The Gain from the Drain
Skill-biased Migration and Global Welfare*

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Abstract

High-skilled workers are four times more likely to migrate than low-skilled workers. It has been shown that this skill bias in migration — often called brain drain — can reduce welfare in the sending countries. In this paper, we contrast these findings by showing that skill-biased migration is globally welfare-enhancing. In a calibrated simulation exercise, we compare the current world to a counterfactual with the same number of migrants but no skill bias in migration. We find particularly large gains for receiving countries with selective immigration policies. Overall, the welfare gains in the receiving countries exceed the losses from brain drain in the sending countries, suggesting that more — not less — high-skilled migration would be optimal for world welfare.

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1 Introduction

High-skilled workers are four times more likely to emigrate from developing countries than low-skilled workers.[1] This skill bias in migration, often referred to as the 'brain drain', has been at the center of a controversial debate about the welfare consequences of migration. The popular argument is that rich countries siphon off the best and brightest workers, thereby harming the economic development in poorer countries. This argument has been backed up by empirical evidence showing that the brain drain decreases the welfare of non-migrants in many sending countries (Beine *et al.*, 2008; Docquier & Rapoport, 2012). It has also led to drastic policy recommendations aimed at limiting the negative consequences, ranging from taxing rich countries (Bhagwati & Hamada, 1974) to restricting high-skilled immigration (Collier, 2013). However, to assess the welfare impact of skilled migration, and to make sensible policy recommendations, it is important to take into account potential gains in the receiving countries, and the global efficiency gains that arise from having the most productive workers in the most productive countries. If these gains are positive, migration restrictions would be a suboptimal policy choice.

In this paper, we provide a global perspective on the brain drain and its welfare implications. Rather than just focusing on the sending countries, we assess its welfare impact on the receiving countries, and the world as a whole. In a quantitative exercise, we compare today's world, in which migration is heavily biased towards high-skilled workers, to a world with the same number of migrants, but without skill bias in migration. In the counterfactual world, all migrants are neutrally selected from their country of origin, such that every bilateral migrant stock has the same skill distribution as the total population of the sending country.

To quantify the welfare impact of the skill bias in migration, we develop a multi-country general equilibrium model, in which countries are linked through trade in differentiated goods. The workforce in each country consists of three education groups, allowing us to consider the aggregate impact of the skill bias in migration through complementarities in production, as well as its impact on the within-country income distribution. A change in the skills of migrants simultaneously changes the skill composition of the sending and the receiving countries, and in addition affects trade patterns. In equilibrium, welfare is mainly affected through two channels: first, switching from skill-biased to skill-neutral migration makes the receiving countries less productive, thereby shrinking their market size. In the sending countries, the opposite occurs. Second, the smaller market size decreases the number of varieties traded, which has an additional negative effect on welfare in both the sending and the receiving countries. We calibrate the model to match key features of the global economy at baseline: bilateral trade flows, differences in GDP per capita across countries, and wage premia for high- and medium-skilled workers within countries, using data from all 34 OECD countries, as well as 111 sending countries.

First simulations reveal substantial welfare gains for the receiving countries, especially for those with a large skill bias in migration. Welfare in Israel, for instance, is 7.2% higher than it would be if every migrant was neutrally skilled. Countries with points-based visa policies

[1] Own calculations from the 2010 OECD DIOC database. Docquier & Rapoport (2012) find similar figures.

experience similarly large gains: 5% for Canada and New Zealand, 4% for Australia. In most sending countries, we find small negative welfare effects. In most countries, losses are small, between 0% and 4%, while in countries with both a high share of emigrants and a high degree of skill bias, such as Jamaica and Haiti, welfare losses amount to 15%. In the sending countries, the brain drain benefits high-skilled workers, while decreasing the wages of low-skilled workers.

A decomposition of the welfare effect shows, however, that welfare per capita is a misleading metric, because the composition of the underlying population differs between baseline and counterfactual, such that the overall effect is a composite of a treatment and a composition effect. We propose as an alternative the effect on *welfare per never-migrant*, which isolates teh treatment effect of a change in the skill composition of migrants on the welfare of non-migrants. The effect on welfare per never-migrant is considerably smaller than the change in welfare per capita. In the receiving countries, the welfare gains range between 0 and 2%, while the losses in the sending countries are marginally smaller compared to the changes in welfare per capita. We also investigate the impact of skill-biased migration on within-country income inequality. The skill bias exacerbates inequality in the sending, while reducing inequality in the receiving countries.

In a further analysis, we conduct a policy experiment in which every OECD country implements the migrant selection of Canada, the OECD country with the most positive selection of immigrants. This measure would increase world welfare by 1.5 percent, and would lead to large gains in the receiving countries, while leading to strong welfare losses in the sending countries. Given the global gains, it would be possible to have a Pareto-improving redistribution scheme, in which receiving countries compensate the sending countries for sending a more positive selection of emigrants.

Overall, our results show that the brain drain leads to global efficiency gains. Due to the skill bias in migration, world welfare is 1-2% higher than under neutral selection, suggesting that more — not less — high-skilled emigration would be beneficial for the world economy. The results demonstrate that restricting high-skilled migration may appear as a beneficial policy for the sending countries, but leads to welfare losses in the receiving countries, and the world as a whole.

To further qualify these results, we extend the model along several dimensions highlighted in the empirical literature, such as remittances, human capital externalities, and network effects in trade. Remittances, while being an important source of income for the sending countries, only have a small additional effect on welfare, because the the number of migrants is held constant in the simulations. Quantitatively more important for the sending countries is the 'brain gain' externality, according to which high-skilled emigration triggers human capital investment at home, thereby dampening the negative effect in the sending countries. Even with a modest brain gain effect, the welfare losses are close to zero in most sending countries, and in some cases even positive. Equally important for the sending and receiving countries are human capital externalities that work through total factor productivity (TFP). If TFP is an increasing function in the share of high-skilled workers, as suggested by Lucas (1988), the skill bias in migration leads to greater welfare losses in the sending countries and larger gains in the sending countries, while the global welfare effect remains constant. In a further extension, we explore the additional welfare impact when high-skilled migrants reduce transaction costs in trade, and find that most receiving countries experience larger gains through these network effects.

This paper contributes to three strands of literature. First, it provides a new perspective on the brain drain from developing countries. Early theoretical work by Bhagwati & Hamada (1974) and Miyagiwa (1991) predicted severe negative consequences of the brain drain for the poorest countries. More recently, this view has been challenged, because the option to emigrate can induce higher investment in human capital, such that countries may actually experience a brain gain and end up with more high-skilled workers than in the absence of migration (Mountford, 1997; Stark *et al.*, 1997; Vidal, 1998; Beine *et al.*, 2001). The empirical evidence on the net effect is mixed. Beine *et al.* (2008), in a study based on macro data, find that the brain gain channel dampens the negative impact for most sending countries, but most sending countries lose from the skill bias in migration.[2] In contrast, recent studies based on micro-data find a substantial positive effect of emigration prospects on investment in education in the sending countries (Chand & Clemens, 2008; Batista *et al.*, 2011; Shrestha, 2015; Dinkelman & Mariotti, 2016). This paper departs from the literature on brain drain by bringing its focus from the sending countries to the global level, and showing that the welfare gains in the receiving countries are quantitatively important and exceed the losses in the sending countries. Moreover, the global welfare gains are even larger once we account for brain gain effects.

More broadly, this paper complements previous studies on the welfare impact of migration, which mainly focus on changes in the number of migrants. One strand of this literature quantifies to what extent more migration — in the extreme case open borders — would increase world welfare (Hamilton & Whalley, 1984; Felbermayr & Kohler, 2007; Klein & Ventura, 2007, 2009; Iranzo & Peri, 2009; Docquier *et al.*, 2015; Kennan, 2013; Battisti *et al.*, 2014; Delogu *et al.*, 2015; Clemens & Pritchett, 2016), while other papers analyze the welfare contribution of migration at its current level, by comparing today's world to a world without migration (Di Giovanni *et al.*, 2014; Aubry *et al.*, 2013). Our paper focuses on changes in the composition rather than the scale of migration. The baseline results show that the composition of migration flows has a substantial impact on welfare in both the sending and the receiving countries. When we compare the composition effect to the scale effect, we find that the skill composition explains most of the overall welfare impact of migration in the sending countries, while making a modest contribution to the overall welfare effect in the receiving countries.

Finally, this paper puts in perspective the widely held view that migrant self-selection has important welfare implications for the receiving countries. Our work builds on Biavaschi & Elsner (2013), who analyze the impact of migrant self-selection on the sending and receiving countries, using two episodes of mass migration to the US. While we do not have equally detailed data for most migration flows in the world, in this paper we are able to provide estimates of the welfare effects of skill-biased migration for almost 150 countries. The welfare calculations reveal that

[2] For a recent overview and critique of the research on emigration and development, see Clemens (2015).

migrant selection has indeed a large impact in some receiving countries, but only in those with both a high share of immigrants and a high degree of skill bias. For most countries, among them prominent destinations like the US and Germany, migrant self-selection has no large welfare impact.

The remainder of the paper unfolds as follows. Section 2 presents stylized facts about skill-biased migration from the perspective of the sending and receiving countries. Section 3 presents the main features of the theoretical model and explains the channels through which skill-biased migration affects welfare. The calibration of the model is explained in Section 4. Section 5 presents the main simulation results of the welfare impact of skill-biased migration. In Section 6, we add a series of extensions and sensitivity checks. Section 7 concludes.

2 Skill-biased migration: stylized facts

Before quantifying the welfare impact of skill-biased migration, we first present some stylized facts about the skill bias. We speak of a skill bias if the skill distribution of emigrants differs from the skill distribution of the total population in the sending country. In most sending countries, the skill distribution of emigrants is heavily skewed towards high-skilled workers. The share of high-skilled workers among emigrants is often a multiple of the share of high-skilled workers in the total population.

Figure 1a) illustrates the extent of the brain drain for selected non-OECD countries in 2010.[3] The vertical axis displays the ratio

$$\text{skill bias}=\frac{\{\text{Share of high-skilled migrants} \mid \text{skill-biased migration}\}}{\{\text{Share of high-skilled migrants} \mid \text{skill-neutral migration}\}},$$

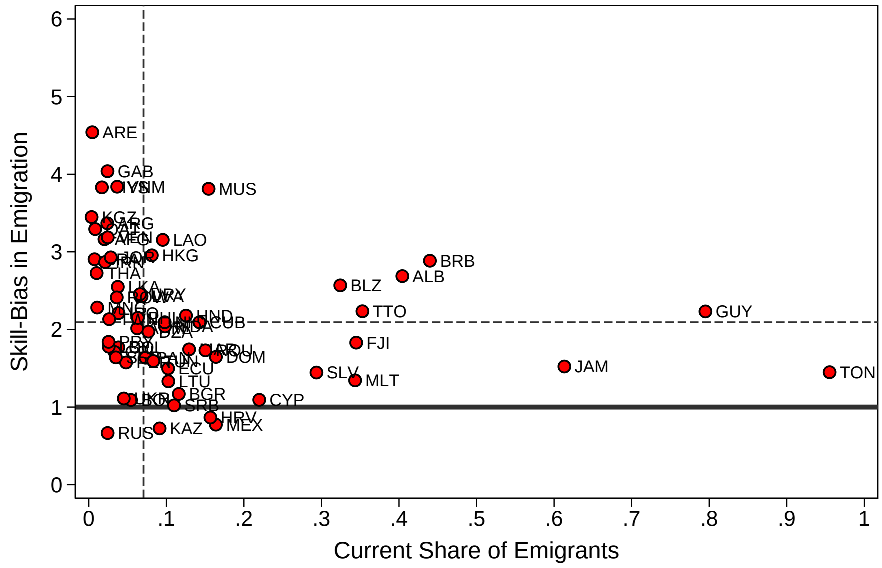
whereas the horizontal axis displays the extent of emigration. The dashed lines represent the median of each axis. At a value of 1 on the vertical axis, indicated by the thick line, the emigration from a particular country would be skill-neutral, as the share of high-skilled among emigrants would equal the share of high-skilled in the total population. For the vast majority of sending countries, the skill bias in emigration is positive. At the median of the countries displayed here, the skill bias is 2, meaning that the share of high-skilled among emigrants is twice the share of high-skilled in the total population. For expositional reasons, we only display countries with a maximum skill bias of 5; but some countries in the sample, for example Mali, have a skill bias greater than 30.[4]

Figure 1b) illustrates the skill bias in migration from the OECD countries' perspective. Here

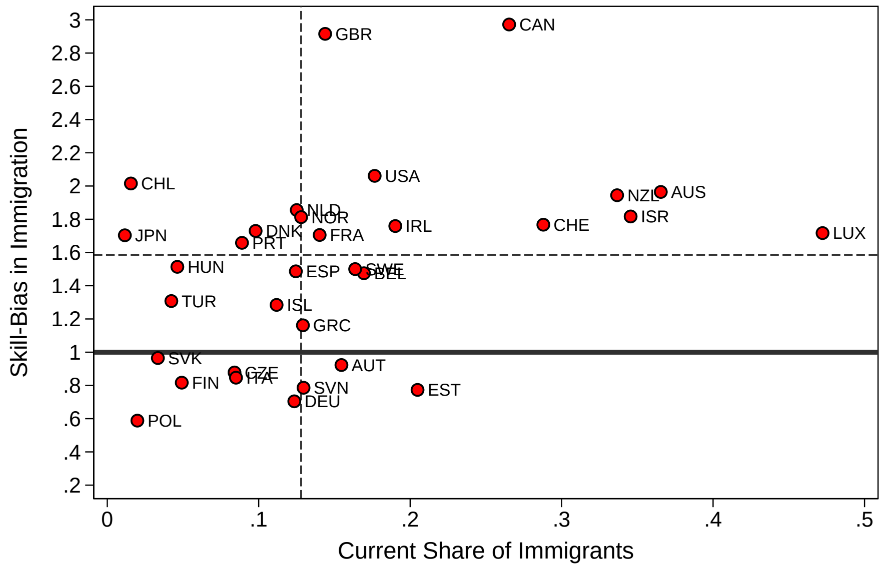
[3] Both figures are based on the 2010 OECD-DIOC database.

[4] These differences in the skill compositions of migrants can be explained by supply and demand factors. On the supply side, they reflect individual self-selection in the migration decision, i.e. the degree to which immigration is an attractive option for tertiary educated workers and the varying level of attractiveness of different destinations for different groups. On the demand side, receiving countries apply different degrees of skill-based migration policies, which determine the characteristics of the immigrant population. The canonical model of migrant self-selection is provided by Borjas (1987). For a discussion of the empirical evidence, see Biavaschi & Elsner (2013).

Figure 1: The skill bias in immigration and emigration



(a) Skill bias in emigration



(b) Skill bias in immigration

Source:. Own calculations from DIOC.

Notes: These graphs plot our measure of the skill bias in migration (vertical axis) on the share of emigrants/immigrants (horizontal axis) for the main sending countries (panel 2a) and the OECD countries (panel 2b). A value of 1 on the vertical axis indicates the absence of a skill bias. The dashed lines represent the median of both axes.

the skill bias is expressed as the share of high-skilled workers among all current immigrants over the share of high-skilled among immigrants if all immigrants were neutrally selected from their home country. The higher the skill bias, the more positive is the selection of migrants hosted in a particular OECD country. Most OECD countries attract a positive selection of immigrants. The skill bias is particularly large in countries with selective migration policies, such as Canada, Great Britain, the US, New Zealand, or Australia. In Canada, for instance, the share of high-skilled immigrants is three times as large as it would be under skill-neutral migration. Some prominent immigration destinations, notably Germany, Italy, and Austria, attract a negative selection of migrants. Their migrant stock would have higher skills under neutral selection.

In the simulation exercise to follow, we quantify the welfare impact of the skill bias in migration by comparing the current world with a strong skill bias in migration to a world with the same number of migrants, but a neutral selection of migrants. We expect the skill bias to have the largest impact in countries that are in the North-Eastern corner of Figures 1a) and b), namely in those with a high skill bias and a high share of migrants. The size of the effect will depend on many factors, such as the stage of a country's economic development, the skill structure of the labor market, or trade flows.

3 Theoretical framework

We quantify the welfare impact of skill-biased migration in a calibrated simulation exercise. To this end, we develop an integrated multi-country model that incorporates the most important adjustment channels through which a change in the skill composition of migrants affects welfare. We will calibrate the model to match key features of today's world, and use it to simulate a world in which the same number of migrants is neutrally selected from their home country population.

The basic set-up of the model is in the spirit of Krugman (1980). We consider a world with J countries, indexed by $i = 1, \dots, J$ and differentiated products. In each country, the economy consists of two broad sectors: a traditional sector producing a homogeneous good T and a horizontally differentiated manufacturing sector. The manufacturing sector is divided into two sub-sectors, one producing a tradable differentiated good X, and one producing a non-tradable differentiated good Y. The market for manufactured goods is monopolistically competitive. Firms can freely enter the market, but pay a sunk entry cost. Good T is traded freely across all countries, and serves as numeraire, while the markets for the tradable differentiated good X are separated by asymmetric iceberg trade costs.

Countries differ in worker productivity. The workforce in every country consists of three education levels. Moreover, in the receiving countries, immigrants and natives are imperfect substitutes in production. In the baseline model we assume that every migrant remits a fixed amount independent of income, in which case the country-pair-specific amount of remittances remains constant as long as the number of migrants does not change. In the following, we present the main building blocks of the model. A more detailed description of the model can be found in Appendix A.

3.1 Preferences and welfare

Consumers have non-homothetic preferences; they always demand a certain amount of agricultural goods independent of income. With non-homothetic preferences, a higher average income translates into an over-proportional shift away from the agricultural good and towards manufactured goods. This is particularly important for developing countries, where consumers spend a high fraction of their income on agricultural goods. A consumer in country i with income w_i maximizes utility

$$\begin{aligned} &\max_{\{T_i, x_{ij}(k), y_i(k)\}} \beta^T (T_i)^{\mu} + \left(1-\beta^T\right) \left[(1-\beta)(Y_i)^{\frac{\theta-1}{\theta}} + \beta(X_i)^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}} \\ &\text{subject to: } T_i + P_i^Y Y_i + P_i^X X_i = w_i, \end{aligned} \tag{1}$$

where β is the relative preference for the tradable differentiated goods, β^T is a preference parameter for the traditional good, and θ is the elasticity of substitution between non-tradable and tradable goods. The consumption of traditional goods is subject to decreasing marginal utility, such that $\mu < 1$. Y_i and X_i are CES composites of different varieties produced in the manufacturing sector,

$$X_i = \left[\sum_{j=1}^{J} \int_0^{N_j^X} (x_{ij}(k))^{\frac{\epsilon-1}{\epsilon}} dk\right]^{\frac{\epsilon}{\epsilon-1}}, \quad Y_i = \left[\int_0^{N_i^Y} (y_i(k))^{\frac{\epsilon-1}{\epsilon}} dk\right]^{\frac{\epsilon}{\epsilon-1}}. \tag{2}$$

N_i^X and N_i^Y are the varieties of goods X_i and Y_i available in country i. Varieties of the composite tradable good X_i are either domestically produced, $x_{ii}(k)$, or imported from other countries $x_{ij}(k), j \neq i$, while all varieties of Y_i are produced domestically. ϵ is the elasticity of substitution between any two varieties within a sector, with $\epsilon > \theta$. We assume that $\epsilon > 1$, such that consumer preferences exhibit love of variety, which means that they derive utility from the number of available varieties.

We measure an individual's welfare via her indirect utility, which equals the weighted average of the utility from consuming the traditional good, and her expenditure on manufactured goods (equal to nominal wages net of expenditures on the traditional good) divided by the price index in country i,

$$U_i = \beta^T \left(\frac{\beta^T \mu}{1-\beta^T} P_i\right)^{\frac{\mu}{1-\mu}} + (1-\beta^T)\frac{w_i - T_i}{P_i}. \tag{3}$$

where P_i is the ideal price index in country i,

$$\begin{aligned} &P_i = \left[(1-\beta)^{\theta} \left(P_i^Y\right)^{1-\theta} + \beta^{\theta} \left(P_i^X\right)^{1-\theta}\right]^{\frac{1}{1-\theta}}, \\ &\text{with: } P_i^X = \left[\sum_{j=1}^{J} \int_0^{N_j^X} (p_{ij}(k))^{1-\epsilon} dk\right]^{\frac{1}{1-\epsilon}}, \text{ and } P_i^Y = \left[\int_0^{N_i^Y} (p_i(k))^{1-\epsilon} dk\right]^{\frac{1}{1-\epsilon}}. \end{aligned} \tag{4}$$

Welfare is derived from base consumption of good T_i (first term in Equation (3)), and the utility-maximizing consumption of varieties of the differentiated goods X_i and Y_i.

A change in the selection pattern of migrants affects welfare through incomes w_i and the overall price level P_i. Both can be affected directly, for example through competition on the labor market or the product market, as well as through changes in market size, complementarities between workers of different skill-levels, or changes in trade patterns.

3.2 Labor force composition and production

Labor is the only production factor in the model. Countries have different levels of total factor productivity (TFP) in the traditional and the manufacturing sector. Labor markets are assumed to be perfectly competitive. Workers sort into whichever sector pays the highest wage given their skill level. The traditional sector only produces with low-skilled workers,

$$Q_i^T = A_i^T L_i^T, \tag{5}$$

where L_i^T is the supply of low-skilled labor that is employed in the traditional sector, and A_i^T is the productivity residual, which equals the wage of low-skilled workers: $W_i^L = A_i^T$.[5]

The manufacturing sector employs workers from all three skill-levels and produces with a constant-elasticity-of-substitution (CES) technology. Workers with different skills are imperfect substitutes in production. The production function of the manufacturing sector is given by

$$Q_i^M = A_i^M L_i^M = A_i^M \left[\alpha_i^L \left(L_i\right)^{\frac{\sigma_s-1}{\sigma_s}} + \left(1-\alpha_i^L-\alpha_i^H\right)\left(M_i\right)^{\frac{\sigma_s-1}{\sigma_s}} + \alpha_i^H \left(H_i\right)^{\frac{\sigma_s-1}{\sigma_s}}\right]^{\frac{\sigma_s}{\sigma_s-1}}, \tag{6}$$

In the above specification, L_i, M_i and H_i represent the supplies of low, medium and high-skilled workers. α_i^L and α_i^H are the country-specific efficiency weights of low-and high-skilled workers.

Each skill group consists of natives (labeled by superscripts N) and foreigners (with superscripts F), which are imperfect substitutes with a constant elasticity of substitution equal to $\sigma_n > 1$. For example, the CES aggregate for high-skilled workers is given by

$$H_i = \left[(1-\alpha_i^F)(H_i^N)^{\frac{\sigma_n-1}{\sigma_n}} + \alpha_i^F (H_i^F)^{\frac{\sigma_n-1}{\sigma_n}}\right]^{\frac{\sigma_n}{\sigma_n-1}}, \tag{7}$$

and likewise for medium- and low-skilled workers. The parameter α_i^F denotes the relative efficiency of foreigners versus natives of a given skill level. We allow α_i^F to vary across countries, but assume that it is the same across skill groups within a country.

The manufacturing sector is monopolistically competitive, such that firms have some price-setting power. Each firm produces one variety of a differentiated good. Firms can freely enter the manufacturing sector, but incur a sunk entry cost of f_i^Y and f_i^X units of efficient labor in the respective sector. Both sub-sectors Y and X use identical production technologies. Firms

[5] Wages of low-skilled workers are equal across sectors and are equal for immigrants and natives. Therefore, any low-skilled worker in sector T has no incentives to move to sectors X and Y.

within a country are homogeneous, and set prices as a constant mark-up over the marginal costs of production,

$$p_i(k) = p_i = \frac{\epsilon}{\epsilon - 1} c_i, \tag{8}$$

where the $c_i = \frac{W_i}{A_i^M}$ is the marginal cost of production, and W_i is the overall wage index of the manufacturing sector, given by

$$W_i = \left[(\alpha_i^L)^{\sigma_s}(W_i^L)^{1-\sigma_s} + (1-\alpha_i^L-\alpha_i^H)^{\sigma_s}(W_i^M)^{1-\sigma_s} + (\alpha_i^H)^{\sigma_s}(W_i^H)^{1-\sigma_s}\right]^{\frac{1}{1-\sigma_s}}. \tag{9}$$

Through the parameterization of the aggregate production function we account for four important differences in the economic structure of OECD countries. First, OECD countries differ in their productivity, and, consequently, in their GDP per capita. The GDP per capita in Luxembourg, the OECD's richest country, is 5 times larger than in Mexico, the OECD's poorest country. Moreover, in poorer countries, the agricultural sector contributes a larger share to aggregate production. The productivity parameters A_i^L and A_i^M account for the differences in aggregate productivity across countries, as well as differences in the sectoral productivity within countries. Second, as shown by Trefler (1993), countries differ considerably in their effective labor endowment due to productivity differences. For instance, the same high-skilled worker is more productive in the US than in Mexico, because in the US she faces a higher complementarity between capital and skill. We account for these differences through country-specific efficiency parameters for high- and low-skilled workers, α_i^L, α_i^H. Third, within a country, workers with similar skills are closer substitutes in production than workers with different skills (Card & Lemieux, 2001). We account for this imperfect substitutability by modelling the production function of the manufacturing sector with a CES structure. Fourth, as shown by Ottaviano & Peri (2012) and Peri & Sparber (2009), migrants and natives are imperfect substitutes even when they have the same skill-level, which we account for in Equation (7) with a CES aggregate and country-specific efficiency parameters α_i^F.

3.3 Market size

Each firm produces a single variety of a differentiated good. In equilibrium, firms make zero profits, and all goods markets clear. These conditions, together with the optimal pricing rule (8), pin down the optimal number of varieties, N_i^X and N_i^Y. To derive an expression for the optimal number of firms in sub-sectors X and Y, we first derive the shares of value-added in the manufacturing sector, which are given by

$$sh_i^X \equiv \frac{P_i^X X_i}{GDP_i^X + GDP_i^Y} = \beta^\theta \left(\frac{P_i^X}{P_i}\right)^{1-\theta}, \text{ and } sh_i^Y = (1-\beta)^\theta \left(\frac{P_i^Y}{P_i}\right)^{1-\theta}. \tag{10}$$

Combining Equation (10) and the optimal pricing rule (8) yields the resource constraints of the economy:

$$sh_i^X A_i^M L_i^M = \frac{\epsilon}{\epsilon-1} N_i^X x_i, \quad sh_i^Y A_i^M L_i^M = \frac{\epsilon}{\epsilon-1} N_i^Y y_i. \tag{11}$$

The resource constraints state that the effective labor supply in a given sector (left-hand side) has to equal labor demand by firms in this sector (right-hand side). The zero profit condition implies that $p_i x_i = \varepsilon W_i f_i^X$ and $p_i y_i = \varepsilon W_i f_i^Y$, which yields the number of units produced by each firm,

$$x_i = A_i^M f_i^X (\epsilon - 1), \quad y_i = A_i^M f_i^Y (\epsilon - 1). \tag{12}$$

Combining (11) and (12), we obtain the optimal market size

$$N_i^X = \frac{sh_i^X L_i^M}{\epsilon f_i^X}, \quad N_i^Y = \frac{sh_i^Y L_i^M}{\epsilon f_i^Y}, \tag{13}$$

which states that the numbers of firms in sectors X and Y, operating in country i, are proportional to the efficient labor supplies employed in these sectors and inversely proportional to the fixed costs of entry.

3.4 International trade

Varieties of good X are traded between countries. The volume of trade depends on trade costs, as well as differences in consumer demand and price levels. Exports from country i to country j, denoted by $Trade_{ji}$ are subject to a iceberg trade costs $\tau_{ji} > 1$. Trade costs are asymmetric, $\tau_{ji} \neq \tau_{ij}$. $Trade_{ji}$ is given by

$$Trade_{ji} = \int_{k \in N_i^X} x_{ji} p_{ji} dk = N_i^X GDP_j^X \left[\frac{\tau_{ji} p_i}{P_{X_j}} \right]^{1-\epsilon}. \tag{14}$$

where p_{ji} and x_{ji} are the price and quantity of a variety produced in country i, consumed in country j. Given that $\varepsilon > 1$, trade depends negatively on import prices including trade costs, $\tau_{ji} p_i$, and positively on the domestic price-level. The total value-added in sector X in country i is then the sum of all trade flows to country i, including domestic consumption $Trade_{ii}$, and is given by

$$GDP_i^X = N_i^X \sum_{j=1}^{J} GDP_j^X \left(\frac{P_{Xj}}{\tau_{ji} p_i} \right)^{\varepsilon - 1}. \tag{15}$$

Solving Equation (15) for N_i^X, and substituting into (14), we can express the share of exports as a total share of production in sector X as

$$\frac{Trade_{ji}}{GDP_i^X} = \frac{GDP_j^X \left(P_{Xj} / \tau_{ji} \right)^{\epsilon - 1}}{\sum_{h=1}^{J} GDP_h^X \left(P_{Xh} / \tau_{hi} \right)^{\epsilon - 1}}. \tag{16}$$

Equation (16) can be interpreted like a gravity equation. Exports from country i to country

j increase with GDP in the foreign country — which reflects foreign consumer demand — , they increase in the foreign price level, and decrease in trade costs. In equilibrium, trade is balanced within each country, which means that the value of imports equals the value of exports, $\sum_{j=1}^{J} Trade_{ij}^{X} = \sum_{j=1}^{J} Trade_{ji}^{X}$. We provide a detailed definition of the equilibrium in Appendix A.4.

3.5 Mechanisms

Within the model, a change in the skill distribution of migrants affects welfare through several channels. We highlight here the most important mechanisms, using as example a receiving country that switches to a more highly skilled migrant population, that is, the number of low-skilled migrants L_i^M decreases, while the number of high-skilled migrants H_i^M increases by the same amount, $-\Delta L_i^M = \Delta H_i^M$. Assume for simplicity that the number of medium-skilled migrants M_i^M remains constant.

The change in the skill distribution directly affects the nominal wage structure. Nominal wages of high-skilled workers decrease, while those of low-skilled workers increase. This affects the average nominal wage level, and especially affects the wages of non-migrants.

However, the change in the nominal wage structure affects inequality more than it affects welfare. A more important channel for welfare is market size, i.e. the number of available varieties. A more highly skilled workforce is more productive, such that any good can be produced at lower unit cost, which in turn induces more firms enter the market, and increases the number of varieties. As shown in Equation (4), a higher number of varieties decreases the price index, thus increasing welfare. This reflects consumers' love of variety; consumers' utility increases in the number of available varieties even if their income remains constant. The market size effect is propagated to other countries through trade linkages, which dampen the positive welfare effect at home, while increasing the welfare of all trading partners.

4 Data and Calibration

We calibrate our model such that it replicates the most important features of the world economy in 2010: bilateral migrant stocks, bilateral trade flows, differences in GDP per capita, and wage differentials within countries. In terms of migration flows, we consider South-North migration from 111 countries to the OECD, as well as migration between the 34 OECD countries. Due to data limitations, we do not consider migration between non-OECD countries, assuming that South-South migration remains constant.

4.1 Data

The exercise requires several types of country-specific and country-pair-specific macro variables for the reference year 2010. The sample consists of 34 OECD countries and 111 non-OECD countries. Non-OECD countries for which data is not available are lumped together in the Rest of the World (ROW).

Migration and population data. Calibration requires data on the size and skill distribution of the migrant and non-migrant population of each country. The 2010 DIOC database provides data on bilateral migrant stocks by education level from 111 sending countries to and within all 34 OECD countries, as well as the population size and skill distribution of natives in the 34 OECD countries. For the non-OECD countries, we use data from Barro & Lee (2010) to obtain the number and skill distribution of non-migrants. For the Rest of the World, we apply the average skill distribution of the available non-OECD countries.

GDP, Trade, and fixed costs of entry. GDP per capita, in current international dollars, is taken from the World Development Indicators (WDI) database of the World Bank. The WDI database also provides the share of workers employed in agriculture and the shares in total GDP of the traded and non-traded manufacturing goods. To compute the trade costs, we require a bilateral matrix of trade in value-added, which we construct by combining gross trade flows in 2010 from the UN Comtrade database and the share of value-added in trade from the OECD TiVA database. We impute missing trade flows based on an estimated gravity equation, details of which can be found in Appendix B.1. To obtain the fixed cost of entry in the tradable sector, f_i^X, we follow Di Giovanni *et al.* (2014), and use a component of the World Bank Ease-of-Doing-Business indicator that measures the number of days necessary to open a business. The longer it takes to open a business, the more difficult it is to enter a market, and the higher are the fixed costs of entering. We normalize the fixed costs for the US to 1, and compute the fixed costs relative to the US for all other countries.

Wage ratios. To calibrate the efficiency parameters for high-, medium-, and low-skilled workers (α_L and α_H), we require country-specific wage ratios for high- vs. medium-skill, W_i^H/W_i^M, and medium-skill to low-skill workers, W_i^M/W_i^L. For the OECD countries, we compute these ratios from the "Education at Glance" report 2010 (OECD, 2010). For the non-OECD countries, we take data from the Wageindicator Foundation, which runs online-based surveys about wages in 80 countries. For the non-OECD countries, Wageindicator provides information on 38 high-vs.-medium-skill, and 27 medium-vs.-low-skill wage ratios.[6] For the remaining countries, we impute the wage ratios based on the returns to education in similar countries. A more detailed description of the imputation procedure can be found in Appendix B.

4.2 Calibration of key parameters

We calibrate the model in order to match country-specific (i.e. GDP, population and wage structure) and bilateral (i.e. migration and trade) moments for the 146 countries in our sample. To calibrate the most important structural parameters — preference parameters and elasticities

[6] See wageindicator.org for more information.

of substitution between types of labor — we use estimates from empirical studies where available, and for the remaining parameters set values similar to those in other quantitative studies. To ensure that the choice of parameters does not fundamentally change the results, we will conduct a series of sensitivity checks. Table 1 summarizes the calibrated parameters.

Table 1: Values of structural parameters

Parameter	Value	Source
Preference parameters		
β	0.5	exogenous
β^T	0.135	calibrated (match consumption to production)
θ	3	exogenous
μ	0.5	exogenous
ε	4	Simonovska & Waugh (2014)
σ_s	5	Docquier *et al.* (2013)
σ_n	20	Ottaviano & Peri (2012)
Worker efficiency parameters		
a_i^F	0.478	calibrated to match OECD average
a_i^L	0.12-0.40	calibrated from FOC of cost minimization
a_i^H	0.24-0.60	calibrated from FOC of cost minimization

Note: This table summarizes the calibration of the structural parameters in the model. A more detailed description of the procedures can be found in Section 4.2 and in Appendix B.

The non-homothetic utility function ensures that the expenditure share of the traditional good decreases with income. This allows to account for the higher fraction of income spent on traditional (i.e. agricultural goods) in developing countries, a standard observation in household datasets.[7] Setting $\mu = 0.5$ implies that the expenditure share on the traditional good decreases with income and increases with the price level P_i.[8]

We set the relative preference for the tradable differentiated good, β, to 0.5, such that individuals have the same preference for the traded and non-traded manufacturing goods.[9] The elasticity of substitution between tradable and non-tradable goods, θ, we set to 3.[10] Following Simonovska & Waugh (2014), the elasticity between any two varieties within a sector, ϵ, has the value of 4.[11]

[7] As shown by the US Department of Agriculture, people in the US in 2011 spend 6.8% of their total expenditure on food, whereas in the expenditure shares in developing countries are considerably higher, for example 36.2% in Vietnam, or 57.1% in Nigeria. http://www.ers.usda.gov/data-products/food-expenditures.aspx, viewed 19 Feb 2016.

[8] Our model formulation imposes that $0 < \mu < 1$ in order to have a negative impact of the price level on the traditional good expenses. Results are very robust to the choice of this parameter.

[9] Note that real demand will also depend on prices such that the quantities demanded for each good are not necessarily equal. A robustness analysis on this parameter shows that results are not affected by this choice.

[10] As we show in Appendix D, the simulation results are robust to a wide range of parameters, ranging from $\theta = 0.5$ to $\theta = 3.9$.

[11] A value slightly higher is obtained by Parro (2013) who uses a tariff based approach to estimate an aggregate trade elasticity for traded goods. Estimation of the shape parameter of the productivity distribution based

The share of output produced by the foreign workers (a_i^F) is calibrated such as to match the wage premia for natives over immigrants of 5 % in OECD countries. For non-OECD countries we use the average value obtained in OECD countries ($a_i^F = 0.478$) as we cannot assess country-specific values due to the lack of immigration data. The production function includes three types of workers. To calibrate its structural parameters, we use parameter values obtained by Ottaviano & Peri (2012). To account for imperfect substitution, the elasticity of substitution between the three skill groups, σ_s is set to 5. We further allow for imperfect substitution between immigrant and native workers within each skill group. The value of the elasticity of substitution, σ_n, is set to 20, and is identical among the three skill groups.

We then calibrate the country-specific efficiency parameters for high- and low-skilled workers, a_i^H and a_i^L, such as to perfectly match the high-vs.-medium- and high-vs.-low-skilled wage ratios within countries. We first use the market clearing condition for the manufacturing sector (Equation (26)) with data on GDP and the number of domestic and foreign workers per skill group in order to obtain the wage index for the manufacturing sector, W_i. The efficiency parameters are then obtained by inserting this information into the first-order conditions of a manufacturing firm's cost-minimization problem. With these parameters and the efficiency parameter of foreign workers, α_i^F, we compute the skill-specific wage aggregates, W_i^L, W_i^M, and W_i^H. Finally, based on the wage aggregates and α_i^F, we compute wages for all six types of workers.

Finally, we calibrate trade costs and TFP, such that the trade flows and cross-country TFP differences match closely their counterparts in the data. Based on these, we are able to compute all equilibrium prices and quantities, as well as the equilibrium number of firms. In Appendix B we provide a more detailed description of the calibration.

5 The gain from the drain - results

We now use the calibrated model to run counterfactual simulations that compare the world with and without skill bias in migration. As we will show, the magnitude of the effects depends crucially on the welfare measure applied. We first quantify the impact of the skill bias in migration on welfare in the sending and receiving countries, and further consider its impacts on wage inequality within countries. We then quantify the global welfare effect of skill-biased migration if all OECD countries were equally selective as Canada, the country with the highest degree of immigrant selectivity. Finally, we extend the model along several dimensions, such as remittances, human capital externalities, and network effects.

5.1 Counterfactual

The simulation exercise aims to quantify the welfare impact of the skill bias in migration, holding bilateral stocks of migrants constant. Our counterfactual is a world without skill bias in migration, in which migrants have the same skill distribution as the population of their country

on firm-level sales data provide estimates in the range of 3.6 to 4.8 (Bernard *et al.*, 2003; Eaton *et al.*, 2011).

of origin. Which counterfactual is appropriate depends on the question at hand. Most studies are interested in the welfare impact of migration *per se*, and compare the current world to a world with more migration (Kennan, 2013), or to a world without migration (Di Giovanni *et al.*, 2014). In this paper, in contrast, we are interested in a different question. Rather than the impact of the *level*, we are interested in the impact of *selectivity* of migration. To isolate the effect of changes in selectivity from the effect of changes in the level of migrants, we hold the level of migration constant.

5.2 Aggregate effects

5.2.1 Measuring welfare

Before turning to the welfare effects, we need to define whose welfare we analyze. In the quantitative exercise, we are interested in the difference in welfare that can be attributed to the skill bias in migration. We measure welfare as the average indirect utility, which is an increasing function of the average real income in a country. If people have higher real incomes, they can consume more, and attain a higher level of utility. However, to produce a meaningful causal estimate of this effect, it is important to define the population whose change in welfare we are measuring.

A straightforward measure would be welfare per capita, which in the receiving countries would include all natives and migrants, and in the sending countries all non-migrants. Within each country, we would then compare the welfare per capita under the baseline and under the counterfactual. But this comparison is of limited value, because the composition of the base population changes when we replace high-skilled with low-skilled migrants. In the language of program evaluation, the difference in welfare per capita is a combination of a *treatment effect* — the causal impact of a change in migrant selectivity on the welfare non-migrants — and a *composition effect* — replacing high-earning with low-earning migrants. What we are interested in is the treatment effect, that is, the impact on the welfare of people who are non-migrants under both the baseline and the counterfactual.

Therefore, our preferred measure is *welfare per never-migrant*. In the receiving countries, never-migrants are all natives. In the sending countries, we construct the population of never-migrants based on the skill distributions of migrants and the total population.[12] In the baseline simulations to follow we report both measures, whereas in the extensions we will only report the effect on welfare per never-migrant.

5.2.2 Baseline results

We begin by analyzing the impact of skill-biased migration on overall welfare. We measure the change in welfare as the percentage difference in indirect utility,

[12] The population of never migrants in the sending countries consists of those people who are in the same sending countries in both scenarios. We compute their skill distribution by taking the minimum number of each skill group under both scenarios. For instance, the number of high-skilled never-migrants is $H_{NM} = \min(H_{baseline}, H_{counterfactual})$.

$$\frac{\Delta U}{U} = \frac{U_{skill-bias} - U_{skill-neutral}}{U_{skill-neutral}}$$

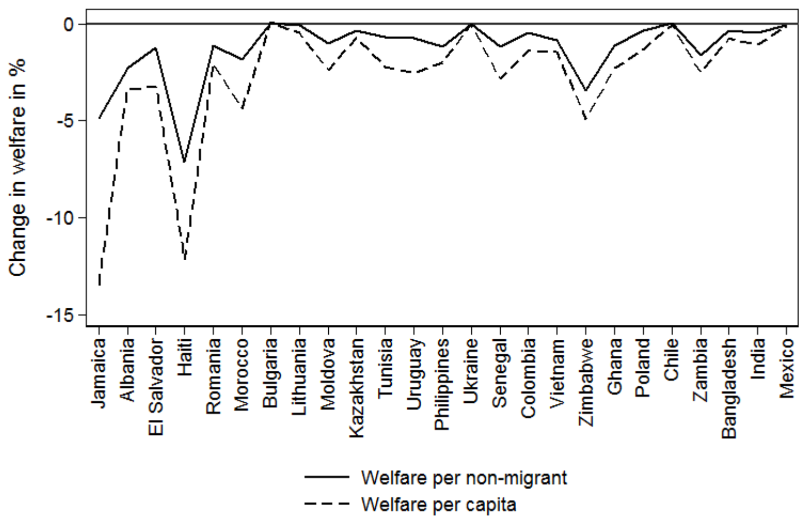
Figure 2 displays the simulation results for selected sending and receiving countries. The countries are ordered from left to right by the share of immigrants or emigrants in the total population. All effects represent the difference in welfare under skill-biased and skill-neutral migration. A positive effect means that people are better off under skill-biased migration. The dotted line represents the effect on welfare per capita, while the solid line represents the effect on welfare per never-migrant.

Figure 2(a) shows the effects for the sending countries. These correspond to the welfare effects of the brain drain that have been estimated in the previous literature (Beine *et al.*, 2008, e.g.). The effects are negative for all countries, and are particularly large for Jamaica and Haiti, which have both large shares of emigrants, and whose emigrants are predominantly high-skilled. Depending on the welfare measure, the brain drain lowers the welfare in these two countries by 5-15%, while in most other countries, the welfare effects are smaller, and lie between 0 and 3%. The difference in the effect under both welfare measures highlight the importance of choosing the base population. The effects are considerably larger when we consider welfare per capita, whereas the effect on welfare per never-migrant is smaller. In contrast to Beine *et al.* (2008), we do not find positive welfare effects for the brain drain, mainly because our baseline model does not include human capital externalities. As we will see in the extensions, once these externalities are included, some countries with low shares of emigrants, i.e. countries towards the right in Figure 2(a) have small positive effects.

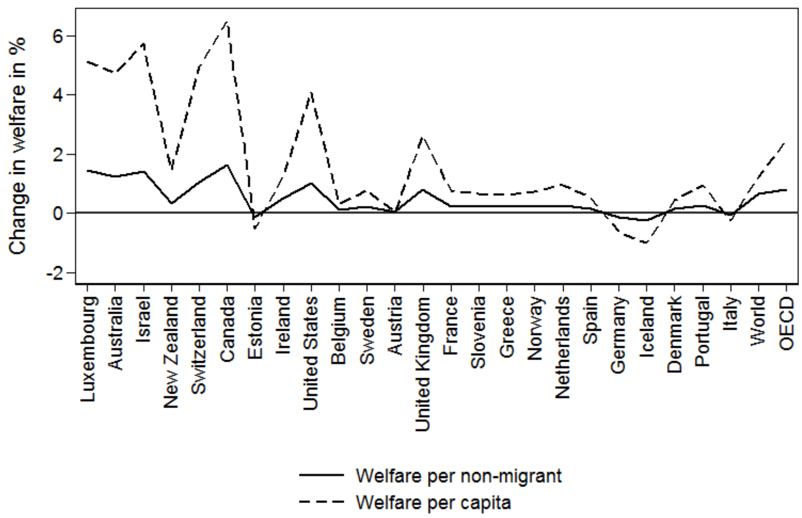
In Figure 2(b), we turn to the receiving countries. As shown in Section 2, the skill bias in migration is positive for most receiving countries, i.e. they receive more high-skilled immigrants than they would if all migrants were randomly drawn from their countries of origin. With the notable exceptions of Iceland and Germany, the impact of skill-biased migration is positive in all countries. The effects are particularly large in Canada, Australia, Israel, the US, and Luxembourg, which all combine high immigration rates with a high degree of selectivity. In the receiving countries, the difference in the effect on both welfare measures is more pronounced than in the sending countries. The impact on welfare per never-migrant is considerably smaller than the impact on welfare per capita. Still, the effect on welfare per never-migrant is positive for most countries, and lies between 0 and 2%. In the OECD as a whole, welfare is 1% higher because of the skill bias in migration.

At first glance, it seems that the effects in the sending countries are larger than in the receiving countries. However, once we weight the effects by population and compute the net effect on the world, we find that the gains in the receiving countries exceed the losses in the sending countries, leading to a 1% gain in world welfare. What seems like a small effect is actually large given the small share of migrants among the world population. Currently, only 3% of the world population are migrants; and just because these 3% are predominantly high- and not low-skilled, world welfare is 1% higher.

Figure 2: Welfare Effects in selected countries



(a) Welfare Effects in the sending countries



(b) Welfare Effects in the receiving countries

Source: Own calculations.

Notes: This graph displays the impact of the skill bias in migration on welfare in the non-OECD countries (Panel 2(a)) and OECD countries (Panel 2(b)). The dashed line represents the effect on welfare per capita; the solid line represents the effect on welfare per never-migrant. The countries on the horizontal axis are ordered by immigration/emigration rates. The vertical axis shows welfare changes, in percentage. Panel 3b focuses on selected receiving countries, while panel 3a focuses on selected sending countries.

5.3 Distributional effects

Besides having an impact on aggregate welfare, the skill bias in migration also affects the income distribution within a country. A change in the skill composition of migrants changes the relative supply of high-skilled vs. low-skilled workers, and in turn the nominal wage structure. Nominal wages are affected through direct competition on the labor market, as well as through complementarities between high-, medium- and low-skilled workers.

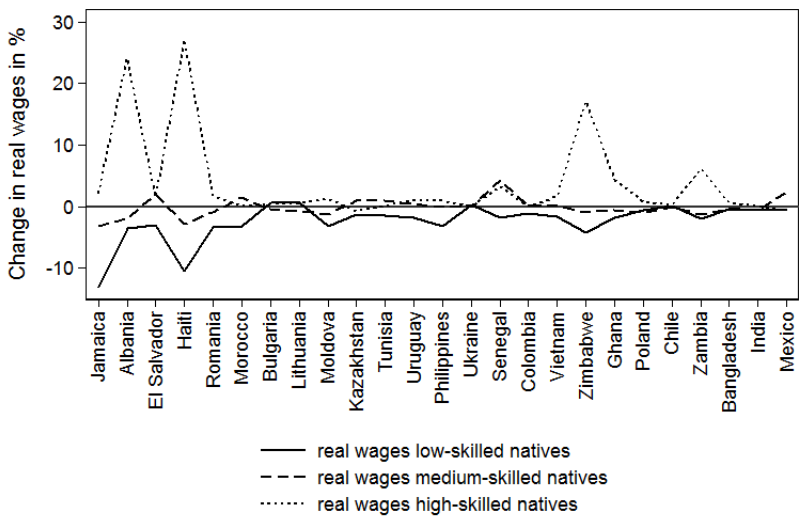
Figure 3 displays the impact of the skill bias in migration on the real wages of high- and low-skilled workers. As in the previous section, a positive value means that the respective groups have higher real wages in a world with skill-biased migration. Figure 3(a) shows the distributional effects in the sending countries. In sending all countries, high-skilled workers gain and low-skilled workers lose, while the impact for medium-skilled workers hovers around zero. The gains in real wages are particularly pronounced for high-skilled workers in Albania (+24%), Haiti (+25%), and Zimbabwe (+20%), while in most other countries the effects are close to zero. In most countries, the gains for high-skilled workers are larger than the losses for the low-skilled workers. The sign of the effects can be explained by a simple supply-and-demand mechanism. Most sending countries experience a severe brain drain, such that high-skilled workers who stay behind become a scarcer resource in the labor market, leading to wage increases for high-skilled workers. The opposite holds true for low-skilled workers. The magnitude of these effects depends on the skill-distribution of the non-migrant population, and on the direction and magnitude of the general equilibrium effects. Overall, skill-biased migration increases wage inequality within sending countries.

As Figure 3(b) shows, the skill bias has the opposite effect in the receiving countries: low-skilled workers gain, while high-skilled workers lose. With skill-biased migration, low-skilled workers face less competition on the labor market, while at the same time, they have more varieties available, and the price per variety decreases. For high-skilled workers, the effects are less clear. In most countries, high-skilled workers lose by a small margin, while they gain in others. High-skilled workers benefit from the same positive market size effect as low-skilled workers, but face more competition on the labor market. If these effects balance out, the net effect may be zero. Overall, the skill bias in migration decreases wage inequality in the receiving countries.

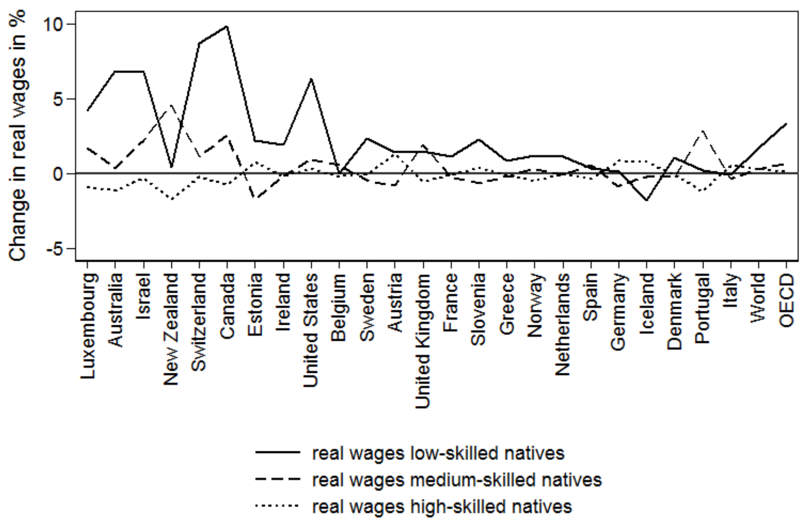
The gains for low-skilled workers in the receiving countries may seem puzzling in light of the evidence that migration decreases the wages of low-skilled natives (Borjas, 2003; Dustmann *et al.*, 2013). The main difference between these studies and ours is the choice of counterfactual. Most studies look at the impact of having *more* immigrants, whereas we are interested in the impact of having *different* immigrants. Given that under skill-biased migration there are fewer low-skilled workers in the receiving countries than under the counterfactual, low-skilled non-migrants are better off from skill-biased migration.

We also report the real wage changes for the OECD and the world as a whole. High-skilled workers in the OECD gain about 3%, and high-skilled workers in the world gain around 2%, while the effects for low-skilled workers are close to zero. Taken together, the results from Section 5.2.2 and from this section suggest that skill-biased migration leads to a more efficient allocation of labor, and greater productivity in the world, but also leads to a higher inequality within countries.

Figure 3: Distributional effects



(a) Wage Effects in selected non-OECD sending countries



(b) Wage Effects in selected OECD receiving countries

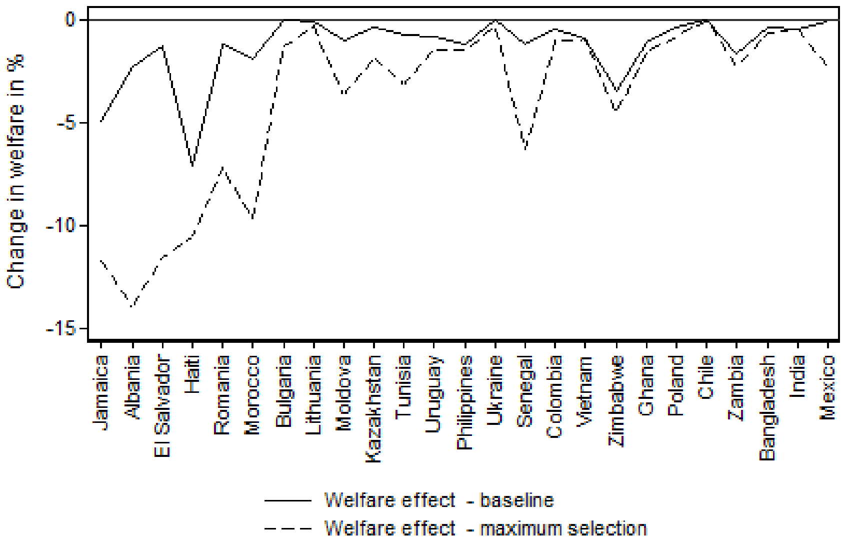
Source:. Own calculations.

Notes: This graph shows the impact of the skill bias in migration on the real wages of low-, medium-, and high-skilled workers. The countries on the horizontal axis are ordered by immigration/emigration rates. The vertical axis shows wage changes, in percent, for high- and low-skilled workers. Panel 3b focuses on selected receiving countries, while panel 3a focuses on selected sending countries.

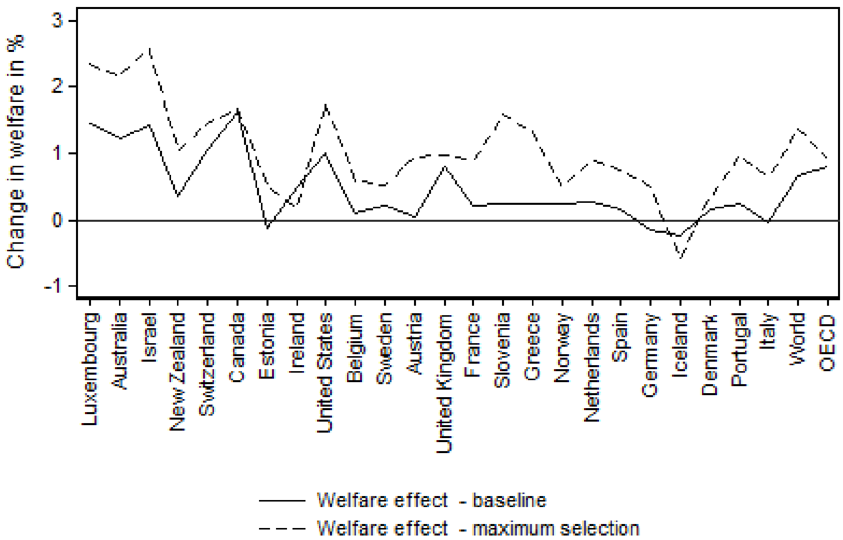
5.4 Simulating the Canadian model for the OECD

The simulation results shown so far indicate the welfare effect of the *actual* skill bias in migration. We now turn to a hypothetical scenario that could occur if the OECD countries introduced a more skill-biased immigration policy towards non-OECD countries. We use as example Canada,

Figure 4: OECD as selective as Canada



(a) Welfare effects in selected non-OECD sending countries



(b) Welfare effects in selected OECD receiving countries

Source:. Own calculations.

Notes: This graph displays the welfare effects of the skill bias in migration if all OECD countries were as selective as Canada. The countries on the horizontal axis are ordered by immigration/emigration rates. The vertical axis shows changes in welfare per never-migrant in percent. Panel 3b focuses on selected receiving countries, while panel 3a focuses on selected sending countries.

which has the largest degree of skill bias among all OECD countries. Based on this example, we carry out the following thought experiment: assuming that immigrants in every OECD country were as heavily selected as in Canada, what would be the impact of this skill bias on global welfare?[13]

Figure 5b gives the answer. The welfare consequences for most sending countries, especially for those with high shares of emigrants, would be drastic. Albania, for example, whose emigrants are currently almost neutrally selected would see a much larger share of high-skilled emigrants, and experience a welfare loss four times larger than under the current skill bias in migration. In the OECD countries, the welfare effects are larger than under the current selection of migrants.[14]

Importantly, the impact on world welfare is larger than under the current selection of migrants. This suggests that it would be globally efficient to have an even greater skill bias in migration, because larger numbers of productive workers would be in countries where their skills are most efficiently used. Yet the consequences for some sending countries could be dire. In light of the global efficiency gains, however, it should be possible to combine a selective immigration policy with a compensation scheme, according to which the receiving countries compensate the sending countries for the welfare losses due to the brain drain.

6 Extensions

Our model incorporates the most important adjustment channels through which a change in the migrant skill distribution affects welfare: market size, trade flows, and changes in the nominal wage structure. In this section, we incorporate several additional mechanisms that have been highlighted in the literature: remittances, incentives to invest in education, TFP externalities, and ethnic networks in trade. We also account for downskilling, that is, the fact that many immigrants work in occupations for which they are over-qualified. Furthermore, we put the welfare impact of the skill bias in perspective by comparing it with the welfare difference between today's world and a world with zero migration.

6.1 Remittances

Remittances are an important source of income in developing countries, and could potentially offset the negative market size effect of the brain drain. In the baseline model, we do not explicitly include remittances, but assume implicitly that every migrant remits the same amount independent of earnings. In this set-up the amount of remittances remains constant, because the number of migrants remains constant under the baseline and the counterfactual. This assumption is supported by the empirical literature, which finds ambiguous results for the relationship between earnings and the amount remitted.

An equally realistic scenario could be that the amount remitted is proportional to earnings (Bollard *et al.*, 2011). To accommodate this possibility, we compute a receiving-country-specific

[13] More specifically, we apply the skill selection of Canada vis-a-vis every sending country to every other OECD country.

[14] In some OECD countries, the effects under the 'Canadian regime' are smaller than under the baseline scenario, despite Canada being the most selective country. But this selectivity is high on average, but may be lower vis-à-vis some sending countries. If for example the Polish immigrants in Canada are less positively selected than Polish immigrants in Ireland, the welfare effect in Ireland can be larger in the baseline simulations.

share of income remitted based on remittance data from the World Bank.[15] In the sending countries, we assume that remittances are given as a lump-sum, and are equally distributed across the population. Under skill-biased migration, the amount of remittances will be higher than under skill-neutral migration, because a larger share of high-skilled migrants is present in the receiving countries. We would therefore expect the remittance channel to mitigate the effects of skill-biased migration in both the sending and the receiving countries.

The welfare effects with and without remittances are presented in Figure 5. The solid line represents the baseline effect, i.e. the difference in welfare per never-migrant in a model without remittances. The dotted line shows the difference in welfare attributable to skill-biased migration when remittances are included in the model. In the non-OECD countries, displayed in panel (a), remittances dampen the negative welfare effect, but only to a small degree. This result may be surprising, given that other studies, for example Di Giovanni *et al.* (2014), show that remittances play a major role in explaining the overall impact of migration on welfare. This would be true in our case if we assumed as counterfactual a world without migration. Yet because the number of migrants remains constant in our simulation, the global volume of remittances is only marginally larger under the baseline than under the counterfactual. In the OECD countries, shown in panel (b)), remittances do not contribute to the overall welfare effect.

In Appendix C.1, we also allow remittances to depend on the education-level.[16] Across all these scenarios, the introduction of remittances marginally dampens the welfare impact of skill biased migration in the receiving and sending countries. Overall, remittances only play a minor role for the welfare effect of the skill-bias in migration. Sending countries would lose a substantial share of national income in a counterfactual world without migration and remittances. But assuming that every migrant remits a given share of his income in both worlds or assuming that propensity to remit changes with skills, the additional welfare effect of remittances is small.

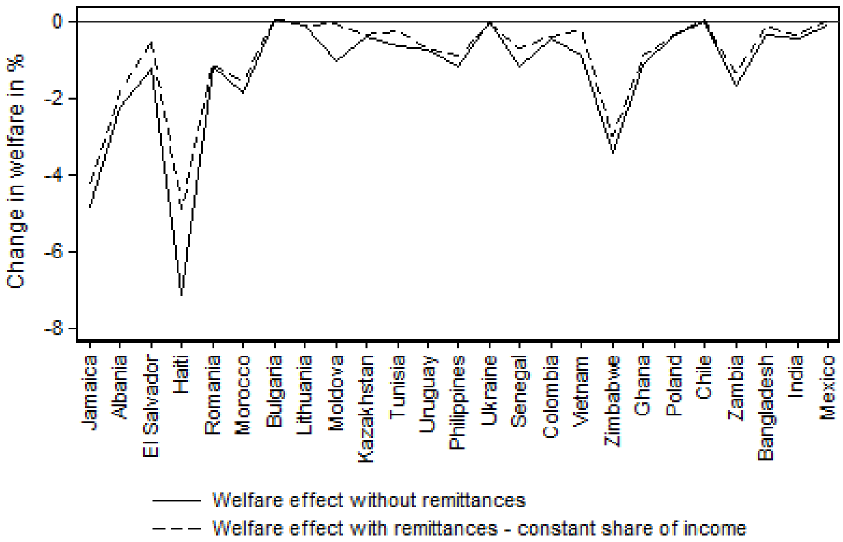
6.2 Brain gain - investment in education

While the traditional literature on the brain drain predicted severe negative welfare effects for the sending countries, the more recent literature has pointed out that human capital externalities may partly offset the losses in the sending countries, and in a more optimistic scenario even lead to a 'brain gain'. As shown in theoretical works by Mountford (1997), Stark *et al.* (1997), and Beine *et al.* (2001), the opportunity to emigrate increases the returns to education, leading to higher investment in education. This can have a positive welfare effect if not everyone who invested in education leaves the country. Several micro-studies provide evidence of a large

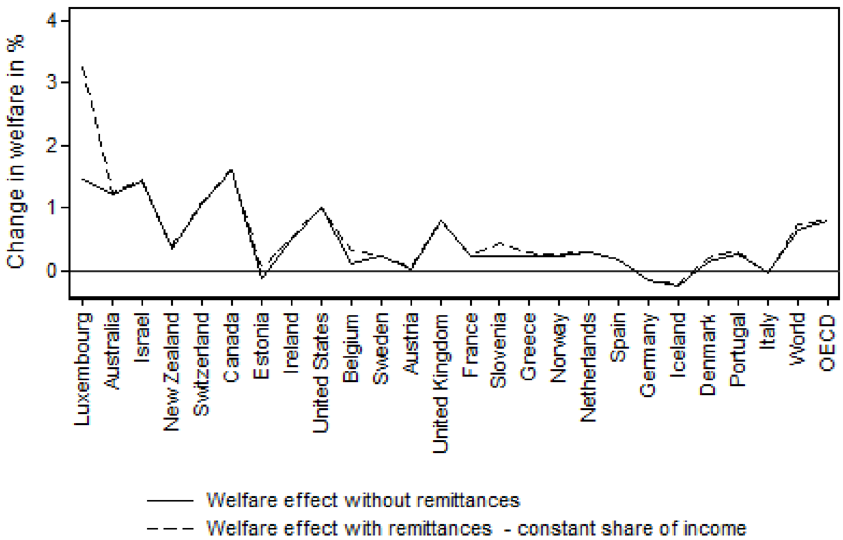
[15] We obtain country-pair-specific remittances based on the methodology developed by Ratha and Shaw, 2007, "South-South Migration and Remittances," Development Prospects Group, World Bank (`www.worldbank.org/prospects/migrationandremittances`). The remittance data cover year 2010, are disaggregated using host country and origin country incomes from 2010, and estimated migrant stocks from 2010. The share of remittances in income is calculated as the total amount of remittances sent from a given receiving country divided by the total immigrant wage bill in that country.

[16] For instance, Faini (2007) and Niimi *et al.* (2008) show that more educated remit a smaller fraction of their income, because they tend to come from poorer families that are less in need of remittances. Bollard *et al.* (2011), on the contrary, show based on microdata that more educated migrants, conditional on remitting at all, remit more.

Figure 5: Welfare effects with and without remittances



(a) Welfare effects in selected non-OECD sending countries



(b) Welfare effects in selected OECD receiving countries

Source:. Own calculations.

Notes: This graph displays the welfare effects of the skill bias in migration with (dashed line) and without remittances (solid line). The countries on the horizontal axis are ordered by immigration/emigration rates. The vertical axis shows changes in welfare per never-migrant in percent. Panel 3b focuses on selected receiving countries, while panel 3a focuses on selected sending countries.

brain gain effect (Chand & Clemens, 2008; Batista *et al.*, 2011; Shrestha, 2015; Dinkelman & Mariotti, 2016). At the macro-level, Beine *et al.* (2008), find that the brain gain offsets the negative brain drain effect in sending countries with low emigration rates, while in countries with high emigration rates the negative effect dominates.

To incorporate a brain gain mechanism into the model, we assume that the share of high-skilled non-migrants is an increasing function in the share of high-skilled emigrants.[17] Define $sh_S = \frac{H_n}{H_n+M_n+L_n}$ and $sh_E = \frac{H_e}{H_e+M_e+L_e}$, respectively, as the observed share of high-skilled stayers and emigrants under the baseline scenario, and $\widehat{sh_S}$ and $\widehat{sh_E}$ as the equivalent shares under the counterfactual. We compute the new counterfactual share of high-skilled stayers as

$$\widehat{sh_S} = sh_S \left(1 + \sigma_b \frac{\widehat{sh_E} - sh_E}{sh_E}\right) \tag{17}$$

The elasticity σ_b describes the strength of the brain gain mechanism. If $\sigma_b = 0$, there is no brain gain mechanism, whereas with any positive value of σ_b, the share of high-skilled stayers becomes an increasing function in the share of high-skilled emigrants.[18] We calibrate the model using elasticities between 0 (no brain gain effect), and 0.05, the brain gain effect estimated in Beine *et al.* (2008). To compute the counterfactual skill distribution in the sending countries, we implement an iterative procedure that simultaneously solves for $\widehat{sh_S}$ and $\widehat{sh_E}$, and computes the shares of low- and medium-skilled stayers as residuals. Appendix C.2 explains the detailed procedure.

The simulation results are displayed in Figure 6. The brain gain channel dampens the welfare losses from the brain gain in the sending countries, and in some cases even leads to an overall welfare gain. The receiving countries are only mildly affected due to different trade patterns. With a brain gain elasticity of $\sigma_b = 0.05$, the impact of the brain drain on world welfare is twice as large as without a brain gain mechanism. One should be cautious, however, when interpreting the difference in results with and without brain gain, because they do not represent marginal effects. In some countries, the share of high-skilled emigrants under the baseline is a multiple of the share of high-skilled emigrants under the counterfactual. Thus, an elasticity of $\sigma_b = 0.05$ is probably too high to account for these substantial differences in high-skilled emigration rates. Yet even at a modest brain gain elasticity of $\sigma_b = 0.01$, the welfare losses in the sending countries are considerably lower than in a world without brain gain.

6.3 Human capital externalities in TFP

A further human capital externality could work through total factor productivity (TFP). As shown by Lucas (1988), an economy with a higher average level of human capital may use its production factors more efficiently, leading to an additional positive impact of human capital on output. We incorporate a Lucas-type externality in the model, with TFP being a concave function of the average level of human capital. Consequently, a given change in the level of human capital has a larger effect in poorer countries, which start from a lower level of human

[17] This represents a reduced-form relationship. The underlying microfoundations have been described in Mountford (1997) and Stark *et al.* (1997).

[18] This represents a reduced-form relationship. The underlying microfoundations have been described in Mountford (1997) and Stark *et al.* (1997).

capital. We parameterize total factor productivity as

$$A_i = a_i \left(\frac{H_i}{H_i + M_i + L_i} \right)^{\sigma_a}, \tag{18}$$

The elasticity σ_a governs the strength of the response of TFP to changes in the share of high-skilled workers in the population. We run separate simulations for $\sigma_s \in \{0.1, 0.3, 0.5\}$.[19] The parameter a_i is country-specific scaling factor, which is implicitly computed from Equation 18, using data on absolute TFP (A_i) and the information on the workforce composition.

As shown in Figure 20, the welfare effects of skill-biased migration are larger once the TFP externality is accounted for, and considerably so at high levels of σ_a. The overall effect on world welfare, however, is of similar size as the effect without the externality.[20] These results suggest that the initial simulation results presented in Figure 2 represent a lower bound, and could be larger in the presence of externalities.

6.4 Downskilling of immigrants

It is common that immigrants, especially those from developing countries, work in jobs for which they are overqualified (Mattoo *et al.*, 2008). This qualification mismatch might imply that we over-estimate the welfare effects of skill-biased migration in the receiving countries. Replacing a high-skilled with a low-skilled worker may not lead to a change in productivity, if both would be working in low-skilled jobs anyways.

To account for the down-skilling of immigrants, we compute origin-country-specific down-skilling rates. These measure, for example, the likelihood that a high-skilled Senegalese migrant works in France in a job in which most French workers are low-skilled. Across all sending countries, on average 29% of all high-skilled emigrants are working in the OECD in medium-skill occupations, 10% in low-skill occupations, and 24% of all medium-skill emigrants are working in low-skill jobs. In Appendix C.3, we explain the construction of these measures in greater detail.

As shown in Figure 9b, downskilling reduces the welfare effects of skill biased migration in the receiving countries, while leaving the effect in the sending countries unchanged.

6.5 Network effects in trade

A growing literature shows that immigrants foster trade with their home countries by reducing trade costs and by demanding home-country-specific goods (Gould, 1994; Rauch & Trindade, 2002; Felbermayr & Toubal, 2012; Egger *et al.*, 2012; Parsons & Vézina, 2014). This channel would not be relevant for our analysis if trade only responded to the number of migrants, but

[19] The parameters estimated in the empirical literature vary widely. While Acemoglu & Angrist (2000) find an elasticity close to zero, Iranzo & Peri (2009) find a value close to 0.44. Moretti (2004b,a) finds values between 0.75 and 1.00. de la Croix & Docquier (2011) use a value of 0.277.

[20] A further — negative — externality through which migration affects TFP in the receiving countries is institutions. As highlighted by Collier (2013) and Borjas (2015), migrants from countries with poor institutions may import these institutions in the receiving country. Recent work by Clemens & Pritchett (2016) suggests, however, that large negative effects only unfold under fairly extreme conditions.

not their composition. If, however, trade flows respond to changes in the skill composition — for example because high-skilled migrants establish better business links — then network effects could add to the overall welfare effect.

To quantify the importance of this channel, we simulate two scenarios: one in which trade costs are reduced by high-skilled migrants, and one in which trade costs are reduced by low-skilled migrants. We compute trade costs as

$$\tau_{ij} = \bar{\tau}_{ij} \left(\frac{H_{ij}}{H_{ij} + M_{ij} + L_{ij}} \right)^{\sigma_t}, \tag{19}$$

where H_{ij}, M_{ij} and L_{ij} are the skill specific stocks of immigrants and $\bar{\tau}_{ij}$ are the bilateral trade costs at baseline. The elasticity of trade costs with respect to the skill share of immigrants is equal to $\sigma_t = -0.04$, as estimated by Parsons & Vézina (2014). Given that this externality is based on immigration, it directly affects affects the receiving countries. The sending countries, having no immigrants by assumption, may be affected indirectly via general equilibrium effects.

Figure 9 displays the welfare effects of skill-biased migration with and without network effects in trade. In most OECD countries, displayed in Figure 10b), the welfare effect is larger when we allow for network effects.

6.6 The role of trade

In our model, all countries are linked through trade in differentiated goods, which propagates changes in the market size across all countries, and mitigates the domestic welfare effect. If a single country becomes more productive, for example because its migrants become more skilled on average, the country's market size increases. In the presence of trade, part of the market size effect is passed on to other countries, as more varieties become available internationally.

Figure 10 displays the welfare effects with and without trade responses. In the non-OECD countries, trade makes a difference. It dampens the negative welfare effect, especially in countries with a high degree of skill bias and a high share of emigrants. In the OECD countries, trade does not account for a large difference in the welfare effects.

6.7 Selection vs. scale effect

So far, we have found moderate effects of the skill bias in migration on the welfare of never-migrants. We now put these estimates into perspective by comparing them with the total welfare impact of migration, that is, the welfare difference between migration at its current level and skill composition, and a world without migration. As shown in Figure 11, in most sending countries, the skill bias accounts for a substantial fraction of the overall welfare effect of migration. In the receiving countries, in contrast, the skill bias in migration only plays a minor role in the overall welfare effect.

6.8 Discussion and further sensitivity checks

The results in this section show that the baseline results are conservative estimates of the global welfare effect of the brain drain. Once we account for remittances, network effects in trade, or human capital externalities, the welfare effects are even higher. The exception here is down-skilling, which reduces the effects in the receiving countries.

In Appendix D we also assess the sensitivity of the baseline results to changes in all exogenous parameters. While the magnitude of the effects is affected by changes in the parameters, the qualitative result of positive effects in the receiving countries, negative effects in the sending countries, and overall a positive effect on global welfare remains.

7 Discussion and conclusion

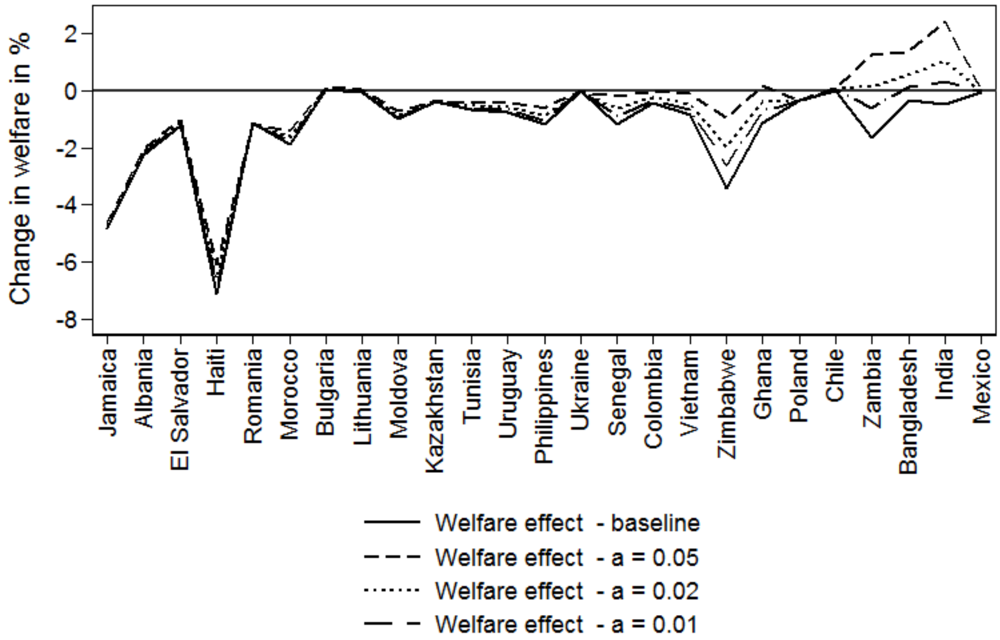
The brain drain is considered a major obstacle for the development of poorer countries, and has dominated many discussions about the welfare impacts of migration. In this paper, we put the welfare effect of the brain drain in perspective by quantifying its impact on the receiving countries as well as on global welfare.

Based on calibrated simulations within a rich multi-country model, we compare the current world with skill-biased migration to a world without skill bias, that is, a world in which the same number of migrants have the same skills as the total native population from the sending countries. We first confirm the findings from previous studies, namely that brain drain decreases welfare in most sending countries. When looking at the receiving countries, however, we find that most countries gain from skill-biased migration: their welfare is around 2% higher because migrants positively and not neutrally selected from their countries of origin.

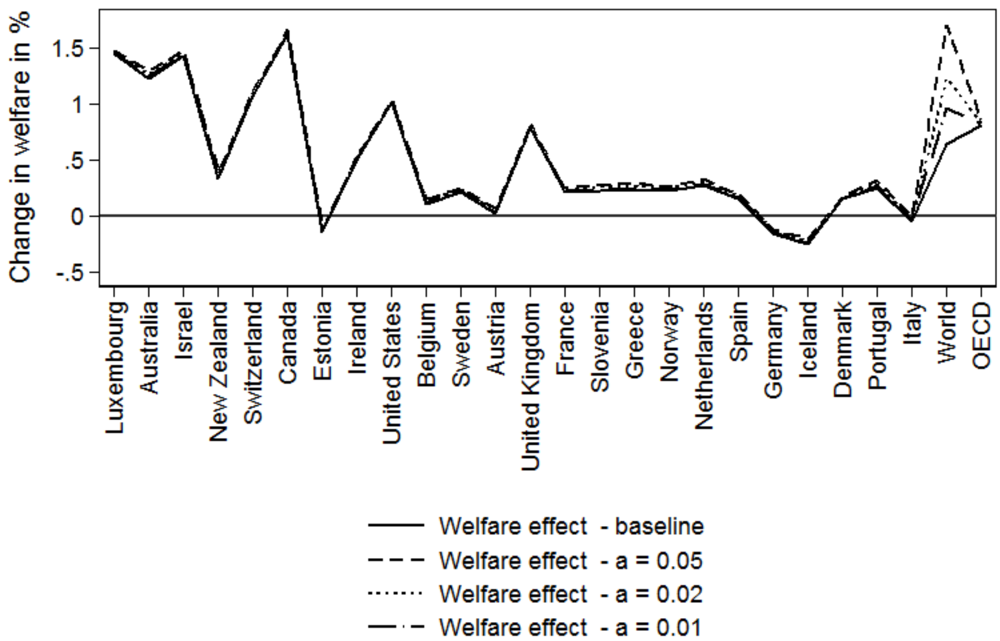
Overall, the impact on global welfare is positive. This can be explained by a greater allocative efficiency of labor. Global welfare is maximized when highly educated workers are in places where they are most productive. The positive selection of migrants brings the world closer to this efficiency frontier. These results suggest that more — not less — skill-biased migration would be optimal for global welfare.

Our results have important implications for the design and evaluation of migration policies. Additional simulations show, for example, that global welfare would increase if the immigration policy in all OECD countries was as selective as in Canada. In light of these results, policies aimed at reducing welfare losses for sending countries by reducing high-skilled migration would be globally inefficient. Rather, the global gains from skill-biased migration support a compensation scheme, based on which receiving countries compensate sending countries for their welfare losses (Bhagwati & Hamada, 1974). Further extensions that include remittances and human capital externalities show, however, that such a scheme may not be necessary after all, because these externalities greatly reduce the welfare losses in most sending countries.

Figure 6: Allowing for brain gain



(a) Welfare effects in selected non-OECD sending countries

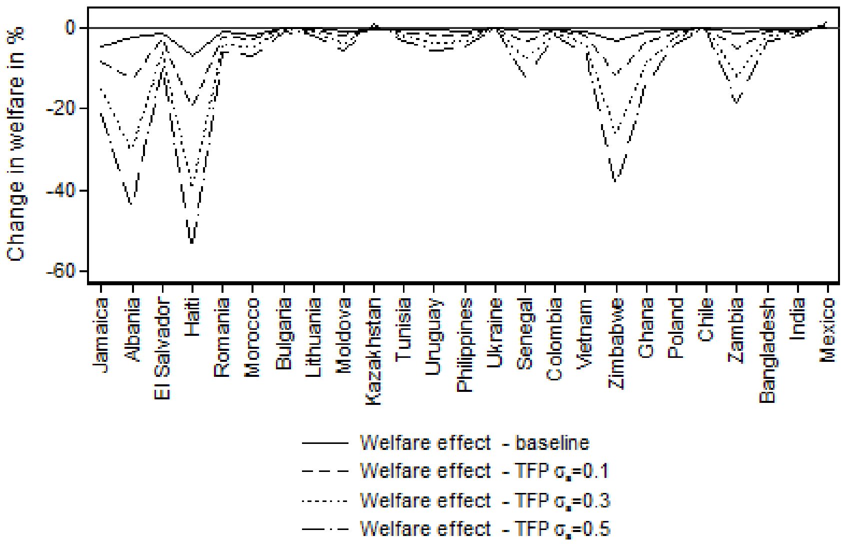


(b) Welfare effects in selected OECD receiving countries

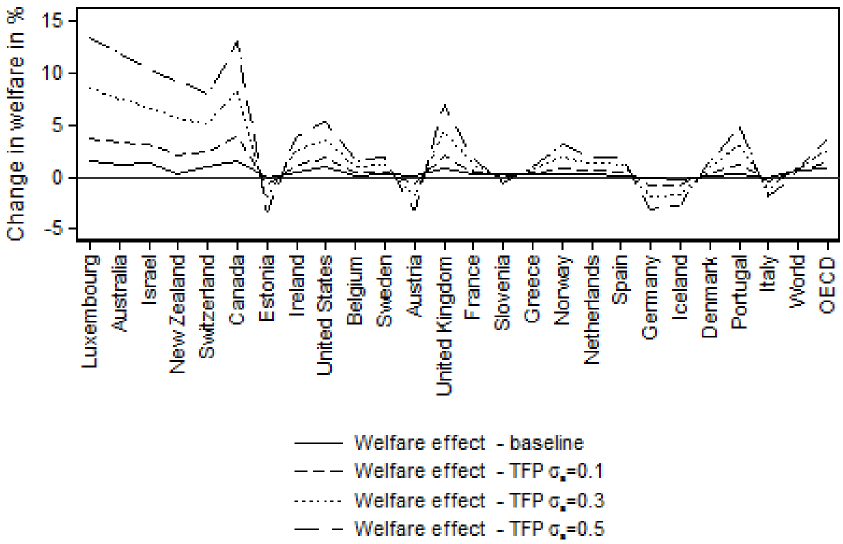
Source:. Own calculations.

Notes: This graph displays the welfare effects of the skill bias in migration allowing for downskilling. The countries on the horizontal axis are ordered by mmigration/emigration rates. The vertical axis shows changes in welfare per never-migrant in percent. Panel 3b focuses on selected receiving countries, while panel reffig:welfs focuses on selected sending countries.

Figure 7: Including Lucas externality on TFP



(a) Welfare effects in selected non-OECD sending countries

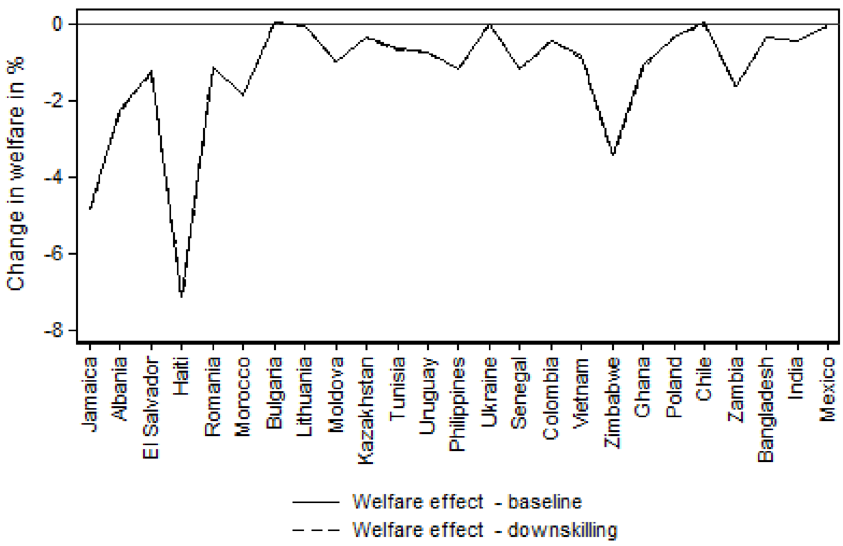


(b) Welfare effects in selected OECD receiving countries

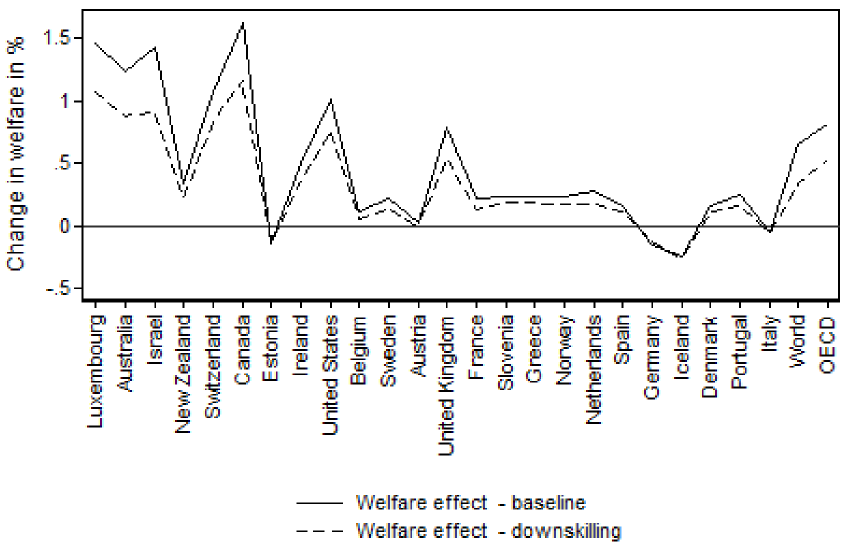
Source:. Own calculations.

Notes: This graph displays the welfare effects of the skill bias in migration with a Lucas-type externality on TFP. We vary the elasticity parametery σ_a. The countries on the horizontal axis are ordered by mmigration/emigration rates. The vertical axis shows changes in welfare per never-migrant in percent. Panel 3b focuses on selected receiving countries, while panel reffig:welfs focuses on selected sending countries.

Figure 8: Allowing for downskilling in the receiving country



(a) Welfare effects in selected non-OECD sending countries

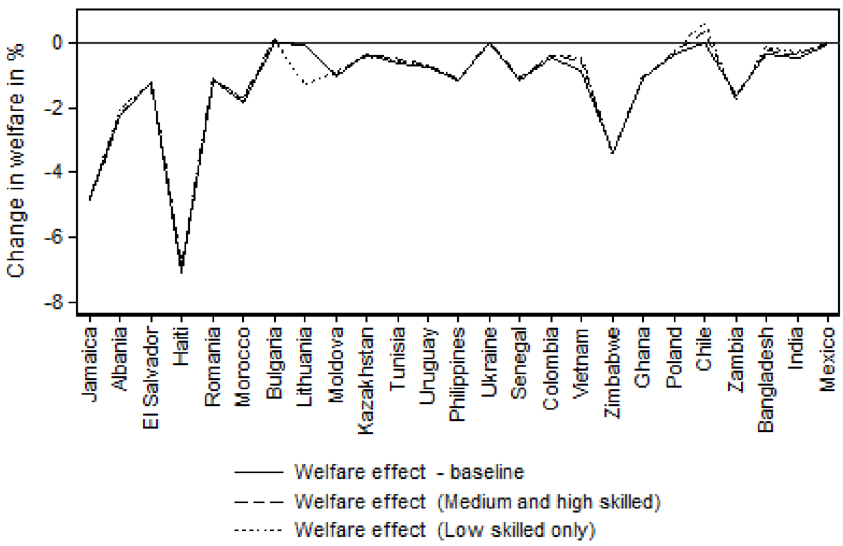


(b) Welfare effects in selected OECD receiving countries

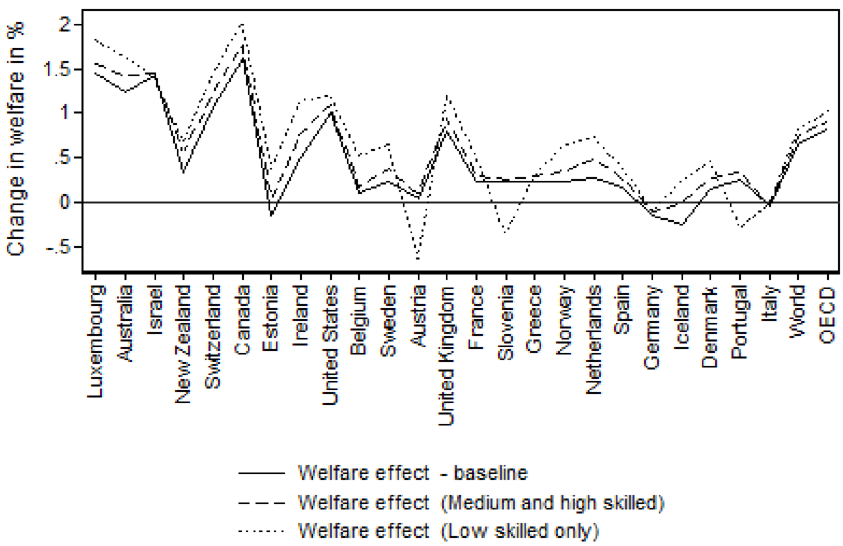
Source:. Own calculations.

Notes: This graph displays the welfare effects of the skill bias in migration with downskilling of migrants. The countries on the horizontal axis are ordered by immigration/emigration rates. The vertical axis shows changes in welfare per never-migrant in percent. Panel 3b focuses on selected receiving countries, while panel 3a focuses on selected sending countries.

Figure 9: Including network effects of migration on trade



(a) Welfare effects in selected non-OECD sending countries

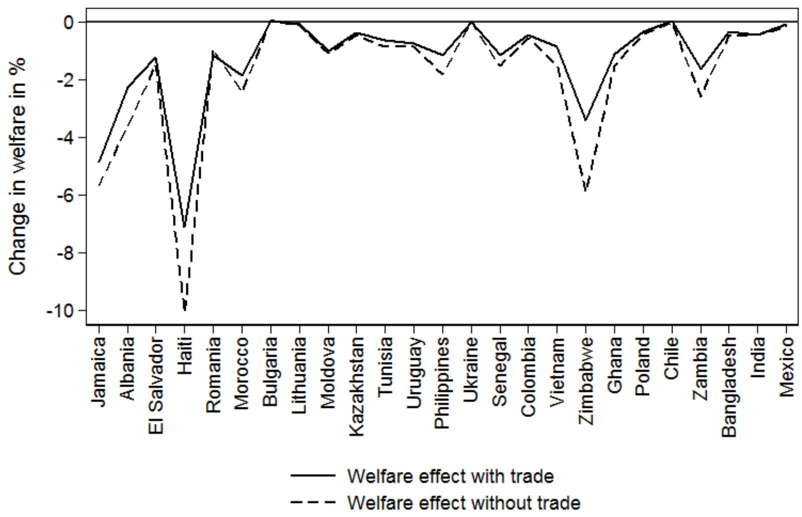


(b) Welfare effects in selected OECD receiving countries

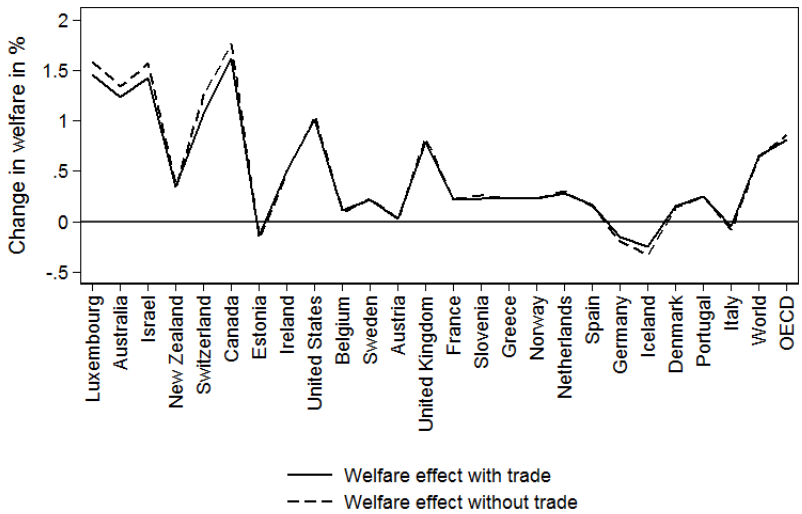
Source:. Own calculations.

Notes: This graph displays the welfare effects of the skill bias in migration with network effects of migration on trade. The countries on the horizontal axis are ordered by immigration/emigration rates. The vertical axis shows changes in welfare per never-migrant in percent. Panel 3b focuses on selected receiving countries, while panel 3a focuses on selected sending countries.

Figure 10: Welfare effects with and without trade



(a) Welfare effects in selected non-OECD sending countries

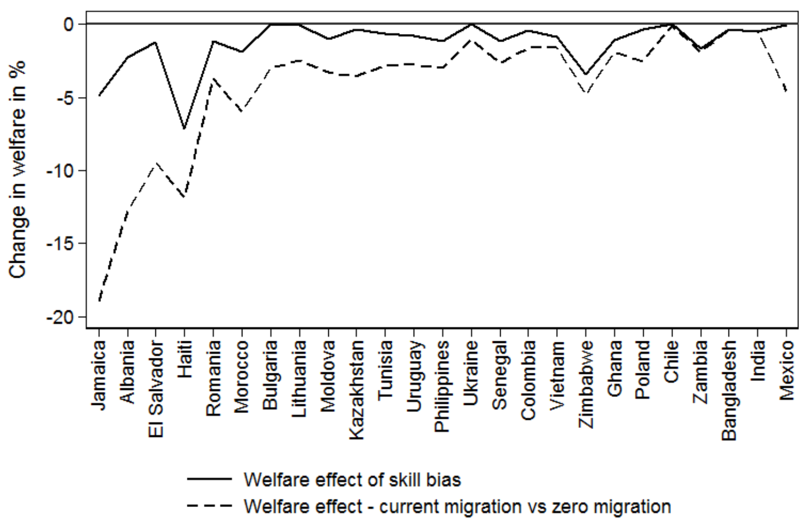


(b) Welfare effects in selected OECD receiving countries

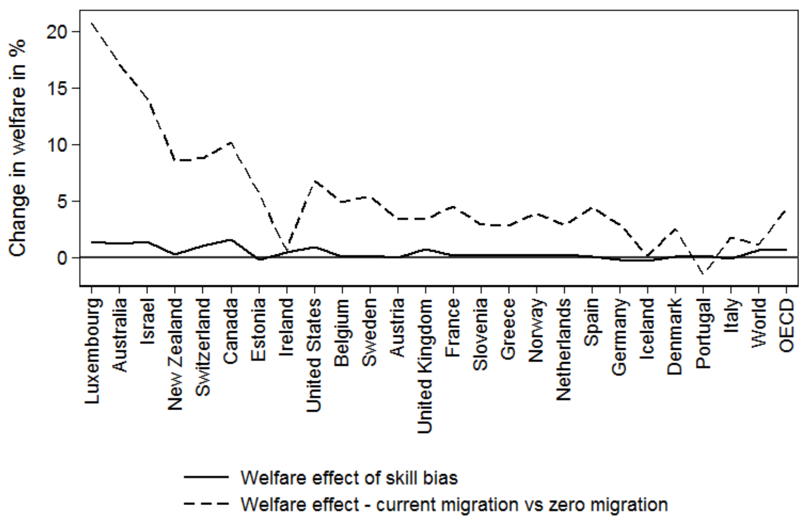
Source:. Own calculations.

Notes: This graph shows the role of trade when quantifying the welfare impact of the skill bias in migration. The countries on the horizontal axis are ordered by immigration/emigration rates. The vertical axis shows changes in welfare per never-migrant in percent. Panel 3b focuses on selected receiving countries, while panel 3a focuses on selected sending countries.

Figure 11: Selection vs. scale effects



(a) Welfare effects in selected non-OECD sending countries



(b) Welfare effects in selected OECD receiving countries

Source:. Own calculations.

Notes: In this graph we compare the welfare effect of the skill bias in migration to the welfare impact of migration *per se*, that is, the welfare difference between the status quo and a world without migration. The countries on the horizontal axis are ordered by immigration/emigration rates. The vertical axis shows changes in welfare per never-migrant in percent. Panel 3b focuses on selected receiving countries, while panel 3a focuses on selected sending countries.

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A Theoretical model - components

A.1 Indirect utility

After maximizing utility subject to the budget constraint (Equation (1)), the individual demands for all types of consumption goods are as follows:

$$\begin{aligned}
T_i^s &= \left(\frac{\beta^T \mu}{1-\beta^T} P_i\right)^{\frac{1}{1-\mu}}, \\
Y_i^s &= (w_i^s - T_i^s)(1-\beta)^{\theta}(P_i)^{\theta-1}(P_i^Y)^{-\theta}, \\
X_i^s &= (w_i^s - T_i^s)\beta^{\theta}(P_i)^{\theta-1}(P_i^X)^{-\theta}, \\
x_{ij}^s &= (w_i^s - T_i^s)\beta^{\theta}(P_i)^{\theta-1}(P_i^X)^{\epsilon-\theta}(p_{ij})^{-\epsilon}, \\
y_i^s &= (w_i^s - T_i^s)(1-\beta)^{\theta}(P_i)^{\theta-1}(P_i^Y)^{\epsilon-\theta}(p_i)^{-\epsilon}.
\end{aligned} \tag{20}$$

The demand for the traditional good is the same for all individuals in country i, and is independent of their real wage. This follows from the assumption of non-homothetic preferences. Consumption of agricultural goods can be seen as expenditure that is necessary for survival. Once consumers have more income, they spend a greater income share on non-agricultural goods. Thus, the demand for the differentiated goods X and Y increases with income.

Inserting the demands (20) into the utility function (1), we obtain an agent's indirect utility,

$$U_i^s = \beta^T \left(\frac{\beta^T \mu}{1-\beta^T} P_i\right)^{\frac{\mu}{1-\mu}} + (1-\beta^T)\frac{w_i^s - T_i^s}{P_i}. \tag{21}$$

A.2 Labor demand and wages

The production functions of the traditional and the manufacturing sector are

$$\begin{aligned}
Q_i^T &= A_i^T L_i^T \\
Q_i^M = A_i^M L_i^M &= A_i^M \left[\alpha_i^L (L_i)^{\frac{\sigma_s-1}{\sigma_s}} + (1-\alpha_i^L-\alpha_i^H)(M_i)^{\frac{\sigma_s-1}{\sigma_s}} + \alpha_i^H (H_i)^{\frac{\sigma_s-1}{\sigma_s}}\right]^{\frac{\sigma_s}{\sigma_s-1}}.
\end{aligned}$$

where L_i^T is the supply of low-skilled labor, employed in the traditional sector, and A_i^T is the productivity residual, which equals the wage rate of the low-skilled workers: $W_i^L = A_i^T$.[21] L_i, M_i and H_i represent the supplies of low, medium and high-skilled workers. α_i^L and α_i^H are, respectively, the efficiency parameters primary and tertiary-educated. Within each skill group there are natives (labeled by superscripts N) and foreigners (with superscripts F). All domestic and foreign workers are assumed to be imperfect substitutes with a constant elasticity of substitution equal to σ_n. We define the efficient labor supplies for each sector and education

[21] This wage is equal across sectors and across workers' origin. Therefore, any low-skilled worker from T sector has no incentives to move to X and Y sectors, because the wages are equal.

group:

$$
\begin{aligned}
L_i^T &= \left[(1-\alpha_i^F)(L_i^{T,N})^{\frac{\sigma_n-1}{\sigma_n}} + \alpha_i^F (L_i^{T,F})^{\frac{\sigma_n-1}{\sigma_n}}\right]^{\frac{\sigma_n}{\sigma_n-1}}, \\
L_i &= \left[(1-\alpha_i^F)(L_i^{N})^{\frac{\sigma_n-1}{\sigma_n}} + \alpha_i^F (L_i^{F})^{\frac{\sigma_n-1}{\sigma_n}}\right]^{\frac{\sigma_n}{\sigma_n-1}}, \\
M_i &= \left[(1-\alpha_i^F)(M_i^{N})^{\frac{\sigma_n-1}{\sigma_n}} + \alpha_i^F (M_i^{F})^{\frac{\sigma_n-1}{\sigma_n}}\right]^{\frac{\sigma_n}{\sigma_n-1}}, \\
H_i &= \left[(1-\alpha_i^F)(H_i^{N})^{\frac{\sigma_n-1}{\sigma_n}} + \alpha_i^F (H_i^{F})^{\frac{\sigma_n-1}{\sigma_n}}\right]^{\frac{\sigma_n}{\sigma_n-1}}.
\end{aligned}
\tag{22}
$$

We assume a fixed, country-specific share of outputs of natives and foreigners ($1-\alpha_F$ and α_F respectively).

Firms solve their cost minimization problem, taking wages as given. Demand for each type of labor is then set as

$$
\begin{aligned}
L_i^N &= \frac{Q_i^M}{A_i^M}\left[\frac{(1-\alpha_i^F)W_i^L}{w_i^{LN}}\right]^{\sigma_n}\left[\frac{\alpha_i^L W_i}{W_i^L}\right]^{\sigma_s}, & L_i^{T,N} &= \frac{Q_i^T}{A_i^T}\left[\frac{(1-\alpha_i^F)W_i^L}{w_i^{LN}}\right]^{\sigma_n}, \\
L_i^F &= \frac{Q_i^M}{A_i^M}\left[\frac{\alpha_i^F W_i^L}{w_i^{LF}}\right]^{\sigma_n}\left[\frac{\alpha_i^L W_i}{W_i^L}\right]^{\sigma_s}, & L_i^{T,F} &= \frac{Q_i^T}{A_i^T}\left[\frac{\alpha_i^F W_i^L}{w_i^{LF}}\right]^{\sigma_n}, \\
M_i^N &= \frac{Q_i^M}{A_i^M}\left[\frac{(1-\alpha_i^F)W_i^M}{w_i^{MN}}\right]^{\sigma_n}\left[\frac{(1-\alpha_i^H-\alpha_i^L)W_i}{W_i^M}\right]^{\sigma_s}, & H_i^N &= \frac{Q_i^M}{A_i^M}\left[\frac{(1-\alpha_i^F)W_i^H}{w_i^{HN}}\right]^{\sigma_n}\left[\frac{\alpha_H W_i}{W_i^H}\right]^{\sigma_s}, \\
M_i^F &= \frac{Q_i^M}{A_i^M}\left[\frac{\alpha_i^F W_i^M}{w_i^{MF}}\right]^{\sigma_n}\left[\frac{(1-\alpha_H-\alpha_i^L)W_i}{W_i^M}\right]^{\sigma_s}, & H_i^F &= \frac{Q_i^M}{A_i^M}\left[\frac{\alpha_i^F W_i^H}{w_i^{HF}}\right]^{\sigma_n}\left[\frac{\alpha_H W_i}{W_i^H}\right]^{\sigma_s},
\end{aligned}
\tag{23}
$$

where the wage indexes for the medium and high-skilled are equal to:

$$
\begin{aligned}
W_i^L &= \left[(1-\alpha_i^F)^{\sigma_n}(w_i^{LN})^{1-\sigma_n} + (\alpha_i^F)^{\sigma_n}(w_i^{LF})^{1-\sigma_n}\right]^{\frac{1}{1-\sigma_n}}, \\
W_i^M &= \left[(1-\alpha_i^F)^{\sigma_n}(w_i^{MN})^{1-\sigma_n} + (\alpha_i^F)^{\sigma_n}(w_i^{MF})^{1-\sigma_n}\right]^{\frac{1}{1-\sigma_n}}, \\
W_i^H &= \left[(1-\alpha_i^F)^{\sigma_n}(w_i^{HN})^{1-\sigma_n} + (\alpha_i^F)^{\sigma_n}(w_i^{HF})^{1-\sigma_n}\right]^{\frac{1}{1-\sigma_n}},
\end{aligned}
\tag{24}
$$

and the overall wage index in the manufacturing sector is given by:

$$
W_i = \left[(\alpha_i^L)^{\sigma_s}(W_i^L)^{1-\sigma_s} + (1-\alpha_i^L-\alpha_i^H)^{\sigma_s}(W_i^M)^{1-\sigma_s} + (\alpha_i^H)^{\sigma_s}(W_i^H)^{1-\sigma_s}\right]^{\frac{1}{1-\sigma_s}}. \tag{25}
$$

A.3 Market clearing conditions

Since all firms earn zero profits, the total wage bill must equal the value added produced in all the sectors:

$$
\begin{aligned}
GDP_i^T &= W_i^L L_i^T = w_i^{LN} L_i^{T,N} + w_i^{LF} L_i^{T,F}, \\
GDP_i^X + GDP_i^Y &= W_i L_i^M = \\
&= w_i^L\left(L_i^N + L_i^F\right) + w_i^{MN} M_i^N + w_i^{MF} M_i^F + w_i^{HN} H_i^N + w_i^{HF} H_i^F.
\end{aligned}
\tag{26}
$$

In equilibrium, when demand equals the value of production, the total value added in the traditional sector equals the expenditures: $GDP_i^T = A_i^T L_i^T$. Then, in the tradable and non-tradable manufacturing sectors the value added equals the aggregated value of production of all N_i^X and N_i^Y firms:

$$\begin{aligned} GDP_i^X &= N_i^X \sum_{j=1}^{J} p_{ji} x_{ji} = N_i^X p_i x_i, \\ GDP_i^Y &= N_i^Y p_i y_i. \end{aligned} \tag{27}$$

where x_{ji} is the demand in country j for a product of any firm operating in X in country i. For simplicity, we aggregate this quantity into one number: the total demand for the products of one firm in country i: $x_i = \sum_{j=1}^{J} \tau_{ji} x_{ji}$. Due to the ice-berg trade costs, in order to sell x_{ji} units in country j, the firm from country i has to ship $\tau_{ji} x_{ji}$ units of this good (with $\tau_{ji} \geq 1$).

The aggregation of the values of agents' individual demands gives the level of nominal GDP in country i (equivalent to the sum of all expenditures):

$$GDP_i = GDP_i^T + GDP_i^X + GDP_i^Y = T_i + P_i^Y Y_i + P_i^X X_i. \tag{28}$$

Consequently, the share of value added produced in the traditional sector is equal to:

$$sh_T \equiv \frac{GDP_i^T}{GDP_i} = \frac{POP_i}{GDP_i} \left(\frac{\beta^T \mu}{1 - \beta^T} P_i \right)^{\frac{1}{1-\mu}}, \tag{29}$$

where POP_i stands for the number of people living in country i (since every person consumes the same amount of good T).[22] The remainder of GDP is will be spent on the differentiated good. We provide expressions for the shares of goods X and Y in Section 3.3. Based on sh_Y and sh_X, we derive the optimal number of varieties in equilibrium using the zero profit and free entry conditions.

A.4 Definition of equilibrium

Definition 1 *For a set* $\{\beta, \beta^T, \theta, \mu, \epsilon, \sigma_s, \sigma_n,\}$ *of structural parameters, a set* $\Big\{A_i^T, A_i^M\ \alpha_i^F, \alpha_i^H, \alpha_i^L, L_i^{T,N}, L_i^{T,F},$ $L_i^N, L_i^F, M_i^N, M_i^F, H_i^N, H_i^F, f_i^X, f_i^Y\}_{\forall i}$ *of country-specific institutional, demographic and technological, exogenous characteristics, a set* $\{\tau_{ji}\}_{\forall i,j}$ *of bilateral trade costs*

- *consumption of the three types of goods* $\Big\{x_{ij}^s, y_i^s, T_i^s\Big\}$ *maximizes agent's utility (1) subject to the budget constraint),*
- *assuming full employment and cost-minimizing behavior of firms, the labor market clearing conditions (23) equalize the wage rates to marginal productivities, and determine the*

[22] Total population has the following structure: $POP_i = L_i^{T,N} + L_i^{T,F} + L_i^N + L_i^F + M_i^N + M_i^F + H_i^N + H_i^F$. The low-skilled natives and foreigners are divided into those who work in the traditional sector and those who are employed in the differentiated good sector. The medium and high-skilled workers are employed only in the Y and X sectors.

nominal wages for all types of workers: $\{w_i^{LN}, w_i^{LF}, w_i^{MN}, w_i^{MF}, w_i^{HN}, w_i^{HF}\}$

- *the price of one variety,* $p_i(k)$*, maximizes firm's profits given the demand that it faces (8),*
- *the number of varieties in sector* X *and* Y*,* N_i^X *and* N_i^Y*, is such that the zero profit conditions hold (13),*
- *the value added equals the aggregated value of production and trade in* X *is balanced.*

B Calibration and simulation strategies

B.1 Imputation of trade flows

To compute the bilateral trade costs, we require a (146×146) matrix of gross trade flows between all countries in the sample (145 countries plus the Rest of the World). The UN Comtrade database offers information to fill 66.5% entries of this matrix; the remaining trade flows are missing. For computational purposes, we require that every trade flow is non-negative. We impute the missing trade flows based on a gravity equation. We first fit the following linear fixed-effect regression on all trade flows with observed trade flows:

$$\ln(trade)_{od} = \boldsymbol{X'_{od}} \boldsymbol{\gamma} + \delta_o + \delta_d + \varepsilon_{od}, \tag{30}$$

where index o denotes the origin and d the destination of a trade flow. $\boldsymbol{X_{od}}$ is a vector of dyad-specific determinants of trade flows, and includes: a common border dummy, a dummy for a common official language, the log distance between the capital cities, a dummy for a common colonial past. These data are taken from the CEPII Gravity dataset (Mayer *et al.*, 2010; Head & Mayer, 2015). ε_{od} is an i.i.d error term. δ_o and δ_d are origin and destination fixed effects. Based on the fitted values, we then predict the trade flows for all dyads.

B.2 Imputation of missing wage ratios

The two country-specific wage ratios (high-skill to medium-skill and medium-skill to low-skill) are obtained in the following way. For the 34 OECD countries, the wage ratios are provided by the OECD education at glance report 2010 (OECD, 2010). WageIndicator provides information on 38 additional high-skill to medium-skill and 27 medium-skill to low-skill wage ratios. For the remaining countries, we construct wage ratios as a function of the average return of one additional year of schooling[23] (λ) and the difference in years of schooling (d) between two education levels (k,m):

$$w_i^k / w_i^m = (1 + \lambda_{km})^d \tag{31}$$

[23] These are assessed on the countries for which wage ratios and average years of education are available.

B.3 Equilibrium prices and quantities

In this section we explain how we calibrate the free parameters of the model, and compute equilibrium prices and quantities. The calibration of bilateral trade flows depends on goods prices in each country, which are a function of TFP levels and bilateral trade costs. For a given matrix of bilateral trade costs, the combination of the zero-profit condition and the expression of units produced per firm in Equation (12) yield the level of country- specific TFP in the manufacturing sector. Based on the TFP level, we can assess the marginal cost of production and recover all prices and price aggregates from Equations (8) and (4). Combining these with trade costs allows us to assess the value of bilateral trade flows. To this end, we use the gravity equation 16 to iterate over TFP and trade costs until the trade flows in the model match the trade flows in the data as closely as possible.

The iterative procedure is carried out in two steps. We first define an outer loop in which the trade cost matrix $[\tau_{ji}]_{j,i\in J}$ is determined iteratively, based on the gravity equation (16). In each iteration, a new matrix of τ's is computed from the gravity equation. A new general equilibrium is then obtained by iterating on A_i^M (i.e. the inner loop) until the distance between the trade matrix from the data and the trade matrix in the model is minimized. The inner loop iterates on the TFP in the manufacturing sector, A_i^M, such that the zero profit conditions are fulfilled for firms in all the countries at the same time (and hence the general equilibrium is guaranteed). The iteration uses the whole vector of country-specific TFP in the manufacturing sector, A_i^M, because profits in country i are dependent on the prices of goods in all other countries (P_i in Equation (4) is a weighted sum of prices of all imported goods, and hence depends on the trade costs defined in the previous step of the outer loop). Once we obtained the vector of TFP, we use the trade costs along with the equilibrium conditions 11 and 12 to compute the vectors of unit prices p_i, and the price indexes, Pi^X and Pi^Y, for both sectors.

To compute the fixed cost of entry for the non-tradable manufacturing sector, we first compute the equilibrium number of varieties produced in sector Y, N_i^Y, given the price level Pi^Y. We then back out the fixed cost f_i^Y from Equation (13) such as to match the number of varieties. The last parameter to be calibrated is the preference towards goods produced in the traditional sector, β^T. Its value, 0.135, is such that we match consumption of the traditional good to its production.

B.4 Simulation algorithm

Having determined the counterfactual scenario, we impose an exogenous shock (on the skill structure of migrants) to the general equilibrium of the system of J economies. We need to compute new wages, price indices and values of production in all sectors. The first equilibrium to compute is the one associated with the traditional good market. Equalizing its demand and supply across countries, we can compute first guesses of the number of people who work in agriculture, and the wage levels of low-skilled workers. Then, taking the first guess on the GDP levels in manufacturing sector, we compute the wage indexes (using the system of J zero profit equations in sectors X and Y). However, we have no information about the shares of GDP^X and GDP^Y in manufacturing (which are driven by peoples' preferences towards different varieties of products and prices). Thus, we make an initial guess of the variable sh^X, on which we iterate, to meet the definitions of price indexes and numbers of varieties (equations 4, and 13). Additionally, according to the current value of sh^X, we calculate the price indexes, numbers of varieties and GDPs in X and Y. With a new guess for sh^X we go back to the outer-loop and re-compute the equilibrium wage for the low-skilled workers and GDP^T, using the T market clearing condition.

Having pinned down the nominal wage of low-skilled workers and the values of GDPs in all sectors, we can easily calculate the exact wage index in the manufacturing sector and the wages of all types of workers (using the system of labor demand equations, 23). Now, unlike in the calibration procedure, the wage premium between high/medium-skilled and medium/low-skilled workers is endogenous and determined by the structure of the society.

The final step is, once again, the computation of the endogenously determined trade matrix for the given levels of GDP^X, price indexes and (taken as given) trade costs. Using the system of gravity equations (16), we are able to determine all the bilateral trade flows across J countries.

C Extensions

C.1 Remittances

To include remittances in the model, we assume that the fraction of income remitted by the emigrants is exogenous, and is country-pair-specific. We use bilateral data on the volume of remittances from the World Bank (2015). Formally, the income after remittances ($\hat{w_{ij}^s}$) of an emigrant of skill type s from country o in receiving country d becomes:

$$\hat{w_{od}^s} = w_{od}^s(1 - \eta_{od}) \tag{32}$$

where (w_{od}^s) is the wage income before remittances and (η_{od}) is the fraction of income remitted. This fractions is assessed using data on the volume of bilateral remittances flowing from country d to country o, denoted $REMIT_{do}$. Thus,

$$REMIT_{do} = \sum_{s=L,M,H} N_{od}^s w_{od}^s \eta_{od} \tag{33}$$

where N_{od}^s is the number of emigrants with skill s from country o living in d. The fraction of income remitted (η_{od}) can the be recovered using equation (38) with data on $REMIT_{do}$ and the emigration matrix (N_{od}^s) and the calibrated values for the wages (w_{od}^s). Next, the total volume of remittances received by natives living in the origin country o is assessed by summing the remittance flows across all destination countries:

$$REMIT_o = \sum_{d} REMIT_{do} \tag{34}$$

In the origin countries the total amount of remittances received is then split equally among the non-migrating nationals, independent of their skill level. The per worker amount, rem_o, is then defined as:

$$rem_o = \frac{REMIT_o}{\sum_{s=L,M,H} N^s_{dd}} \tag{35}$$

Thus, the total income after remittances of a non-migrant in country o of type s is given by:

$$\hat{w^s_{oo}} = w^s_{oo} + rem_o \tag{36}$$

where w^s_{oo} is the skill-specific wage rate.

Note that Equation (38) can be adapted in order to account for skill-specific remitting behavior among emigrants. Assume that emigrants of skill level $s1$ remit $\alpha\%$ more than individuals of skill level $s2$ or $s3$. Rewriting equation (38), we have now:

$$REMIT_{do} = N^{s1}_{od} w^{s1}_{od}(1+\alpha)\eta'_{od} + \sum_{s=s2,s3} N^s_{od} w^s_{od} \eta'_{od} \tag{37}$$

The fraction of income remitted in this case (η'_{od}) is then:

$$\eta'_{od} = \frac{REMIT_{do}}{N^{s1}_{od} w^{s1}_{od}(1+\alpha) + \sum_{s=s2,s3} N^s_{od} w^s_{od}} \tag{38}$$

Once the fraction of income remitted is know, the same procedure as explained above applies to asses the amount received by each native at origin. Note that if $\alpha > 1$ (i.e. one type of individual remits more), $\tau'_{od} < \tau_{od}$ (i.e. the individuals with a different education level remit a lower fraction of their income as compared to the benchmark case with equal remitting behavior).

Figure 12 displays the welfare effects under different assumptions about the propensity to remit for high- vs. low-skilled workers. As shown in Panel (a), the losses for the sending countries are smaller if we assume that high-skilled workers remit a larger share of their income.

C.2 Brain Gain

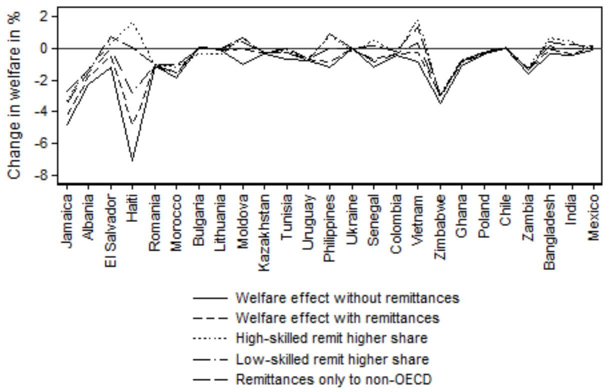
In Section 6.2, we include a brain gain mechanism in the model, allowing the share of high-skilled stayers to be an increasing function of the share of high-skilled emigrants. Here we explain the extension in greater detail.

Define $sh_S = \frac{H_n}{H_n+M_n+L_n}$ and $sh_E = \frac{H_e}{H_e+M_e+L_e}$, respectively, as the observed share of high-skilled stayers and emigrants under the baseline scenario, and $\widehat{sh_S}$ and $\widehat{sh_E}$ as the equivalent shares under the counterfactual. We compute the new counterfactual share of high-skilled stayers as

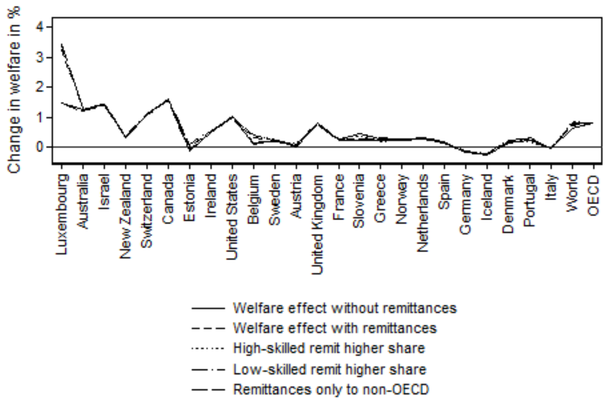
$$\widehat{sh_S} = sh_S \left(1 + \sigma_b \frac{\widehat{sh_E} - sh_E}{sh_E}\right) \tag{39}$$

Further, define the total number of stayers and emigrants in the counterfactual world as $\widehat{Stay} =$

Figure 12: Welfare effects with a skill-dependent propensity to remit



(a) Welfare effects in selected non-OECD sending countries



(b) Welfare effects in selected OECD receiving countries

Source:. Own calculations.

Notes: This graph displays the welfare effects of the skill bias in migration with a skill-dependent propensity to remit. The countries on the horizontal axis are ordered by immigration/emigration rates. The vertical axis shows changes in welfare per never-migrant in percent. Panel 3b focuses on selected receiving countries, while panel 3a focuses on selected sending countries.

$\hat{H_n} + \hat{M_n} + \hat{L_n}$ and $\widehat{Emig} = \hat{H_e} + \hat{M_e} + \hat{L_e}$. The new share of high-skilled workers in the total population ($\hat{sh_N}$) is then:

$$\hat{sh_N} = \frac{\widehat{sh_S}\widehat{Stay} + \widehat{sh_E}\widehat{Emig}}{\widehat{Stay} + \widehat{Emig}} \tag{40}$$

In the neutrally selected world, the share of skilled workers among the emigrants, the stayers and the total population is equal. However, the skilled emigrants in the neutrally selected world will induce a brain gain mechanism as the new share of skilled among emigrants becomes $\widehat{sh_E} = \widehat{sh_N}$. We therefore need to iterate on $\hat{sh_E}$ until $\widehat{sh_E} = sh_E$. Thus, we first compute the share of skilled stayers using Equation (39). We save the value of the share of skilled emigrants used in the computation in order to replace it in the next iteration ($sh_E = \hat{sh_E}$). Then, we asses the new share of skilled natives $\hat{sh_N}$ using equation (40). Given that in a neutrally selected world $\hat{sh_E} = \hat{sh_N}$ we use this value in the next iteration, by inserting it jointly with the value of sh_E previously saved into equation ($C.2$). Hence, we iterate on sh_E until the new equilibrium share of skilled natives (and emigrants) is obtained (i.e. $sh_S = \hat{sh_S}$ in equation ($C.2$)). We can then assess the new skill distribution of the population. The total population and emigration size does not change (by assumption) and the share of tertiary educated workers allows to recover the number of educated workers in each population group (emigrants and stayers). The remaining workers are split among the medium and low skill groups using the relative weight of the groups in our baseline counterfactual exercise. That is, for the medium skill $sh_{Med} = \frac{Med}{Med+Low}$ and $sh_{Low} = \frac{Low}{Med+Low}$. Hence, the new share of medium skilled and low skilled workers become respectively: $\hat{sh_{Med}} = sh_{Med}(1 - \hat{sh_N})$ and $\hat{sh_{Low}} = sh_{Low}(1 - \hat{sh_N})$. Multiplying the total number of stayers and emigrants respectively by these shares allows to recover the full distribution of workers.

C.3 Downskilling of migrants

In Section 6.4, we accounted for down-skilling of immigrants in the receiving countries. In this section, we explain how we compute the down-skilling rates. We compute three down-skilling rates: the share of high-skilled migrants working in medium-skilled occupations, $d^H_{M,o}$, the share of high-skilled migrants in low-skilled occupations, $d^H_{L,o}$, and the share of medium-skilled migrants in low-skilled occupations, $d^M_{L,o}$. We assume each down-skilling rate to be specific to the sending country (index o), and apply the same factor for to all immigrants in the OECD for both the baseline and the counterfactual. We use sending-country-specific rather than country-pair-specific down-skilling rates, because many country-occupation-skill-specific immigrant numbers are zero or very small.

To compute the down-skilling rates for a given sending country, we use the OECD-DIOC data, which has information on the skill requirement for occupations at the ISCO one-digit level, as well as the skill distribution of immigrants within each occupation by sending country. Thus, we know how many high-skilled Senegalese are working in low-skilled occupations in France, Canada, the UK, and all other OECD countries. Based on this information, we can compute the three down-skilling rates for every country pair, for example $d^H_{M,od}$. To compute the sending-country-specific down-skilling rates, we compute a weighted average over all receiving countries (index d),

$$d^H_{M,o} = \sum_d \left(\frac{H^{emig}_{od}}{H^{emig}_o} \right) d^H_{M,od},$$

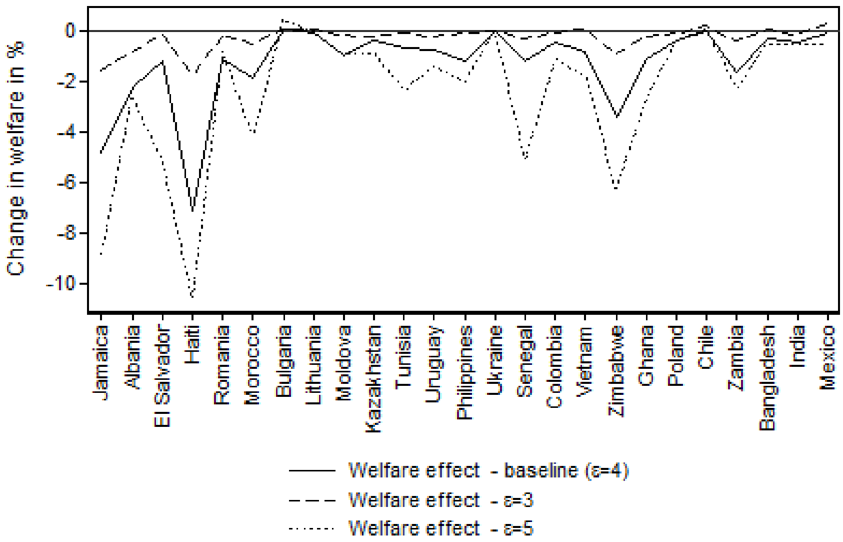
with the weights w_{od} being the share of high-skilled emigrants in receiving country d among all high-skilled emigrants from sending country o. The remaining down-skilling rates are computed analogously.

D Sensitivity checks

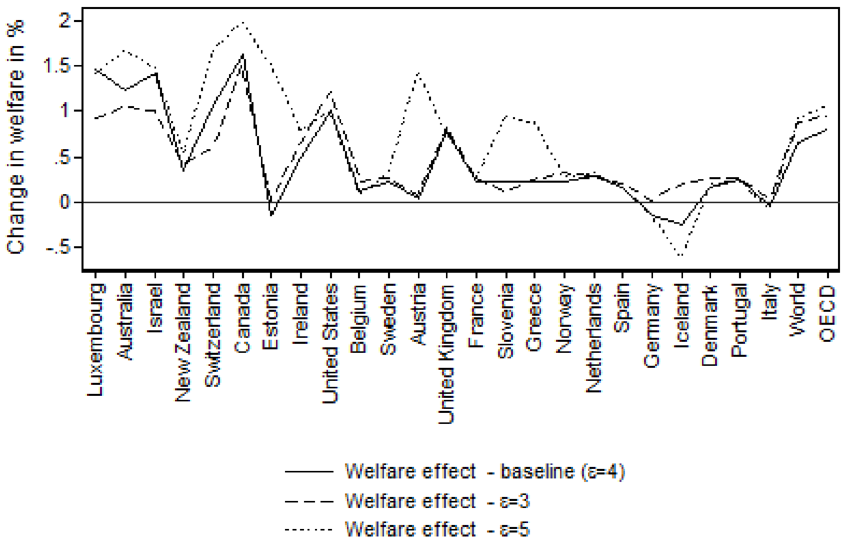
In Figures 13-19, we perform a series of sensitivity checks with respect to the structural parameters. Overall, the results are both quantitatively and qualitatively robust to changes in parameters, but some parameters have a greater influence than others. The details are as follows:

- In Figure 13, we vary the elasticity of substitution between varieties of X and Y. A higher elasticity of substitution translates into a more pronounced market size effect, which leads to higher gains in the receiving and higher losses in the sending countries.
- In Figure 14, we vary the elasticity of substitution between tradable and non-tradable goods. The results are very similar compared to the baseline results. A higher elasticity of substitution leads to a greater response in trade flows, and dampens the overall effect.
- In Figure 15, we vary the elasticity of substitution between different education levels, σ_s. A low substitutability between high- and low-skilled workers has a particularly strong impact on the sending countries, because it becomes more difficult for low-skilled workers to replace high-skilled emigrants.
- In Figure 16, we vary the elasticity of substitution between migrants and natives, σ_n. In the sending countries, this parameter only affects the overall welfare effect through trade, but effects hardly respond to changes in σ_n. In the receiving countries, the effects are larger when migrants and natives are closer substitutes, but the overall results do not change by a large amount.
- In Figure 17, we vary the preference parameter for the output from the traditional sector. If this parameter is very low, the effects are smaller because a given change in consumption of T has a smaller impact on utility.
- In Figure 18, when we vary β, the relative preference for the tradable manufactured good, it turns out that the largest effect in the sending countries occurs if both goods receive equal weight, and the increase in market size is spread across both sectors, X and Y. In the receiving countries, the welfare effect is almost unaffected by changes in β.
- In Figure 19, we increase the fixed costs of entry by multiplying the original fixed costs with a factor 10. The effects in the sending countries are stronger, because even fewer varieties are being produced in the baseline compared to the counterfactual.

Figure 13: Varying ε



(a) Welfare effects in selected non-OECD sending countries

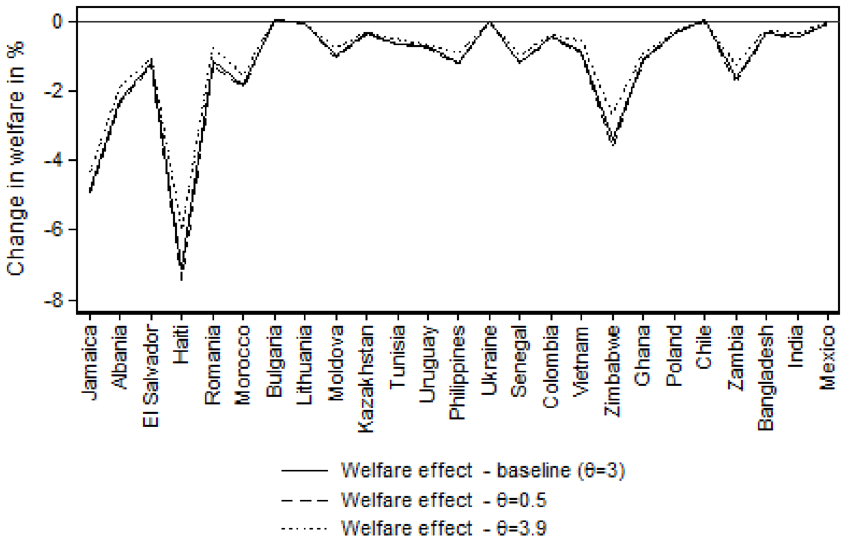


(b) Welfare effects in selected OECD receiving countries

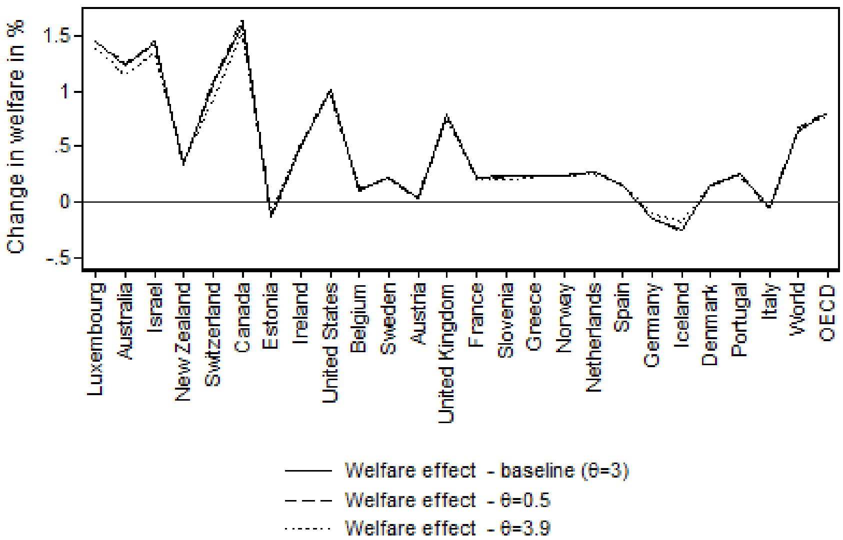
Source:. Own calculations.

Notes: This graph displays the welfare effects of the skill bias in migration with varying elasticity of substitution between differentiated goods, $\varepsilon \in \{3, 4, 5\}$. The countries on the horizontal axis are ordered by immigration/emigration rates. The vertical axis shows changes in welfare per never-migrant in percent. Panel 3b focuses on selected receiving countries, while panel 3a focuses on selected sending countries.

Figure 14: Varying θ



(a) Welfare effects in selected non-OECD sending countries

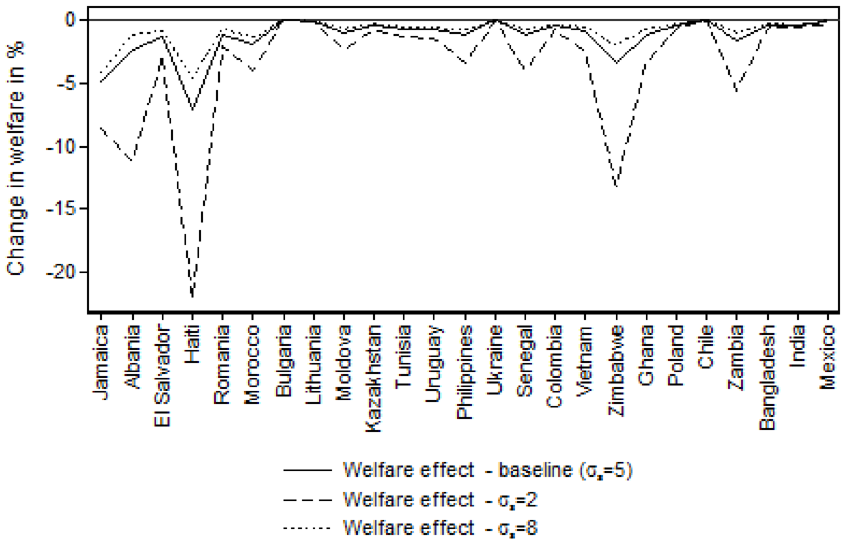


(b) Welfare effects in selected OECD receiving countries

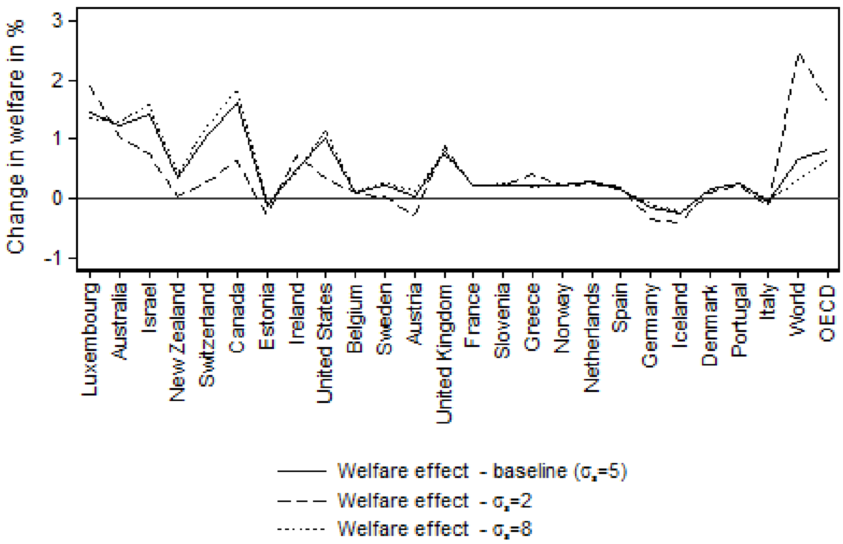
Source:. Own calculations.

Notes: This graph displays the welfare effects of the skill bias in migration with varying elasticity of substitution between tradable and non-tradable goods, $\theta \in \{2, 3, 3.9\}$. The countries on the horizontal axis are ordered by immigration/emigration rates. The vertical axis shows changes in welfare per never-migrant in percent. Panel 3b focuses on selected receiving countries, while panel 3a focuses on selected sending countries.

Figure 15: Varying σ_s



(a) Welfare effects in selected non-OECD sending countries

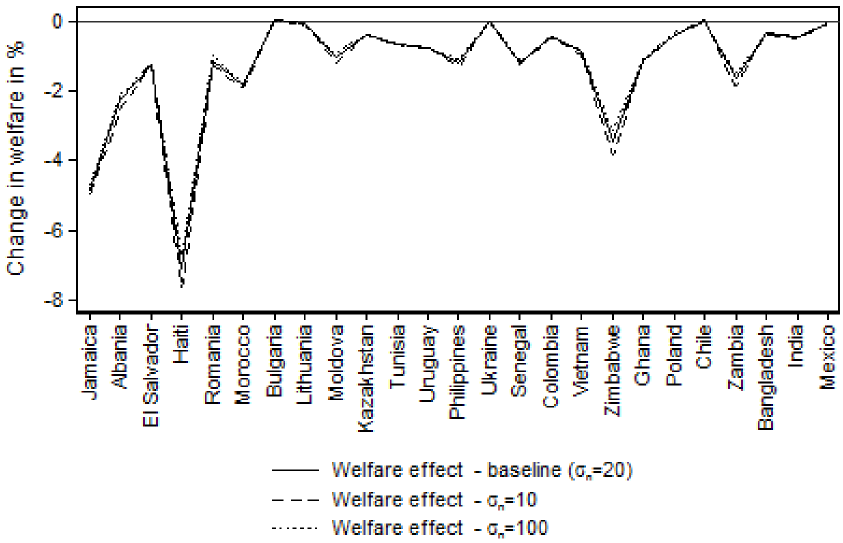


(b) Welfare effects in selected OECD receiving countries

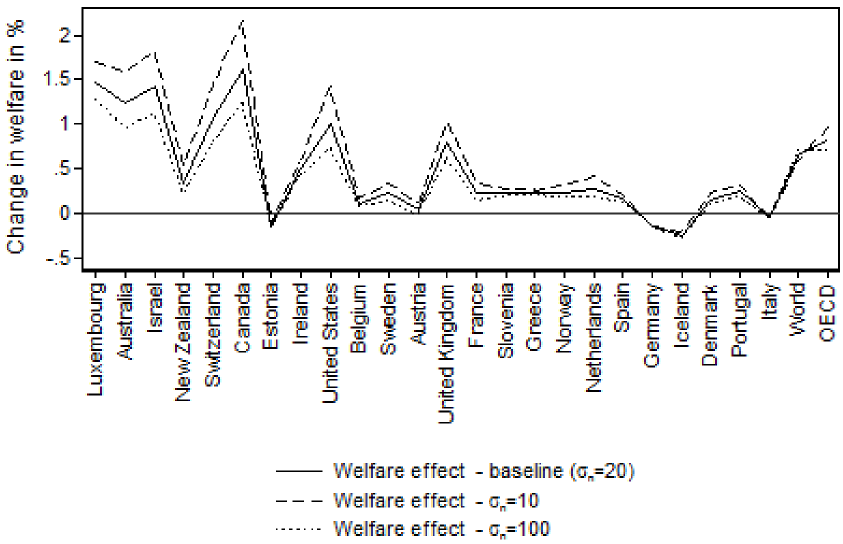
Source:. Own calculations.

Notes: This graph displays the welfare effects of the skill bias in migration with varying elasticity of substitution between education groups, $\sigma_s \in \{2, 5, 8\}$. The countries on the horizontal axis are ordered by immigration/emigration rates. The vertical axis shows changes in welfare per never-migrant in percent. Panel 3b focuses on selected receiving countries, while panel 3a focuses on selected sending countries.

Figure 16: Varying σ_n



(a) Welfare effects in selected non-OECD sending countries

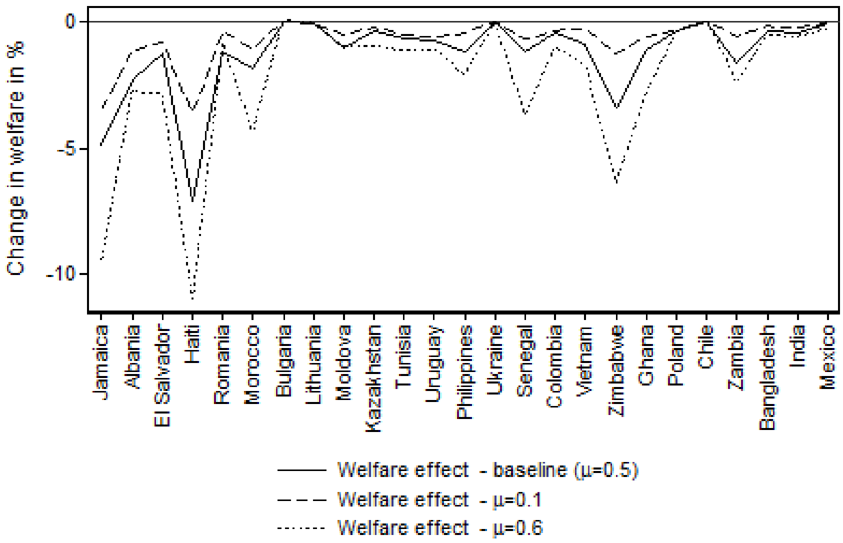


(b) Welfare effects in selected OECD receiving countries

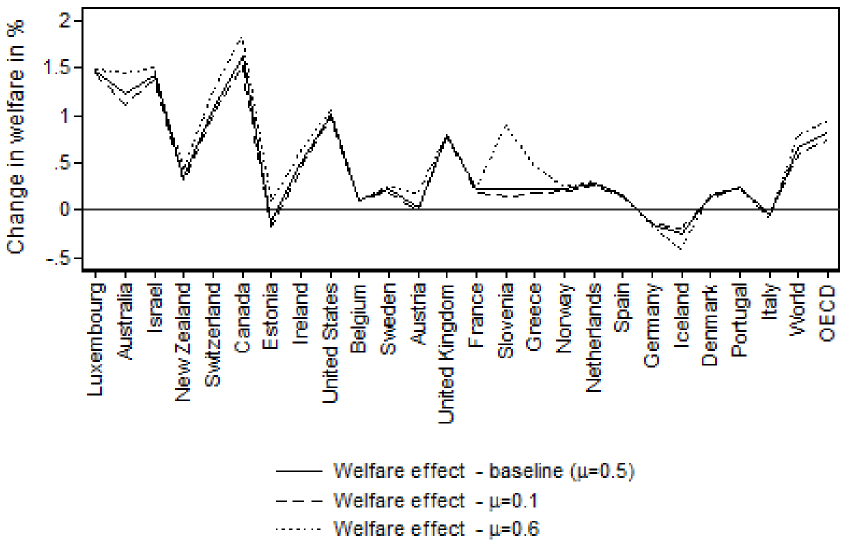
Source:. Own calculations.

Notes: This graph displays the welfare effects of the skill bias in migration with varying elasticity of substitution between immigrants and natives, $\sigma_s \in \{10, 20, 100\}$. The countries on the horizontal axis are ordered by immigration/emigration rates. The vertical axis shows changes in welfare per never-migrant in percent. Panel 3b focuses on selected receiving countries, while panel 3a focuses on selected sending countries.

Figure 17: Varying μ



(a) Welfare effects in selected non-OECD sending countries

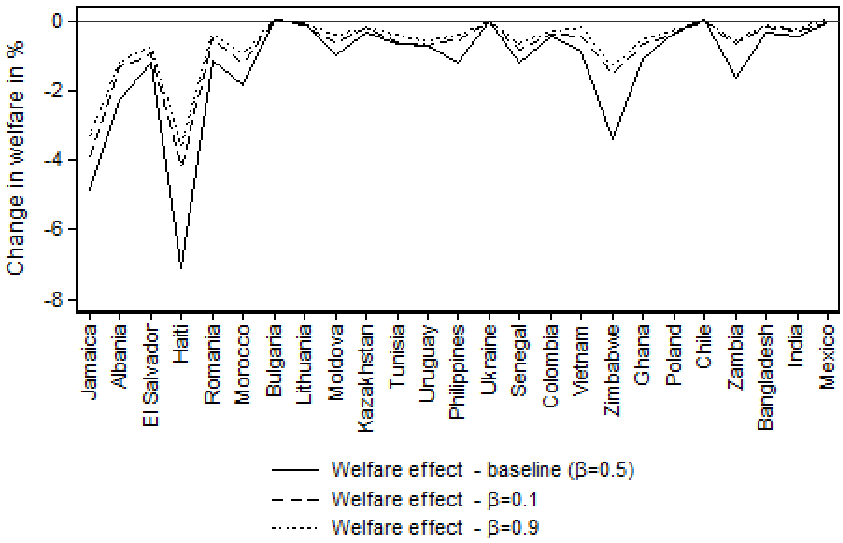


(b) Welfare effects in selected OECD receiving countries

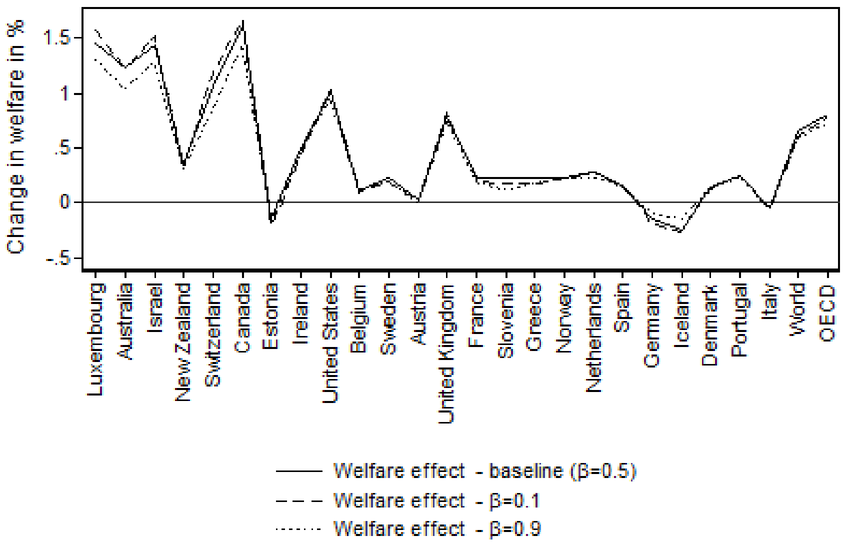
Source:. Own calculations.

Notes: This graph displays the welfare effects of the skill bias in migration with a varying preference parameter for the traditional good, $\mu \in \{0.1, 0.7, 0.6\}$. The countries on the horizontal axis are ordered by immigration/emigration rates. The vertical axis shows changes in welfare per never-migrant in percent. Panel 3b focuses on selected receiving countries, while panel 3a focuses on selected sending countries.

Figure 18: Varying β



(a) Welfare effects in selected non-OECD sending countries

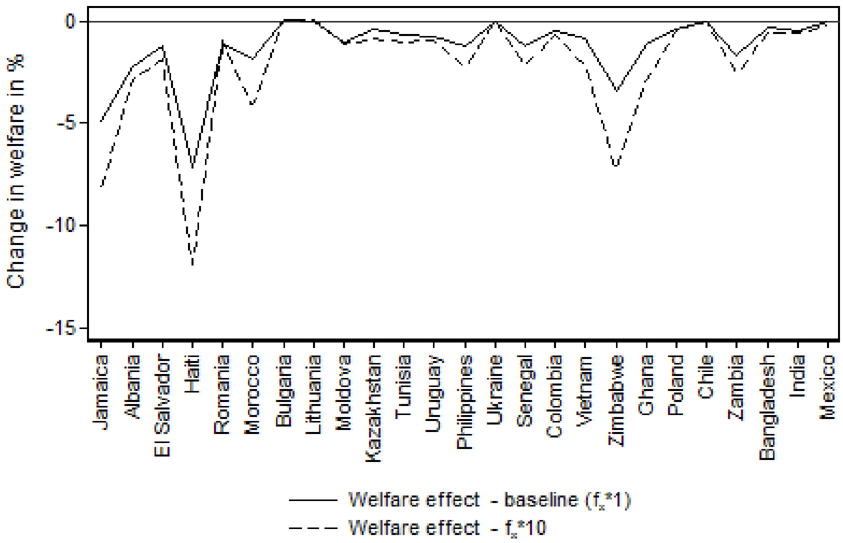


(b) Welfare effects in selected OECD receiving countries

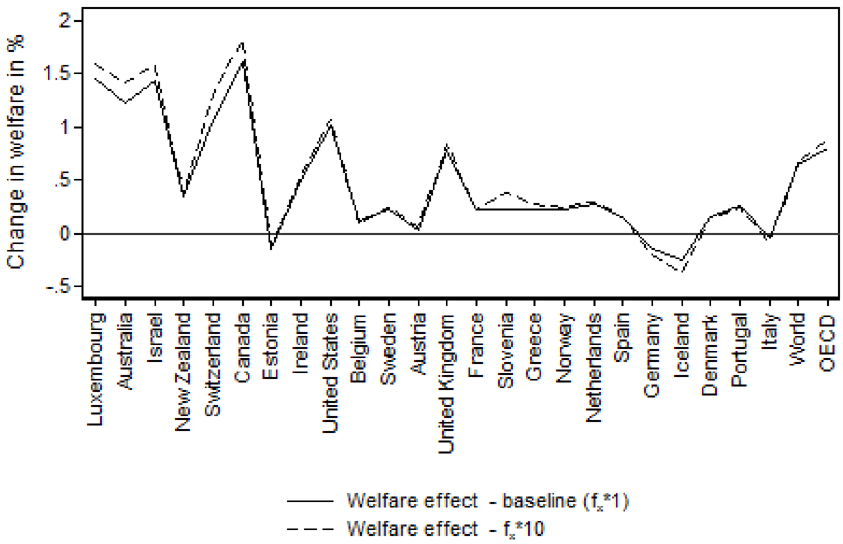
Source:. Own calculations.

Notes: This graph displays the welfare effects of the skill bias in migration with varying relative preference for the tradable good, $\beta \in \{0.1, 0.7, 0.9\}$. The countries on the horizontal axis are ordered by immigration/emigration rates. The vertical axis shows changes in welfare per never-migrant in percent. Panel 3b focuses on selected receiving countries, while panel 3a focuses on selected sending countries.

Figure 19: Varying f_x



(a) Welfare effects in selected non-OECD sending countries

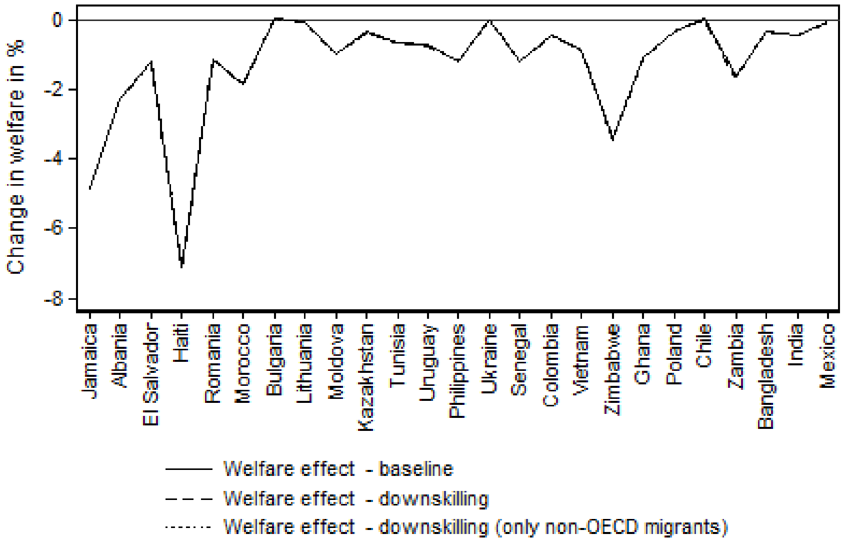


(b) Welfare effects in selected OECD receiving countries

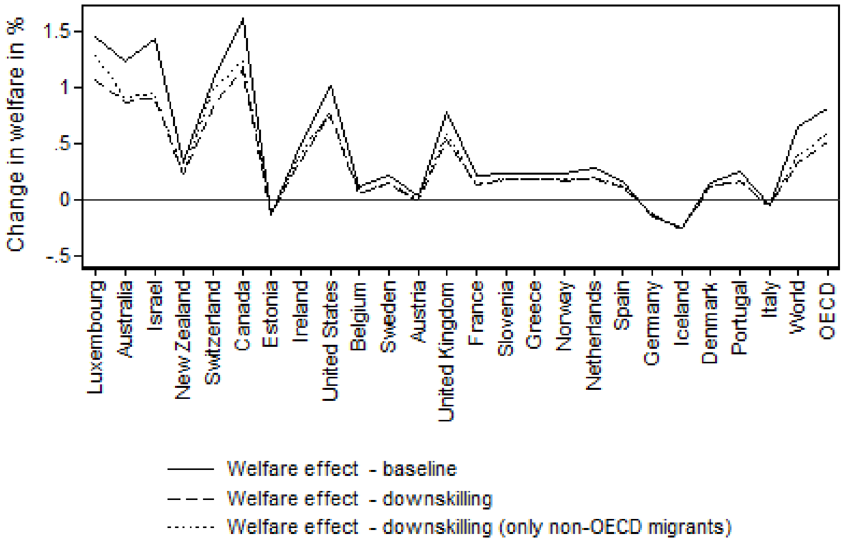
Source:. Own calculations.

Notes: This graph displays the welfare effects of the skill bias in migration with varying fixed costs of entry (baseline vs. fixed cost under baseline multiplied by 10). The countries on the horizontal axis are ordered by immigration/emigration rates. The vertical axis shows changes in welfare per never-migrant in percent. Panel 3b focuses on selected receiving countries, while panel 3a focuses on selected sending countries.

Figure 20: Varying assumptions on downskilling



(a) Welfare effects in selected non-OECD sending countries



(b) Welfare effects in selected OECD receiving countries

Source:. Own calculations.

Notes: This graph displays the welfare effects of the skill bias in migration allowing for downskilling. The countries on the horizontal axis are ordered by mmigration/emigration rates. The vertical axis shows changes in welfare per never-migrant in percent. Panel 3b focuses on selected receiving countries, while panel reffig:welfs focuses on selected sending countries.