# Online appendix to

**Does High-Skilled Migration Affect Publicly Financed Investments?**

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*Proof of Proposition 1.* We start by deriving wage rates for high- and low-skilled labor, denoted by $w_S$ and $w_L$, respectively. The wage rate per unit of high-skilled labor is given by its marginal revenue product in the intermediate goods sector, $w_S = pB$, where $p$ denotes the price of the intermediate good. Price $p$ is equal to the marginal product in the final goods sector (inverse demand for the intermediate good), $p = \partial Y/\partial X$. Consequently, we find

$$w_S = A\left(\alpha^{\sigma}B^{\sigma-1} + (1-\alpha)\alpha^{\sigma-1}B^{\frac{(\sigma-1)^2}{\sigma}}\left(\frac{L}{S}\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{1}{\sigma-1}}, \tag{1}$$

according to the production function of final output and $A = a(N)$. Moreover, combining $w_S = B \cdot (\partial Y/\partial X)$ with $w_L = \partial Y/\partial L$ and using $X = BS$, we find

$$\frac{w_S}{w_L} = \frac{\alpha}{1-\alpha}B^{\frac{\sigma-1}{\sigma}}\left(\frac{L}{S}\right)^{\frac{1}{\sigma}}. \tag{2}$$

for the relative wage rate.

In an equilibrium where at least some skilled natives remain in the domestic economy, individuals (which are ex ante identical) must be indifferent whether or not to acquire education. Thus, in view of time cost $e$, the no arbitrage condition

$$(1-e)w_S = w_L \tag{3}$$

must hold. Combining (2) and (3), we find that the ratio of low-skilled to high-skilled units of labor is given by

$$\frac{L}{S} = \left(\frac{1-\alpha}{(1-e)\alpha}\right)^{\sigma}B^{1-\sigma}. \tag{4}$$

Substituting (4) into (1) leads to

$$w_S = A\left[\alpha^{\sigma}B^{\sigma-1} + (1-\alpha)^{\sigma}(1-e)^{1-\sigma}\right]^{\frac{1}{\sigma-1}}. \tag{5}$$

Thus, the wage rate per unit of high-skilled labor, $w_S$, is increasing in $B$. For later use, also note that $\sigma \leq 2$ is sufficient (but not necessary) for $w_S$ to be concave as a function of $B$.

We next derive the number of non-migrating high-skilled workers, $N$, when $m$ workers migrate. High-skilled labor input at home is given by $S = (1-e)N$.

Combining this with (4), we obtain $L = \left(\frac{1-\alpha}{(1-e)\alpha}\right)^{\sigma} B^{1-\sigma}(1-e)N$. Substituting the latter expression into resource constraint $N + m + L = 1$ and solving for $N$ leads to

$$N = \frac{1-m}{1+\left(\frac{1-\alpha}{\alpha}\right)^{\sigma}\left[(1-e)B\right]^{1-\sigma}}. \tag{6}$$

Hence, under optimal education decisions, an increase in the number of emigrants $m$ lowers the number of high-skilled workers remaining in the economy, whereas the total number of natives who choose to acquire education, $N + m$, rises. Moreover, higher productivity $B = b(G)$, which may be triggered by an increase in the public investment level, $G$, raises the number of high-skilled workers in the domestic economy, $N$, if and only if $\sigma > 1$. Also note that $\sigma \leq 2$ is sufficient (but not necessary) for $N$ to be strictly concave as a function of $B$. Combining $A = a(N)$ with (6) and substituting into (5) confirms the result. *Q.E.D.*

Table A1 shows data sources and summary statistics for the variables employed in the empirical analysis.

In Table A2 we provide OLS and IV results of level-regressions for other public expenditure categories than government gross fixed capital formation. For specifications (1) to (3), we employ total government R&D expenditure per capita ($R\&DTotal$), specifications (4) to (6) use R&D expenditure in higher education per capita ($R\&DHigherEdu$), and specifications (7) to (9) take public education expenditure per capita ($ExpEdu$) as dependent variable.[1] The coefficient of interest, $\alpha_1$, is negative and statistically significant at least at the 10 percent level for the IV-estimates. Coefficients are smaller for IV-estimates than for OLS-estimates. But the magnitude of $\alpha_1$ is comparable to the estimates in Table 2 when the full set of controls is included (and higher otherwise).[2]

With respect to education, however, it is possible that a different mix between private and public education expenses across countries biases the results.[3] This problem would be mitigated in when we consider expenditure changes over time, provided the private-public education mix does not change over time.

[1] The negative impact of higher net emigration on public investment still holds when we employ spending *as fraction of GDP* rather than per capita spending as dependent variable even though this would be different to variable $G$ in the theoretical model. A negative impact of a higher emigration rate on the fraction of public investment in GDP is less likely to hold than on public investment per capita, since both $G$ and income change in the same direction as response to migration flows, according to the proposed theory.

[2] We experimented with other public expenditure categories such as social spending, the OECD measure for expenditure for economic affairs, public expenditures for housing, and total government expenditures. These measures do not reflect measures of public investment in spirit of our theory, as they include government consumption or transfers. For these measures, effects of an increase in the net emigration rate of high-skilled labor are either insignificant (for housing and total expenditure) or positive (for social expenditures and spending on economic affairs).

[3] For instance, English-speaking countries have a higher proportion of private education expenses. Including a dummy for English-speaking countries does not substantially alter the results. A proper control for different education systems is, however, beyond the scope of this paper.

Table A3 presents OLS and IV estimations of equation when growth rates of the same expenditure measures than in Table A2 are used as dependent variables. For all measures, $\beta_1$ is again negative and significant in the OLS settings. The IV-estimate of $\beta_1$ is moderately significant when the dependent variable is the growth rate in total R&D expenditure. However, it becomes insignificant (though still negative) for R&D in higher education and for public education expenditure. We thus conclude that the evidence supports our theory for public infrastructure and R&D investments. It provides only moderate support with respect to education expenses (not counted as public investment in national accounts).

**Table A1: Descriptive statistics and sources**

| *Variable* | *Description & Source* | *N* | *Mean* | *SD* |
|---|---|---|---|---|
| Mig | Net emigration rate in year 2000. See description in section 4.1 for construction, with data from Docquier, Marfouk and Lowell (2007). | 30 | 0.01243 | 0.109 |
| DeltaMig | Mig of year 2000 minus Mig of year 1990. | 30 | -0.02455 | 0.049 |
| PubInv | Log of government gross fixed capital formation per capita in year 2000. SourceOECD (Beyond 20/20). | 22 | 6.506 | 0.573 |
| DeltaPubInv | PubInv in 2000 minus PubInv in 1990. | 22 | 0.1478 | 0.209 |
| R&DTotal | Log of total government R&D expenditure per capita in year 2000. SourceOECD (Education Statistics Database). | 30 | 5.807 | 1.001 |
| *DeltaR&DTotal* | R&DTotal in 2000 minus by R&DTotal in 1990. | 25 | 0.6278 | 0.341 |
| R&DHigherEdu | Log of (publicly financed) R&D expenditure in higher education per capita in year 2000. SourceOECD (Education Statistics Database). | 30 | 4.175 | 1.034 |
| DeltaR&DHigherEdu | R&DHigherEdu in 2000 minus R&DHigherEdu in 1990. | 22 | 0.6389 | 0.313 |
| ExpEdu | Log of expenditure per capita for education in 2000. SourceOECD (Beyond 20/20). | 25 | 7.201 | 0.407 |
| DeltaExpEdu | ExpEdu in 2000 minus by ExpEdu in 1990. | 22 | 0.3254 | 0.321 |
| Pop | Log Population mid-year estimate in year 2000. OECD Population and Labor Force Statistics Database. | 30 | 9.617 | 1.551 |
| DeltaPop | Pop in 2000 divided by Pop in 1990. | 30 | 1.075 | 0.068 |
| Pop16 | Population under 16 as share of whole population in year 2000. OECD Population and Labor Force Statistics Database. | 30 | 19.28 | 4.238 |
| SocialExp | Log of social expenditure per capita in year 2000. Government Regulation Size. SourceOECD (Beyond 20/20). | 30 | 8.007 | 0.660 |
| DeltaGDP | Log real GDP in 2000 minus log real GDP in 1990. Penn World Tables 6.2. | 30 | 1.243 | 0.177 |
| $M_{ij}$ | Stock of emigrants of educational category “high” aged 25+ born in country i and living in OECD country j in year 2000. Docquier, Marfouk and Lowell (2007). | 3560 | 5.296 | 2.704 |
| $TotalMig_{ij}$ | Log size of total emigrant population from country i living in country j in year 1990. Docquier, Marfouk and Lowell (2007). | 3560 | 5.761 | 2.839 |
| $Dist_{ij}$ | Log geodesic distance in kms between country i and j. Mayer and Soledad (2006). | 3515 | 8.476 | 0.928 |
| $ComLang_{ij}$ | Identifier if same language is spoken by at least 9 % of the population in country i and j. Mayer and Soledad (2006). | 3525 | 0.123 | 0.329 |
| $SameRegion_{ij}$ | Identifier if countries i and j are in the same region. See text for construction. | 3560 | 0.130 | 0.336 |
| $Colony_{ij}$ | Identifier countries i and j had/have a colonial link. Mayer and Soledad (2006). | 3525 | 0.006 | 0.024 |
| $Transition_{ij}$ | Dummy variable capturing if country i and j were economic transition countries. See text for construction. | 3560 | 0.019 | 0.138 |

**Notes:** The range, mean and standard deviations are based on the respective number of observations.

**Table A2: Effect of high-skilled net emigration rates on alternative measures of public investment per capita: level estimates**

| | *R&DTotal* | | | *R&DHigherEdu* | | | *ExpEdu* | | |
|---|---|---|---|---|---|---|---|---|---|
| | *OLS* | *IV* | *IV* | *OLS* | *IV* | *IV* | *OLS* | *IV* | *IV* |
| | *(1)* | *(2)* | *(3)* | *(4)* | *(5)* | *(6)* | *(7)* | *(8)* | *(9)* |
| Intercept | 5.872*** | 5.854*** | 4.492 | 4.216*** | 4.211*** | 2.103 | 7.232*** | 7.226*** | 3.338*** |
| | (0.145) | (0.165) | (3.834) | (0.182) | (0.181) | (2.848) | (0.063) | (0.070) | (0.913) |
| Mig | -5.218*** | -3.762*** | -2.848*** | -3.357** | -2.939** | -2.745** | -2.251*** | -1.846** | -1.614*** |
| | (1.480) | (1.663) | (1.338) | (1.990) | (1.669) | (1.420) | (0.782) | (0.959) | (0.501) |
| Pop | | | -0.098 | | | 0.092 | | | -0.018 |
| | | | (0.108) | | | (0.183) | | | (0.023) |
| Pop16 | | | -0.053 | | | -0.048* | | | 0.102*** |
| | | | (0.040) | | | (0.032) | | | (0.020) |
| SocialExp | | | 0.414 | | | 0.267 | | | 0.275*** |
| | | | (0.354) | | | (0.291) | | | (0.071) |
| F-value (First Stage) | | 88.180 | 31.420 | | 88.180 | 31.420 | | 85.830 | 36.380 |
| Adj. R2 | 0.300 | 0.097 | 0.298 | 0.095 | 0.040 | 0.096 | 0.263 | 0.119 | 0.654 |
| N | 30 | 30 | 30 | 30 | 30 | 30 | 25 | 25 | 25 |

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

**Table A3: Effect of high-skilled net emigration rates on alternative measures of public investment per capita: first difference estimates**

| | *DeltaR&DTotal* | | *DeltaR&DHigherEdu* | | *DeltaExpEdu* | |
|---|---|---|---|---|---|---|
| | *OLS* | *IV* | *OLS* | *IV* | *OLS* | *IV* |
| | *(1)* | *(2)* | *(3)* | *(4)* | *(5)* | *(6)* |
| Intercept | 0.549*** | 0.525*** | 0.588*** | 0.570*** | 0.210*** | -2.8e-16 |
| | (0.063) | (0.075) | (0.071) | (0.071) | (0.092) | (0.256) |
| Mig | -2.833*** | -3.689* | -1.895* | -2.598 | -3.553*** | -1.002 |
| | (1.277) | (2.437) | (1.140) | (2.292) | (1.757) | (0.764) |
| F-value (First Stage) | | 22.030 | | 20.410 | | |
| Adj. R2 | 0.135 | 0.105 | 0.074 | 0.172 | 0.168 | 0.122 |
| N | 25 | 25 | 22 | 22 | 22 | 22 |

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