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Does High-skilled Migration Affect Publicly Financed Investments?

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Abstract

This paper analyzes the interaction between migration of high-skilled labor and publicly financed investment. We develop a theoretical model with multiple, *ex ante* identical jurisdictions where individuals decide on education and subsequent emigration. Migration decisions are based on differences in net income across jurisdictions which may occur endogenously. The interaction between income differences and migration flows gives rise to the potential of multiple equilibria: a symmetric equilibrium without migration and an asymmetric equilibrium in which net income levels differ among jurisdictions and trigger migration flows. In the former equilibrium, all jurisdictions have the same public investment level. In the latter one, public investment is high in host economies of skilled expatriates and low in source economies. We empirically test the hypothesis that emigration rates are negatively associated with publicly financed investment levels for OECD countries.

1. Introduction

Governments have become increasingly aware of international factor mobility when designing public policy. This paper examines the relationship between migration of skilled labor and public investment expenditure. The particular interest in this link stems from the empirically well-supported notion that brain drain is largely triggered by low earning prospects at home, and may further reduce income levels, whereas publicly financed investments may increase output capacity and therefore boost economic prosperity. Prima facie, one may therefore suspect that economies experiencing outflows of skilled labor are particularly prone to invest in public infrastructure in order to mitigate or reverse brain drain.

However, a first look at the data reveals that public investment levels in countries which benefit from high net immigration such as the US and Switzerland are comparatively high, whereas public investment in countries which suffer from high net emigration like Portugal and Mexico is comparatively low. In fact, as Figure 1 shows, the change in net emigration rates of the tertiary educated between 1990 and 2000 is negatively related to the change in (log) per capita public investment levels among OECD countries. Thus, a larger migration outflow is associated with slower growth of per capita public investment expenditure.[1]

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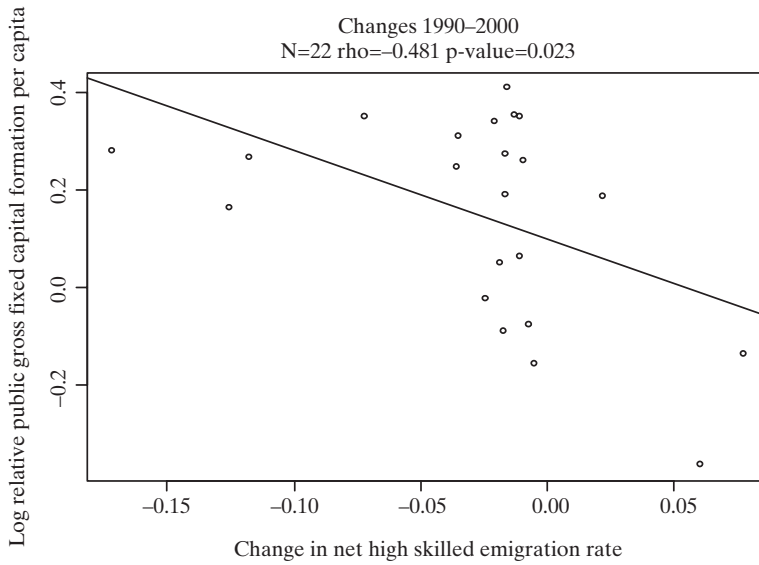

Figure 1. Net Emigration Rates and Government Investment in OECD Countries

Notes: rho represents the correlation coefficient. The p-value results from a test of the significance of the correlation. For the construction of the net emigration rate see description in subsection 4.1.

To understand this empirical pattern, we develop a theoretical model with many *ex ante* identical jurisdictions. We examine how migration flows interact with public investment levels set by benevolent policy-makers. Source and host economies of high-skilled expatriates can endogenously emerge despite symmetry *ex ante*, which has implications for the pattern of public investment choices. There are three key features of the model. First, migration decisions are based on differences in net wage rates for the skilled across jurisdictions.[2] The possibility of migration is taken into account when the education decision is made. Second, not only do income differences trigger migration outflows, but higher emigration also raises income gaps to host economies of skilled expatriates. This is implied by assuming human capital externalities on productivity, as in Lucas (1988). Such externalities give rise to the possibility of multiple equilibria, i.e. in addition to an equilibrium without migration, there may be migration flows between *ex ante* identical economies. Third, we assume that higher public investments are productivity-enhancing and thus raise income per capita.

As a consequence of these basic premises and consistent with Figure 1, it is optimal for host economies to have higher public investment levels than source economies. Interestingly, according to our model, welfare-maximization is equivalent to minimization of brain drain in a source economy. Our analysis therefore suggests that it is optimal for source economies to adjust the public investment level in order to mitigate the brain drain problem. However, it is a low rather than a high spending level, compared to host economies, which achieves this goal. In host economies it is optimal to set public investment expenditure at a level which maximizes the number of high-skilled immigrants.

In order to establish causal effects in our empirical analysis, we construct an instrument for the aggregate net emigration rate of a country's skilled workers. The

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instrumentation strategy is motivated by the innovative way to predict of aggregate trade flows in the widely cited contribution of Frankel and Romer (1999) on the effects of trade on growth. We regress bilateral emigration stocks of tertiary educated workers on several presumably exogenous factors (like the distance between countries). We then use the predicted bilateral stocks to construct an aggregate net emigration rate for each country. The instrumental variable (IV) estimates tend to confirm results from OLS estimations.

Our contribution shares several features with the previous literature. First, as in our model, Miyagiwa (1991) and Grossmann and Stadelmann (2011) allow for socially increasing returns to scale. However, these studies assume that income of the host economy is exogenous. Second, similar to seminal papers like Bhagwati and Hamada (1974), albeit for different reasons, our framework emphasizes adverse effects of outward migration. This is not to deny the possibility of potentially beneficial wage effects of emigration for source economies. However, empirically, this mechanism is supported mainly for poor countries with rather low levels of human capital (Beine et al., 2001, 2008). We instead focus on *ex ante* similar economies in the theoretical part and provide evidence for OECD countries. Finally, our research is related to the by now large literature on the consequences of high-skilled labor mobility on the public sector, like the implications of declining mobility costs for public education finance under fiscal competition (see Justman and Thisse, 1997, 2000; Poutvaara and Kanniainen, 2000; Andersson and Konrad, 2003; Poutvaara, 2004, 2008; Egger et al., 2012). Our paper has a different focus. We develop the theoretical hypothesis that a negative relationship between high-skilled emigration and productive government spending endogenously arises. This complements the literature on migration and fiscal competition. For instance, Egger et al. (2012) show that governments may strategically reduce public education spending in order to mitigate a brain drain problem.[3] The testable implication is, again, that emigration has a negative effect on productive government spending and we present empirical support for that hypothesis.

2. The Model

Consider a continuum of *ex ante* identical jurisdictions with unit mass. Each jurisdiction is initially populated by a unit mass of natives. There is perfect competition in goods and labor markets.

In each jurisdiction, there is a representative firm which produces a homogenous consumption good, chosen as numeraire. Output Y is given by the linearly homogenous function F, specified in *CES*-form:

$$Y = F(X, L) = A \cdot \left(\alpha X^{\frac{\sigma-1}{\sigma}} + (1-\alpha) L^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma-1}{\sigma}}, \tag{1}$$

$\sigma > 0$, $0 < \alpha < 1$, where L is employment of low-skilled labor and X is the input of an intermediate capital good. Total factor productivity (TFP), A, depends on the number of high-skilled workers, N, in the economy.[4] We have

$$A = a(N), \tag{2}$$

where $a(\cdot)$ is an increasing and concave function with $a(0) \geq 0$. Thus, a reduction in the skilled labor force, as result of emigration, reduces output for given input levels.[5] A is

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taken as given by the representative firm. Our formulation thus captures human capital externalities on productivity as in Lucas (1988); there are socially increasing but privately constant returns to scale.

Production of the intermediate good is skill-intensive. For simplicity it only uses high-skilled labor. Output is given by

$$X = B \cdot S, \tag{3}$$

where S denotes the amount of high-skilled labor which is used for the production of the intermediate good and B measures its productivity. Productivity is affected by the public investment level of a jurisdiction, G, measured in units of the final good. We assume

$$B = b(G), \tag{4}$$

where $b(\cdot)$ is an increasing and concave function with $b(0) > 0$; moreover, we assume $\lim_{G \to 0} b'(G) \to \infty$ and $\lim_{G \to \infty} b'(G) = 0$.[6] According to (4), public investment G is a local public good (i.e. there are no spillovers to other jurisdictions).

Public investment is financed by proportional wage taxation. The tax rate is denoted by $\tau \in (0, 1)$. It applies to all workers employed in the domestic economy.[7]

Individuals are endowed with one unit of time. They decide whether or not to become high-skilled, at cost of $e \in (0, 1)$ units of time. If not spending time e in school, an individual remains low-skilled. Time not used for education is in-elastically supplied to a perfect labor market.[8]

Utility of individual i is given by his/her consumption level (equal to after-tax wage income $c(i)$ of the final good when working at home. If the individual works abroad, utility is a discounted measure compared to that of non-migrants; formally, utility is given by $c(i)/(1 + \theta(i))$.[9] Mobility cost parameter φ is distributed according to a continuous p.d.f. $\varphi(\theta)$ with positive support; the corresponding c.d.f. is denoted by $\Phi(\theta)$. There are no immigration quotas. When deciding whether or not to become skilled, individuals take both migration incentives and costs into account. To focus on migration patterns of high-skilled workers, we assume that low-skilled labor is immobile.[10]

We close the model description with a remark on the role of public investment, G, for economic performance of a jurisdiction. What matters for the main insights of our theory is that an increase in G affects labor productivity in the aggregate economy. However, rather than assuming that an increase in G raises productivity of skilled labor in the intermediate goods sector, and thus is high-skilled labor saving, one may alternatively assume that TFP A in the final goods sector is positively affected by a higher G. It is easy to show that in this case, an increase in G would leave the educational choice unaffected. In contrast, in our formulation public investment will generally affect education decisions. Using (3) in (1) we see that CJ equals the elasticity of substitution between high-skilled and low-skilled labor. In our model, if $\sigma > 1$, an increase in G induces more individuals to become educated. This result is consistent with empirical evidence in the case of public education spending (e.g. Egger et al., 2010, 2012). Throughout we maintain the assumption

$$1 < \sigma \leq 2. \tag{A1}$$

Empirical estimates show that the elasticity of substitution between high and low-skilled labor, σ, is between 1.5 and 2 (e.g. Freeman, 1986; Johnson, 1997; Card, 2009).

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3. Equilibrium Analysis

Small Open Economy

We first analyze the education and migration decision in a single jurisdiction for a given public investment level and given the income opportunities abroad (small open economy).

Proposition 1. *In equilibrium, for a given number of (skilled) emigrants, m, the wage rate of skilled labor is given by*

$$w_S = a\left(\frac{1-m}{1+\left(\frac{1-\alpha}{\alpha}\right)^{\sigma}[(1-e)B]^{1-\sigma}}\right)\left[\sigma^{\sigma}B^{\sigma-1}+(1-\alpha)^{\sigma}(1-e)^{1-\sigma}\right]^{\frac{1}{\sigma-1}} \equiv \tilde{w}^S(B,m). \tag{5}$$

Proof. See online appendix (www.unifr.ch/makro). □

Hence, $\tilde{w}^S(B,m)$ is increasing and strictly concave as a function of B under assumption A1 ($\tilde{w}^S_B > 0$, $\tilde{w}^S_{BB} < 0$).[11] Moreover, $\sigma > 1$ is sufficient (but not necessary) for the cross-derivative of $\tilde{w}^S$ to be negative ($\tilde{w}^S_{Bm} < 0$). This will turn out to be a key property of the model. It may be understood as follows: due to human capital externalities, higher emigration lowers TFP and therefore reduces wage rates; in particular, $\tilde{w}^S_m < 0$. The decline in TFP lowers the marginal product of the intermediate good in final goods production; thus, an increase in the productivity of skilled labor B has a lower impact on wage rates if m increases. As B is positively affected by a higher public investment level G, this implies that an increase in G has a lower impact on wage rates, if more skilled workers emigrate.

We now turn to the migration decision. Let the highest net wage rate per unit of high-skilled labor among jurisdictions abroad be given by $\bar{w}^S_{net}$. For the purpose of this subsection, we treat $\bar{w}^S_{net}$ as exogenous whereas in an international equilibrium analyzed below, wages everywhere are affected by migration flows.

Due to of disutility from emigrating for given consumption, individual i emigrates if

$$\frac{\bar{w}^S_{net}}{w^S_{net}} \geq 1+\theta(i), \tag{6}$$

where $w^S_{net} \equiv (1-\tau)w_S$ is the after-tax wage rate of skilled labor in the considered economy. Thus, if $w^S_{net} < \bar{w}^S_{net}$, the number of emigrants is

$$m = \int_0^{\bar{w}^S_{net}/w^S_{net}-1} \varphi(\theta)\,\mathrm{d}\theta = \Phi\left(\bar{w}^S_{net}/w^S_{net}-1\right). \tag{7}$$

From the government budget constraint, $\tau[w_S(1-e)N + w_L L] = G$. Employing no arbitrage condition $(1-e)w_S = w_L$ and resource constraint $N + L = 1 - m$, we find that $\tau w_S = \dfrac{G}{(1-m)(1-e)}$. Thus, we have

$$w^S_{net} = w^S - \tau w^S = \tilde{w}^S(b(G),m) - \frac{G}{(1-m)(1-e)} \equiv W(G,m). \tag{8}$$

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From the properties of (5) and function b, the net wage rate $w^S_{net} = W(G, m)$ is decreasing in the number of emigrants m, for two reasons. The first reason is that an increase in m lowers TFP, as discussed above. The second reason is that higher emigration reduces the tax base, which means that for a given public investment level G, the tax rate τ has to increase in order to balance the government budget. Both effects go in the same direction. If we alternatively assumed that emigrants still pay taxes where they are born, such that the second effects would vanish, $W_m < 0$ would still hold.

There are two further interesting properties of function W, which give rise to our main results, as will become apparent. First, under assumption A1, after-tax wages are strictly concave as a function of G, $W_{GG} < 0$.[12] Second, the effect of an increase in G on wages is smaller, if emigration is higher; formally, $W_{Gm} < 0$. The property also arises for two reasons: first, as discussed, pre-tax wage rates are rising less as a response of an increase in productivity parameter B when m increases (recall $\tilde{w}^S_{Bm} < 0$). Moreover, it holds that the additional tax burden of an increase in G is higher, if emigration rises. Again the second effect would vanish if emigrants still paid taxes in the economy where they are born. According to (7), if $\bar{w}^S_{net} \geq W(G, m)$, the number of emigrants $m \geq 0$ is implicitly given by

$$m = \Phi\left(\frac{\bar{w}^S_{net}}{W(G, m)} - 1\right) \equiv RHS. \tag{9}$$

Figure 2 depicts the right-hand side, RHS, of (9), as a ($\mathcal{S}$-shaped) function of m (given $\bar{w}^S_{net}$ and G). An equilibrium is reached if RHS intersects with the 45-degree line. Figure 2 shows three equilibria, with migration levels denoted by m_0, m' and m_1. Multiple equilibria easily arise due to the following interaction: on the one hand, (after-tax) income differences trigger migration flows. On the other hand, higher emigration triggers income reductions in the source economy, due to negative human capital externalities of brain drain; this gives further incentives to emigrate. Consequently, either emigration and the wage gap to the exogenous level $\bar{w}^S_{net}$ are high or bot are low. Figure 2 is drawn in such a way that at $m_0 = 0$ (no emigration or immigration in the considered economy) the net wage rate is the same as the highest

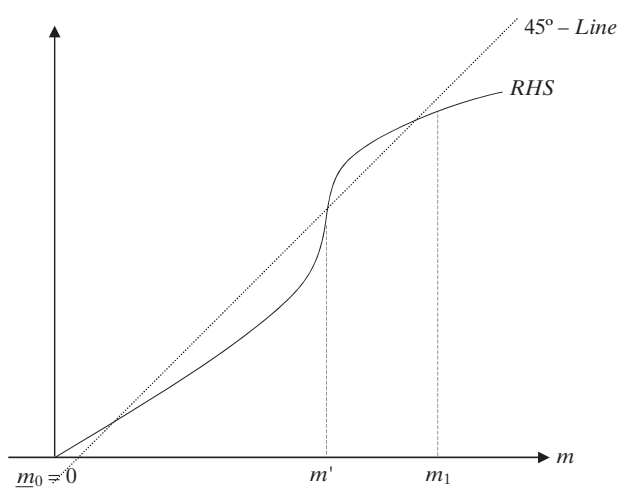

Figure 2. Migration in Equilibrium for Given Public Investment

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one abroad, $W(G,0) = \bar{w}^S_{net}$. The two other equilibria in Figure 2, m' and m, feature emigration.

Throughout, we invoke the standard notion of tatonnement stability; here, this means that we focus on migration levels where small perturbations of an equilibrium gives rise to a tendency of m to return to its initial level. In Figure 2, this is the case when RHS crosses the 45-degree line from above (i.e. $\partial RHS/\partial m < 1$). Thus, $m_0 = 0$ and m_1 are stable equilibrium migration levels, whereas at m' the equilibrium is unstable. Suppose, e.g. that the number of emigrants m would be slightly below m_1. In this case, $RHS > m$, implying that emigration tends to rise. If to the contrary the number of emigrants m is slightly higher than m_1, then $RHS < m$ and the number of migrants tends to fall. The opposite holds at m'.

International Equilibrium

We now turn to the international equilibrium, where all income levels are endogenous. Such an equilibrium could be analyzed for any given distribution of (local) public investment levels in the world economy. We focus on the particular case where all jurisdictions choose their public investment levels "optimally."[13] As we are interested in the relationship between public investment and the pattern of migration, we need a plausible government objective function. In our context, with *ex ante* identical individuals, a plausible candidate is the utility of non-migrating individuals. These most plausibly represent the median voter. For a jurisdiction which does not expect to have immigration, $m \geq 0$, this means that net wage rate $W(G, m)$ is maximized subject to the education and migration decisions as reflected by (9). The after-tax wage rates abroad are taken as given.[14]

So far we focused on emigration. Regarding immigration, suppose a jurisdiction expecting an inflow of skilled workers takes into account that the number of immigrants, I, depends on the domestic net wage rate of high-skilled labor and the income opportunities of high-skilled labor abroad. Formally, suppose host economies with $I > 0$ immigrants take into account schedule $I = \tilde{I}(w^S_{net})$, with $\tilde{I}' > 0$ (i.e. higher after-tax wage rates at home makes host economies more attractive).[15] Analogously to the derivation of (8) higher immigration has positive productivity effects; formally, we have $w^S_{net} = W(G, -I)$. Thus,

$$I = \tilde{I}(W(G, -I)) \tag{10}$$

implicitly defines the immigration level I as a function of G; we denote this level by $I = \hat{I}(G)$. Fortunately, as will become apparent, we do not have to know functions $\tilde{I}$ or $\hat{I}$ to characterize an international (perfect foresight) equilibrium. We require the following equilibrium conditions to hold:

- Individuals optimally choose whether to acquire education and whether to migrate if educated, by taking wage rates at home and abroad as given.
- Representative firms in both the final goods sector and the intermediate goods sector maximize profits by taking factor prices as given.
- In all jurisdictions, public investment levels are chosen such that net wage rates of the non-migrants are maximized, taking into account educational choices, migration behavior, choices of firms, and taking as given wage rates abroad.
- Migration patterns are tatonnement-stable.
- The number of immigrants in the world equals the number of emigrants.

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We will now show that, despite symmetry of jurisdictions *ex ante*, there may exist an equilibrium where there is a group of host economies which have the same immigration level I and a group of source economies which have the same emigration level m. Denoting the fraction of host economies by λ, we then have

$$\lambda I = (1-\lambda)m. \tag{11}$$

What agents take as given must of course be correct *ex post*. For governments, this includes the expectation whether to be a host or source economy of migrating workers. Expecting $m = 0$, a jurisdiction solves $\max_G W(G, 0)$. As $W_{GG} < 0$, this leads to optimal public investment level G_0 as given by $W_G(G_0, 0) = 0$. Moreover, expecting $m > 0$, a jurisdiction solves $\max_G W(G, \hat{m}(G))$, where $\hat{m}$ denotes the level of emigration which is implicitly given by (9).[16] The first-order condition reads

$$W_G + W_m \hat{m}_G = 0. \tag{12}$$

Applying the implicit function theorem to (9) implies that

$$\hat{m}_G(G) = -\frac{\varphi\left(\dfrac{\bar{w}^S_{net}}{W(G,\hat{m})} - 1\right)\dfrac{\bar{w}^S_{net}}{W(G,\hat{m})^2} W_G(G,\hat{m})}{1 - [\partial RHS/\partial m]_{m=\hat{m}}}. \tag{13}$$

Thus, under stability ($\partial RHS/\partial \mathrm{m} < 1$), the first order condition (12) can be rewritten as $W_G(G, \hat{m}(G)) = 0$. At the so-defined public investment level, we have $\hat{m}_G = 0$, according to (13). Thus, $W_{GG} < 0$ is sufficient for the second-order condition to hold. Finally, expecting $I = \hat{I}(G) > 0$, a jurisdiction solves $\max_G W\left(G, -\hat{I}(G)\right)$.[17] The first-order condition reads

$$W_G - W_m \hat{I}_G = 0, \tag{14}$$

where the implicit function theorem implies that

$$\hat{I}_G(G) = \frac{\tilde{I}'\left(W\left(G, -\hat{I}\right)\right) W_G\left(G, -\hat{I}\right)}{1 + \left[\tilde{I}'(\cdot) W_m\right]_{I=\hat{I}}}. \tag{15}$$

Under stability, analogously to (13), the denominator of the right-hand side of (15) is positive. Thus, the first order condition (14) for a source economy becomes $W_G\left(G, -\hat{I}(G)\right) = 0$. Again, the second order condition holds.

It is interesting to note that, at the optimal public investment levels, emigration is minimized in a source economy of high-skilled expatriates and immigration is maximized in host economies. To see this formally, note that so-defined level of G, $\hat{m}_{GG} > 0$, according to (13). Similarly, $\hat{I}_G = 0$ if $W_G = 0$ and $\hat{I}_{GG} < 0$ at that level of G. These results are implied by the basic properties of the model. Recall that the government objective is to maximize net wage income of workers at home. Income opportunities abroad relative to those at home form the basis for migration decisions. Both skilled workers and the government take net wage rates abroad as given. The government problem and individual migration decisions are thus based on the same variable, the wage rate for skilled labor at home, w^S_{net}. The question now is in which way the migration of skilled labor affects public investment levels.[18]

In equilibrium, the expectation whether to be host or source economy is self-fulfilling. Any fraction of host economies λ is a potential equilibrium value. For concreteness, we focus on $\lambda = 0.5$.[19] According to (11), this implies $I = m$. Let us denote by

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G_1^* and G_2^* the equilibrium public investment level of a source economy and host economy, respectively.

Proposition 2. *In international equilibrium, the number of migrants in or out of a jurisdiction, $m^* \geq 0$, and investment levels (G_1^*, G_2^*) are simultaneously given by equation system*

$$W_G(G_1^*, m^*) = 0 \tag{16}$$

$$W_G(G_2^*, -m^*) = 0, \tag{17}$$

$$m^* = \Phi\left(\frac{W(G_2^*, -m^*)}{W(G_1^*, m^*)} - 1\right). \tag{18}$$

Let us write public investment levels defined by $W_G(G, m) = 0$ and $W_G(G, -m) = 0$ as $\tilde{G}_1(m)$ and $\tilde{G}_2(m)$, respectively, and define

$$M(m) \equiv \Phi\left(\frac{W\left(\tilde{G}_1(m), -m\right)}{W\left(\tilde{G}_2(m), m\right)} - 1\right)[= RHS]. \tag{19}$$

Thus, equilibrium migration is given by $m^* = M(m^*)$. As follows from the notion of stability of equilibrium emigration, we must have that $M'(m^*) < 1$ for $m^* \geq 0$. Note that $M(0) = M'(0) = 0$.

Property $M'(0) < 1$ ensures that there exists a symmetric international equilibrium, in which there is no migration ($m = 0$) and all jurisdictions choose public investment level G_0 as defined by $W_G(G_0, 0) = 0$. Moreover, there may be an asymmetric equilibrium with $m^* > 0$ (like m_1 in Figure 2), such that (16)–(18) and $M'(m^*) < 1$ holds. The key characteristic of this equilibrium is that $G_1^* < G_2^*$; that is, source economies have a lower public investment level than host economies. This important result follows from property $W_{Gm} < 0$ and the definition of $\tilde{G}_1(m)$ and $\tilde{G}_2(m)$, respectively; that is, $\tilde{G}_1'(m) < 0$ and $\tilde{G}_2'(m) > 0$. Because the marginal impact of increasing the public investment level on the utility of non-migrants decreases with higher brain drain and increases when more skilled workers immigrate, the analysis suggests a negative relationship between net emigration of an economy and its public investment level.

4. Empirical Support

The theoretical analysis suggests three main hypotheses. First, emigration incentives depend on relative income to potential destination economies. The prediction that income differences trigger migration flows has been examined empirically elsewhere. Recently, both Beine et al. (2011) and Grogger and Hanson (2011) provide convincing evidence for the critical role of wage differences between country pairs on emigration rates of tertiary educated workers. Second, our increasing returns framework suggests that there is a feedback mechanism working from higher emigration to lower wage rates and income levels. Based on an alternative theoretical framework in Grossmann and Stadelmann (2011), this prediction is supported by evidence provided in Grossmann and Stadelmann (2010). Third, and most important for the purpose of this study, we have highlighted the interaction between emigration of high-skilled labor and an

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economy's public investment level. We have shown that the marginal impact of an increase in public investments on income of domestic workers decreases with higher emigration. The novel hypothesis we explore thus is that a higher net emigration rate of high-skilled workers in an economy causes lower public investment levels, all other things equal. We test this prediction with OECD data.

Examining the correlation between public expenditure and emigration cannot identify the direction of causation between the two. We therefore construct an instrument for net migration rates of skilled workers and provide instrumental-variable (IV) estimations in addition to OLS. For this we use a measure of social networks of migrants and exogenous country characteristics, both potentially affecting mobility costs of individuals, to explain bilateral migration flows.

Data and Estimation Strategy

The first challenge is to find a measure for the net emigration rate of high-skilled individuals for OECD countries. Docquier and Marfouk (2006) have established a dataset of (gross) 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% of educated migrants in the world.[20] Docquier et al. (2007) extend the initial dataset by Docquier and Marfouk (2006) and provide bilateral emigration stocks of high-skilled persons from country i living in OECD country j, denoted by M_{ij}. Furthermore, let $\mathcal{S}_{All}$ denote the set of countries in the data set (each one is a potential source country) and denote by $\mathcal{S}_{OECD}$ the set of OECD countries (only these are potential host countries).

We construct the net emigration stock of an OECD country j by aggregating its total emigration stock, $\sum_{i \in \mathcal{S}_{OECD}} M_{ji}$, and deducting its total immigration stock, $\sum_{i \in \mathcal{S}_{All}} M_{ij}$. The net emigration stock of OECD country j is denoted by $NetEmig_j := \sum_{i \in \mathcal{S}_{OECD}} M_{ji} - \sum_{i \in \mathcal{S}_{All}} M_{ij}$. To adjust the emigration variable for the size of the skilled labor force, we divide the high-skilled net emigration stock by the stock of skilled residents in country j, N_j, and thereby obtain a net emigration rate: $Mig_j := NetEmig_j / N_j$.

Denoting by G_j the public investment level per capita of country j we estimate the following equation for the year 2000:

$$\log G_j = \alpha_0 + \alpha_1 Mig_j + \mathbf{x}_j' \boldsymbol{\alpha}_x + \varepsilon_i. \tag{20}$$

As the theoretical model predicts a negative impact of higher emigration on public investment, we expect $\alpha_1 < 0$. $\mathbf{x}_j$ is a vector of other controls potentially affecting public investment in country j. We include (log) population size in order to control for economies of scale associated with public goods. That is, if anything, population size should be negatively related to public expenditure per capita. Moreover, to account for the age structure of a country, which may affect public investments, we include the fraction of population under the age of 16. Finally, to deal with spending determinants which are not based on the optimality criterion employed in the theoretical model, we also control for social spending per capita. Thereby we want, on the one hand, account for the possibility that governments' spending levels on both investment and non-investment expenditure categories are higher in some countries than in others for

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ideological or cultural reasons. This would suggest a positive relationship between government investment and social spending. On the other hand, governments may substitute public investments for welfare expenses. This would imply a negative relationship between the two spending categories. ε_j is an error term.

We use four different measures of public expenditure as dependent variable: government gross fixed capital formation, total publicly financed R&D spending, R&D spending on higher education, and total public education expenditure (all in logs). The first category may be most suited in light of the theoretical model, as it represents public infrastructure spending. We focus on the effects of this category first and discuss the other measures which have qualitatively similar results in an online appendix.

To mitigate potential omitted variable bias, we also take first differences of equation (20) and regress the (approximate) growth rate of public investment per capita in country j on the change in the emigration rate of skilled migrants between 1990 and 2000:

$$\log(G_{j,t}/G_{j,t-1}) = \beta_0 + \beta_1 DeltaMig_j + \mathbf{z}_j'\boldsymbol{\beta}_z + \eta_j, \tag{21}$$

where time indices t and $t-1$ refer to years 2000 and 1990, respectively, and $DeltaMig_j := Mig_{j,t} - Mig_{j,t-1}$. According to the theoretical model, we expect ($\beta_1 < 0$. $\mathbf{z}_j$ is a vector of other controls potentially affecting the rate of change of public investment over time. We include the difference of log population size between 1990 and 2000 and the growth rate of GDP per capita in that time period as controls. The latter accounts for adjustment in spending due to business cycle phenomena. η_j is an error term. The data sources and summary statistics of the employed variables are presented in the online appendix.

To deal with potential endogeneity bias regarding the relationships of interest, we construct an instrument for the net emigration rate of the year 2000 ($Mig_{j,t}$) as well as its change between 1990 and 2000 ($DeltaMig_j$) to estimate equations (20) and (21), respectively. To obtain our instrument for net emigration rates of skilled labor, we exploit the availability of bilateral migration stocks. The procedure is similar to the instrumentation strategy to construct aggregate trade flows of country in the widely-cited contribution of Frankel and Romer (1999) on the impact of higher trade flows on income per capita. Instead of predicting trade we predict total net emigration rates of countries.

We first estimate the (log) stock of skilled expatriates from i living in OECD country j in year 2000, $\log M_{ij,t}$, as function of variables which are supposed to capture migration costs: the total stock of emigration (sum over all education categories) in the year 1990 (in logs) migrating from country i to j, $TotalMig_{ij,t-1}$, countries' log geodesic distances, $Dist_{ij}$, a dummy indicating whether at least 9% of the population in i and j speak a common language, $ComLang_{ij}$, a dummy indicating whether i and j are situated in the same geographical region, $SameRegion_{ij}$,[21] a dummy indicating whether i and j have had colonialties, $Colony_{ij}$, a dummy indicating whether i and j were both transition economies in 1990, $Transition_{ij}$ and source country fixed effects. The inclusion of $TotalMig_{ij,t-1}$ is motivated by the notion that a larger community of people from the same nation already living abroad create mobility-cost reducing network effects, as argued by Beine et al. (2011), among others. To include geographical distance, colonial ties and common language as potential determinants of are also typically used in the brain drain literature. The region dummy is supposed to further capture cultural factors which could be related to language groups (Arabic language

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group, Slavic language group, etc.) and are not necessarily captured by common language. For example, it might be easier for Germans than for Russians to migrate to the UK due to lower cultural barriers between German and English speaking countries. The dummy may also capture historical ties (other than colonial ties) of countries. The dummy on transition countries is potentially important as well, since the time period we consider was shortly after the fall of the iron curtain. This event has newly created the possibility to emigrate from a former communist country to non-transition countries.

The following equation presents the estimated value of bilateral migration stocks with 3515 bilateral observations:

$$\log \hat{M}_{ij,t} = -\underset{(0.394)}{1.702} + \underset{(0.006)}{0.865} \times TotalMig_{ij,t-1} - \underset{(0.025)}{0.252} \times Dist_{ij} + \underset{(0.045)}{0.798} \times ComLang_{ij} + \underset{(0.059)}{0.222} \times SameRegion_{ij} + \underset{(0.155)}{0.158} \times Colony_{ij} - \underset{(0.101)}{1.024} \times Transition_{ij}. \quad (22)$$

All coefficients have the expected sign and are significantly different from zero at the 1% level. Notably, this also applies for the region dummy and the dummy for transition countries, which are usually not considered in the literature as determinants of migration. Moreover, the left-hand side variables explain about 92% of the variation of bilateral migration stocks ($R^2 = 0.917$).

We then recover $\hat{M}_{ij}$ from (22) to construct a predicted net migration rate for the year 2000, $\widehat{Mig}_j$, analogously to the use of M_{ij} to construct Mig_j. The correlation coefficient of the true overall net emigration rate Mig_j with the constructed net emigration rate, $\widehat{Mig}_j$ is 87.6%.

In our instrumental-variable estimations we use $\widehat{Mig}_j$ and $\widehat{DeltaMig}_j = \widehat{Mig}_{j,t} - Mig_{j,t-1}$ instead of their actual values for estimating (20) and (21), respectively. The key identifying assumption for a causal effect of emigration on public investment is that the instruments are uncorrelated with residuals in equations (20) and (21).

Results

Table 1 presents OLS estimates of level-regressions (20) in specifications (1) to (4) and change- regressions (21) in specifications (5) to (10) using both OLS and IV. We use the measure for government investment (government gross fixed capital formation) in logs, *PubInv*, for all regressions.

In specifications (1) to (4) the coefficient of interest, α_1, is always negative. In column (1), we look at the effect of the net emigration rate (*Mig*) on public investment in 22 OECD countries using OLS without any controls. Column (2) uses instead the constructed net emigration rate $\left(\widehat{Mig}\right)$ as an instrument for the actual net emigration rate. The results provide no evidence that ordinary least-squares estimates overstate the negative effect on public investment. The two coefficients in column (1) and column (2) roughly have the same size. Standard errors are quite high, however, given the limited number of observations. The instrument itself proves to be highly significant when considering the first stage F-Test. Columns (3) and (4) represent OLS and IV regressions, respectively, when controlling for log population size (*Pop*), fraction of population under 16 (*Pop* 8) and (log) social expenditure per capita (*SocialExp*) in addition to the net migration rate. The influence of emigration on public investment remains negative when the controls are added and statistical significance increases. Quantitatively, the estimates suggest that effects of brain drain on public investment

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Table 1. Effect of High-skilled Net Emigration Rates on Government Gross Fixed Capital Formation Per Capita: Level and First Difference Estimates

	PubInv				*DeltaPubInv*					
	OLS (1)	*IV* (2)	*OLS* (3)	*IV* (4)	*OLS* (5)	*IV* (6)	*OLS* (7)	*IV* (8)	*OLS* (9)	*IV* (10)
Intercept	6.509***	6.509***	11.947***	11.745***	0.099***	0.090**	1.155***	1.104***	0.884	0.866*
	(0.107)	(0.109)	(1.514)	(1.649)	(0.047)	(0.052)	(0.505)	(0.561)	(0.620)	(0.578)
Mig	–2.159*	–2.203*	–2.328***	–1.932**						
	(1.330)	(1.354)	(0.895)	(1.002)						
DeltaMig					–1.818***	–2.187***	–1.601***	–1.839**	–1.154***	–1.796***
					(0.669)	(1.076)	(0.531)	(0.910)	(0.547)	(0.788)
Pop			–0.143***	–0.138**						
			(0.063)	(0.071)						
Pop16			–0.085***	–0.086***						
			(0.027)	(0.032)						
SocialExp			–0.298***	–0.279***						
			(0.109)	(0.117)						
DeltaPop							–0.967***	–0.927**	–1.045***	–0.936**
							(0.457)	(0.507)	(0.459)	(0.487)
DeltaGDP									0.293	0.199
									(0.208)	(0.199)
F-value—First Stage		61.750		25.160		27.440		13.040		19.170
Adj. R^2	0.138	0.097	0.430	0.334	0.193	0.154	0.243	0.193	0.255	0.308
N	22	22	22	22	22	22	22	22	22	22

Notes: *** indicates a significance level below 5 percent; ** indicates significance level between 5 and 10%; * indicates significance level between 10 and 15%. Robust standard errors in parenthesis.

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are non-negligible. With a being approximately equal to –2, an increase in the net emigration rate of one standard deviation (equal to 0.11) leads to a reduction in public investment expenditure per capita of about 22%.

Turning to the estimates of change-regressions (21) confirms the results of the level-regressions. An increase in the difference of the net emigration rate between 1990 and 2000 has a negative effect on the growth rate of the public investment level per capita. According to columns (5) to (10) in Table 1, β_1 is significantly different from zero below the 5% level, except for the IV regression in column (8), with significance being between the 5 and 10% level. Again, OLS- and IV-estimates are in the same range. As expected, also the growth rate of GDP per capita (*DeltaGDP*) has a positive effect. Controlling for it as well as for the growth rate of population size (*DeltaPop*) reduces β_1 considerably. Still, the evidence from this estimate suggests that an increase in the change in the net migration rate over time (*DeltaMig*) by one standard deviation reduces the growth rate of public investment per capita by about (0.05×1.1=) 55 percentage points. Like for the level-regressions, also for the change-regressions which give IV-estimates, in columns (6), (8) and (10) of Table 1, the F-Test shows that the first stage is always significant with the proposed instrument.

Conclusion

We analyzed theoretically and empirically the relationship between migration of high-skilled individuals, income differences, and differences in public investment levels across jurisdictions. According to the theoretical model, migration of skilled labor may endogenously arise despite symmetry of jurisdictions *ex ante*. This possibility arises from the assumption of human capital externalities, which imply that outflows of skilled labor reduce wage rates in source economies whereas inflows raise them in destination economies. Most importantly, the analysis suggests that higher outward migration reduces the impact of an increase in productivity-enhancing public expenditure on both gross and net income levels of workers, whereas higher inward migration increases it. Consequently, governments who care about welfare of the domestic labor force adjust public investment levels downward when facing brain drain and upward when experiencing inflows of skilled labor.

We presented empirical evidence which is consistent with this main prediction of the theory. The innovation in the empirical part was to construct and employ an instrument for the net emigration rate of a country in order to establish a causal effect. We showed that an increase in the predicted net emigration rate causes quite substantial reductions of public investment levels per capita. Consequently, our analysis suggests that more pronounced international migration patterns for skilled labor are likely to aggravate differences in public investment levels across countries, along with income differences.

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Notes

1. The relationship roughly holds when excluding English-speaking countries from the dataset.
2. See Beine et al. (2011) and Grogger and Hanson (2011) for recent empirical support.
3. Technically, we abstract from fiscal competition by assuming that jusrisdictions are small and do not strategically interact.
4. Such a "scale effect" does not necessarily mean that more largely populated economies are richer than small ones. What may matter for TFP is the density of the skilled population in an

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economy rather than its size. Normalizing the area of a jurisdiction to unity gives equivalently rise to formulation (2).

5. In Grossmann and Stadelmann (2011), a similar property arises from a "love of variety" monopolistic competition model in which brain drain reduces the number of intermediate good firms.

6. The boundary conditions ensure an interior solution for the optimal choice of G of local governments.

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

8. To formulate our model in a static way is for simplicity. Our main results would be unchanged if we set up an overlapping generations structure where individuals acquire education in the first period of life and work in the second period.

9. See Stark et al. (1997), among others.

10. This common assumption of brain drain literature could be justified by the fact that workers with lower education levels often face severe institutional migration barriers in potential host economies. Moreover, the low-skilled may be more likely to have difficulties in finding a job, learning a foreign language and integrating in the foreign society.

11. $\sigma \leq 2$ is sufficient but not necessary for strict concavity.

12. Recall that $\tilde{w}^S_{BB} < 0$ and $b'' \leq 0$.

13. Although this may not literally be the case, focusing on optimal choices is meaningful to explain empirical evidence if the basic economic trade-offs faced by governments, which we identify here, are taken into account in real life.

14. Note that there is no strategic interaction in choosing public investment levels as each jurisdiction is infinitesimally small.

15. The immigration level also depends on income opportunities abroad, which are suppressed in the formal representation.

16. We suppress argument $\bar{w}^S_{net}$ in $\hat{m}$.

17. Recall that $\hat{I}$ is the level of immigration which is implicitly given by (10).

18. According to our theory, if governments are maximizing, regressing the emigration rate on productive public expenditure would reveal zero effect. Thus, in theory, there is no reverse causality bias. We nevertheless employ an instrumental variable strategy to estimate the impact of emigration on public expenditure.

19. The choice of λ does not affect the insights of the following analysis.

20. See Docquier and Marfouk (2006) for a detailed discussion concerning data collection and construction issues.

21. We consider the following eight regions in the world: (i) East Asia and Pacific, (ii) East Europe and Central Asia, (iii) Middle East and North Africa, (iv) South Asia, (v) West Europe, (vi) North America, (vii) Sub Sahara Africa, (viii) Latin America and Caribbean.

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