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How skilled immigration may improve economic equality

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Abstract

Mobile workers involve flows of labor and human capital and contribute to a more efficient allocation of resources. However, migration also changes relative wages, alters the distribution of skills and affects equality in the receiving society. The paper suggests that skilled immigration promotes economic equality in advanced economies under standard conditions. This is discussed and theoretically derived in a core model, and empirically supported using unique data from the WIID database and OECD.

JEL codes: D33; E25; F22; J15; J61; O15

Keywords: Inequality; Income distribution; Human capital; Skill allocation; Migration; Ethnicity; Minority; Gini coefficient

1. Introduction

Economic migration involves flows of labor, human capital, and other production factors. At least in theory, it contributes to a more efficient allocation of resources and a larger welfare of nations. However, the distributional effects of migration may change the skill composition of labor in the receiving and sending countries. This is the case if, for example, a country experiences a steady inflow of workers whose skill level is on average higher than the skill level of the average native worker. The induced changes in the labor force have the direct effects on inequality through changing the shares of "poor" and "rich" people in the economy, as long as skills are correlated with wealth. They affect the wages of high and low skilled labor in the economy. Individuals may react to such changes in labor force quality by changing their investment decisions, including those regarding their investment into human capital acquisition. As another example, low skill immigration may increase the overall quality of the labor force, if it brings about a larger increase in the quality of the native labor force. We measure the quality of the labor force by the incidence of skilled workers in it. We define skilled and unskilled workers by their highest attained levels of education, albeit we understand that skill is a broader category than education.

The economic consequences of migration have been one of the central topics of labor economics since Chiswick (1978, 1980) and Borjas (1983, 1985). While various distributional effects have been considered in the ensuing literature summarized in Kahanec and Zimmermann (2009), there is little empirical evidence on the relationship between migration and inequality, although the distributional effects of migration drive

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public attitudes towards immigration and the related policy discourse (Constant, Kahanec, and Zimmermann, 2009; Epstein, 2013).

We consider the relationships between economic inequality, the quality of the labor force, and international migration from the perspective of developed countries receiving inflows of migrants. We first start from Kahanec and Zimmermann (2009) to link inequality to the share of skilled workers in the labor force. In the Appendix, we prove in a theoretical framework that skilled immigration promotes income equality. We econometrically investigate the relationship between (i) labor force quality and immigration and (ii) inequality and labor force quality using country statistics from the OECD Statistical Compendium and a unique compilation of inequality data provided by the WIDER institute at the United Nations University. We find evidence supporting the hypothesis that skilled immigration supports equality.

2. A mathematical analysis

We consider an economy with a labor force of size one with L low-skilled workers earning wages w_l and $S = 1 - L$ high-skilled workers earning wages w_h. We define $\theta = w_l/w_h$. L denotes also the share of low-skilled workers. For a constant elasticity of substitution (CES) production function $C = \left(L^{1-\rho} + (\alpha S)^{1-\rho}\right)^{\frac{1}{1-\rho}}$, where $\rho = 1/\varepsilon$ and $\varepsilon > 0$ is the (finite) elasticity of substitution of high- and low-skilled labor in a competitive industry and $\alpha > 1$ is the efficiency shift factor of skilled relative to unskilled labor, $\theta = (L/(\alpha(1-L)))^{-\rho}$ and the earnings of an unskilled relative to a skilled worker are θ/α. When high-skilled workers earn more than low-skilled workers, $\theta/\alpha < 1$.

The Gini coefficient is the area between the line of perfect equality, the 45 degree line, and the Lorenz curve $z\ (\lambda)$, depicting the share of economy's income accruing to the λ poorest individuals, divided by the area between the line of perfect equality and the line of perfect inequality. The line of perfect inequality attains zero for any $\lambda \in [0, 1)$ and $z(1) = 1$. In the Appendix, we show that the Gini coefficient is

$$G(L) = \frac{L(1-L)(\alpha-(\alpha(1-L))^{\rho}/L^{\rho})}{\alpha-\alpha L + (\alpha(1-L))^{\rho}/L^{\rho-1}} \tag{1}$$

and that there is a nondegenerate range $[L_1, L_2]$, where values L_1 and L_2 satisfy $0 \le L_1 \le L_2 \le 1$, on which $G(L)$ is increasing in L. Whenever $\varepsilon \in (0, 1]$, $dG(L)/dL > 0$ for any $L \in (0, 1)$. For $\varepsilon > 1$, $G(L)$ is increasing within and decreasing outside of $[L_1, L_2]$. The range $[L_1, L_2]$ is large. For example, if the substitutability of skilled and unskilled labor is about 2.5, as estimated by Chiswick (1978b), and high skilled labor is twice as productive as its low skilled counterpart, the corresponding values $L_1 = 0.07$ and $L_2 = 0.83$. This is further corroborated by Table 1, which provides the values of L_1 and L_2 for a range of values of ε. Parametric values determine which $L \in (0, 1)$ are admissible with respect to the condition $\theta/\alpha < 1$ and which are not. We denote L^* the value of L, where $\theta/\alpha = 1$.

Table 1 The range of L for which $G(L)$ is increasing

ε	$\varepsilon \le 1$	1.1	2.5	5	10	100	$\varepsilon \to \infty$
L_1	0	0.02	0.07	0.02	0	0	0
L_2	1	0.98	0.83	0.73	0.66	0.59	0.59

Source: Own calculations; $\alpha = 2$.

In the Appendix, we show that $L^* = \alpha^{1-1/\rho}/(1+\alpha^{1-1/\rho})$, $L_1 < L^* < L_2$, and $\theta/\alpha < 1$ for any $L \in (L^*, 1)$ and $\theta/\alpha > 1$ for any $L \in (0, L^*)$. If $\varepsilon > 1$ ($\varepsilon \in (0, 1)$), it must be that $L < 0.5$ ($L > 0.5$) for $\theta/\alpha < 1$ to hold. $L^* = 0.26$ if $\varepsilon = 2.5$ and $\alpha = 2$ as in the example above. For the values of $L \in (0, L^*)$, the Gini coefficient equals $-G(L)$: for OECD economies with a large share of skilled labor, the relevant segment of $G(L)$ is decreasing in the share 1-L of skilled labor, for the most part and may become decreasing in 1-L for $L \in (0, L^*)$, where, counterfactually, the low-skilled earn more than the high-skilled.

This enables us to consider the effects of changes in L that occur when immigrants of different skill composition from that of natives enter or leave the country under the conditions of flexible wages. For example, for $L \in (L^*, L_2)$, an inflow of immigrants who are on average more skilled than the natives decreases inequality, in case of $\varepsilon > 1$. We then predict that inequality is decreasing with skilled immigration, or more generally immigration that increases the quality of the labor force, for moderate to high values and may be increasing for very high values of the share 1-L of skilled labor. In OECD countries where skilled labor is abundant and earns more than unskilled labor, skilled immigration should decrease inequality.

Skills develop with age, and age and migration are related through the migration decision. Therefore, skilled immigrants may first not directly compete with natives, since they are typically male, young and often over-skilled for the job they do. Their interaction with natives also depends on their willingness of investing in country-specific knowledge and human capital. Natives may also react with educational decisions. Hence, skilled immigrants can increase the share of skilled workers in the country right upon arrival, but also after they or the natives adjust.

In a similar way, even mixed or less-skilled immigration may increase the average skill level in the receiving labor market through immigrants' or natives' adjustment. Natives may react not only ex post by adjusting their educational or training decisions, but also before actual immigration takes place in expectation of increased labor market competition.

3. Empirical specification and data

The relationship between inequality, the quality of the labor force, and migration is modeled using a recursive econometric specification of the following type:

$$G = f_1(S, X) + \mu_G \tag{2}$$

$$S = f_2(F, Z) + \mu_S \tag{3}$$

G stands for inequality measured as the Gini coefficient, S is the share of skilled labor force as in our theoretical model, and F is the share of foreigners in the labor force measuring migration. X and Z are vectors of contextual variables, and μ_G and μ_S are error terms. Equation (2) captures the derived trade-off between inequality and educational attainment, while Equation (3) measures the optimal relationship between the share of skilled workers in an economy and the share of foreign labor of total employment resulting from the standard firm optimization principle.

What is the empirical relationship between inequality and educational attainment levels in the labor force? To address this question, we combine data on education, labor force characteristics and other national indicators from the OECD Statistical

Compendium 2007 with the Gini measures reported in the World Income Inequality Database (WIID 2007) version 2.0b compiled by the WIDER institute at the United Nations University and published in May 2007. The OECD Statistical Compendium provides statistics on labor force characteristics, national accounts, and education, mainly for developed country members of OECD.

The WIID 2007 dataset reports Gini coefficients for many countries covering many years of collection and estimation of this inequality indicator. In those cases where WIID 2007 reports multiple Gini coefficients per year and country, we prefer those of the highest quality if based on gross rather than net takings and earnings rather than broader measures of income to quantify those components of economic inequality that stem from the labor market as precisely as possible. Whether earnings inequality is measured at the individual or household level is a non-trivial issue in the context of measuring the relationship between inequality and immigration. In particular, immigrants often have larger households and different family structures than natives. Measures of inequality based on individual and household earnings may give different pictures of inequality. We control for individual against household level at which the Gini coefficient was measured. The combined dataset covers 29 OECD member states and provides 109 observations with non-missing information on the Gini coefficient and the shares of the labor force with at least upper secondary or post-secondary education. Table 2 reports descriptive statistics of the main variables. The mean Gini coefficient is 32%, the mean share of workers with upper secondary or higher education is 73%, the corresponding figure for post-secondary or higher education is 51%, and the mean share of foreigners in the labor force is about 7%.

4. Labor force quality and migration

Figures 1 and 2 showing line plots of nonparametric locally weighted regressions reveal that inequality is mostly a negative function of labor force quality for both quality measures that we apply. Indeed, this relationship is negative for about 80% of the

Table 2 Descriptive statistics of key dependent and independent variables

	Mean	Standard deviation	Number of observations
Gini coefficient	31.95	6.14	109
Share of upper secondary or higher education	72.84	17.17	109
Share of post-secondary or higher education	50.64	20.26	109
Share of foreign labor force	5.11	3.85	110
Inflation rate	2.63	2.50	109
Share of population 15–64 years of age	66.86	1.56	109
Unemployment rate	7.49	3.53	109
Women's unemployment rate	8.37	4.61	109
Participation rate	73.01	6.24	109
Women's participation rate	65.00	8.44	109
Share of labor force in agriculture	5.68	4.00	109
Government size	20.25	3.38	109
GDP per capita, 1000s USD	19.95	12.15	109

The share of foreign labor force computed for the sample including observations with missing information on the Gini coefficient but excluding Luxembourg, which has a high share of foreigners.

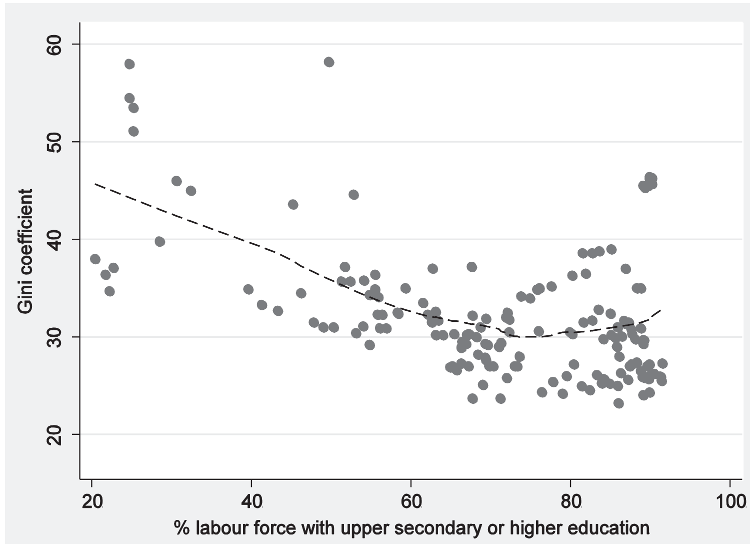

Figure 1 Scatter plot of the Gini coefficient as a function of the share of labor force with upper secondary or higher education. OECD members except for Iceland. Data on Gini coefficients are from the WIID 2007 database. Data on the shares of labor force with given education are from the OECD Compendium. 1992–2003. Line plot of the nonparametric locally weighted regression of the Gini coefficient as a function of the share of labor force with upper secondary or higher education.

observations in case of post- secondary or higher education. The corresponding percentage for upper secondary or higher education is about 60%. The relationships are not too different from simple quadratic fits.

Before we scrutinize the relationship between labor force quality and inequality more deeply, we first investigate how labor force quality relates to migration. Figures 3 and 4

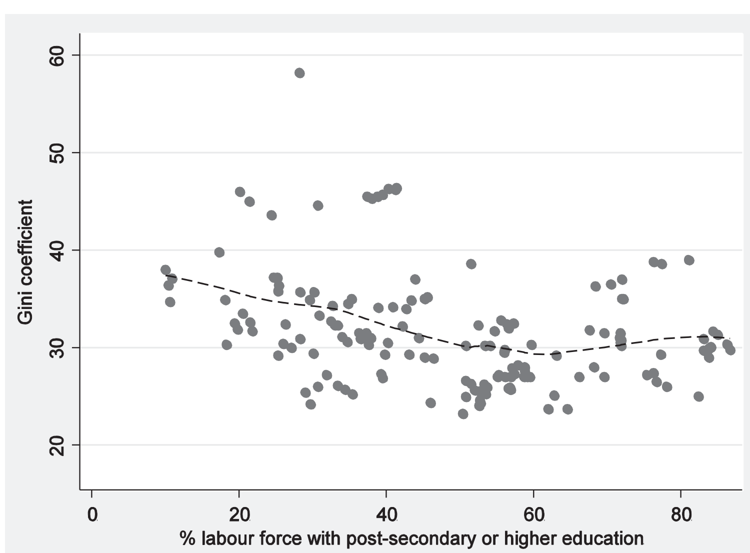

Figure 2 Scatter plot of the Gini coefficient as a function of the share of labor force with post-secondary or higher education. OECD members except for Iceland and Mexico. Data sources see Figure 1. 1992–2003. Line plot of the nonparametric locally weighted regression of the Gini coefficient as a function of the share of labor force with post-secondary or higher education.

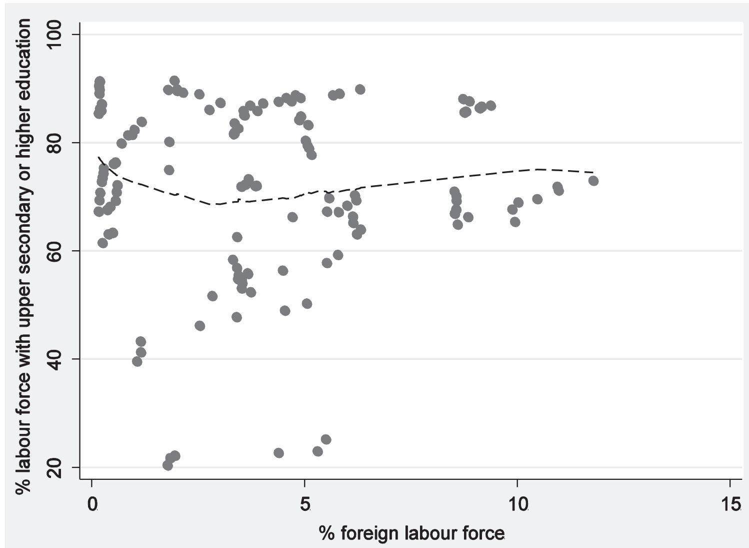

Figure 3 Scatter plot of the share of labor force with upper secondary or higher education as a function of the share of foreigners in the labor force. OECD members. Data on the shares of labor force with given education and foreigners are from the OECD Compendium. 1992–2003. Line plot of the nonparametric locally weighted regression of the Gini coefficient on the share of labor force with upper secondary or higher education.

show that across OECD countries the share of labor force with upper secondary or higher educational attainment is a predominantly positive function of the share of foreign labor force in the economy, while the same relationship is monotonously increasing in case of post-secondary or higher education.

To consider this relationship (Equation 3) as a causal phenomenon requires accounting for the endogeneity of the decision of migration, the effects of migration on the educational attainment of the native labor force, and the skill level of the immigrants relative to native workers. While such causal evaluation would require a much more detailed dataset than we have, we evaluate the association between the share of foreign labor force and its quality controlling for a number of potential covariates such as the size of the government and the age composition of the labor force.

Table 3 contains our findings. The sample included also those observations for which the information on the Gini coefficient was missing. Luxembourg was dropped from the analysis due to its unusually high share of foreigners. The results are robust with respect to inclusion of Luxembourg. The analysis strongly confirms that the quality of the labor force increases with the share of foreigners in the labor force. This finding is valid for all econometric models and for any measure of education (post-secondary or higher and upper-secondary or higher) that we have considered. It is also robust with respect to the fixed effects model specification as well as for the restricted sample of observations for which the Gini coefficient is available.

Government size as well as GDP per head have positive effects on the quality of labor force in the OLS models in columns 2 and 5 of Table 3, but these effects have a different sign in the random effects models. This reversal is consistent with the hypothesis that the association of these variables is positive between but negative within countries.

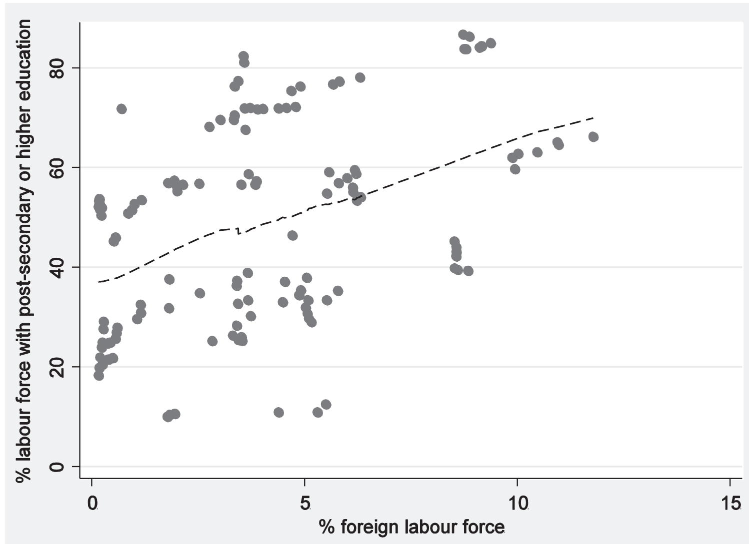

Figure 4 Scatter plot of the share of labor force with post-secondary or higher education as a function of the share of foreigners in the labor force. OECD members. Data sources see Figure 3, 1992–2003. Line plot of the nonparametric locally weighted regression of the Gini coefficient on the share of labor force with post-secondary or higher education.

5. Inequality and the quality of the labor force

The question that remains to be addressed is whether inequality indeed tends to be a negative function of labor force quality as suggested by our theoretical argument as well as Figures 1 and 2. We therefore now estimate Equation 2, accounting for a number of potential confounding factors. Besides the distribution of educational levels in the labor force, Katz and Murphy (1992) report that increased demand for skilled workers and women as well as changes in the allocation of labor between industries

Table 3 Share higher education as a function of share foreign labor force

	(1)	(2)	(3)	(4)	(5)	(6)
	Upper secondary and higher			Post-secondary and higher		
	OLS	OLS	Random effects	OLS	OLS	Random effects
Share of foreign labor force	0.91**	1.14**	0.65**	2.62**	2.88**	1.43**
	(0.29)	(0.30)	(0.23)	(0.33)	(0.43)	(0.42)
Share of population 15-64 years of age		1.99	−0.16		1.85	−0.16
		(1.57)	(0.46)		(1.77)	(0.86)
Government size		1.79**	−0.57**		1.38*	−1.58**
		(0.56)	(0.27)		(0.76)	(0.50)
GDP per capita, 1000 s USD		0.68**	−0.00		0.47**	−0.13**
		(0.14)	(0.03)		(0.18)	(0.06)
Year dummies		Yes	Yes		Yes	Yes
Constant	66.28**	−112.35	85.60**	37.51**	−110.04	87.21
	(2.75)	(115.00)	(34.39)	(2.71)	(128.11)	(63.90)
Observations	110	110	109	110	110	109
R-squared	0.04	0.27	0.73[a]	0.22	0.30	0.52[a]

Robust standard errors in parentheses. *significant at 10%; **significant at 5%.
[a]Within R-squared.

contributed to increasing inequality in the US in recent years. Gustafsson and Johansson (1999) provide evidence that the share of industry in employment, per head gross domestic product, international trade, the relative size of the public expenditures, as well as the demographic structure of the population affect inequality measured by the Gini coefficient across countries and years. Topel (1994) finds that technological and economic development determines economic inequality.

We examine the effects of the aggregate and women's labor force participation rates, aggregate and women's unemployment rates, share of the population between 15 and 64 years of age, labor force in the agricultural sector, share of the government in the economy, defined as the expenditures of the central government divided by the aggregate GDP, gross domestic product, and inflation rate. We control for the year, country, and the method of computing the Gini coefficient, distinguishing various income measures, net and gross figures and the unit of analysis used to calculate the Gini coefficient.

Our regression analysis reported in Table 4 confirms that the observed decreasing and convex relationship is robust for both considered measures of education and across a number of model specifications, including the standard OLS model, the weighted least squares model with quality weights for the Gini coefficient from the WIID database, and the model with random country effects. This result remains robust in alternative models with weighting by country size, clustering, and fixed effects. The coefficients on post-secondary or higher education measure of labor force quality retain the correct signs, but become insignificant in the fixed effect model. The share of educated labor force is negatively and its square positively associated with inequality in all specifications. The estimated coefficients yield the minimum of the U-shaped relationship between the share of skilled labor and the Gini coefficient to lie at about 80% of the labor force with upper secondary or higher education and 66% of the labor force with post-secondary or higher education. In our sample these numbers imply a downward sloping relationship between the share of skilled labor and inequality for 67% and 84% of the observations for the two applied measures of skilled labor.

The aggregate unemployment rate is positively associated with inequality, but women's unemployment rate affects inequality negatively. The same should hold for aggregate and women's participation rates, but we do not find this. One reason could be the effect of women's selection into the labor force, whereby high women's unemployment and participation rates indicate that women with less favorable earnings opportunities are joining the labor force, increasing the dispersion of earnings. The size of the government, government spending as a percentage of GDP, is negatively associated with inequality, which is consistent with the hypothesis that redistribution decreases inequality.

6. Conclusion

First, our theory predicts that inequality is decreasing in labor force quality for advanced economies under standard conditions. This effect is mainly a consequence of the standard economic law of diminishing marginal product of production factors: as the share of skilled workers in the economy increases, its value decreases and thus also the wage differential between high and low skilled labor decreases. In our theoretical

Table 4 Gini coefficient as a function of labor force quality

	(1)	(2)	(3)	(4)	(5)	(6)
	Upper secondary and higher			Post-secondary and higher		
	OLS	Quality weighted	Random effects	OLS	Quality weighted	Random effects
Share of highly educated in the labor force	−0.83**	−0.75**	−0.81**	−0.31**	−0.32**	−0.29**
	(0.16)	(0.17)	(0.17)	(0.13)	(0.12)	(0.13)
Share of highly educated in the labor force, sq/100	0.56**	0.49**	0.54**	0.24**	0.24**	0.22*
	(0.15)	(0.14)	(0.14)	(0.11)	(0.11)	(0.12)
Inflation rate	0.21	0.18	0.18	0.11	0.09	0.08
	(0.26)	(0.24)	(0.25)	(0.24)	(0.26)	(0.28)
Share of population	−0.52	−0.44	−0.60	−0.68	−0.44	−0.78
15-64 years of age	(0.48)	(0.48)	(0.49)	(0.57)	(0.51)	(0.53)
Unemployment rate	2.95**	2.92**	2.95**	2.09**	2.19**	2.11**
	(0.83)	(0.52)	(0.54)	(0.71)	(0.56)	(0.59)
Women's unemployment rate	−1.87**	−1.86**	−1.88**	−1.34**	−1.42**	−1.36**
	(0.59)	(0.39)	(0.40)	(0.53)	(0.42)	(0.44)
Participation rate	0.11	0.32	0.16	0.47	0.67*	0.54
	(0.40)	(0.39)	(0.39)	(0.34)	(0.38)	(0.41)
Women's participation rate	−0.31	−0.44	−0.35	−0.47*	−0.59**	−0.52*
	(0.32)	(0.30)	(0.31)	(0.24)	(0.28)	(0.30)
Share of labor force in agriculture	−0.34	−0.29	−0.32*	−0.20	−0.18	−0.16
	(0.26)	(0.18)	(0.18)	(0.21)	(0.18)	(0.19)
Government size	−0.41	−0.36*	−0.40**	−0.43*	−0.36*	−0.41**
	(0.25)	(0.19)	(0.19)	(0.23)	(0.19)	(0.20)
GDP per capita, 1000 s USD	0.06	0.05	0.05	−0.08	−0.08	−0.10
	(0.06)	(0.07)	(0.08)	(0.07)	(0.07)	(0.08)
Gini definition controls	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Constant	115.40**	99.31**	118.89**	93.42**	68.78*	95.98**
	(34.24)	(34.20)	(34.02)	(40.97)	(35.82)	(37.06)
Observations	109	109	108	109	109	108
R-squared	0.70	0.71	0.70	0.62	0.66	0.62

Robust standard errors in parentheses, *significant at 10%; **significant at 5%.

model, migration affects inequality in the economy as it changes the quality of the labor force. In particular, inflows of workers with average skill level above that of the receiving country decrease inequality, and the opposite holds for low-skilled immigration.

Second, we confirm empirically that the relationship between inequality and the quality of the labor force is predominantly negative. The econometric analysis accounting for many covariates confirms what already appears from the raw data. We show that, in the sample of OECD countries, inequality decreases with a higher labor force quality for most values of educational attainment; and a positive relationship shows up for observations with the quality of the labor force above a certain high threshold level as predicted by the theory.

Third, we empirically evaluated the relationship between migration and labor force quality as observed across OECD countries. We find that the share of foreigners in the labor force and its quality as measured by educational attainment are throughout strongly positively associated. Given our finding that labor force quality and inequality are negatively associated, this result implies that immigration is negatively associated with inequality.

Appendix

Gini coefficient and immigration

Consider an economy of size 1 with L low-skilled earning wages w_l and $S = 1 - L$ high-skilled workers earning wages w_h. We denote $\theta = w_l/w_h$ and normalize the total income to unity, $w_l L + w_h(1 - L) = 1$. Consider the case with endogenous wages such that $\theta = (L/(\alpha(1 - L)))^{-\rho}$ where $\rho > 0$.

Proposition

For $L \in \left[\alpha^{1-1/\rho}/(1 + \alpha^{1-1/\rho}), 1\right)$ the Gini coefficient equals

$$G(L) = \frac{L(1-L)(\alpha-(\alpha(1-L))^{\rho}/L^{\rho})}{\alpha-\alpha L + (\alpha(1-L))^{\rho}/L^{\rho-1}}. \tag{A1}$$

For $L \in (0, \alpha^{1-1/\rho}/(1 + \alpha^{1-1/\rho})]$ the Gini coefficient equals $-G(L)$.

If $\rho \geq 1$, $dG(L)/dL > 0$ for any $L \in (0, 1)$.

For $0 < \rho < 1$ and $L \in (0, 1)$, there exist $L_1 \in (0, \alpha^{1-1/\rho}/(1 + \alpha^{1-1/\rho}))$ and $L_2 \in (\alpha^{1-1/\rho}/(1 + \alpha^{1-1/\rho}), 1)$ such that $dG(L)/dL > 0$ for $L \in (L_1, L_2)$, $dG(L)/dL < 0$ for $L \in (0, 1) - [L_1, L_2]$, and $dG(L)/dL = 0$ for $L \in \{L_1, L_2\}$. Also, $L_1 < L^* < L_2$, where $L^* = \alpha^{1-1/\rho}/(1 + \alpha^{1-1/\rho})$.

Proof

Given $\theta = (L/(\alpha(1 - L)))^{-\rho}$, $L \in (\alpha^{1-1/\rho}/(1 + \alpha^{1-1/\rho}), 1)$ implies $\theta/\alpha = w_l/\alpha w_h < 1$, that is, high-skilled workers earn more than low-skilled ones. Then the Lorenz curve is defined by

$$z(\lambda) = \frac{\theta\lambda}{\theta L + \alpha(1-L)} \text{ for } \lambda \in [0, L] \text{ and} \tag{A2}$$

$$z(\lambda) = \frac{\theta L + \alpha(\lambda-L)}{\theta L + \alpha(1-L)} \text{ for } \lambda \in [L, 1] \tag{A3}$$

We integrate the Lorenz curve over $\lambda \in [0, 1]$ and substitute for θ to obtain

$$G(L) = \frac{L(1-L)(\alpha-(\alpha(1-L))^{\rho}/L^{\rho})}{\alpha-\alpha L + (\alpha(1-L))^{\rho}/L^{\rho-1}} \tag{A4}$$

to depict the Gini coefficient in this case and

$$\frac{dG(L)}{dL} = \frac{\alpha^2(1-L)^2L^{2\rho} + L^2\alpha^{2\rho}(1-L)^{2\rho} - \alpha^{\rho+1}L^{\rho}(1-L)^{\rho}(1-\rho-2L(1-L))}{(\alpha^{\rho}(1-L)^{\rho}L + \alpha(1-L)L^{\rho})^2}. \tag{A5}$$

If $L \in (0, \alpha^{1-1/\rho}/(1 + \alpha^{1-1/\rho}))$, $\theta/\alpha = w_l/\alpha w_h > 1$ and high-skilled workers earn less than low-skilled ones. The Lorenz curve becomes

$$z(\lambda) = \frac{\alpha(1-L)}{\theta L + \alpha(1-L)} \text{ for } \lambda \in [0, L] \text{ and} \tag{A6}$$

$$z(\lambda) = \frac{\alpha(1-L) + \theta(L-\lambda)}{\theta L + \alpha(1-L)} \text{for } \lambda \in [L, 1]. \tag{A7}$$

Integrating the Lorenz curve over $\lambda \in [0, 1]$ we obtain that the Gini coefficient is $-G(L)$. $L = \alpha^{1-1/\rho}/(1+\alpha^{1-1/\rho})$ is the case of perfect equality.

For $\rho \geq 1$ we see from the expression for $dG(L)/dL$ that this derivative is positive for any $L \in (0, 1)$.

For $0 < \rho < 1$, first $G(L)$ and $dG(L)/dL$ are continuous functions for $L \in (0, 1)$, $G(L) \to 0$ for $L \to 1$ or $L \to 0$ and substituting $L = \alpha^{1-1/\rho}/(1+\alpha^{1-1/\rho})$ into $G(L)$ in equation (A4) yields $G(\alpha^{1-1/\rho}/(1+\alpha^{1-1/\rho})) = 0$, because

$$\lim_{L\to 0^+} G(L) = \lim_{L\to 0^+} \frac{L^{1-\rho}(1-L)(\alpha L^\rho - (\alpha(1-L))^\rho)}{\alpha - \alpha L + (\alpha(1-L))^\rho / L^{\rho-1}} = 0, \text{and} \tag{A8}$$

$$\lim_{L\to 1^-} G(L) = \lim_{L\to 1^-} \frac{L(1-L)^{1-\rho}(\alpha - (\alpha(1-L))^\rho / L^\rho)}{\alpha(1-L)^{1-\rho} + \alpha^\rho L^{1-\rho}} = 0, \tag{A9}$$

where we made use of $0 < \rho < 1$.

$dG(L)/dL \to -\infty$ when $L \to 1$ or $L \to 0$ and substitution yields $dG(L)/dL > 0$ at $L = \alpha^{1-1/\rho}/(1+\alpha^{1-1/\rho})$. In fact, $dG(L)/dL = \rho$. This last result involves tedious algebra; one can show this by evaluating $dG(L)/dL$ at L^*, simplifying it, and realizing that $dG(L)/dL = 1 + f(\alpha, \rho)(\rho - 1)$ where the term $f(\alpha, \rho) = 1$. These properties imply that there exists a minimum of $G(L)$ on the interval $L \in (0, \alpha^{1-1/\rho}/(1+\alpha^{1-1/\rho}))$ and a maximum on the interval $L \in (\alpha^{1-1/\rho}/(1+\alpha^{1-1/\rho}), 1)$, where $dG(L)/dL = 0$.

To show the uniqueness of each and the maxima of $dG(L)/dL$, assume for the moment that $\alpha = 1$; we extend the argument to the case where $\alpha > 1$ below. First

$$\frac{d^2G(L)}{dL^2} = -\frac{(\rho-1)(L(1-L))^{\rho-1}}{(-L(1-L)^\rho + L^\rho(L-1))^3}(L^\rho(1-L)(2L-\rho) + L(1-L)^\rho(2L+\rho-2)). \tag{A10}$$

The ratio $\frac{(\rho-1)(L(1-L))^{\rho-1}}{(-L(1-L)^\rho + L^\rho(L-1))^3}$ is positive for $0 < \rho < 1$ and $L \in (0, 1)$, then the second derivative has the sign of

$$-(L^\rho(1-L)(2L-\rho) + L(1-L)^\rho(2L+\rho-2)). \tag{A11}$$

For $0 < \rho < 1$ and $L \in (0, 0.5)$, equation (A11) becomes

$$-L^\rho(1-L)\left((2L-\rho) + \left(\frac{L}{1-L}\right)^{1-\rho}(2L+\rho-2)\right). \tag{A12}$$

As $2L + \rho - 2 < 0$ and $L/(1-L) < 1$ we write

$$(2L-\rho) + \left(\frac{L}{1-L}\right)^{1-\rho}(2L+\rho-2) \leq (2L-\rho) + \frac{L}{1-L}(2L+\rho-2) = \rho\frac{2L-1}{1-L} \leq 0, \tag{A13}$$

which, together with $-L^\rho(1-L) < 0$, implies

$$-(L^\rho(1-L)(2L-\rho) + L(1-L)^\rho(2L+\rho-2)) > 0 \text{ for } 0 < \rho < 1 \text{ and } L \in (0, 0.5). \tag{A14}$$

Similarly, rewriting equation (A11) as

$$-L(1-L)^{\rho}\left(\left(\frac{1-L}{L}\right)^{1-\rho}(2L-\rho)+(2L+\rho-2)\right), \tag{A15}$$

$-(L^{\rho}(1-L)(2L-\rho)+L(1-L)^{\rho}(2L+\rho-2))<0$ for $0<\rho<1$ and $L\in(0.5,1)$.

That $d^2G(L)/dL^2>0$ for any $L\in(0,0.5)$ ($G(L)$ is strictly convex) and $d^2G(L)/dL^2<0$ for any $L\in(0.5,1)$ ($G(L)$ is strictly concave), $dG(L)/dL<0$ for $L\to 1$ or $L\to 0$ and $dG(L)/dL>0$ for $L=\alpha^{1-1/\rho}/(1+\alpha^{1-1/\rho})=0.5$, and the continuity of $dG(L)/dL$ for $L\in(0,1)$ imply the uniqueness of the extrema and the properties of $dG(L)/dL$ for $\alpha=1$.

To extend the argument to the case where $\alpha>1$, for $dG(L)/dL=0$ to have at most two solutions within $L\in(0,1)$, it suffices to show that $d^2G(L)/dL^2=0$ has at most one solution.

$$\frac{d^2G}{dL^2}=\frac{L^{\rho-1}(1-L)^{\rho}\alpha^{\rho+1}(\rho-1)}{(L-1)((L-1)L^{\rho}\alpha-L(1-L)^{\rho}\alpha^{\rho})^3}((L-1)L^{\rho}\alpha(-2L+\rho)+L(1-L)^{\rho}\alpha^{\rho}(-2+2L+\rho)) \tag{A16}$$

and

$$\begin{aligned}&(L-1)L^{\rho}\alpha(-2L+\rho)+L(1-L)^{\rho}\alpha^{\rho}(-2+2L+\rho)\\&\quad=\alpha L^{\rho}(1-L)\left(2L-\rho+\left(\frac{L}{(1-L)\alpha}\right)^{1-\rho}(2L+\rho-2)\right).\end{aligned} \tag{A17}$$

We need to show that

$$H(L)=2L-\rho+\left(\frac{L}{(1-L)\alpha}\right)^{1-\rho}(2L+\rho-2)=0$$

has at most one solution within $L\in(0,1)$ for $\alpha>1$ and $0<\rho<1$. For this to be true it suffices that $H(L)$ is monotonous for $L\in(0,1)$, that is, for $L'>L$ it must be that $H(L')>H(L)$. Consider $L'>L$. Then

$$2L'-\rho+\left(\frac{L'}{(1-L')\alpha}\right)^{1-\rho}(2L'+\rho-2)>2L-\rho+\left(\frac{L}{(1-L)\alpha}\right)^{1-\rho}(2L+\rho-2), \tag{A18}$$

which is:

$$2(L'-L)+\alpha^{\rho-1}\left(\left(\frac{L'}{(1-L')}\right)^{1-\rho}(2L'+\rho-2)-\left(\frac{L}{(1-L)}\right)^{1-\rho}(2L+\rho-2)\right)>0. \tag{A19}$$

Equation (A19) holds whenever

$$\left(\left(\frac{L_1}{(1-L_1)}\right)^{1-\rho}(2L_1+\rho-2)-\left(\frac{L_2}{(1-L_2)}\right)^{1-\rho}(2L_2+\rho-2)\right) \tag{A20}$$

is non-negative. If the term in equation (A20) is negative, we already know that the inequality in equation (A19) holds for $\alpha=1$. As $\alpha^{\rho-1}$ is decreasing for $\alpha\in(1,\infty)$, that the term in equation (A20) is negative and the fact that the inequality in equation (A19) holds for $\alpha=1$ imply that the inequality in equation (A19) holds for a negative (A20), too.

Given their continuity, $d^2G(L)/dL^2=0$ has at most one and $dG(L)/dL=0$ at most two solutions and thus $G(L)$ has at most two interior extrema within $L\in(0,1)$. We already know that there exists at least one minimum of $G(L)$ on $L \in (0, \alpha^{1-1/\rho}/(1+\alpha^{1-1/\rho}))$ and at least one maximum on $L \in (\alpha^{1-1/\rho}/(1+\alpha^{1-1/\rho}), 1)$. Therefore, these extrema are unique and we denote $L_1 \in (0, \alpha^{1-1/\rho}/(1+\alpha^{1-1/\rho}))$ the minimum and $L_2 \in (\alpha^{1-1/\rho}/(1+\alpha^{1-1/\rho}), 1)$ the maximum. It also follows that $L_1 < L^* < L_2$, where $L^* = \alpha^{1-1/\rho}/(1+\alpha^{1-1/\rho})$.

Competing interest
The IZA Journal of Migration is committed to the IZA Guiding Principles of Research Integrity. The authors declare that they have observed these principles.

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