Curse of low-skilled emigration on human capital formation Evidence from the migration surge of the 2000s

Tang, Sam Hak Kan; Wang, Yichen; Wang, Yong

Published in:
World Development

Published: 01/05/2025

Document Version:
Final Published version, also known as Publisher's PDF, Publisher's Final version or Version of Record

Published version (DOI):
10.1016/j.worlddev.2025.106931

Publication details:
Tang, S. H. K., Wang, Y., & Wang, Y. (2025). Curse of low-skilled emigration on human capital formation: Evidence from the migration surge of the 2000s. *World Development*, *189*, Article 106931. https://doi.org/10.1016/j.worlddev.2025.106931

World Development 189 (2025) 106931

Contents lists available at ScienceDirect

World Development

journal homepage: www.elsevier.com/locate/worlddev

Regular Research Article

Curse of low-skilled emigration on human capital formation: Evidence from the migration surge of the 2000s

Sam Hak Kan Tang [a,*], Yichen Wang [b], Yong Wang [c]

[a] Department of Economics Business School the University of Western Australia Australia
[b] Shanghai Advanced Institute of Finance Shanghai Jiao Tong University China
[c] Department of Economics and Finance City University of Hong Kong Hong Kong

ARTICLE INFO

JEL:
F22
I21
I25

Keywords:
Human capital formation
Migration
Low-skilled emigration
High-skilled emigration
Developing countries

ABSTRACT

Low-skilled emigration is generally construed as benign and even beneficial for the migrant-sending countries. However, it can also lead to a disincentive effect on human capital formation in the source countries. Using a panel bilateral migration dataset that captures the surge of low-skill migrants in OECD countries in the 2000s, we study how low-skilled emigration affects human capital formation in the migrant-sending countries. We find that the expected returns to low-skilled emigration reduce long-run human capital formation as measured by the average years of schooling and the human capital index of the migrant-sending countries in the subsequent decade. This negative effect on overall human capital formation is manifested through a substantial reduction in tertiary educational attainment, which is both statistically significant and robust to various sensitivity tests and alternative model specifications. Additionally, there is some evidence of a positive association between the expected returns to low-skilled emigration and secondary educational attainment in the subsequent decade. An important qualification is that only middle- and high-income countries are strongly affected by low-skilled emigration, while low-income countries show little to no disincentive effect.

1. Introduction

A recurrent theme in international migration studies is how the emigration of high-skilled workers affects the welfare of those who remain in the migrant-sending countries (Commander et al., 2004; Docquier & Rapoport, 2012; Gibson & McKenzie, 2011; Hanson, 2010). In this discourse, the brain-drain literature emphasizes the various negative effects of high-skilled emigration on the source countries,[1] whereas the brain-gain literature argues that the prospect of high-skilled emigration can increase human capital formation in the source countries by providing an incentive for potential migrants to become highly skilled.[2] Despite the contrasting views, much of the literatures share a common focus of considering only the emigration of high-skilled workers. The exclusion of low-skilled workers in the analysis is partly justified by the lower emigration rate of low-skilled workers compared to that of high-skilled workers.[3] Furthermore, some studies find that the emigration of low-skilled workers increases remittances, investments in education, and income in the source countries (Dinkelman & Mariotti, 2016; Yang, 2008, 2009). Consequently, the existing international migration literature rarely considers the effects of low-skilled emigration on the source countries.[4]

There are several reasons for including low-skilled emigration in

* Corresponding author.
E-mail address: sam.tang@uwa.edu.au (S.H.K. Tang).

[1] Contrary to some of the earliest studies which found that brain drain has no welfare impact on those remaining in the migrant-sending countries (Grubel & Scott, 1966; Johnson, 1967), Bhagwati and Hamada (1974), Bhagwati and Rodriguez (1975) and McCulloch and Yellen (1977) find that brain drain can increase fiscal deficits and reduce the pay or employment levels of those remaining in the migrant-sending countries.

[2] See, among others, Mountford (1997), Stark et al. (1997), Vidal (1998), Stark and Wang (2002) and Beine et al. (2001).

[3] According to IAB Brain Drain Data (2013), in 2010, the average cross-country emigration rate of migrants to OECD countries was 5.7% for those with only primary school education, 5.4% for those who have secondary school education, and 20.1% for those who have tertiary education (Brücker, Capuano, & Marfouk, 2013).

[4] Schiff et al. (2005) and Stark and Byra (2012) are notable exceptions that articulate a mechanism through which low-skilled emigration gives rise to an adverse effect on human capital formation in the source countries.

https://doi.org/10.1016/j.worlddev.2025.106931
Accepted 21 January 2025
Available online 5 February 2025

studies of the effects of out-migration on the welfare of those remaining in the source countries.[5] First, despite the emigration rate for high-skilled workers being higher than that of the low-skilled workers, the number of low-skilled migrants living in the OECD countries has been larger than the number of high-skilled migrants. For example, there were about 43 million low-skilled migrants living in the OECD countries in 2010 compared to only 29 million high-skilled migrants (IAB Brain Drain Data, 2013).[6] In particular, the United States, a country with the largest number of migrants among all OECD countries, experienced an epochal wave of low-skilled immigration between 1970 and 2000 (Hanson et al., 2017). Thus, ignoring low-skilled migration not only contradicts observations but can also lead to incorrect conclusions. Second, Borjas (1987) points out that emigrants are not necessarily drawn from the upper tail of the ability (income) distribution in the source country. If skill premia and income inequality in the source country are larger than those in the destination country, out-migration from the source country can be negatively selected from the lower tail of the source country's ability (income) distribution. Thus, the assumption that emigrants are only drawn from the upper tail of the source country's income distribution is questionable.[7] Third, as mentioned above, many studies have already found strong evidence of benefits of low-skilled emigration to the source countries including increases in remittances, investments in education, and income. This study, however, argues that low-skilled emigration may not only be a "boon" to the source countries, but may also be a "curse" to the source countries. Therefore, it is necessary to study low-skilled emigration in conjunction with high-skilled emigration to assess their relative impacts on the welfare of those remaining in the source countries.

Our empirical tests in this paper are motivated by the following line of theoretical argument. When emigration is only possible for high-skilled workers, an individual's decision to pursue further education depends on the expected returns to high-skilled emigration and the skill wage premium in the source country. However, when emigration is possible for both high-skilled and low-skilled workers, the potential returns to emigration as a low-skilled worker introduce an incentive for an individual to remain low-skilled and forgo the costly education needed to become high skilled. Thus, while the incentive for pursuing further education increases with the expected returns to high-skilled emigration and skill wage premium, it decreases with the expected returns to low-skilled emigration. Consequently, the prospect of low-skilled emigration reduces the relative expected returns of becoming high-skilled and thereby hampers human capital formation in the source countries. This disincentive effect is analogous to the brain-gain effect as documented by Stark and Wang (2002) and Beine et al. (2008) in that they both arise from individuals' responses to the prospect of wage gains from migration.[8]

This paper uses a panel dataset of bilateral migration to study the effects of high-skilled and low-skilled emigration on human capital formation in the source countries. As Hanson (2010) points out, education and migration are likely to be jointly determined. To estimate the causal effect of migration on education, one would need to observe changes in human capital accumulation in source countries before and after they experienced unexpected and exogenous shocks in the opportunity to emigrate. Our identification strategy relies on the significant increase in low-skilled migration to OECD countries from 2000 onwards, as discussed in Section 2. While the rise in low-skilled emigration had already begun in the 1990s, a sharp surge did not occur until after 2000, when the number of migrants in OECD countries with secondary schooling increased by 130% between 2000 and 2010. This sharp and exogenous upsurge in emigration enables us to estimate its impact on the human capital formation of source countries in the subsequent decade. Specifically, our interest lies in identifying the potential heterogeneous impacts of this surge in emigration by low-skilled workers on tertiary, secondary, and primary educational attainment.

Some previous studies have also empirically examined similar disincentive effects of migration in developing countries. McKenzie and Rapoport (2011) found that Mexican children aged 16 to 18 in migrant households have lower levels of schooling than children in non-migrant households. De Brauw and Giles (2017) identified a robust, negative relationship between migrant opportunities and high school enrolment in rural China. Using internal migration data from Spain, Blanco-Álvarez et al. (2022) found that a one standard deviation increase in the returns to low-skilled emigration leads to a 4 percentage-points reduction in post-secondary school enrolment. This paper is related to these studies, but instead of focusing solely on internal migration within a country or bilateral migration between a pair of countries, it uses an international migration dataset to examine the topic. There can be important similarities and differences in results among country income groups, which can only be revealed in a macro study. Moreover, unlike previous studies focusing solely on migrant households, this paper focuses on the impact of low-skilled emigration at the extensive margin which includes both migrant and non-migrant households. As argued by Theoharides (2020), an explicit analysis of the welfare effects of emigration on the source countries should be conducted at the extensive margin.

The main findings of the current study are as follows. First, we observe that an increase in the expected returns to low-skilled emigration leads to a reduction in the average years of schooling and the human capital index in the source countries in the subsequent decade. Our estimates indicate that a one standard deviation increase in the expected returns to low-skill emigration results in a reduction of the average years of schooling by 0.05 years and a reduction of the human capital index by 0.014 points. Second, we find that an increase in the expected returns to low-skilled emigration leads to a substantial reduction in tertiary educational attainment, which is both statistically significant and robust to various sensitive tests and alternative model specifications. Additionally, there is some evidence of a positive association between the expected returns to low-skilled emigration and secondary educational attainment in the subsequent decade. Third, we find that only middle- and high-income countries are strongly affected by the prospect of low-skilled emigration while low-income countries showing little to no disincentive effect. Fourth, our counterfactual analysis reveals that the disincentive effect of the expected returns to low-skilled emigration becomes statistically insignificant when we artificially reduce the low-skilled emigration rate by 40% or more in the top migrant-sending countries. This result suggests that, without the sharp surge in low-

[5] Although it is less commonly used, some previous studies have coined the term "brawn drain" to describe the international migration of low-skilled workers (Commander et al., 2013).

[6] In this study, those who have only primary or secondary education are referred to as low skilled, while those who have tertiary education are being referred to high skilled. The IAB Brain Drain Data (2013) defines migrants as foreign-born individuals aged 25 years and older living in each of the 20 OECD destination countries.

[7] Hanson (2010) reports that the highly educated have a higher propensity to migrate abroad than those who are less educated (positive selection). However, the same study finds that the positive selection of emigrants is at odds with much of the recent empirical literature. Chiquiar and Hanson (2005) find that Mexican immigrants in the United States are concentrated in the middle of Mexico's wage distribution, which suggests that there is intermediate selection of immigrants from Mexico. A study by Leopold et al. (2024) finds that migrants from Mexico to the United States are negatively selected if migrant ability is measured by occupational skills rather than educational attainment.

[8] Bertoli and Rapoport (2015) argue that the size of migration networks affects the quality of migrants not only through their decisions to self-select into migration but also through their decisions to invest in education, which respond to changes in the prospect of migrating.

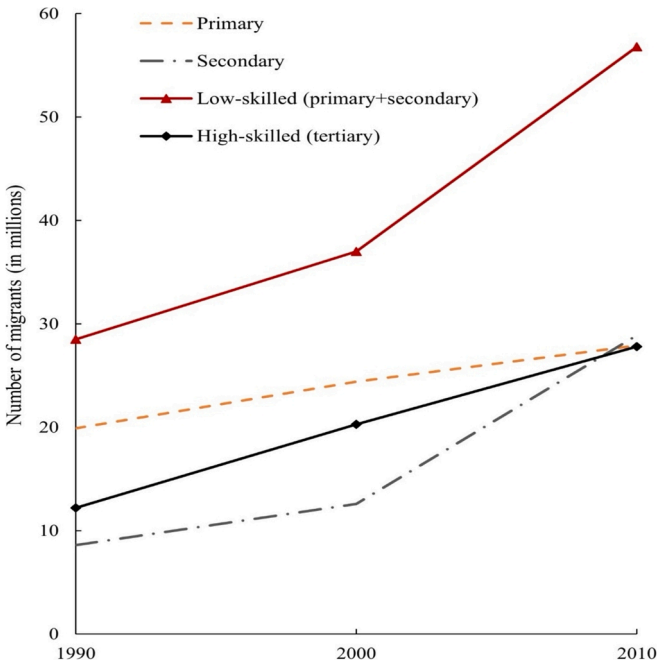

Fig. 1. Migration to OECD Countries by Educational Attainment (1990–2010). Notes: The figure shows the total number (stock) of high-skilled and low-skilled migrants living in OECD countries. High-skilled migrants are those who are aged 15 and above and have tertiary education, and low-skilled migrants are those who are aged 15 and above and have primary or secondary education. Migrants without formal education are not included in the data and thus not considered in this study.
Source: Arslan et al. (2015)

skilled emigration during the 2000s, there would have been little disincentive effect on human capital formation.

The remainder of this paper is organized as follows: Section 2 briefly discusses the migration surge of the 2000s. Section 3 presents a simple static theoretical framework to better understand the disincentive effect of low-skilled emigration and to guide empirical tests. Sections 4 and 5 discuss the baseline empirical model and the construction of samples and variables, respectively. Section 6 presents and discusses the main results, while Section 7 considers various robustness checks. Finally, Section 8 concludes.

2. The migration surge of the 2000s in OECD countries

Recent data reveal a significant surge in the number of low-skilled migrants living in OECD countries since 2000, as shown in Fig. 1.[9] The figure illustrates that the number of low-skilled migrants, defined as those with either secondary or primary education, increased from 28.5 million in 1990 to 37 million in 2000, and to 56.8 million in 2010.[10] This corresponds to increases of 8.5 million from 1990 to 2000 and 19.8 million from 2000 to 2010, indicating that the growth of low-skilled migration more than doubled over these two decades. On the other hand, Fig. 1 shows that the number of high-skilled migrants, defined as those with tertiary education, grew from 12.2 million in 1990 to 20.3 million in 2000, and to 27.8 million in 2010. This represents increases of 8.1 million from 1990 to 2000 and 7.5 million from 2000 to 2010, showing a slowdown in the growth of high-skilled migration. Notably, the growth of low-skilled migrants during the 2000–2010 period was 2.6 times that of high-skilled.

Therefore, Fig. 1 highlights a stark contrast between the decadal growth in low-skilled and high-skilled migration: while both types of migration experienced steady increases from 1990 to 2000, the growth in low-skilled migration became significantly more pronounced from 2000 to 2010, both in absolute numbers and in the rate of increase.[11]

Fig. 1 also reveals the driving force behind the accelerating growth rate of low-skilled migrants in OECD countries during the 2000s. It shows that the number of migrants with secondary education more than doubled between 1990–2000 and 2000–2010.[12] However, the number of migrants with primary education increased only modestly, from 24.4 million in 2000 to 27.9 million in 2010. Thus, the steep growth in the number of secondary-educated migrants is the primary driver of the accelerating rate of low-skilled migration in OECD countries.

Several factors can explain the upsurge in low-skilled migration in the 2000s. First, the demand for low-skilled labour in high-income OECD countries is one of the main reasons for the increase in the emigration of low-skilled labour in the 2000s. High-income OECD countries are increasingly reliant on migrant workers to perform low-skilled services. These services include care for children and the elderly, hospitality services, retail, cleaning, and maintenance, as well as work in the primary, construction, and industrial sectors (OECD, 2008). According to OECD statistics, the percentage of migrant workers among the low-educated labour force in the OECD countries increased between 1995 and 2006, and on average, migrant workers account for about 32% of all low-educated workers in OECD countries (OECD, 2008).

In the United States, the top destination country for low-skilled migrants, construction is the third-largest sector of employment for low-skilled migrants (Hanson et al., 2017). The housing boom of the early 2000s in the United States contributed to the surge in demand for low-skilled migrants, which only subsided when the housing bubble burst in 2007. Moreover, the increased demand for low-skilled migrants is linked to demographic changes in both the destination and source countries. On one hand, the high fertility rates in Mexico and other Latin American countries until the late 1970s generated waves of low-skilled migrants for the United States. On the other hand, the shrinking number of young people in the labour force and the increase in educational attainment reduced the supply of low-skilled workers in the United States. However, it is predicted that the demographic push factor of low-skilled migrants to the United States will remain stable or even decline after the Global Financial Crisis in 2008 (Hanson et al., 2017).

Second, a significant factor in the emigration surge of low-skilled migrants is the relaxation of the immigration policy in the OECD countries since the 1990s. Low-skilled migrants were able to find employment opportunities in the destination countries through temporary work

[9] The migration data come from Arslan et al. (2015), which provides an update of the Database on Immigrants in OECD Countries (DIOC) for 2010/11.
[10] Migrants without formal education are not included in the data and thus not considered in this study.

[11] Although the total numbers of low-skilled and high-skilled migrants to OECD countries increase over time, as shown in Fig. 1, their bilateral emigration rates exhibit only a moderate positive correlation, with a pairwise correlation coefficient of 0.44. To further explore this relationship, we applied a panel fixed-effects OLS approach to assess whether the bilateral emigration rate of low-skilled individuals can be predicted by that of high-skilled individuals, controlling for country-pair fixed effects, year fixed effects, and baseline controls. As reported in Table A.2, our results show that the two bilateral emigration rates are correlated when the regression excludes fixed effects; however, this correlation disappears once country-pair and year fixed effects are included. These findings indicate that low-skilled emigration cannot be predicted based on high-skilled emigration within each source country.
[12] According to Hanson et al. (2017), the number of working-age immigrants with 12 or fewer years of schooling more than doubled in the United States between 1990 and 2007, rising from 8.5 million to 17.8 million. These low-skilled immigrants mostly came from Mexico as well as the rest of Latin America and the Caribbean. In particular, the proportion of low-skilled immigrants with 12 years of schooling increased from 45% in 1990 to 49.8% in 2000, and to 55.3% in 2015, indicating that secondary education has become the dominant educational background of low-skilled immigrants in the United States.

programs, shortage lists or seasonal work programs (OECD, 2008). In the United States, various policy changes since the 1990s made it easier for some legal and illegal migrants to stay and work (Clark et al., 2007). These policies include the increase in annual employment quota from 54,000 to 140,000 in 1992, Temporary Protected Status (1990-92, 2001-), Deferred Enforced Departure (1992), and Nicaraguan Adjustment and Central American Relief Act (1997). Australia introduced the "Migration Occupations in Demand List" (MODL) for its permanent skilled migration scheme. Occupations on the MODL provide additional points in the point-based system and can include low-wage occupations such as hairdressers, bakers, pastry-chefs, bricklayers, and butchers. Other OECD countries such as France, Canada, Italy, and the United Kingdom have implemented similar schemes to import low-skilled migrants. Additionally, some OECD countries, such as those in the European Union, as well as Canada and the United States, allow temporary low-skilled migrants to settle permanently without the obligation to demonstrate employment after a certain period of renewable permits, making it easier for low-skilled migrant workers to stay in high-income OECD countries.

Third, institutional changes in Eastern Europe in the 2000s facilitated low-skilled emigration from former Soviet bloc countries to Germany, Italy, and other Western European countries. The bilateral low-skilled emigrations of Poland-Germany, Russia-Germany, Kazakhstan-Germany, and Romania-Italy became some of the top 15 bilateral low-skilled emigrations in 2010. Several factors contributed to the emergence of these new top bilateral low-skilled emigrations: the German government's policy of granting residency and support to those with German ancestry, the entry of Poland and Romania into the European Union in 2004 and 2007 respectively, and a high demand for low-skilled labour in German and Italian industries during the 2000s.

In sum, the surge in low-skilled emigration to OECD countries during the 2000s can be attributed to the increased demand for low-skilled workers in these countries, coinciding with demographic changes in both source and destination countries, institutional changes in Eastern Europe, and the relaxation of immigration policies in destination countries.

3. The theoretical framework

To best elucidate the central idea of the paper, we utilize the theoretical framework of Blanco-Álvarez et al. (2022), which considers a simple static decision-making problem where an individual worker in a developing country decides on his/her human capital investment in the presence of migration possibilities. For clarity and completeness, we briefly outline this framework as follows.

Suppose that individuals working in a source country will receive a wage of W^S as a high-skilled worker and W^U as a low-skilled worker. However, a high-skilled (low-skilled) worker faces an exogenously given probability of P^S (P^U) to migrate to a destination country, where wages are higher for both the high-skilled and low-skilled migrants at W^{S*} and W^{U*}, respectively.[13] Each worker, indexed by l, needs to make the decision prior to participating in the labour market whether to invest in acquiring the necessary human capital to become high-skilled at a cost of C_l, which is assumed to be uniformly distributed over an interval of $[C_{min}, C_{max}]$. This cost C_l can be interpreted as a composite parameter that reflects factors such as ability and family background. Assuming risk neutral, a worker's decision to acquire human capital then hinges upon the comparison between the expected earnings from acquiring human capital and that from remaining low-skilled, subject to the migration possibilities. The marginal worker l^* who is indifferent between becoming high-skilled and remaining low-skilled is given by the following condition:

$$\left(1-P^S\right)W^S + P^S W^{S^*} - C_{l^*} = \left(1-P^U\right)W^U + P^U W^{U^*} \tag{1}$$

where the right-hand side represents the expected earnings if worker l^* acquires the human capital of a high-skilled worker and the left-hand side the expected earnings if such worker forgoes human capital investment to remain as low-skilled. Rearranging Eq. (1) yields the cut-off cost of acquiring high-skilled human capital:

$$C^* \equiv C_{l^*} = P^S\left(W^{S^*} - W^S\right) - P^U\left(W^{U^*} - W^U\right) + \left(W^S - W^U\right) \tag{2}$$

For an interesting analysis, it is assumed that $C_{min} < C^* < C_{max}$. Thus, worker l will acquire human capital to become high-skilled if $C_l < C^*$ and otherwise remains low-skilled if $C_l > C^*$. It follows from Eq. (2) that (i) an increase in the expected returns to emigration, for a high-skilled worker, P^S ($W^{S*} - W^S$), (ii) a decrease in the expected returns to emigration for a low-skilled worker, P^U ($W^{U*} - W^U$), and (iii) an increase in the wage premium between high-skilled and low-skilled, ($W^S - W^U$), would increase the cut-off cost level of C^* and hence the number of workers acquiring high-skilled human capital in the source country.

Denote H^S and H^U (with $H^S > H^U$) as the levels of human capital embodied in a high-skilled worker and a low-skilled worker, respectively. Given the human capital accumulation decision outlined above, the aggregate human capital remaining in the source country is:

$$H = \left(1-P^S\right)(C^* - C_{\min})H^S + \left(1-P^U\right)(C_{\max} - C^*)H^U = N^S H^S + N^U H^U \tag{3}$$

where $N^S = (1-P^S)(C^* - C_{min})$ denotes the mass of high-skilled workforce and $N^U = (1-P^U)(C_{max} - C^*)$ low-skilled workforce remaining in the source country. Therefore, the average post-migration human capital in the source country is given by:

$$\overline{H} = \frac{N^S}{N^S + N^U}H^S + \frac{N^U}{N^S + N^U}H^U = \lambda_s H^S + \lambda_u H^U \tag{4}$$

where λ_s and λ_u represent the post-migration proportions of high-skilled and low-skilled, respectively, and $\lambda_s + \lambda_u = 1$. Since N^S rises and N^U falls with the cut-off level of cost C^*, the average human capital remaining in the source country in Eq. (4) increases with C*. Therefore, combining Eqs. (2) and (4) predicts that the post-migration average human capital level in the source country correlates positively with the expected returns to high-skilled emigration, P^S ($W^{S*} - W^S$), and skilled wage premium, ($W^S - W^U$), but *negatively* with the expected returns to low-skilled emigration, P^U ($W^{U*} - W^U$). In addition, Eq. (3) implies a direct "brain drain" effect on the average human capital from high-skilled emigration and hence changing the composition of post-migration population in favour of the low-skilled, i.e. λ_s decreases and λ_u increases (i.e., negative correlation with P^S). Conversely, the emigration of low-skilled migrants directly raises the average human capital by lowering the proportion of the low-skilled in the post-migration

[13] The theoretical framework outlined here takes the probabilities of migration and wages of high-skilled (P^S and W^S) and low-skilled (P^U and W^U) in the source country as exogenous. However, as discussed by Dustmann and Glitz (2011), the emigration of high-skilled and/or low-skilled workers will affect the post-migration composition of the labour force, and hence the probabilities of migration and wages, in the source country. One way, albeit not perfect, to allay this concern is to interpret P^l and W^l (l=S, U) not as arbitrarily given numbers, but rather the endogenously determined equilibrium probabilities and wages, and that the workers in the source country can correctly anticipate these probabilities and wages (i.e., having rational expectations) when making human capital investment decisions. Empirically, since the emigration rates and wage incomes for different skill levels – the proxies for P^l and W^l (l= S, U), respectively – in our estimations are constructed from actual data, they presumably already reflected the effect of emigration on the composition of labour force remaining in the source country.

population (i.e., positive correlation with P^U).[14]

4. The baseline empirical models

Guided by Eqs. (2) and (4) in the theoretical framework, we formulate the baseline empirical model to estimate the effects of the prospects of high-skilled and low-skilled emigration on the average level of human capital in the source countries as follows:

$$H_{it} = \beta_0 + \beta_1 P^S_{i,j,t} + \beta_2 P^U_{i,j,t} + \beta_3 T^S_{i,j,t} + \beta_4 T^U_{i,j,t} + \beta_5 S_{it} + \beta_6 \boldsymbol{X}_{it} + C_{i,j} + Y_t + \mu_{it} \quad (5)$$

where H_{it} is the average level of human capital in the i^{th} source country at time t, $P^S_{i,j,t}$ and $P^U_{i,j,t}$ are the bilateral emigration rates for high-skilled and low-skilled from the i^{th} source country to the j^{th} destination country, $T^S_{i,j,t} = P^S_{i,j,t}\left(W^{S^*}_{j,t} - W^S_{i,t}\right)$ and $T^U_{i,j,t} = P^U_{i,j,t}\left(W^{U^*}_{j,t} - W^U_{i,t}\right)$ represent the expected returns to high-skilled and low-skilled emigration, respectively, and $S_{it} = \left(W^S_{i,t} - W^U_{i,t}\right)$ is the wage premium for high-skilled workers in the source countries.

$\boldsymbol{X}_{i,t}$ is a vector of time-varying covariates that are likely to affect human capital formation of the source countries. In the baseline regressions, we add only those control variables which are consistent with the existing literature for comparison (Beine et al., 2008). These covariates include remittances as a share of GDP, population density, and GDP per capita growth. In the section of robustness checks, we add emigration to non-OECD countries, migrant networks, democratic institutions, and relative earnings inequality as further controls. Past migration studies have highlighted the importance of bilateral variables such as geographical, linguistical and cultural factors (Mayda, 2010; Ozden et al., 2017). Thus, we add dummy variables for every pair of source and destination countries, $C_{i,j}$, which control for the effects of all those time-invariant bilateral country characteristics such as geographical, linguistical and cultural factors. Moreover, the regression includes time fixed effects, Y_t, which controls for the effects of the time-varying factors that are common to every pair of source and destination countries. The error term, μ_{it} is assumed to be independent and identically distributed.

Eq. (5) captures how the prospect of emigration for high-skilled and low-skilled workers affects the average level of human capital in the source country at time t. While potential migrants consider their prospective returns of emigration when they are still in the source countries at time t (pre-migration), their decisions and migration outcomes can only influence the measure of human capital formation in the source countries in periods beyond time t. Therefore, to capture the impact of the human capital investment decision at time t, we need to focus on the change in human capital levels beyond time t. Hence, Eq. (5) is specified as a β-convergence model, similar to Beine et al. (2008), as follows:

$$\Delta H_{i,t+1} = \beta_0 + \beta_1 H_{it} + \beta_2 P^S_{i,j,t} + \beta_3 P^U_{i,j,t} + \beta_4 T^S_{i,j,t} + \beta_5 T^U_{i,j,t} + \beta_6 S_{it} + \beta_9 \boldsymbol{X}_{it} + C_{i,j} + Y_t + \mu_{it} \quad (6)$$

where $\Delta H_{i,t+1} = \left(H_{i,t+1} - H_{i,t}\right)$ is the change of human capital of the i^{th} source country between time $t + 1$ and t. The discussion in the theoretical section leads us to expect that $\beta_2 < 0$ (the direct effect of high-skilled emigration or the brain-drain effect), $\beta_3 > 0$ (the direct effect of low-skilled emigration), $\beta_4 > 0$ (the indirect incentive effect of high-skilled emigration or the brain-gain effect), $\beta_5 < 0$ (the indirect incentive effect of low-skilled emigration), and $\beta_6 > 0$. The direct effects of high- and low-skilled emigration are rather mechanical and well understood. Our key hypothesis to be tested is $\beta_5 < 0$, which, if turns out true and statistically significant, implies that low-skilled emigration has a detrimental disincentive effect on human capital formation in the source countries. We are also interested in the coefficient of the expected returns to high-skilled emigration, β_4, which is argued by the brain gain literature to be positive and statistically significant, suggesting that the prospect of high-skilled emigration creates a positive incentive effect on human capital formation.

It is worth noting that Eq. (6) can mitigate the concern of potential endogeneity posing a risk to the validity of the results of Eq. (5). For example, people living in a source country with a low level of human capital may find limited opportunities in education and employment and thus more likely to emigrate, which raises the concern of reverse causality and its potential biases in the estimates of Eq. (5). Rather than using the average level of human capital at time t as the dependent variable as in Eq. (5), Eq. (6) uses the change in human capital in the decade following the surge in low-skilled emigration as the dependent variable. This approach ensures that human capital formation does not influence the surge of low-skilled emigration and thus mitigates the concern of reverse causality. Additionally, Eq. (6) is consistent with the suggestion by Hanson (2010) that "Valid instruments for migration are very difficult to find. For causal analysis, one would need to observe changes in human-capital accumulation in sending countries before and after they experienced unexpected and exogenous shocks in the opportunity to emigrate" (Hanson, 2010, p. 4377).

5. Data and variables

This paper exploits the 2010/11 update of the DIOC in a panel data analysis of the reverse brain-gain effect. Previous studies in the brain-drain/gain literature were hampered by a lack of longitudinal migration data by educational attainment. Consequently, most previous studies could only adopt cross-sectional approaches. It is well-known that misspecification biases and unobserved heterogeneity issues cannot be fully addressed in cross-sectional approaches (Beine et al., 2011). Thus, this study pursues a panel-data approach using the migration data from Arslan et al. (2015), which provides an update of the Database on Immigrants in OECD Countries (DIOC) for 2010/11.[15] These data are supplemented with data for 1990 from Docquier et al. (2009). It is valuable to reassess the validity of the conclusions of previous studies with the use of recent data that have incorporated new rounds of censuses in OECD destination countries (Docquier & Rapoport, 2012).

The sample is a panel dataset of bilateral migration from 194 source countries to 29 OECD destination countries in 1990, 2000, and 2010. Because the source and destination countries cannot be the same, the dataset consists of a maximum of 16,791 observations. The panel data are unbalanced due to missing observations. The following subsections describe in detail the definition and source of the key right-hand side variables and the outcome variables in the study.

5.1. Outcome variables: Educational attainment

The main outcome variables in this study are the decadal changes in

[14] While the simple theoretical framework here offers a clear intuition on how migration prospects can affect workers' human capital investment decisions, it certainly has the limitation of abstracting from other considerations. For instance, other than the discussion in Footnote 13, the static nature of the model also precludes the possibility of considering endogenous changes of variables such as the cost of migration (which can be introduced into the current model as another constant) and the cost of education in a dynamic setting where they are affected by past migration experience through network effects and remittances. However, a full treatment of these issues would go beyond the current scope of the study.

[15] Although the DIOC-E data includes information for 100 destination countries and over 200 countries of origin, it is only available for the years 2000 and 2010. Therefore, using this dataset in our analysis would prevent us from identifying any changes in bilateral migrations before and after the 2000s.

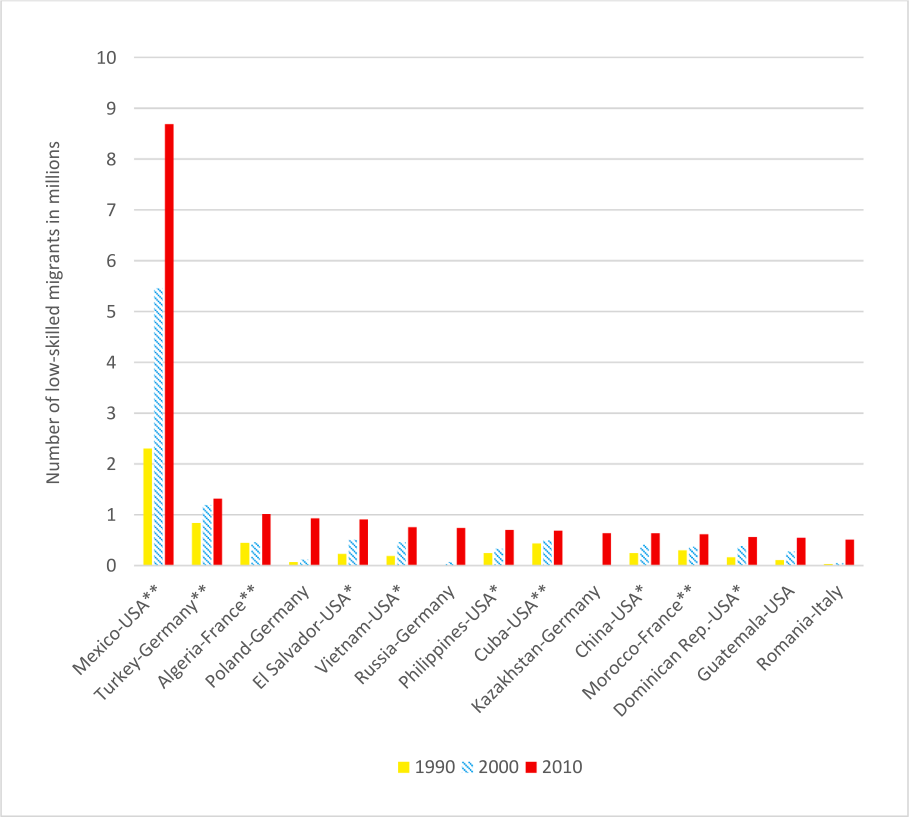

Fig. 2. Top 15 Bilateral Low-skilled Emigrations in 2010. Notes: Low-skilled migrants are those aged 15 and above with primary or secondary education. ** indicates that the bilateral low-skilled emigration is among the top 15 in both 1990 and 2000, while * indicates that it is among the top 15 in either 1990 or 2000, but not both. Source: Arslan et al. (2015)

average years of schooling and human capital index for people aged 15 and above in the source countries.[16] The average years of schooling is a commonly used measure of a country's human capital formation. However, it has its limitations because it does not consider the quality of education or its impact on productivity. Therefore, in addition to the average years of schooling, we adopt the long-run human capital index from Lee and Lee (2016), which is a broader measure of human capital formation as it considers both the quantity and quality of education in a source country.

Data on the average years of schooling are obtained from the Barro and Lee Education Attainment Dataset (2013) which provides various measures of educational attainment for 146 countries from 1950 to 2010 in 5-year intervals. Data on the human capital index are obtained from Lee and Lee (2016). The human capital index is a measure of a country's long-run human capital stock, reflecting the country's educational attainment. For an uneducated worker, the human capital index is one. In our regressions, we use the decadal changes in the average years of schooling and human capital index as the dependent variables, defined as their respective differences between 1990 and 2000, 2000 and 2010, and 2010 and 2020. For the year 2020, data on the average years of schooling and human capital index are obtained from the Projection of Educational Attainment by Country (Barro & Lee, 2015).

In addition to the decadal changes in the average years of schooling and the human capital index, we also use the decadal changes in tertiary, secondary, and primary educational attainment as outcome variables in the study. Tertiary, secondary, and primary educational attainment are the percentages of the population aged 15 and above who have had at least some tertiary, secondary, or primary education. These variables are obtained from Barro and Lee (2013) and Barro and Lee (2015).

5.2. Emigration rates of high-skilled and low-skilled migrants

The bilateral emigration rate of high-skilled (HS) migrants, $P^{S}_{i,j,t}$, between source country i and destination country j at time t is defined by:

$$P^{S}_{i,j,t} = \frac{No.\ of\ HS\ migrants\ from\ country\ i\ living\ in\ country\ j\ at\ time\ t}{No.\ of\ HS\ persons\ in\ country\ i} \tag{7}$$

Similarly, the bilateral emigration rate of low-skilled (LS) migrants, $P^{U}_{i,j,t}$, between source country i and destination country j at time t is defined by:

$$P^{U}_{i,j,t} = \frac{No.\ of\ LS\ migrants\ from\ country\ i\ living\ in\ country\ j\ at\ time\ t}{No.\ of\ LS\ persons\ in\ country\ i} \tag{8}$$

Data on the number of high-skilled and low-skilled migrants from source country i living in destination j at time t are obtained from Arslan et al. (2015). This dataset provides the numbers of migrants by educational attainment in three groups (primary, secondary, and tertiary education) who are aged 15 and above migrating to OECD countries from 194 source countries in 1990, 2000 and 2010. For the definition of high-skilled migrants, this study follows the widely used approach of using tertiary education as the benchmark: those migrants who have had at least some tertiary education are considered high-skilled (13 years of schooling or more). It is worthy to note that some studies define high-skilled migrants as those who have had at least some upper-secondary schooling (more than 9 years of schooling). In this study, we use

[16] We also use the educational attainment of two other age groups as the dependent variable in the robustness checks: one group consists of people who are aged 15–24, and the other group consists of people who are aged 19 and above.

Table 1
Summary Statistics of Key Variables.

	Average years of schooling	Human capital index	Emigration rate of HS migrants (%)	Emigration rate of LS migrants (%)	HS income gap ($1,000)	LS income gap ($1,000)	Skill wage premium ($)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Low-income Countries							
Mean	3.30	1.37	0.75	0.05	18.39	24.44	8.89
SD	2.01	0.18	4.24	0.33	50.38	97.47	0.58
Obs.	2,204	1,740	1,972	1,972	1,456	1,456	2,146
Panel B: Middle-income Countries							
Mean	6.60	1.97	0.56	0.11	24.13	20.72	8.59
SD	2.18	0.41	3.36	0.81	18.86	10.15	1.66
Obs.	7,888	6,148	6,612	6,612	6,384	6,384	9,628
Panel C: High-income Countries							
Mean	9.47	2.79	0.71	0.18	3.37	2.20	9.27
SD	1.61	0.40	4.35	0.95	26.76	21.41	3.21
Obs.	5,800	4,408	4,872	4,872	5,152	5,152	5,800

Notes: The World Bank's classification of low-income, middle-income, and high-income country groups in 2000 are used. Human capital index measures the average educational attainment of a country. For an uneducated worker, the human capital index is one (Lee & Lee, 2016). Emigration rate of high-skilled (low-skilled) is the number of high-skilled (low-skilled) migrants migrating from a source country to a destination country divided by the sum of the number of high-skilled (low-skilled) population in a source country. HS (LS) income gap refers to the wage income difference for high-skilled (low-skilled) workers between the destination and source countries. Skill premium is the difference of hourly real wage rates between high-skilled and low-skilled workers in the source country. See the section Data and Variable for details and sources.

tertiary schooling as the definition of high skills.

Fig. 2 presents a bar chart illustrating the top 15 bilateral low-skilled emigrations in 2010, which together accounted for approximately 30% of all low-skilled migrants living in OECD countries in 2010. The chart reveals a persistent pattern of low-skilled emigration over the decades, with 10 of the top 15 bilateral low-skilled emigrations in 2010 also ranking in the top 15 in either 1990, 2000, or both. Notably, low-skilled emigration from Mexico to the United States was by far the largest in 2010, as it was in 1990 and 2000. As discussed in Section 2, the unexpectedly large scale of the early 2000s housing boom in the United States, coupled with relaxed immigration policies, contributed to a notable upsurge in low-skilled immigration from Mexico, other parts of Latin America, and the Caribbean.

Additionally, five new top bilateral low-skilled emigrations appeared in 2010: Poland-Germany, Russia-Germany, Kazakhstan-Germany, Guatemala-USA, and Romania-Italy. All but Guatemala-USA involved former Soviet bloc countries. Key contributing factors to these new top bilateral low-skilled emigrations include the German government's policy of granting residency and support to those with German ancestry, the entry of Poland and Romania into the European Union in 2004 and 2007 respectively, and a high demand for low-skilled labour in German and Italian industries during the 2000s. In sum, as Fig. 2 highlights, the unexpectedly large-scale housing booms in the United States, institutional changes in Eastern Europe, and relaxed immigration policies in OECD countries unique to the 2000s are likely important contributing factors to the upsurge in low-skilled emigration during this period.

Table 1 presents summary statistics of the mean bilateral emigration rates of high-skilled and low-skilled migrants for low-, middle-, and high-income countries. First, the mean bilateral emigration rates of high-skilled migrants are much higher than those of the low-skilled migrants. For example, the mean bilateral emigration rate of high-skilled migrants is 0.75%, compared to only 0.05% for low-skilled migrants in low-income countries, indicating that high-skilled workers in low-income countries are 15 times more likely to emigrate than low-skilled workers. Second, the mean bilateral emigration rate of low-skilled migrants is highest in high-income countries and lowest in low-income countries, suggesting that low-skilled workers in high-income countries face fewer obstacles to emigration compared to those in the low-income countries. Finally, for both high-skilled and low-skilled migrants, the variation in the bilateral emigration rate across countries is large as indicated by their large standard deviation.[17] Some countries have a significant proportion of their high-skilled/low-skilled workforce emigrating, while others have none.

We calculate the number of high-skilled workers in a source country by multiplying the total size of its labour force by the proportion of the labour force with at least some tertiary education. The Barro and Lee (2013) dataset on educational attainment provides the data on the proportion of the labour force with at least some tertiary education from 1950 to 2010. Similarly, we calculate the number of low-skilled workers in a source country by multiplying the total size of its labour force by the proportion of the labour force with only secondary or primary education.

5.3. Wage incomes of high-skilled and low-skilled workers

In this study, the wage incomes of high-skilled workers, W_i^S, and low-skilled workers, W_i^U, are calculated as follows,

$$W_i^S = \frac{\omega_i y_i}{\omega_i \alpha_i^h + \alpha_i^l}, \text{ and } W_i^U = \frac{y_i}{\omega_i \alpha_i^h + \alpha_i^l} \tag{9}$$

where y_i is the real GDP per capita at chained Purchasing Power Parity (PPP) in 2011 USD from *Penn World Table Version 9*. σ_i^h and σ_i^l are the proportions of high-skilled (tertiary educated) and low-skilled (without tertiary education) workers in the population, which are derived from Barro and Lee education attainment database. ω_i is the wage ratio between the high-skilled and low-skilled workers. We obtain the data on the wage ratio from Zhou and Bloch (2019) who estimate the real hourly wage rates of high-skilled, medium-skilled, and low-skilled workers using data from the Socio-Economic Accounts (SEA) of the World Input-Output Database (WIOD). Before we can use the hourly real wage rates from Zhou and Bloch (2019) to calculate the wage ratio, ω_i, we need to make certain assumptions and adjustments to harmonize the wage data

[17] Table A1 in the appendix presents the total emigration rates (as opposed to the average bilateral emigration rates) of high-skilled and low-skilled migrants for the top ten migrant-sending countries in 1990, 2000, and 2010. The top ten migrant-sending countries in 2010 were Mexico, the United Kingdom, India, Germany, Poland, China, the Philippines, Turkey, Italy, and Morocco.

with those of the emigration rates.[18]

Columns 5 and 6 in Table 1 summarize the mean wage income differences of high-skilled and low-skilled workers between the destination and source countries for low-, middle- and high-income countries. It is worth noting that the mean wage income differences of low-skilled workers between the destination and source countries are large relative to those of high-skilled workers for low- and middle-income countries. Take, for example, the mean wage income difference for low-skilled workers in middle-income countries was $20,720 compared to the mean wage income difference of high-skilled workers of $24,130. The large wage income difference for low-skilled workers can strongly motivate workers in the source countries to forgo costly human capital investment in favour of seeking employment opportunities in the destination countries.

5.4. Control variables

- Remittances: remittances as a share of GDP are included to account for family members receiving financial support from migrant workers to pay for their education. Ambler et al. (2015) find strong evidence that remittances lead to increased educational expenditure, higher private (secondary) school attendance, and crowd-in educational investment. Also, Rapoport and Docquier (2006) find that remittances are often used as preparations for migrant returning home. They also find that remittances decrease as migrants become better integrated into the destination country. Beine et al. (2008) add remittances in their regression as a control for the returns of migrant workers. Total remittance inflows as a share of GDP for each source country are obtained from the World Bank's Migration and Remittances Database (2021).
- Population density: population density is used as a proxy for the cost of education in Beine et al. (2008). The cost of education is influenced by various factors such as public expenditures on education, distance to school and school fees. Since public expenditures on education and human capital are highly correlated, population density serves as a proxy for the cost of education. A higher population density is expected to reduce the distance to school and cost of education. The data are sourced from the World Bank's dataset, World Development Indicators.
- Growth rate of GDP per capita: a higher rate of economic growth allows more resources to be invested in health, education and training which enhance human capital formation. Also, both physical and human capital are key factors of production and economic growth. Therefore, controlling for GDP per capita growth enables us to account for the potential two-way causation between GDP growth and human capital.
- Migration to non-OECD countries: human capital formation of the source country can be affected not only by migration to the OECD countries but also by migration to other non-OECD countries.[19] Our dataset provides the numbers of high-skilled and low-skilled migration to OECD countries only. Since we do not have high-skilled and lower-skilled migration to non-OECD countries, we include total migration from the source country to non-OECD countries in our regressions as a control. The International Migrant Stock (United Nations, 2019) presents estimates of international migrants by age, gender, and origin.
- Democratic institutions: democratic institutions can potentially influence human capital formation in the source countries by changing the returns to education. It is likely that democracy increases the returns to education, as education is a viable channel for social mobility in a democratic state, whereas family connection, personal relationship, party membership, and loyalty are more critical in an undemocratic state. Moreover, democracy has been shown to be an important factor in emigration (Docquier et al., 2016). This variable is measured by a 6-point index, with 6 being the most democratic and 1 the least democratic (International Country Risk Guide).
- Migrant networks: Sjaastad (1962) argues that potential migrants weigh the returns against the costs of migration in making their migration decisions. Migrant networks can reduce the cost of emigration and influence migration incentives (Bertoli & Rapoport, 2015). McKenzie and Rapoport (2010) find positive or education-neutral selection in communities with weak migrant networks but negative self-selection in communities with stronger networks. We use the total number of emigrants from a source country residing in a destination country as a measure of migrant networks.
- Relative earnings inequality: Borjas (1987) finds that relative earnings inequality can directly affect the skill levels of migrants moving to the destination country and indirectly influence human capital formation in the source country. For each unique source–destination country pair, we calculate the variance of the earnings distributions separately for the source and destination countries, based on the income shares of the lowest 20% to the top 20% of the population. We then use the ratio of the variance of the earnings distribution in the destination country to that in the source country as a variable in our regression, capturing the effect of relative earnings inequality for each source–destination pair on human capital formation in the source country. The data on earnings distribution are obtained from the World Development Indicators.

Table 2
Change in Years of Schooling and Expected Returns to Low-skilled Emigration.

Dependent variable is decadal change in average years of schooling				
	(1)	(2)	(3)	(4)
Exp. returns to LS emigration	−2.384**	−2.830**	−3.524*	−3.606*
(x 10,000)	(1.127)	(1.195)	(1.950)	(1.991)
Exp. returns to HS emigration		0.105***	0.120***	0.117***
(x 10,000)		(0.023)	(0.025)	(0.031)
LS emigration rate			2.087	1.364
			(5.018)	(5.132)
HS emigration rate			−1.505***	−0.895***
			(0.439)	(0.336)
Skill premium (‰)				32.871***
				(10.794)
Remittance				1.018***
				(0.039)
Pop. density (x 10,000)				5.303***
				(0.368)
GDP per capita growth				−0.318**
				(0.127)
Initial years of schooling	Yes	Yes	Yes	Yes
Bilateral countries FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	8,736	8,708	8,708	8,176
Within R-sq.	0.73	0.73	0.73	0.75

Notes: Heteroskedastic-robust standard errors clustered at the level of source–destination country pairs are reported in parentheses. * denotes statistical significance at the 10% level, ** at the 5% level, and *** at the 1% level. See the section Data and Variable for details and sources.

6. Baseline results

6.1. Interpretating the baseline results

Table 2 reports the fixed-effects OLS regression results of equation (6) using the change in the average years of schooling as the dependent variable. The coefficient of the expected returns to low-skilled emigration, β_5, is our key interest, as it indicates the effect of the expected

[18] We discuss these assumptions and adjustments in the Appendix.

[19] See Artuc et al. (2015) for a discussion of brain drain in non-OECD countries.

returns to low-skilled emigration on human capital formation of the source countries. In all specifications, we add initial average years of schooling, bilateral country fixed effects and year fixed effects to control for the convergence effect, both observed and unobserved time-invariant bilateral country effects, and the time-varying factors that are common to every pair of bilateral countries, respectively.

The first row of Table 2 reports the coefficient of the expected returns to low-skilled emigration across Column 1 to 4, where control variables are consecutively added to the regression. In Column 1, we include only the expected returns to low-skilled emigration, and its coefficient is −2.384, which is negative and statistically significant. Column 2 further adds the expected returns to high-skilled emigration, Column 3 includes the low-skilled and high-skilled emigration rates, and Column 4 adds skill premium and the baseline controls of remittance, population density and GDP per capita growth. It is noteworthy that our preferred specification is in Column 4 which corresponds to equation (6) and the theoretical discussion in Section 3.[20]

In all columns of Table 2, the coefficient of the expected returns to low-skilled emigration is negative and statistically significant at the conventional levels, but the size of the coefficient varies from −2.384 to −3.606 depending on the specification. For example, in our preferred specification in Column 4, the coefficient is −3.606 for the expected returns to low-skilled emigration, which is statistically significant at the 10% level. This coefficient can be interpreted as the change in the average years of schooling in a source country in the decade following the change in the expected returns to low-skilled emigration. Specifically, since the expected returns to low-skilled emigration has a standard deviation of 0.014, multiplying the standard deviation by the coefficient (0.014 × −3.606) gives us −0.05 years. This represents the impact of one standard deviation change in the expected returns to low-skilled emigration on the average years of schooling in the source countries.

Although the impact of −0.05 years may seem small, its effect on a source country's human capital formation can be substantial, depending on the magnitude of the country's expected returns to low-skilled emigration. To illustrate this, we can examine the bilateral migration from the Philippines to the United States. In 2000, the expected returns to low-skilled emigration from the Philippines to the United States were 0.027, which is about 1.94 standard deviations (0.027/0.014) above the global mean of expected returns to low-skilled emigration. This suggests that the average years of schooling in the Philippines were lowered by about −0.1 years (1.94 × −0.05) in the following decade compared to the rest of the world. While the absolute size of this decrease may seem small, it represents an approximate 17% reduction in the average years of schooling when compared to the actual increase of 0.557 years in the Philippines between 2000 and 2010. This is a significant reduction in human capital stock. In other words, had the Philippines reduced its level of expected returns to low-skilled emigration to the global mean, its average years of schooling would have been about 17% higher from 2000 to 2010. Therefore, a reduction in the expected returns to low-skilled emigration can lead to a substantial long-term increase in human capital formation for a developing country.

In Table 2, the coefficient of the expected returns to high-skilled emigration is positive and highly statistically significant in Columns 3 and 4. This provides strong evidence of the indirect effect of high-skilled emigration, also known as the brain-gain effect, in the sample. Specifically, the coefficient of 0.117 for the expected returns to high-skilled emigration in Column 4 suggests that a one standard deviation (0.1337) increase in the expected returns to high-skilled emigration is estimated to increase the average years of schooling by 0.016 years in the following decade (0.1337 × 0.117).

To illustrate the impact of brain gain on the average years of schooling, we can again examine the bilateral migration from the Philippines to the United States. Given that the Philippines' expected returns to high-skilled emigration in 2000 were 0.3374, which is 2.52 standard deviations above the global mean, the effect of brain gain is estimated to raise the Philippines' average years of schooling by about 0.04 years in the following decade. This increase represents approximately 7% of the actual increase in the average years of schooling in the Philippines, which was 0.557 years between 2000 and 2010.

Therefore, while the emigration of high-skilled Filipinos to the United States generates a positive incentive effect on the Philippines' human capital formation (0.04 years), this positive effect is outweighed by the negative disincentive effect of the prospect of low-skilled emigration to the United States (−0.1 years).

Columns 3 and 4 of Table 2 include both low-skilled and high-skilled emigration rates as separate variables in the regression. These represent the direct effects of low-skilled and high-skilled emigration on human capital formation. In Column 4, the coefficient of low-skilled emigration is 1.364, but is statistically insignificant. In contrast, the coefficient for high-skilled emigration is −0.895, which is highly statistically significant, suggesting that the departure of high-skilled migrants from the source countries directly lowers these countries' human capital formation, as predicted by the brain-drain literature.

In Column 4 of Table 2, the regression includes the baseline control variables of the skill premium, population density, remittances, and GDP per capita growth of the source country. First, we find that the coefficient for skill premium is positive and highly statistically significant (32.871), suggesting that people in the source countries are motivated by the skill premium to pursue higher education and become highly skilled. Second, the coefficient for remittances is positive and highly statistically significant (1.018), indicating that remittances increase educational expenditure and school attendance. This result is consistent

Table 3
Change in Human Capital Index and Expected Returns to Low-skilled Emigration.

Dependent variable is decadal change in human capital index				
	(1)	(2)	(3)	(4)
Exp. returns to LS emigration	−0.800**	−0.745**	−1.098*	−1.021*
(x 10,000)	(0.334)	(0.330)	(0.612)	(0.593)
Exp. returns to HS emigration		−0.013*	−0.009	−0.009
(x 10,000)		(0.007)	(0.006)	(0.008)
LS emigration rate			1.099	0.686
			(1.680)	(1.599)
HS emigration rate			−0.447***	−0.359***
			(0.113)	(0.093)
Skill premium (‰)				−1.696
				(3.735)
Remittance				0.208***
				(0.009)
Pop. density (x 10,000)				−1.435**
				(0.707)
GDP per capita growth				−0.038
				(0.033)
Initial years of schooling	Yes	Yes	Yes	Yes
Bilateral countries FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	5,012	5,012	5,012	4,788
Within R-sq.	0.68	0.68	0.68	0.69

Notes: Heteroskedastic-robust standard errors clustered at the level of source–destination country pairs are reported in parentheses. * denotes statistical significance at the 10% level, ** at the 5% level, and *** at the 1% level. See the section Data and Variable for details and sources.

[20] We have also regressed a specification which includes all the constituent components of the expected returns to low-skilled and high-skilled emigration, i.e., adding the wage income gaps of low-skilled and high-skilled workers between the source and destination countries to the control variables in Column 4. The results of these regressions are very similar to those in Column 4, and therefore we do not report here.

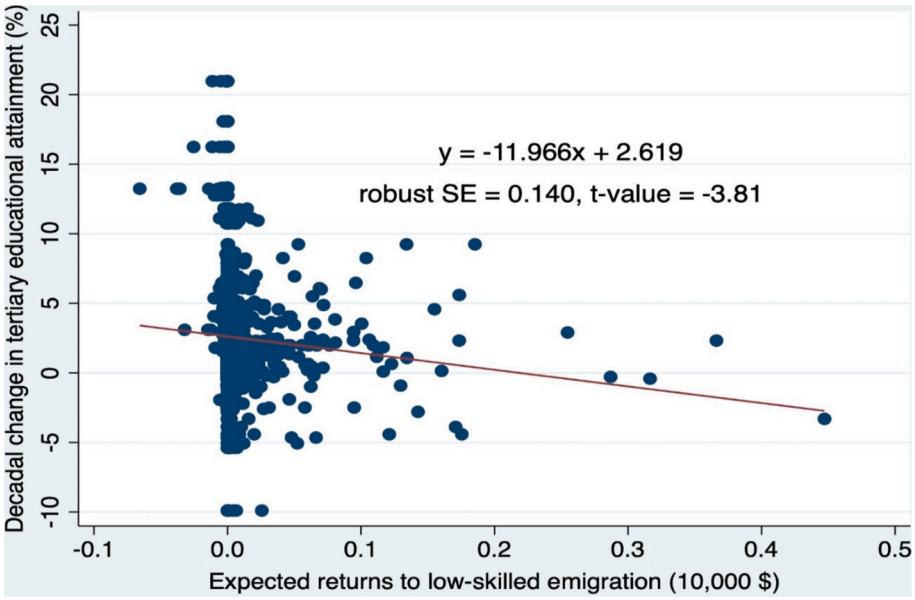

Fig. 3. Tertiary Educational Attainment and Expected Returns to Low-skilled Emigration. Notes: This diagram shows the bivariate correlation between the decadal change in tertiary educational attainment and the expected returns to low-skilled emigration, including observations from all years (1990, 2000, and 2010). The decadal change in tertiary educational attainment represents the change in the proportion of the labour force with tertiary education between 1990 and 2000, 2000 and 2010, and 2010 and 2020. Expected returns to low-skilled emigration are calculated as the product of the emigration rate of low-skilled migrants and the wage income difference for low-skilled workers between destination and source countries, expressed in PPP USD. See the section Data and Variables for details.

with the findings of previous studies that remittances enhance human capital formation in the source countries (Ambler, Aycinena, & Yang, 2015; Yang, 2008). Third, the coefficient for population density is positive and statistically significant (5.303), which aligns with expectations and suggests that the availability of educational resources and opportunities positively affects human capital formation. Finally, the coefficient for GDP per capita growth of the source country is negative and significant (−0.318), implying that a higher GDP growth rate may reduce the cost of job search, leading more people to enter the workforce instead of attending school in the source countries.

Table 2 presents the estimation results of regressions that use the decadal change in the average years of schooling as the dependent variable. However, using the average years of schooling as a measure of a country's overall human capital formation has its limitations, as it does not consider the quality of education or its impact on productivity. Therefore, we adopt the long-run human capital index from Lee and Lee (2016), which is a broader measure of human capital formation because it accounts for both the quantity and quality of education in a source country.

Table 3 presents the estimation results of regressions that use the decadal change in the human capital index as the dependent variable. Except for the coefficients of skill premium and population density, the estimation results in Table 3 are similar to those in Table 2 in terms of their signs and statistical significances. Notably, the coefficient of the expected returns to low-skilled emigration is negative and statistically significant in all columns. In Column 4, our preferred specification, the coefficient of the expected returns to low-skilled emigration is −1.021, which is statistically significant at the 10 % level. This indicates that an increase of one standard deviation in the expected returns to low-skilled emigration is estimated to reduce the human capital index by 0.014 in the following decade.

To illustrate this, we can again examine the bilateral migration from the Philippines to the United States. In 2000, the Philippines was 1.94 standard deviations above the global mean of expected returns to low-skilled emigration, which is estimated to have reduced the Philippines's human capital index by 0.027 (1.94 × −0.014) between 2000 and 2010. The Philippines experienced an actual increase in the human capital index of 0.214 during that period. Therefore, the estimated reduction of 0.027 represents about 12.6% of the increase in the Philippines's human capital index between 2000 and 2010. In other words, had the Philippines reduced its expected returns to low-skilled emigration to the global mean, its human capital index could have increased by approximately 12.6% more.

Table 4
Change in Tertiary Schooling and Expected Returns to Low-skilled Emigration.

Dependent variable is decadal change in tertiary schooling (share of tertiary-educated population)				
	(1)	(2)	(3)	(4)
Exp. returns to LS emigration(x 10,000)	−58.344***	−57.109***	−81.605***	−51.068**
	(13.690)	(13.776)	(24.971)	(20.946)
Exp. returns to HS emigration(x 10,000)		−0.293	−0.264	−0.574
		(0.243)	(0.240)	(0.484)
LS emigration rate			81.212	21.709
			(67.179)	(54.702)
HS emigration rate			−0.088	0.647
			(4.737)	(3.646)
Skill premium (‰)				440.704***
				(96.046)
Remittance				−0.572
				(0.433)
Pop. density(x 10,000)				95.151***
				(3.992)
GDP per capita growth				−4.243***
				(0.781)
Initial years of schooling	Yes	Yes	Yes	Yes
Bilateral countries FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	8,736	8,708	8,708	8,176
Within R-sq.	0.68	0.68	0.68	0.72

Notes: Heteroskedastic-robust standard errors clustered at the level of source–destination country pairs are reported in parentheses. * denotes statistical significance at the 10% level, ** at the 5% level, and *** at the 1% level. See the section Data and Variable for details and sources.

Table 5
Change in Secondary Schooling and Expected Returns to Low-skilled Emigration.

Dependent variable is decadal change in secondary schooling (share of secondary-educated population)				
	(1)	(2)	(3)	(4)
Exp. returns to LS emigration(x10,000)	59.029***	52.837***	76.080**	23.631
	(20.921)	(20.179)	(37.131)	(32.189)
Exp. returns to HS emigration(x 10,000)		1.460**	1.454**	1.858*
		(0.659)	(0.644)	(1.012)
LS emigration rate			−77.388	15.553
			(100.390)	(80.805)
HS emigration rate			−2.212	−5.703
			(7.865)	(7.323)
Skill premium (‰)				167.460
				(165.453)
Remittance				13.095***
				(0.278)
Pop. density (x10,000)				−120.089***
				(5.931)
GDP per capita growth				4.940***
				(1.720)
Initial years of schooling	Yes	Yes	Yes	Yes
Bilateral countries FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	8,736	8,708	8,708	8,176
Within R-sq.	0.72	0.72	0.72	0.72

Notes: Heteroskedastic-robust standard errors clustered at the level of source–destination country pairs are reported in parentheses. * denotes statistical significance at the 10% level, ** at the 5% level, and *** at the 1% level. See the section Data and Variable for details and sources.

Table 6
Change in Primary Schooling and Expected Returns to Low-skilled Emigration.

Dependent variable is decadal change in primary schooling (share of primary-educated population)				
	(1)	(2)	(3)	(4)
Exp. returns to LS emigration (x 10,000)	−2.162	−6.077	18.413	28.667
	(24.617)	(24.837)	(33.287)	(33.534)
Exp. returns to HS emigration (x 10,000)		0.926	0.825	0.676
		(0.656)	(0.616)	(0.954)
LS emigration rate			−80.050	−90.442
			(84.039)	(84.044)
HS emigration rate			7.360	9.290
			(8.557)	(9.376)
Skill premium (‰)				−586.329***
				(140.591)
Remittance				−12.104***
				(0.391)
Pop. density (x 10,000)				60.983***
				(5.561)
GDP per capita growth				5.513**
				(2.145)
Initial years of schooling	Yes	Yes	Yes	Yes
Bilateral countries FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	8,736	8,708	8,708	8,176
Within R-sq.	0.81	0.81	0.81	0.80

Notes: Heteroskedastic-robust standard errors clustered at the level of source–destination country pairs are reported in parentheses. * denotes statistical significance at the 10% level, ** at the 5% level, and *** at the 1% level. See the section Data and Variable for details and sources.

6.2. Mechanism and sample heterogeneity

In this section, we further explore two issues that are crucial to understanding the effect of low-skilled emigration on human capital formation. The first issue is how the expected returns to low-skilled emigration lower the overall human capital formation, as measured by the average years of schooling (Table 2) and the human capital index (Table 3)? The second issue relates to sample heterogeneity: do the baseline results hold for different country income groups, and a sample that excludes those observations capturing the low-skilled emigration of the 2000s?

Fig. 3 visually presents a scatterplot of the relationship between expected returns to low-skilled emigration in 1990, 2000, and 2010 and the subsequent decadal change in tertiary educational attainment. The diagram shows a negative correlation, statistically significant at the 1 % level, between expected returns to low-skilled emigration and the change in tertiary educational attainment in the following decade. This suggests that increases in expected returns to low-skilled emigration are strongly associated with subsequent reductions in tertiary schooling.

In Table 4, where the dependent variable is the change in the proportion of population receiving tertiary schooling, the coefficient of the expected returns to low-skilled emigration ranges from −51.068 to −81.605, all of which are statistically significant at the 5% or 1% level in every column. These results suggest that the expected returns to low-skilled emigration lower the proportion of tertiary-educated population in the subsequent decade. Specifically, using the coefficient of −51.068 for expected returns to low-skilled emigration in Column 4 of Table 4, we calculate that one standard deviation above the mean expected returns to low-skilled emigration leads to a reduction of about 0.715 percentage points in the proportion of tertiary-educated population in the next decade.

To illustrate this, consider the bilateral migration from the Philippines to the United States. In 2000, the proportion of the tertiary-educated population in the Philippines was 25.8%, which dropped to 23.2% in 2010, a decrease of 2.59 percentage points. Our estimates suggest that about 53.6% of this 2.59 percentage points decrease in the tertiary-educated population can be attributed to the Philippines' higher expected returns to low-skilled emigration (0.715 percentage points per SD × 1.94 SD / 2.59 percentage points = 0.536). Thus, the negative impact of expected returns to low-skilled emigration on tertiary education is both substantial and highly statistically significant.

In Table 5, where the dependent variable is the proportion of population that received secondary schooling, the coefficient of the expected returns to low-skilled emigration is positive in all columns, but it is statistically significant at the 5% or 1% level only in Columns 1 to 3, not in Column 4. This indicates a positive effect of expected returns to low-skilled emigration on secondary schooling, but this effect is sensitive to different model specifications. In Table 6, where the decadal change in the proportion of population that received primary schooling is the dependent variable, the coefficient of expected returns to low-skilled emigration is not statistically significant in any columns, suggesting that expected returns to low-skilled emigration have little effect on children receiving primary schooling.

The results from Tables 4–6 provide insights into mechanism through which the expected returns to low-skilled emigration affect the overall human capital formation. The evidence suggests that higher expected returns to low-skilled emigration can deter individuals from pursuing tertiary schooling while encouraging them to complete secondary schooling. Thus, there are both positive and negative effects of expected returns to low-skilled emigration on human capital formation. Most countries worldwide have already implemented at least 7 to 9 years of compulsory education for children (UNESCO, 2015), which explains why the proportion of population receiving primary schooling is not affected by expected returns to low-skilled emigration. Additionally, because many low-skilled jobs in OECD countries require a high school diploma, higher expected returns to low-skilled emigration provide an incentive for those seeking to migrate as low-skilled workers to complete secondary schooling in their home countries. Moreover, the overall effect of expected returns to low-skilled emigration on the average years of schooling and the human capital index is negative because secondary schooling is at least partially included in the national compulsory education system, while tertiary schooling is entirely voluntary in all countries.

Table 7
Sensitivity of the Baseline Results to Sample Heterogeneity.

Dependent variable is change in tertiary schooling	Low-income countries	Middle-income countries	High-income countries	Excluding 2000s
	(1)	(2)	(3)	(4)
Exp. returns to LS emigration(x 10,000)	−11.418	−16.357*	−35.625***	1.885
	(9.961)	(9.475)	(12.732)	(7.077)
Exp. returns to HS emigration(x 10,000)	0.050	−0.335	1.979***	−0.143
	(0.036)	(0.362)	(0.683)	(0.196)
Baseline controls	Yes	Yes	Yes	Yes
Initial tertiary schooling	Yes	Yes	Yes	Yes
Bilateral countries FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	1,008	5,292	3,612	4,704
Within R-sq.	0.69	0.20	0.13	0.24

Notes: All regressions include the baseline control variables (remittance, population density, and GDP per capita growth), low-skilled emigration rate, high-skilled emigration rate, skill premium, and the dependent variable at time *t*. Heteroskedastic-robust standard errors clustered at the level of source–destination country pairs are reported in parentheses. * denotes statistical significance at the 10% level, ** at the 5% level, and *** at the 1% level. See the section Data and Variable for details and sources.

Table 7 reports the regression results of equation (6) using subsamples of low-income countries, middle-income countries, and high-income countries, as well as a sample excluding observations in the 2000s. The dependent variable in Table 7 is the decadal change in the proportion of tertiary-educated population. The results in Columns 1–3 show that the coefficient of expected returns to low-skilled emigration is negative across all country income groups, but it is only statistically significant for middle- and high-income countries, not for low-income countries. The high-income group in Column 3 has the largest coefficient at −35.625, which is statistically significant at the 1% level. For middle-income countries, the coefficient is −16.357, statistically significant at the 10% level. These results indicate that expected returns to low-skilled emigration have the largest effect on high-income countries, followed by the middle-income countries.

In low-income countries, where tertiary education is often unaffordable or unavailable to most of the population, changes in expected returns to low-skilled emigration do not significantly affect human capital formation, as the option to acquire tertiary schooling is not feasible for many. This explains the statistically insignificant coefficient for low-income countries. In contrast, in middle- and high-income countries, where individuals have the option to pursue tertiary schooling, an increase in expected returns to low-skilled emigration reduces the incentive to pursue higher education. As a result, more people may forgo tertiary schooling, leading to lower human capital formation. This explains the larger negative coefficients for middle- and high-income countries.

In Column 4 of Table 7, we further examine the baseline results by including only those bilateral migrations that took place before 2000. Since the shape surge in low-skilled emigration occurred after 2000, the expected return to low-skilled emigration is anticipated to have a weaker effect, if any, on the human capital formation of the source country. The results in Column 4 show that the coefficient of the expected returns to low-skilled emigration is not statistically significant. This suggests that, without the post-2000 surge in low-skilled emigration, the relationship between expected returns to low-skilled emigration and human capital formation in the source country is not observed.

Another interesting result from Table 7 is that the coefficient of the expected returns to high-skilled emigration is positive and highly statistically significant for high-income countries in Column 3 (1.979). This finding provides some support for the brain-gain literature concerning high-income countries: the expected returns to high-skilled emigration increase the incentive for human capital accumulation and enhance the formation of human capital in the source countries.

Table 8
Counterfactual Tests-Trimming 2000's Expected Returns from LS Emigration.

Dependent variable is change in human capital index	No trimming	Trimming 40%	Trimming 50%	Trimming 60%	Trimming 70%
	(1)	(2)	(3)	(4)	(5)
Exp. returns to LS emigration (x 10,000)	−1.021*	−0.543	−0.203	−0.053	0.015
	(0.593)	(0.629)	(0.501)	(0.398)	(0.324)
Exp. returns to HS emigration (x 10,000)	0.068	-0.066	-0.051	-0.034	-0.020
	(0.100)	(0.106)	(0.112)	(0.114)	(0.115)
Baseline controls	Yes	Yes	Yes	Yes	Yes
Initial human capital index	Yes	Yes	Yes	Yes	Yes
Bilateral countries FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	8,176	8,176	8,176	8,176	8,176
Within *R*-sq.	0.69	0.69	0.69	0.69	0.69

Notes: All regressions include the baseline control variables (remittance, population density, and GDP per capita growth), low-skilled emigration rate, high-skilled emigration rate, skill premium, and the dependent variable at time *t*. Any bilateral migrations with the expected return to low-skilled emigration in the 75th percentile or above in 2000s are trimmed. Heteroskedastic-robust standard errors clustered at the level of source–destination country pairs are reported in parentheses. * denotes statistical significance at the 10% level, ** at the 5% level, and *** at the 1% level. See the section Data and Variable for details and sources.

6.3. A counterfactual test: Pinpointing the sources of the low-skilled emigration effect

This study relies on the emigration surge of low-skilled migrants from 2000 onwards to identify the effect of the expected returns to low-skilled emigration on human capital formation of the source country. In this section, we hypothetically reduce the size of the emigration surge of low-skilled migrants in the top migrant-sending countries during the 2000s. By identifying and trimming progressively the extent of those bilateral migrations responsible for the surge, we can observe how the effect of the expected returns to low-skilled emigration on human capital formation of the source country changes.

To implement the counterfactual exercise, we examine the average expected returns to low-skilled emigration from 1990 to 2010 and identify the bilateral migrations responsible for the increase in the average expected returns to low-skilled emigration between 2000 and 2010. We then hypothetically trim the expected returns to low-skilled emigration in the 2000′s for those bilateral migrations in the 75th percentile or above. One such country in this group is El Salvador: it had 505,606 low-skilled migrants in the United States in 2000, which jumped to 908,194 in 2010, an 80% increase over the decade.

Table 8 reports the results of the counterfactual test that progressively trims the strength of the emigration surge of low-skilled migrants of the 2000s. Column 1 reiterates the baseline result from Column 4 of Table 3 that uses the decadal change in human capital index as the dependent variable. It shows that the coefficient of the expected returns to low-skilled emigration is −1.021, statistically significant at the 10% level. Columns 2, 3, 4, and 5 show that when the low-skilled emigration surge of the 2000s is hypothetically trimmed by 40% or more, the

Table 9
Dynamic Panel Model (Arellano and Bond GMM Estimator).

Dependent variable is change in:	Average years of Schooling	Human capital index	Tertiary educational attainment	Secondary educational attainment	Primary educational attainment
	(1)	(2)	(3)	(4)	(5)
Exp. returns to LS emigration	−2.019**	−0.546**	−15.726**	3.451	4.045
	(1.022)	(0.261)	(7.939)	(17.308)	(17.412)
Exp. returns to HS emigration	0.062	0.018	0.625***	−0.439	−0.214
	(0.052)	(0.013)	(0.242)	(0.285)	(0.429)
Baseline controls	Yes	Yes	Yes	Yes	Yes
Bilateral countries FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
AR2 test *p*-value	0.38	0.25	0.51	0.00	0.00
Observations	5,172	4,628	5,172	5,172	5,172

Notes: All regressions include the baseline control variables (remittance, population density, and GDP per capita growth), low-skilled emigration rate, high-skilled emigration rate, skill premium, the dependent variable at time *t*, and its first lag. The AR2 row reports the *p*-value for a test of serial correlation of the residuals. Heteroskedastic-robust standard errors clustered at the level of source–destination country pairs are reported in parentheses. * denotes statistical significance at the 10% level, ** at the 5% level, and *** at the 1% level. See the section Data and Variable for details and sources.

coefficients of the expected return to low-skilled emigration become statistically insignificant. This demonstrates that the disincentive effect of the expected returns to low-skilled emigration on human capital formation disappears when the strength of the emigration surge in the group of the highest bilateral migrations is reduced by 40% or more. For example, El Salvador's human capital index increased by 1.031 between 1990 and 2000, but by only 0.409 between 2000 and 2010. According to the counterfactual test, if El Salvador's emigration of low-skilled migrants to the United States had been reduced by 40% or more in the 2000s, the deterioration in El Salvador's human capital formation could have been avoided.

7. Robustness checks

This section presents the results of various robustness checks on the baseline findings. First, we address the concern that the effects of the expected returns to low-skilled emigration on human capital formation may be subject to endogeneity issues. Second, instead of using the educational attainment of those aged 15 and older for the outcome variable, we use the educational attainment of those who are aged 15 to 24 as the outcome variable. Additionally, we examine whether the effect of the expected returns to low-skilled emigration on tertiary educational attainment remains consistent when we exclude those aged 15 to 18 from the population. Third, we include additional covariates in the baseline regression as controls, specifically, non-OECD migration, migrant networks, democratic institutions, and relative earnings inequality. Fourth, we explore the possibilities that the modest increase in secondary educational attainment in the source countries may be driven by the source countries' efforts to improve secondary educational attainment rather than by the expected returns to low-skilled emigration. Ultimately, our main conclusions are robust across these various checks.

7.1. The dynamic linear panel model (Arellano and Bond GMM estimator)

Our baseline results may be affected by endogeneity issues, including reverse causality and omitted variables. For example, an unexpected positive shock to human capital formation may lead to an increase in the wages of low-skilled workers in the source country, thereby decreasing the low-skilled wage gap between the source and destination countries and reducing the expected returns to low-skilled emigration. Consequently, the negative coefficient of the expected returns to low-skilled emigration in our baseline results may simply reflect this reverse causality.

Considering the dynamic nature of human capital formation and the potential endogeneity of some regressors, we adopt a linear dynamic panel model (DPM) to estimate the effect of expected returns to low-skilled emigration on human capital formation in source countries. The DPM is specified as follows:

$$\Delta H_{i,t+1} = \beta_0 + \beta_1 \Delta H_{i,t} + \beta_2 H_{it} + \beta_3 P^S_{i,j,t} + \beta_4 P^U_{i,j,t} + \beta_5 T^S_{i,j,t} + \beta_6 T^U_{i,j,t} + \beta_7 S_{it} + \beta_8 \boldsymbol{X}_{it} + C_{ij} + Y_t + \mu_{it} \quad (10)$$

where $\Delta H_{i,t}$ is the lag of human capital formation, and the other variables are as defined earlier. Eq. (10) is a linear DPM that assumes the current realizations of the dependent variable are influenced by the past values. This model can be estimated using the Arellano and Bond GMM estimator, which addresses endogeneity by using internal instruments - specifically, lagged values of the dependent and independent variables - to control for unobserved heterogeneity and omitted variable bias.[21]

Table 9 presents the results of the Arellano and Bond GMM estimator. In Column 1, where the dependent variable is the decadal change in the average years of schooling, the coefficient of the expected returns to low-skilled emigration is −2.019, which is statistically significant at the 5% level. The *p*-value of the AR2 test shown in Column 1 is 0.38, indicating that the null hypothesis of no serial correlation in the error terms cannot be rejected. In Columns 2 and 3, where the dependent variables are the decadal change in the human capital index and decadal change in the proportion of tertiary-educated population, the coefficients of the expected returns to low-skilled emigration are −0.546 and −15.726, respectively, both of which are statistically significant at the 5% level.

In Columns 4 and 5, where the dependent variables are the decadal changes in secondary schooling and primary schooling, the coefficients of expected returns to low-skilled emigration are positive but statistically insignificant. Moreover, their AR2 tests for these models reveal that the DPM's assumption of serially uncorrelated error terms is violated, rendering these estimates biased and inconsistent. Therefore, the results suggest that while the effects of expected returns to low-skilled emigration on secondary and primary educational attainments

[21] The standard assumption of a DPM is sequential exogeneity. This means that the idiosyncratic error in each time period is assumed to be uncorrelated with past and present values of the explanatory variables but may be correlated with future values of the explanatory variables. Additionally, under sequential exogeneity, the idiosyncratic error terms are serially uncorrelated. Economically, this assumption requires that current human capital formation does not feedback to current and past expected returns to low-skilled emigration but may influence future expected returns to low-skilled emigration. We believe this assumption is reasonable in our context because any changes in human capital formation would take time to affect wages and therefore unlikely to affect current and past expected returns to low-skilled emigration. Furthermore, the assumption of serial-uncorrelated error terms can be tested.

Table 10
Population Aged 15–24 and Average Years of Schooling.

Dependent variable is decadal change in average years of schooling				
	(1)	(2)	(3)	(4)
Exp. returns to LS emigration (x 10,000)	−0.844 (1.816)	−2.459 (1.648)	−5.685** (2.576)	−6.294** (2.723)
Exp. returns to HS emigration (x 10,000)		0.381*** (0.072)	0.401*** (0.077)	0.390*** (0.089)
LS emigration rate			10.464 (7.557)	11.275 (8.145)
HS emigration rate			−1.602* (0.922)	−0.671 (0.813)
Skill premium (‰)				116.344*** (20.382)
Remittance				1.091*** (0.061)
Pop. density (x 10,000)				9.727*** (0.832)
GDP per capita growth				−1.083*** (0.212)
Initial years of schooling	Yes	Yes	Yes	Yes
Bilateral countries FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	5,824	5,824	5,824	5,432
Within R-sq.	0.71	0.71	0.71	0.75

Notes: The dependent variable is the decadal change in the average years of schooling of people aged 15–24 years old. Heteroskedastic-robust standard errors clustered at the level of source–destination country pairs are reported in parentheses. * denotes statistical significance at the 10% level, ** at the 5% level, and *** at the 1% level. See the section Data and Variable for details and sources.

Table 11
Population Aged 19 or Older and Tertiary Schooling.

Dependent variable is change in tertiary schooling in the population aged 19 or above				
	(1)	(2)	(3)	(4)
Exp. returns to LS emigration (x 10,000)	−63.288*** (14.899)	−62.031*** (15.009)	−88.934*** (26.304)	−49.595** (22.389)
Exp. returns to HS emigration (x 10,000)		−0.299 (0.265)	−0.255 (0.259)	−0.233 (0.364)
LS emigration rate			89.005 (70.639)	13.738 (60.960)
HS emigration rate			−1.305 (4.846)	−2.950 (3.600)
Skill premium (‰)				695.069*** (100.499)
Proportion of pop. aged 15 - 19 (%)				−0.855*** (0.079)
Remittance				−1.563*** (0.467)
Pop. density (x 10,000)				97.914*** (4.062)
GDP per capita				−5.823*** (0.866)
Initial tertiary schooling	Yes	Yes	Yes	Yes
Bilateral countries FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	5,824	5,824	5,824	5,432
Within R-sq.	0.68	0.68	0.68	0.73

Notes: The dependent variable is the decadal change in the proportion of tertiary-educated population who are at least 19 years old. Heteroskedastic-robust standard errors clustered at the level of source–destination country pairs are reported in parentheses. * denotes statistical significance at the 10% level, ** at the 5% level, and *** at the 1% level. See the section Data and Variable for details and sources.

are positive, they are imprecisely estimated.

In sum, this section finds that the expected returns to low-skilled emigration exert a negative causal effect on the decadal changes in the average years of schooling, the human capital index, and the proportion of tertiary-educated population. However, for the proportions of the secondary-educated and primary-educated populations, the positive coefficients of the expected returns to low-skilled emigration are imprecisely estimated. Additionally, the estimated coefficients from the fixed-effects OLS estimator are larger than those from the Arellano and Bond GMM estimator, indicating that endogeneity biases the fixed-effects OLS estimates upward. Despite their smaller coefficients, the highly statistically significant GMM estimates in Columns 1 to 3 of Table 9 indicate that the relationship between the expected returns to low-skilled emigration and human capital formation remains robust even after addressing endogeneity concerns.

7.2. *Educational attainment for different age groups as outcome variable*

The outcome variables in our baseline regressions are different measures of educational attainment for people aged 15 and above. However, most people acquire their formal education when they are young and do not typically adjust their formal education later in life. Therefore, our outcome variables of educational attainment for people aged 15 and above may potentially capture effects of different age pyramids, death, and emigration. We now look at educational attainment of young people who are between the age of 15 and 24 as our outcome variable and examine whether the baseline results hold for this age group.

Table 10 presents the results of the robustness check using the decadal change in the average years of schooling for people aged 15 to 24 as the outcome variable. While the coefficient of expected returns to low-skilled emigration is not statistically significant in Columns 1 and 2, it becomes statistically significant at the 5% level in Columns 3 and 4. In Column 4, our preferred specification, the coefficient of expected returns to low-skilled emigration is −6.294, which is statistically significant at the 5% level. These results suggest that expected returns to low-skilled emigration tend to reduce the overall years of schooling not only for the population aged 15 and above, but also for the youth population aged 15 to 24.

Another concern is that using the population aged 15 and above in the analysis of tertiary educational attainment can be problematic because it includes individuals who are “too” young to attend tertiary institutions. For example, if the relative size of the 15–18 age group increases during the sample period, using the population aged 15 and above to examine the effect of expected returns to low-skilled emigration on tertiary educational attainment may introduce a downward bias in the result. To avoid this potential pitfall, we exclude those aged 15 to 18 from the population and add the proportion of people aged 15 to 18 as a control variable in the regression to account for its potential effect on tertiary educational attainment.

Table 11 presents the results of using the proportion of people aged 19 and above who have a tertiary education as the dependent variable. The first row of Table 11 reports the coefficient of the expected returns to low-skilled emigration, which is negative and statistically significant across all columns. In Column 4, our preferred specification, the coefficient is −49.595, which is statistically significant at the 5% level. It is also noteworthy that the coefficient of −49.595 is similar to that in Column 4 of Table 4, where the population includes people aged 15 to 18 (−41.810). Additionally, in Column 4, the coefficient of the proportion of population aged 15 to 18 is negative and highly significant (−0.611), suggesting that an increase in the relative size of this age group negatively affects tertiary educational attainment, which is consistent with our expectation.

Table 12
Controlling for Additional Covariates.

Dependent variable is change in human capital index	+Non-OECD migration	+Migrant networks	+Democratic Institutions	+Relative earnings inequality
	(1)	(2)	(3)	(4)
Exp. returns- LS emigration	−1.378*	−1.694*	−1.506**	−4.291**
	(0.831)	(0.886)	(0.740)	(1.696)
Exp. returns- HS emigration	0.040	0.058	0.073	0.090
	(0.098)	(0.109)	(0.090)	(0.302)
Non-OECD migration	0.034***			
	(0.012)			
Migrant networks		−0.010		
		(0.010)		
Democratic institutions			0.010***	
			(0.004)	
Relative earnings inequality				−0.204
				(0.145)
Initial human capital index	Yes	Yes	Yes	Yes
Baseline controls	Yes	Yes	Yes	Yes
Bilateral countries FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	4,104	2,252	3,944	1,318
Within *R*-sq.	0.55	0.53	0.55	0.61

Notes: All regressions include the baseline control variables (remittance, population density, and per capita GDP growth), low-skilled emigration rate, high-skilled emigration rate, skill premium, and the dependent variable at time *t*. Both non-OECD migration and migrant networks are expressed in logarithmic form. Heteroskedastic-robust standard errors clustered at the level of source–destination country pairs are reported in parentheses. * denotes statistical significance at the 10% level, ** at the 5% level, and *** at the 1% level. See the section Data and Variable for details and sources.

7.3. Additional control variables

The baseline regression includes only skill premium, remittance, population density and GDP per capita growth of the source country as control variables because we aimed to closely follow the standard controls used in the existing literature. In this section, we introduce additional variables that could potentially affect the human capital formation of the source country: emigration to non-OECD countries, migration networks, democratic institutions, and relative earnings inequality. This allows us to check the robustness of the baseline results.

The DIOC dataset provides the numbers of migrants by educational attainment living in OECD countries only and does not include migrants living in non-OECD countries.[22] However, the prospect of emigration to non-OECD countries can also influence human capital formation in the source country, making it essential to control for this factor. The United Nations' International Migration Stock (2019) provides estimates of international migrants by age, gender, and origin, but not by educational attainment, so that we can only add the total number of migrants to non-OECD countries as a control. Since we do not know the educational attainment of these migrants, we are unable to separate the effects of low-skilled and high-skilled emigration to non-OECD countries.

Table 12 presents the results when additional control variables are included in the baseline regression, where the dependent variable is the decadal change in the human capital index. Column 1 of Table 12 shows that adding emigration to non-OECD countries does not change the sign or statistically significance of the coefficient of the expected returns to low-skilled emigration, which is −1.378. The coefficient of non-OECD emigration is 0.034, which is statistically significant at the 1% level, suggesting that emigration to non-OECD countries positively impacts human capital formation in the source country.

Another potential covariate of human capital formation is migrant networks. McKenzie and Rapoport (2010) find that migrant networks play an important role in affecting migration incentives at different education levels: stronger networks, which represent lower migration costs, lead to a self-selection of low-skilled into migration (negative self-selection), while weaker networks, representing higher migration costs, lead to a self-selection of high-skilled into migration (positive self-selection). Therefore, migrant networks can directly affect migration costs and incentives and indirectly affect self-selection into migration and human capital formation.

We include the variable for migrant networks, measured by the total number of migrants from a source country living in a destination country, in the baseline regression. Column 2 of Table 12 reports the result when migrant networks are added to the baseline regression. The coefficient of the expected returns to low-skilled emigration remains negative and statistically significant at the 10% level (−1.694). The coefficient of migrant networks is −0.010, which is imprecisely estimated, suggesting that the indirect effect of migrant networks on human capital formation is not observable in the sample.

Democratic institutions can potentially affect human capital formation in source countries by altering the returns to education. In a democratic state, education is likely to be a viable channel for social mobility, whereas in an undemocratic state, factors like family connections, personal relationships, party membership, and loyalty may play a more significant role. Additionally, democracy has been shown to be an important factor for emigration (Docquier et al., 2016). The result in Column 3 of Table 9 shows that the coefficient of democratic institutions is 0.010, statistically significant at the 1% level. This finding aligns with our expectations and with the results of Baum and Lake (2003), which suggest that human capital formation is higher in more democratic states compared to the less democratic ones. The coefficient of the expected returns to low-skilled migration remains similar to the baseline result at −1.506, statistically significant at the 5% level.

Borjas (1987) argues that low-skilled individuals are more likely to self-select into migration from countries with high skill premia and earnings inequality to countries with low skill premia and earnings inequality. However, Chiquiar and Hanson (2005) provide contrasting evidence, showing that Mexican migrants to the United States came from the middle of Mexico's earnings distribution. Borjas and Bratsberg (1994) examine the factors influencing immigrants in the United States returning to their home countries and find that immigrants from wealthy neighbouring countries are more likely to return home. These studies suggest that the earnings distribution of the source country relative to that of the destination country can affect the skill levels of migrants and their likelihood of remaining in the destination country.

To control for the effect of relative earnings inequality on human capital formation in the source countries, we calculate the variances of the earnings distributions of the source and destination countries based on the income shares of the lowest 20% to the top 20% of the population. We then add the ratio of the variance of the earnings distribution of the destination country to that of the source country in the regression. In Column 4 of Table 12, the coefficient of the relative earnings inequality is −0.204, which is not statistically significant at the conventional levels. However, the coefficient of the expected returns to low-skilled emigration is negative and statistically significant at the 5% level.

In sum, we conclude that adding non-OECD emigration, migrant networks, democratic institutions, and relative earnings inequality to the baseline controls does not seem to alter the disincentive effect of the expected returns to low-skilled emigration on human capital formation

[22] The DIOC-E dataset contains information on the skill levels of immigrants in both OECD and non-OECD countries. However, since the dataset starts in 2000, it does not allow us to observe the effects of the migration surge that occurred before and after the 2000s.

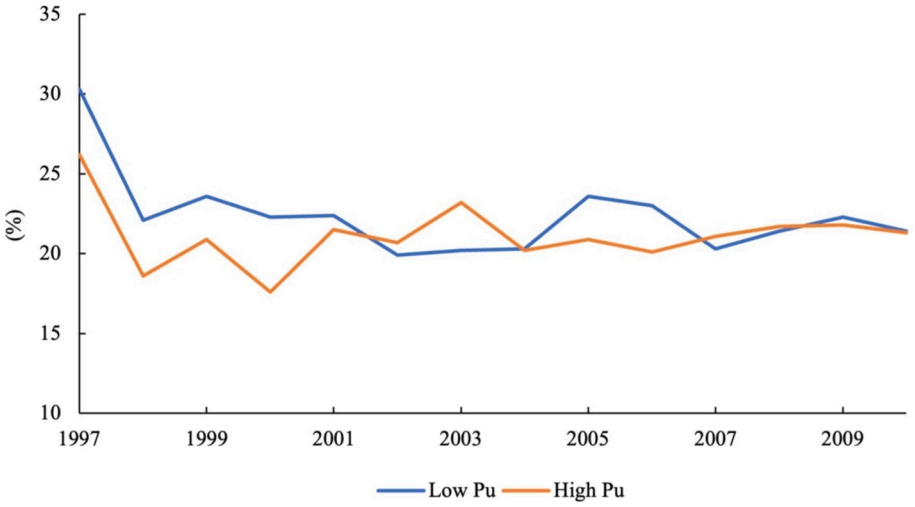

Fig. 4. Government Expenditure per Secondary Student (% of GDP per capita).
Source: World Development Indicator (World Bank). Note: High Pu refers to those countries with the total low-skilled emigration rate in the top 25%

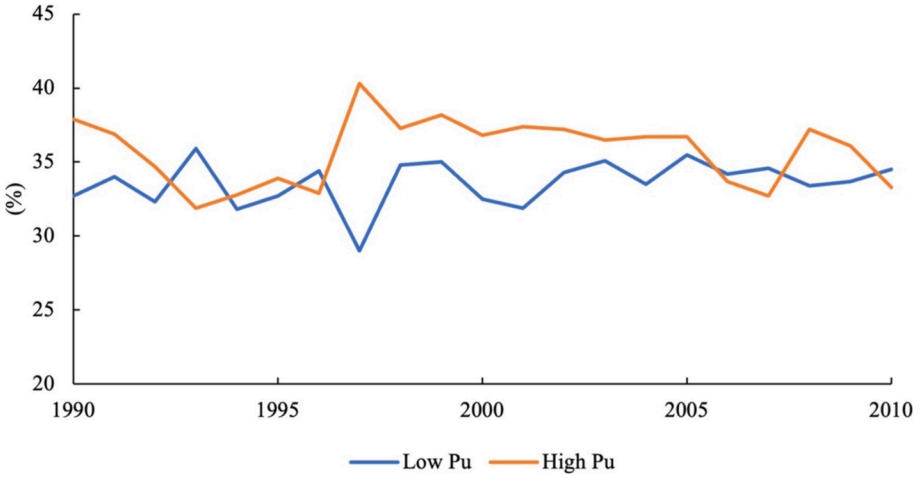

Fig. 5. Expenditure on Secondary Education (% of Government Expenditure on Education) .
Source: World Development Indicator (World Bank). Note: High Pu refers to those countries with the total low-skilled emigration rate in the top 25%

in the source countries.[23]

7.4. Do the results simply reflect better provision of secondary education?

Our results in Table 5 provide some evidence that the prospect of low-skilled emigration increases the proportion of population received secondary schooling in the subsequent decade. Since many OECD countries require a high-school certificate for low-skilled emigration,[24] these results can be interpreted as the incentive effect of the prospect of low-skilled emigration on human capital formation in the source countries. However, it is possible that the increase in secondary educational attainment of the source country is not related to the prospect of low-skilled emigration but simply reflects the source country's effort in improving secondary educational attainment of the country over time.

To address this concern, we examine whether there have been increasing investments in secondary education during the 2000s in countries with high rates of low-skilled emigration. We also compare the differences in secondary education expenditures between countries with low and high rates of low-skilled emigration. If countries with high rates of low-skilled emigration have experienced little increase in secondary education expenditures over the 1990s and 2000s, and if their expenditures are similar to those of countries with low rates of low-skilled emigration, then it is unlikely that their improvement in secondary educational attainment is due to increased investment in secondary schooling.

Fig. 4 illustrates that government expenditure per secondary student has hovered around 20–25% of GDP per capita since the late 1990s for countries with both high and low emigration rates of low-skilled migrants. This provides evidence that there were no substantial increases in government expenditures on secondary education over the sample period for either group of countries. In fact, the figure shows a marked decline in government expenditure on secondary education per student in the late 1990s.

Fig. 5 shows the expenditure on secondary education as a percentage of total government expenditure on education. Again, the figure demonstrates that the share of government expenditure on secondary

[23] We also regress all four additional control variables as well as the baseline control variables in the regression. After adding all these control variables in the regression, the number of observations is reduced to only 682. We find that the coefficient of the expected returns to low-skilled emigration is no longer statistically significant in this very small sample.

[24] For example, Canadian Provincial Nominee Programs and the United States' Diversity Visa (Green Card Lottery).

schooling remained relatively constant throughout the sample period for both groups of countries. Thus, there is little evidence to suggest that countries with high rates of low-skilled emigration shifted resources from other levels of education to secondary schooling.

In sum, based on Figs. 3 and 4, it is difficult to conclude that the modest improvement in secondary educational attainment in countries with high rates of low-skilled emigration can be attributed to increased government investment in secondary education.

8. Conclusion

We set out in this paper to investigate empirically how low-skilled emigration affects the welfare of those who remain in the migrant-sending countries. This question has received little attention in the existing international migration literature. The neglect is partly justified by the small emigration rate of low-skilled migrants relative to that of high-skilled migrants, and partly by the view that low-skilled emigration can only benefit the source countries. This paper exploits a sharp surge of low-skilled migrants in OECD countries in the 2000s to address this research gap. We hypothesize that the prospect of low-skilled emigration creates a disincentive effect on human capital formation for potential migrants in the source countries and tests this hypothesis by using a large sample of bilateral migration panel data.

Our main results suggest that the expected returns to low-skilled emigration reduces the average years of schooling and the long-run human capital index of the source countries in the subsequent decade. This negative effect on overall human capital formation is manifested through a substantial reduction in tertiary educational attainment, which is statistically significant and robust to various sensitive tests and different model specifications. There is also some evidence suggesting that the expected returns to low-skilled emigration are positively associated with secondary educational attainment. An important qualification is that only middle- and high-income countries are strongly affected by the emigration of low-skilled workers, while low-income countries showing little to no disincentive effect. Moreover, a caveat of the above results is that the disincentive effect of low-skilled emigration is likely to be noticeable, and hence relevant, only for source countries that experience large outflows of low-skilled migrants.

Our findings can have important policy implications. For high-income OECD countries, policy changes that allow large inflows of low-skilled migrants may have unintended negative effect on human capital formation in the source countries. Particularly, high-income countries with increasingly aging populations are becoming more reliance on migrants to perform low-skilled services and thus are likely to relax their migration policies towards low-skilled migrants.[25] Japan, for example, has introduced the Special Skilled Worker Scheme in 2019 to import 350,000 migrants to work in primarily low-skilled industries. Such a new policy may lead to a worsening of human capital formation in a particular source country, and thus its implementation should be carefully considered. For developing migrant-sending countries, sending low-skilled migrants overseas has the benefits of reducing unemployment, increasing remittances, and stimulating the local economy. However, human capital is one of the most important factors of long-run economic growth, and if its formation is compromised by the prospect of low-skilled emigration, these developing countries may end up with lower growth trajectories that potentially prevent them from escaping the "middle-income trap".

CRediT authorship contribution statement

Sam Hak Kan Tang: Writing – original draft, Project administration, Formal analysis, Conceptualization. **Yichen Wang:** Writing – review & editing, Validation, Investigation, Data curation. **Yong Wang:** Writing – review & editing, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We extend our heartfelt gratitude to the Associate Editor, Christelle Dumas, and the two anonymous referees for their invaluable feedback, which significantly improved this paper. We are also grateful to David McKenzie, Dean Yang, and Harry Bloch for their insightful suggestions on an earlier version of this paper. Additionally, we thank the seminar participants at the Economics Department of the University of Western Australia, the Crawford School of Public Policy at Australian National University, and the attendees of the 11th Hong Kong Economic Association Biennial Conference for their constructive comments. Special thanks go to Harry Bloch and Yixiao Zhou for providing their cross-country skill-specific wage dataset.

Appendix 1

Table A1
Top Ten Migrant-Sending Countries and Their Emigration Rates.

1990				2000				2010			
Country	N (1,000)	HS (%)	LS (%)	Country	N (1,000)	HS (%)	LS (%)	Country	N (1,000)	HS (%)	LS (%)
UK	2,876	16.1	4.6	Mexico	6,435	12.7	10.3	Mexico	9,565	5.9	13.7
Mexico	2,687	9.8	5.8	UK	2,995	14.4	4.2	UK	3,287	10.6	4.8
Italy	2,557	11.1	5.5	Italy	2,357	9.7	4.7	India	3,198	2.9	0.2
Germany	2,274	9.4	2.7	Germany	2,337	7.9	2.6	Germany	2,866	7.8	3.2
Turkey	1,386	3.0	6.0	Turkey	1,972	4.4	5.4	Poland	2,852	15.2	7.3
Portugal	1,059	12.4	15.7	India	1,697	2.1	0.2	China	2,840	2.8	0.2
Poland	1,015	18.6	2.7	Philippines	1,670	8.9	1.7	Philippines	2,651	10.4	2.5

(*continued on next page*)

[25] The reliance on low-skilled migrants in the United States can be summed up by a New York Times article titled "The Danger From Low-Skilled Immigrants: Not Having Them" by Eduardo Porter (August 8, 2017): "Ten years from now, there are going to be lots of older people with relatively few low-skilled workers to change their bedpans," said David Card, a professor of economics at the University of California, Berkeley. "That is going to be a huge problem.".

Table A1 (*continued*)

1990				2000				2010			
Country	N (1,000)	HS (%)	LS (%)	Country	N (1,000)	HS (%)	LS (%)	Country	N (1,000)	HS (%)	LS (%)
Philippines	1,000	9.2	1.3	China	1,639	1.7	0.1	Turkey	2,381	5.1	4.9
India	969	2.1	0.2	Portugal	1,211	13.1	15.7	Italy	2,189	7.3	4.1
China	862	2.2	0.1	Poland	1,133	13.6	2.5	Morocco	2,066	17.0	15.6

Notes: Vietnam is ranked ninth in 2000 with a total of 1,258,936 migrants, but it is not listed above because the emigration rates of high-skilled and low-skilled migrants are unavailable. N denotes the number of migrants in 1,000. HS denotes the emigration rate of high-skilled migrants and LS the emigration rate of low-skilled migrants in percentage. Emigration rates are calculated by dividing the total number of migrants of a certain skill level by the total number of migrants of that skill level in the source country. See the section Data and Variables for further details and sources.

Table A2
Can the High-skilled Emigration Rate Predict Low-skilled Emigration Rate?

	The dependent variable is the low-skilled emigration rate		
	(1)	(2)	(3)
High-skilled emigration rate	0.034***	−0.001	−0.001
	(0.007)	(0.002)	(0.003)
Baseline controls	No	No	Yes
Bilateral countries FE	No	Yes	Yes
Year FE	No	Yes	Yes
Observations	13,456	13,456	12,238

Notes: Baseline controls include remittances, population density and per capita GDP growth. Heteroskedastic-robust standard errors clustered at the level of source–destination country pairs are reported in parentheses. * denotes statistical significance at the 10% level, ** at the 5% level, and *** at the 1% level. See the section Data and Variable for details and sources.

Appendix 2

The wage ratio between high-skilled and low-skilled workers (ω_i)

The wage ratio between high-skilled and low-skilled workers, ω_i, in the source countries are calculated using the Purchasing Power Parity (PPP)-adjusted hourly real wage rates of low-skilled and high-skilled workers obtained from Zhou and Bloch (2019). Using data from the Socio-Economic Accounts (SEA) of the World Input-Output Database (WIOD), Zhou and Bloch (2019) estimate the real hourly wage rates of high-skilled, medium-skilled, and low-skilled workers for 1995 and 2008.

Before we can use the hourly real wage rates of Zhou and Bloch (2019), we need to make certain assumptions and adjustments to harmonize the wage data with those of the emigration rates. First, we define the hourly real wage rates of low-skilled workers as the average hourly real wage rates of low- and medium-skilled workers. Second, we assume that the hourly real wage rates of 1990 are the same as those of 1995 and that the hourly real wage rates of 2010 are the same as those of 2008. Moreover, we assume that the hourly real wage rates of 2000 are the average of those of 1995 and 2008. Third, because the WIOD provides data for only 40 major countries in the world, we estimate the hourly real wage rates for those countries not included in the WIOD dataset by regressing the equation: $Wage_i = \beta_0 + \beta_1 PCGDP_i + \beta_2 DMS + \beta_3 DHS + \beta_4 D2008 + \mu_i$, where *Wage* is hourly real wage rate for country *i*, *PCGDP* is per capita GDP, *DMS* is a dummy variable for medium-skilled workers, *DHS* is a dummy variable for high-skilled workers, and a dummy variable for 2008.

Data availability

The authors do not have permission to share data.

References

Ambler, K., Aycinena, D., & Yang, D. (2015). Channeling remittances to education: A field experiment among migrants from El Salvador. *American Economic Journal: Applied Economics, 7*, 207–232.

Arslan, Cansin, Jean-Christophe Dumont, Zovanga Kone, Yasser Moullan, Caglar Ozden, Christopher Parsons, & Theodora Xenogiani. (2015). *A new profile of migrants in the aftermath of the recent economic crisis*. OECD Social, Employment and Migration Working Papers No. 160.

Artuc, E., Docquier, F., Özden, Ç., & Parsons, C. (2015). A Global Assessment of Human Capital Mobility: The Role of Non-OECD Destinations. *World Development, 65*, 6–26.

Barro, R. J., & Lee, J. W. (2013). A new data set of educational attainment in the world, 1950–2010. *Journal of Development Economics, 104*, 184–198.

Barro, R. J., & Lee, J.-W. (2015). *Education matters: Global schooling gains from the 19th to the 21st century*. Oxford University Press.

Baum, M. A., & Lake, D. A. (2003). The political economy of growth: Democracy and human capital. *American Journal of Political Science, 47*, 333–347.

Beine, M., Docquier, F., & Oden-Defoort, C. (2011). A panel data analysis of the brain gain. *World Development, 39*, 523–532.

Beine, M., Docquier, F., & Rapoport, H. (2001). Brain drain and economic growth: Theory and evidence. *Journal of Development Economics, 64*, 275–289.

Beine, M., Docquier, F., & Rapoport, H. (2008). Brain drain and human capital formation in developing countries: Winners and losers. *The Economic Journal, 118*, 631–652.

Bertoli, S., & Rapoport, H. (2015). Heaven's swing door: Endogenous skills, migration networks, and the effectiveness of quality-selective immigration policies. *The Scandinavian Journal of Economics, 117*, 565–591.

Bhagwati, J., & Hamada, K. (1974). The brain drain, international integration of markets for professionals and unemployment: A theoretical analysis. *Journal of Development Economics, 1*, 19–42.

Bhagwati, J., & Rodriguez, C. (1975). Welfare-theoretical analyses of the brain drain. *Journal of Development Economics, 2*, 195–221.

Blanco-Álvarez, Jose, Christopher Parsons, Sam H.K. Tang, & Yong Wang. (2022). *Brain Refrain and Human Capital Formation in Spain*. IZA Institute of Labor Economics, 15400.

Borjas, G. J. (1987). Self-selection and the earnings of immigrants. *The American Economic Review, 77*, 531–553.

Borjas, G. J., & Bratsberg, B. (1994). Who leaves? The outmigration of the foreign-born. *The Review of Economics and Statistics, 78*, 165–176.

Brücker, Herbert, Stella Capuano, & Abdeslam Marfouk. (2013). *Education, gender and international migration: insights from a panel-dataset 1980-2010*. Technical report, mimeo.

Chiquiar, D., & Hanson, G. H. (2005). International migration, self-selection, and the distribution of wages: Evidence from Mexico and the United States. *Journal of Political Economy, 113*, 239–281.

Clark, X., Hatton, T. J., & Williamson, J. G. (2007). Explaining U.S. Immigration. *Review of Economics and Statistics, 89*, 359–373.

Commander, Simon, Mari Kangasniemi, & L. Alan Winters. (2004). *The brain drain: curse or boon? A survey of the literature, Challenges to globalization: Analyzing the economics 235–278*.

Commander, S., Nikolaychuk, O., & Vikhrov, D. (2013). *Migration from Ukraine: Brawn or Brain?* (p. 7348) IZA Discussion Paper No: New Survey Evidence.
De Brauw, Alan, & Giles, John (2017). Migrant opportunity and the educational attainment of youth in rural China. *Journal of Human Resources, 52*, 272–311.
Dinkelman, T., & Mariotti, M. (2016). The long-run effects of labor migration on human capital formation in communities of origin. *American Economic Journal: Applied Economics, 8*, 1–35.
Docquier, F., Lodigiani, E., Rapoport, H., & Schiff, M. (2016). Emigration and democracy. *Journal of Development Economics, 120*, 209–223.
Docquier, F., Lowell, B. L., & Marfouk, A. (2009). A gendered assessment of highly skilled emigration. *Population and Development Review, 35*, 297–321.
Docquier, F., & Rapoport, H. (2012). Globalization, brain drain, and development. *Journal of economic literature, 50*, 681–730.
Dustmann, C., & Glitz, A. (2011). Migration and education. *Handbook of the Economics of Education, 4*, 327–439.
Gibson, J., & McKenzie, D. (2011). Eight questions about brain drain. *Journal of Economic Perspectives, 25*, 107–128.
Grubel, H. B., & Scott, A. D. (1966). The international flow of human capital. *The American Economic Review, 56*, 268–274.
Hanson, G. H. (2010). International migration and the developing world. *Handbook of development economics, 5*, 4363–4414.
Hanson, G., Liu, C., & McIntosh, C. (2017). *The rise and fall of us low-skilled immigration.* National Bureau of Economic Research: Technical report.
Johnson, Jesse Harlan, 1967, Harvest migration from nineteenth-century Ireland, Transactions of the Institute of British Geographers, 97-112.
Lee, J.-W., & Lee, H. (2016). Human capital in the long run. *Journal of Development Economics, 122*, 147–169.
Leopold, S., Ruhose, J., & Wiederhold, S. (2024). *Why is the Roy–Borjas model unable to predict international migrant selection on education?* The World Economy: Evidence from urban and rural Mexico. forthcoming.
Mayda, A. M. (2010). International migration: A panel data analysis of the determinants of bilateral flows. *Journal of Population Economics, 23*, 1249–1274.
McCulloch, R., & Yellen, J. L. (1977). Factor mobility, regional development, and the distribution of income. *Journal of Political Economy, 85*, 79–96.
McKenzie, D., & Rapoport, H. (2010). Self-selection patterns in Mexico-US migration: The role of migration networks. *Review of Economics and Statistics, 92*, 811–821.
McKenzie, D., & Rapoport, H. (2011). Can migration reduce educational attainment? evidence from Mexico. *Journal of Population Economics, 24*, 1331–1358.
Mountford, A. (1997). Can a brain drain be good for growth in the source economy? *Journal of Development Economics, 53*, 287–303.
OECD. (2008). *International Migration Outlook 2008.*
Ozden, C., Packard, M., & Wagner, M. (2017). International migration and wages. *Revue d'économie du développement, 31*, 93–133.
Rapoport, H., & Docquier, F. (2006). The economics of migrants' remittances. *Handbook of the economics of giving, altruism and reciprocity, 2*, 1135–1198.
Schiff, M., et al. (2005). *International migration, remittances, and the brain drain.* World Bank Publications.
Sjaastad, L. A. (1962). The costs and returns of human migration. *Journal of Political Economy, 70*, 80–93.
Stark, O., & Byra, L. (2012). A back-door brain drain. *Economics Letters, 116*, 273–276.
Stark, O., Helmenstein, C., & Prskawetz, A. (1997). A brain gain with a brain drain. *Economics letters, 55*, 227–234.
Stark, O., & Wang, Y. (2002). Inducing human capital formation: Migration as a substitute for subsidies. *Journal of Public Economics, 86*(1), 29–46.
Theoharides, C. (2020). The unintended consequences of migration policy on origin country labor market decisions. *Journal of Development Economics, 142*, Article 102271.
Vidal, J.-P. (1998). The effect of emigration on human capital formation. *Journal of Population Economics, 11*, 589–600.
Yang, D. (2008). International migration, remittances and household investment: Evidence from philippine migrants' exchange rate shocks. *The Economic Journal, 118*, 591–630.
Yang, Dean. (2009). *International migration and human development.*
Zhou, Y., & Bloch, H. (2019). Wage convergence and trade. *The World Economy, 42*, 988–1011.