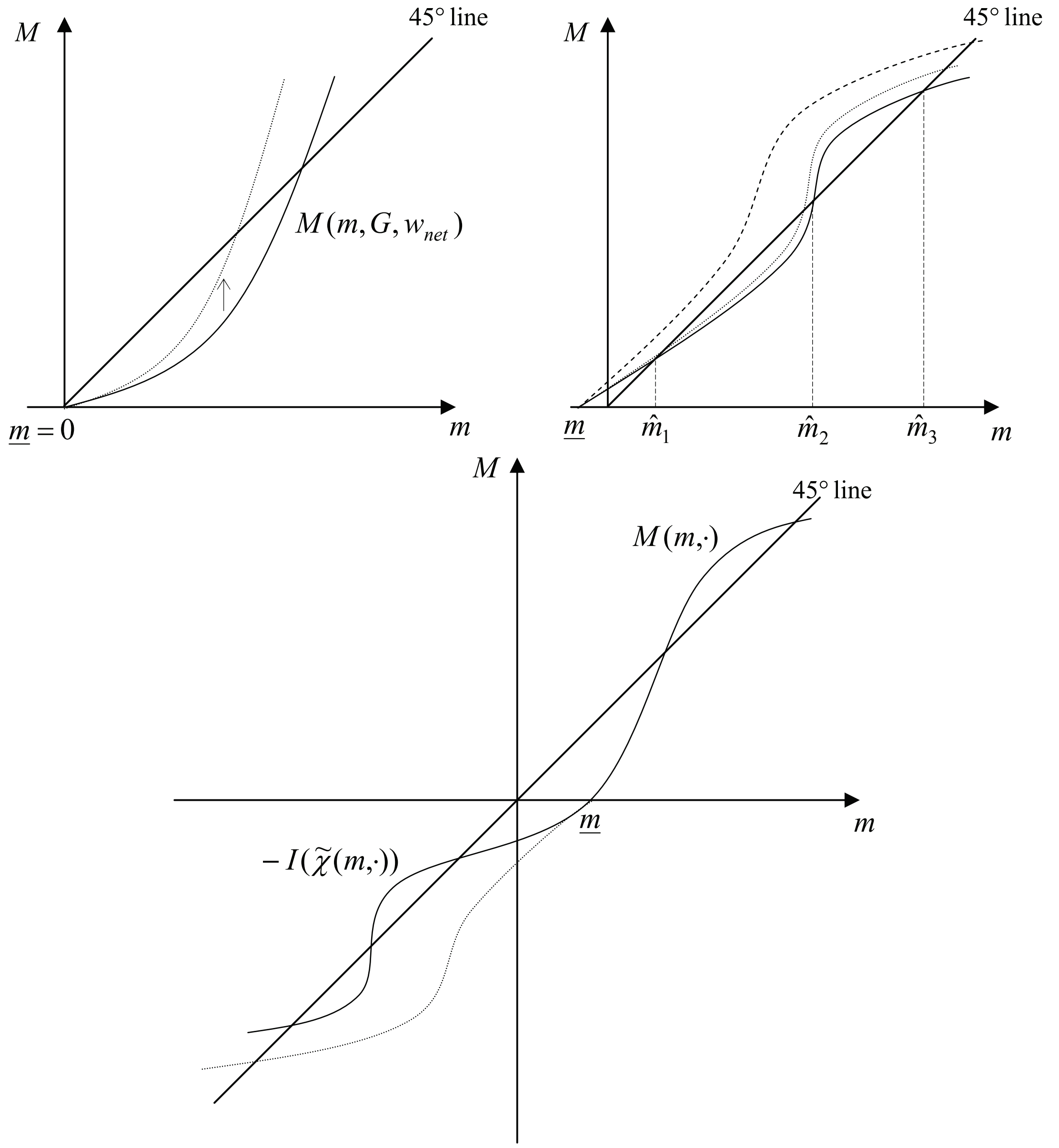


Figure 4

Welfare as a function of *G* for a given migration flow, $m_2 > m_1$

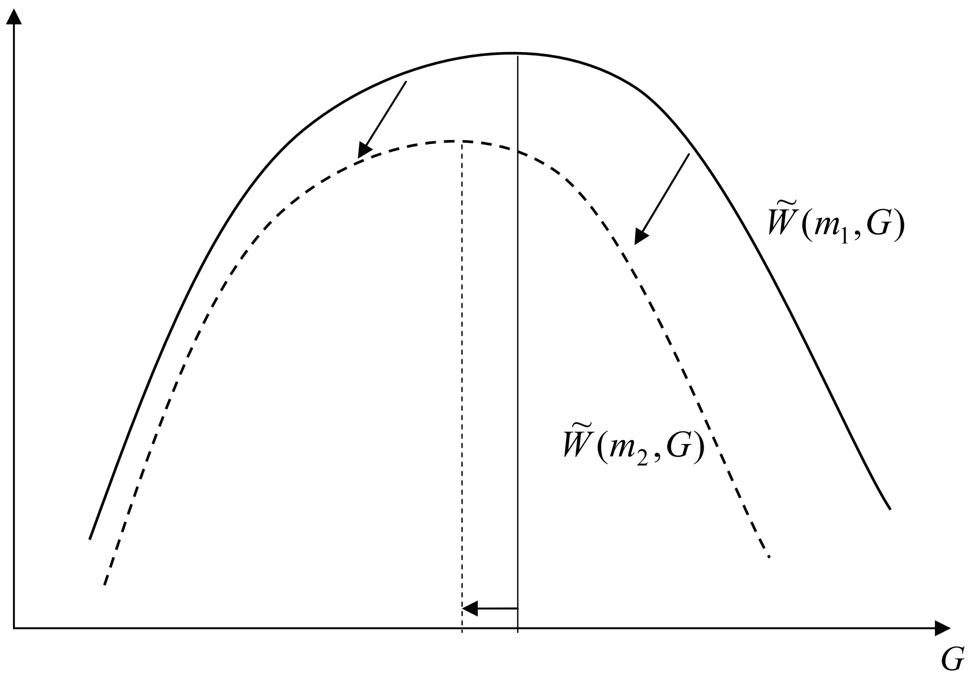


Table 1
Data description and sources

Variable	*Description and source*	*N*	*Mean*	*S.D.*
$Mig2000_{ij}$ *[$Mig1990_{ij}$]*	Stock of emigrants of educational category "high" aged 25+ born in country *i* and living in OECD country *j* in year 2000 [1990] divided by stock of residents of educational category "high" in country *i* in year 2000 [1990]. Stock of emigration and stock of residents of educational category "high" from Docquier, Marfouk and Lowell (2007).	3463	0.02572	0.20112
$DeltaMig_{ij}$	Stock of emigration of educational category "high" in year 2000 minus stock of emigration of education category "high" in year 1990 relative to stock of residents of educational category "high" in country *i* in year 1990 (increase in high skilled emigration rate over time).	3463	0.01922	0.17572
$log(y_j/y_i)$	Log of GDP per capita of country *j* minus log of GDP per capita of country *i* in year 2000. GDP data from Penn World Table Version 6.2.	3463	1.434	1.24421
$DeltaGDP_{ij}$	Difference in $log(y_j/y_i)$ between year 2000 and 1990 (increase in income gap over time).	3092	0.06689	0.31503
$RelPrimSchool1990_{ij}$	Primary school enrolment in country *j* divided by primary school enrolment in country *i* in year 1990. Primary school enrolment rate from Global Development Finance & World Development Indicators.	2699	1.189	0.49461
$RelTertSchool1990_{ij}$	Tertiary school enrolment in country *j* divided by tertiary school enrolment in country *i* in year 1990. Tertiary school enrolment rate from Global Development Finance & World Development Indicators.	2848	9.398	21.21693
$RelInvest1990_{ij}$	Investment share in country *j* divided by investment share in country *i* in year 1990. Investment share from Penn World Table Version 6.2.	3050	2.335	1.95663
$RelUrban1990_{ij}$	Urban population share in country *j* divided by urban population share in country *i* in year 1990. Urban population share from Global Development Finance & World Development Indicators.	3423	1.976	1.79933
$TotalMig_{ij}$	Log size of total emigrant population from country *i* living in country *j* in year 1990. Docquier, Marfouk and Lowell (2007).	3463	5.698	2.94541
$Dist_{ij}$	Log geodesic distance in kms between country *i* and *j*. Mayer and Soledad (2006).	3453	8.476	0.92755
$ComLang_{ij}$	Dummy variable capturing if same language is spoken by at least 9 % of the population in country *i* and *j*. Mayer and Soledad (2006).	3463	0.1231	0.32862
$Contig_{ij}$	Dummy variable capturing if country *i* and *j* are contiguous. Mayer and Soledad (2006).	3463	0.0261	0.15945
$OECD_i$	Dummy variable capturing if country *i* is member of OECD.	3463	0.2121	0.40884
$RegionSsa_i$	Dummy variable capturing if country *i* is in region "Sub Sahara Africa".	3436	0.2166	0.41199
$RegionEap_i$	Dummy variable capturing if country *i* is in region "East Asia and Pacific".	3092	0.06689	0.31503

Notes: The range, mean and standard deviations are not weighted and based on the respective number of observations. Destination countries are the 30 OECD members. Total number of observations depends on data availability for destination and source countries. An observation is excluded if bilateral data is not available or source country does not have any emigrant in destination country.

Table 2

Effect of high skilled emigration rates on income gaps

Variable	*OLS (1)*	*OLS (2)*	*OLS (3)*	*OLS (4)*	*OLS (5)*	*OLS (6)*	*OLS (7)*	*OLS (8)*
	Dependent variable: **log(y_j/y_i)**							
Mig2000$_{ij}$	0.1423[b]	0.1381[a]	0.1734[a]	0.1344[b]	0.1922[a]	0.1630[a]		
	(0.0617)	(0.0397)	(0.0528)	(0.0654)	(0.0358)	(0.0276)		
Mig1990$_{ij}$							0.1524[b]	0.1386[a]
							(0.0613)	(0.0418)
OECD$_i$	-1.3676[a]	-1.2402[a]	-1.1882[a]	-1.1815[a]	-1.0241[a]		-1.0245[a]	
	(0.0261)	(0.0323)	(0.0289)	(0.0248)	(0.0316)		(0.0316)	
RegionSsa$_i$	1.3761[a]	0.1178[a]	0.1679[a]	-0.0668[a]	0.0176		0.0165	
	(0.0317)	(0.0327)	(0.0264)	(0.0258)	(0.0281)		(0.0283)	
RegionEap$_i$	0.1293[a]	0.9545[a]	1.1141[a]	0.9491[a]	0.6282[a]		0.6259[a]	
	(0.0301)	(0.0389)	(0.0262)	(0.0250)	(0.0373)		(0.0370)	
RelPrimSchool1990$_{ij}$		0.4075[a]			0.3225[a]	-0.3658	0.3231[a]	-0.3683
		(0.0365)			(0.0310)	(0.7655)	(0.0309)	(0.7668)
RelTertSchool1990$_{ij}$		0.0097[a]			0.0037[a]	0.0046	0.0038[a]	0.0047[c]
		(0.0021)			(0.0010)	(0.0028)	(0.0010)	(0.0028)
RelInvest1990$_{ij}$			0.1525[a]		0.0811[a]	0.2331[c]	0.0812[a]	0.2317[c]
			(0.0134)		(0.0108)	(0.1216)	(0.0108)	(0.1215)
RelUrban1990$_{ij}$				0.2388[a]	0.1856[a]	0.2113[a]	0.1854[a]	0.2109[a]
				(0.0150)	(0.0141)	(0.0805)	(0.0140)	(0.0806)
(incercept)	1.4198[a]	0.8597[a]	1.0763[a]	1.0120[a]	0.4707[a]	3.6064	0.4709[a]	3.6211
	(0.0653)	(0.0661)	(0.0792)	(0.0754)	(0.0735)	(3.0786)	(0.0733)	(3.0845)
Origin FE	NO	NO	NO	NO	NO	YES	NO	YES
N	3438	2592	3026	3417	2275	2275	2275	2275
Adj. R2	0.5270	0.5939	0.5749	0.6190	0.6725	0.9395	0.6722	0.9393
Destination clusters	YES	YES	YES	YES	YES	YES	YES	YES

Notes: Robust clustered standard errors in parenthesis. [a] indicates a significance level of below 1 %; [b] indicates a significance level between 1 and 5 %; [c] indicates significance level between 5 and 10 %; [d] indicates significance level between 10 and 15 %.

Table 3

Effect of high skilled emigration rates on income gaps and changes in income gaps (instrumental variable estimations)

Variable	*IV* *(1)*	*IV* *(2)*	*IV* *(3)*	*IV* *(4)*	*IV* *(5)*	*IV* *(6)*	*IV* *(7)*	*IV* *(8)*
	Dependent variable: **log(y_j/y_i)**				Dependent variable: **DeltaGDP$_{ij}$**			
Mig2000$_{ij}$	0.28670[a]	0.2554[c]	0.3327[c]	0.11409[c]				
	(0.10372)	(0.1351)	(0.2038)	(0.06812)				
DeltaMig$_{ij}$					0.0156[b]	0.1002[b]	0.1394	0.1132[d]
					(0.0070)	(0.0413)	(0.1693)	(0.0784)
OECD$_i$	-0.9455[a]							
	(0.0404)							
RegionSsa$_i$	0.0372							
	(0.0335)							
RegionEap$_i$	0.7181[a]							
	(0.0569)							
RelPrimSchool1990$_{ij}$	0.3361[a]	-0.3943	-0.3844[a]	-0.4430		0.2660[a]	0.2553[a]	0.2665[a]
	(0.0300)	(0.7558)	(0.1100)	(0.7662)		(0.0243)	(0.0236)	(0.0242)
RelTertSchool1990$_{ij}$	0.0012	0.0018	0.0045[a]	0.0033		0.0005[a]	0.0006[a]	0.0005[a]
	(0.0012)	(0.0023)	(0.0010)	(0.0025)		(0.0002)	(0.0001)	(0.0001)
RelInvest1990$_{ij}$	0.0913[a]	0.2391[b]	0.2317[a]	0.2393[b]		-0.0092[b]	-0.0107[a]	-0.0089[b]
	(0.0101)	(0.1096)	(0.0263)	(0.1155)		(0.0045)	(0.0041)	(0.0043)
RelUrban1990$_{ij}$	0.1893[a]	0.1831[b]	0.2083[a]	0.1934[b]		-0.0079[a]	-0.0094[a]	-0.0078[a]
	(0.0143)	(0.0830)	(0.0261)	(0.0822)		(0.0031)	(0.0030)	(0.0030)
(incercept)	0.3506[a]	3.8160	3.6978[a]	3.9724	1.4789[a]	0.5221[a]	0.5740	0.5192[a]
	(0.0864)	(3.0059)	(0.4775)	(3.0644)	(0.0176)	(0.1076)	(0.7751)	(0.1064)
Origin FE	NO	YES	YES	YES	YES	YES	YES	YES
N	2275	2275	2266	2266	2275	2275	2266	2266
Adj. R2	0.6788	0.9425	0.9387	0.9411	0.9034	0.9087	0.9088	0.9088
Destination clusters	YES	YES	YES	YES	YES	YES	YES	YES
F-Test (first stage)	14.83	18.05	17.17	19.96	46.24	47.93	11.05	46.77
J-Test	-	-	0.324	0.315	-	-	0.361	0.479
Instruments used	*TotalMig$_{ij}$*	*TotalMig$_{ij}$*	*Dist$_i$ + ComLang$_{ij}$ + Contig$_{ij}$*	*TotalMig$_{ij}$ + Dist$_i$ + ComLang$_{ij}$ + Contig$_{ij}$*	*TotalMig$_{ij}$*	*TotalMig$_{ij}$*	*Dist$_i$ + ComLang$_{ij}$ + Contig$_{ij}$*	*TotalMig$_{ij}$ + Dist$_i$ + ComLang$_{ij}$ + Contig$_{ij}$*

Notes: Robust clustered standard errors in parenthesis. [a] indicates a significance level of below 1 %; [b] indicates a significance level between 1 and 5 %; [c] indicates significance level between 5 and 10 %; [d] indicates significance level between 10 and 15 %.