Immigration and Economic Growth in the OECD Countries 1986-2006

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Abstract

This paper offers a reappraisal of the impact of migration on economic growth for 22 OECD countries between 1986-2006 and relies on a unique data set we compiled that allows us to distinguish net migration of the native - and foreign - born populations by skill level. Specifically, after introducing migration in an augmented Solow-Swan model, we estimate a dynamic panel model using a system of generalized method of moments (SYS-GMM) to address the risk of endogeneity bias in the migration variables. Two important findings emerge from our analysis. First, there exists a positive impact of migrants' human capital on GDP per capita, and second, a permanent increase in migration flows has a positive effect on GDP per worker. Moreover, the growth impact of immigration is high even in countries that have non-selective migration policies.

Keywords

Immigration ; Growth ; Human capital ; Generalized Methods of Moments.

JEL codes

C23, F22, J24, J61, O41, O47

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1 Introduction

International migration to OECD countries, notably labour migration, has increased significantly over the past decades. Between 1997 and 2007, in most southern European countries, the United Kingdom, the United States, and several Nordic countries, immigrants contributed to more than 40% of net job creation. In 2007, the share of immigrants in employment reached 12% on average in OECD countries (OECD, 2009). In many developed countries, the first effects of population ageing can already be felt within the working age population as baby boomers begin to retire in large numbers while younger cohorts are still too few to replace them. In this context, labour migration will continue to play a significant role over the medium and long term. Specifically, international migration is expected to account for all labour force growth between 2005 and 2020 in the OECD area as a whole.

At the same time, many countries have recently adapted their migration systems to make them more selective vis-à-vis skills and education. The traditional settlement countries (Australia, Canada, New Zealand, and the United States) have relied on skills-based migration programmes for a long time, which now serve as models to other countries. The United Kingdom, Denmark, and the Netherlands have recently instituted reforms to prioritize highly educated migrants through a points-based migration system. Furthermore, the European Union has adopted a new directive, the *European Blue Card*, to attract highly qualified migrants to the European labour market. This directive does not prevent EU Member States from maintaining their own systems of national residence permits for highly skilled migrants, but such national permits cannot grant the right of residence in other EU Member States as is guaranteed under the Blue Card Directive. Accordingly, most European countries have also implemented specific migration programmes to attract highly skilled foreign workers. For instance, Austria adopted a points-based immigration scheme, the Red-White-Red Card, in July 2011. This system aims to attract highly qualified persons and skilled workers in shortage occupations who wish to settle, with their families, permanently in Austria. Additionally, the United Kingdom changed its points system in 2011 to increase selectivity. The highly skilled migrant programme has been replaced by an 'Exceptional Talent' visa for applicants who are 'internationally recognised leaders or emerging leaders' in their fields. This trend is likely to continue, and may even be reinforced, in the future.

These changes in migration trends and policies prompted us to reconsider the economic impact of migration. Empirical economic analyses have been flourishing in recent years in two key areas that are likely to influence public opinion on migration, namely, the labour market (Borjas, 2003; Angrist and Kugler, 2003) and the fiscal effects of immigration (Auerbach and Oreopoulos, 1999; Storesletten, 2000; Rowthorn, 2008). However, debate is relatively quiet regarding a third major area of interest: the impact of migration on economic growth. This is precisely the question addressed by this paper.

Although there are few doubts about the impact of a labour shock due to migration on aggregate GDP, the effect is less obvious with regard to per capita GDP. Indeed, in the standard augmented neoclassical growth model developed by Mankiw *et al.* (1992), a permanent increase in migration flows has a negative impact on long-term GDP per capita because of capital dilution, which might be compensated by a positive contribution of new migrants to human capital accumulation (Dolado *et al.*, 1994 ; Barro and Sala-i-Martin, 1995). Consequently, in this framework, whether migration positively affects per capita GDP crucially depends on the scope of migration and its demographic and educational structures.

Due to a lack of harmonized international data on migration, few empirical studies have attempted to estimate the impact of permanent immigrant flows on economic growth while accounting for educational attainment. The most closely related paper is Dolado *et al.* (1994). They estimate –as we do herein– a structural model including immigrants' human capital. However, they do not observe migrants' education, so they use the educational attainment of the population in the country of origin as a proxy. Moreover, their analysis covers the period from 1960–1985, which was characterized (until the second oil shock at the end of the 1970s) by low-skilled migration concentrated in the manufacturing sector. Over the past two decades, the characteristics of international migration have evolved considerably, and its impact must therefore to be reconsidered. That is the purpose of this paper.

This paper is also related to recent studies that analyse the effects of economic openness and diversity on GDP per capita. For example, Felbermayr *et al.* (2010) estimate the effect of the stock of migrants on per capita income using cross-sectional country data. Andersen and Dalgaard (2011) consider temporary cross-border flows of people as a measure of global integration and evaluate the effect of the intensity of travel on GDP per capita. Ortega and Peri (2014) estimate the effect of economic openness by jointly considering migration and trade on income per person. In line with studies on birthplace diversity and economic development, they take into account diversity by country of origin within the stock of immigrants. Alesina *et al.* (2013) estimate the effect of diversity in migrant birthplaces on growth. They build diversity indicators from data on immigration population by country of birth and education.

This paper departs from existing studies by considering the effect of permanent flows of immigrants by country of birth and skill level on GDP per capita. We focus on permanent migration –movements that the receiving country considers to be long term. We exclude temporary visitors (i.e., for tourism and business purposes) because we are mainly interested in the economic consequences of long-term immigrants. Moreover, we focus on newly arrived immigrants rather than the immigrant population as a whole. Indeed, the socioeconomic characteristics of immigrants have changed over time and flows reflect these changes better than the stock of immigrants. We also independently identify the effect of net migration of the foreign- and native-born by skill level.

Specifically, we contribute to the existing literature in two ways. First, we compile a unique data set on net migration that includes data on country of birth and skill level from various data sources for 22 OECD countries for 1986–2006. Moreover, specific attention is devoted to producing robust measures of the educational attainment of recent immigrants as well as of native-born expatriates who return to their home countries. Second, our estimations are based on the system of generalized method of moments (SYS-GMM) for dynamic panel data models developed by Arellano and Bover (1995) and Blundell and Bond (1998), which address the (potential) endogeneity of migration variables. However, the consistency of the SYS-GMM crucially depends on the validity of the instruments used. Therefore, in contrast to previous studies, we carefully follow some of the recommendations of Roodman (2009) and Bazzi and Clement (2013), introducing both internal and external instruments in our estimation. We consider this method to be a useful complement to standard specification tests for obtaining valid instruments and robust econometric results.

Our econometric investigation provides evidence that, over the period considered, the impacts of a permanent increase in net migration on GDP per capita via human capital accumulation and capital dilution are significant and with the expected signs (i.e., positive and negative, respectively). Furthermore, simulations based on these results indicate that the former dominates the latter, in almost all OECD countries. Thus, all else being equal, a 50% increase in foreign-born net migration generates, on average, a short-run increase in GDP per worker of three-tenths of a percentage-point per year for the 22 OECD countries considered. The long-run effect is on average about two percent. Therefore, migration flows tend to have a positive and significant impact on the level of GDP per capita, even in countries that have non-selective migration policies.

The remainder of the paper is organised as follows. Section 2 provides a short review of the literature. Section 3 outlines the theoretical model. Section 4 describes the econometric strategy, data and empirical results. Section 5 discusses the implications of the results. Finally, Section 6 offers some concluding remarks.

2 Direct and indirect effects of migration on economic growth: an overview of the literature

International migration potentially has both direct and indirect effects on economic growth. First, migration can be viewed as a demographic shock. Indeed, in the textbook Solow-Swan growth model, an increase in migration has a negative impact on the transitional path to the long-term steady state, in which all per capita variables are nonetheless stable. Even in this framework, however, migration affects the age structure of the destination country population because migrants tend to be more concentrated in active age groups compared to natives. Consequently, migration reduces dependency ratios and potentially has a positive impact on aggregate savings,[1] which may eventually result in higher total factor productivity (TFP) growth. Yet, this transmission channel has not been directly considered in the literature.
Second, migrants arrive with skills and abilities, that supplement the stock of human

[1]This effect may be partially offset by remittances sent by migrants to their country of origin.

capital in the host country. To our knowledge, Dolado *et al.* (1994) were the first to introduce migration into the Solow-Swan model augmented by human capital. In this framework, the contribution of immigrants to human capital accumulation compensates (at least partially) for the negative capital dilution effect associated with population growth. The authors estimate their model for 23 OECD countries between 1960 and 1985.

More recently, several authors have included migration in endogenous economic growth models. This literature considers the impact of immigrants on technological progress, notably, their contributions to innovation.[2] Walz (1995), for instance, introduces migration in a two country endogenous growth model. He finds that the sign of the growth rate effect depends on the initial specialization of the two countries and that migration is selective towards high-skilled individuals. Robertson (2002) also analyses the impact of migration in an Uzawa-Lucas model with unskilled labour and shows that an inflow of relatively unskilled immigrants results in lower transitional growth.
Lundborg and Segerstrom (2000, 2002) include migration in a quality ladders growth model. They find that free migration stimulates growth, especially if it responds to differences in labour force endowments. Similarly, in an expansion-in-varieties framework, Bretschger (2001) shows that skilled migration can promote growth by decreasing the costs of research and development and by increasing the market share of certain types of goods.

Most of the previous studies are theoretical, and there exist very few empirical assessments of the impact of migration on economic growth. Furthermore, when such analyses exist, they are not based on structural models and are often hampered by data constraints. For instance, Ortega and Peri (2009) analyse the effects of immigration flows on total employment, physical capital accumulation and TFP in 14 OECD countries between 1980 and 2005. They find that migration increases employment and capital stocks but does not have a significant effect on TFP. Because immigration shocks lead to an increase in total employment and a proportional response in production, output per capita is not affected by inflows of migrants. However, this study does not take into account the human capital of migrants, or diversity in their country of origin. More recently, Felbermayr *et al.* (2010) and Ortega and Peri (2014) use bilateral migration stocks around the year 2000 to estimate a positive relationship between the immigrant share of the population and GDP per capita in the host country. Moreover, Ortega and Peri (2014) find that this positive relationship is magnified when diversity in the country of origin within the immigrant population is taken into account. These results are in line with the findings from studies on birthplace diversity and economic development. For example, Alesina *et al.* (2013) find a positive effect of immigrant population diversity in country of birth and education on growth.

Another approach is to use time-series analysis. Morley (2006), for instance, anal-

[2] Hunt and Gauthier-Loiselle (2010) provide evidence on the impact of highly skilled migration in the United States on innovation. They find that a one percentage-point increase in the share of immigrant college graduates in the population increases patents per capita by 6%.

yses the causality between migration and economic growth using data for Australia, Canada, and the United States between 1930 and 2002. He finds evidence of long-run causality running from per capita GDP to immigration but not the reverse. In another example, Boubtane *et al.* (2013) find a positive bidirectional relationship between immigration and GDP per capita for 22 OECD countries from 1987–2009. Note that due to the lack of harmonized data on characteristics of migration flows, time-series studies do not take into account the educational attainment of immigrants.

The main contribution of this paper is to provide robust estimates of the impact of net migration flows on GDP per capita, controlling for the skill composition of recent immigrants, using a clear theoretical framework. This framework is presented in the next section.

3 The theoretical model

As in Dolado *et al.* (1994), migration is introduced in a standard augmented neoclassical Solow-Swan model where aggregate output is produced from physical capital (K), human capital (H) and labour (L) using a Cobb-Douglas function with constant returns to scale:

$$Y = K^{\alpha} H^{\beta} \left(A\ L\right)^{1-\alpha-\beta} \qquad \alpha+\beta<1 \tag{1}$$

where A is labour-augmenting (or Harrod-neutral) technological progress. It is a productivity parameter that grows at the constant exponential rate g_A.

The first channel through which migration affects the economy of the host country is essentially demographic as new inflows of foreign workers fuel labour force growth. This impact can be decomposed into net migration of foreign-born workers (M) and net migration (net return) of native-born workers (E). As we shall see in Section 4.2, it is necessary to make this distinction because the dynamics and skill composition of these two migration streams are quite dissimilar. Note that net migration is the difference between immigration into and emigration out of the country during the period. Labour force growth is therefore given by the following equation (time subscripts are omitted for convenience):

$$\dot{L} = \tilde{n}L + M + E$$

where $\widetilde{n}$ is the natural population growth rate (i.e., new entries of young people into the labour force minus retirements and deaths). We let m be the net migration rate of the foreign-born ($m = M/L$) and e be the net migration rate of the native-born ($e = E/L$). Then, the model follows the Solow model and assumes that the labour force increases at a constant rate : $n = \widetilde{n} + m + e$.

Immigrants and native-born returnees bring human capital (skills and abilities) that supplements the domestic stock of human capital. Inversely, those who leave the country take their human capital with them. This is the second channel through which migration impacts production factor endowments in this basic model. Here, h^M denotes the average quantity of human capital that each foreign-born migrant brings with him or her, h^E is the average human capital of native-born migrants, and $\hat{h}$ is the average human capital per worker ($\hat{h} = H/L$). The accumulation of human capital is thus given by:

$$\begin{aligned} \dot{H} &= s_H Y - \delta H + M\ h^M + E\ h^E \\ &= s_H Y - \left(\delta - \left(m\kappa^M + e\kappa^E\right)\right) H \end{aligned} \tag{2}$$

where s_H is the fraction of resources devoted to human capital accumulation, δ is the rate of depreciation and $\kappa^M = h^M/\hat{h}$ ($\kappa^E = h^E/\hat{h}$) is the relative human capital of foreign-born (native-born) migrants compared to the average human capital per worker in the host economy. We assume that the relative human capital of immigrants, $m\kappa^M + e\kappa^E$, is constant.

The dynamics of physical capital are the same as in the Solow model. A fraction s_K of output is saved and capital depreciates at an exogenous rate δ:[3]

$$\dot{K} = s_K Y - \delta K \tag{3}$$

Following Barro and Sala-i-Martin (1995), migrants are not assumed to bring significant amounts of physical capital with them. If we consider the costs of migration, it is reasonable to expect that, on average, the physical capital of migrants is small compared to that of the resident population. Additionally, remittances represent a small share of GDP in OECD countries (di Giovanni *et al.*, 2014), and moreover, immigrants who wish to settle permanently in the receiving country remit less (Dustmann and Mestres, 2010).

Using units of effective labour (i.e., $y \equiv Y/AL$, $k \equiv K/AL$, $h \equiv H/AL$), the production function is given in intensive form by:

$$y = k^\alpha h^\beta \tag{4}$$

The evolution of the economy is determined by:

$$\begin{gathered} \dot{k} = s_K\ y - (\delta + g_A + n)\, k \\ \dot{h} = s_H\ y - \left(\delta + g_A + n - \left(m\kappa^M + e\kappa^E\right)\right) h \end{gathered} \tag{5}$$

The economy converges to a steady state defined by:

$$\begin{aligned} \ln y^* = {} & \frac{\alpha}{1-\alpha-\beta} \ln s_K + \frac{\beta}{1-\alpha-\beta} \ln s_H \\ & - \frac{\alpha}{1-\alpha-\beta} \ln\left(\delta + g_A + n\right) \\ & - \frac{\beta}{1-\alpha-\beta} \ln\left(\delta + g_A + n - \left(m\kappa^M + e\kappa^E\right)\right) \end{aligned} \tag{6}$$

[3]Following Mankiw *et al.* (1992), we assume that human capital depreciates at the same rate as physical capital.

Assuming that all countries are in their steady state, Eq.(6) could be used for empirical analysis. Instead, we suppose that countries are growing near their steady state. It may be shown that (see Appendix A.1):

$$\ln y(t) - \ln y(t-1) \cong (1-e^{-\lambda})(\ln y^* - \ln y(t-1)) \tag{7}$$

The parameter λ indicates the speed of convergence towards the steady state.
For estimation purposes, we require an expression in terms of income per worker, $\widehat{y}$, rather than income per effective worker, y. Because y can be expressed in term of $\widehat{y}$ ($\widehat{y} \equiv Y/L$), $\ln y\,(t) = \ln \widehat{y}(t) - \ln A(0) - g_A t$, and using Eq.(6), we finally obtain the productivity growth rate around the steady state:

$$\begin{aligned}
\ln \widehat{y}(t) - \ln \widehat{y}\,(t-1) \;\cong\;& g_A\left(t - e^{-\lambda}(t-1)\right) + (1-e^{-\lambda})\ln A(0) \\
& -(1-e^{-\lambda})\ln \widehat{y}\,(t-1) \\
& +(1-e^{-\lambda})\frac{\alpha}{1-\alpha-\beta}\left(\ln s_K - \ln\left(\delta + g_A + n\right)\right) \\
& +(1-e^{-\lambda})\frac{\beta}{1-\alpha-\beta}\ln s_H \\
& -(1-e^{-\lambda})\frac{\beta}{1-\alpha-\beta}\ln\left(g_A + \delta + n - \left(m\kappa^M + e\kappa^E\right)\right)
\end{aligned} \tag{8}$$

Eq.(8) shows that for a given α, β, δ, λ, and g_A, productivity growth is negatively related to the net migration rate because of the capital dilution effect associated with labour force growth, n. However, this effect is counterbalanced by the positive impact of the human capital content of migration flows ($m\kappa^M + e\kappa^E$). The net effect of migration is therefore ambiguous and depends on the relative human capital contribution of foreign- and native-born migrants (κ^M and κ^E), net migration rates (m and e) and parameters of the production function (α and β).
In this framework, *ceteris paribus*, the inflow of foreign workers will have a positive impact on long-term GDP per worker, and hence on productivity growth around the steady state, only if new migrants are more qualified, on average, than the resident population ($\kappa^M > 1$). However, this is not a sufficient condition, as the human capital of migrants should also offset the capital dilution effect. Indeed, it may be shown that, provided there is not a net outflow of human capital associated with total net migration (i.e., $m\kappa^M + e\kappa^E \geq 0$), $\kappa^M \geq (\alpha+\beta)/\beta$ is a sufficient condition for migration to have a positive impact on GDP per worker (see Appendix A.2). Below that threshold, however, the impact will depend on other parameters of the model.

The fact that migration has a positive impact on GDP per worker if and only if its contribution to human capital accumulation more than compensates for the effect on capital dilution is a direct consequence of the augmented Solow-Swan theoretical framework. This would not have necessarily been the case in an endogenous growth framework or in a framework that considers the imperfect substitution of natives and immigrants in production (Manacorda *et al.*, 2012; Ottaviano and Peri, 2012).

4 Econometric analysis

4.1 Empirical Model Specification

Eq.(8) suggests a useful specification for the model that can be used to evaluate the impact of immigration on GDP per worker in receiving countries. We can rewrite Eq.(8) as follows (see Appendix A.3):

$$\begin{aligned}
\ln \widehat{y}_{i,t} - \ln \widehat{y}_{i,t-1} \cong\ & g_A \left(t - (t-1)e^{-\lambda}\right) + \left(1 - e^{-\lambda t}\right) \ln A\left(0\right) \\
& - \left(1 - e^{-\lambda}\right) \ln \widehat{y}_{i,t-1} \\
& + \left(1 - e^{-\lambda}\right) \frac{\alpha}{1-\alpha-\beta} \ln s_{K_{i,t}} \\
& + \left(1 - e^{-\lambda}\right) \frac{\beta}{1-\alpha-\beta} \ln s_{H_{i,t}} \\
& - \left(1 - e^{-\lambda}\right) \frac{\alpha+\beta}{1-\alpha-\beta} \ln\left(g_A + \delta + n_{i,t}\right) \\
& + \left(1 - e^{-\lambda}\right) \frac{\beta}{1-\alpha-\beta} \frac{m_{i,t}\kappa^M_{i,t} + e_{i,t}\kappa^E_{i,t}}{g_A + \delta + n_{i,t}}
\end{aligned} \tag{9}$$

Following standard practice in the literature,[4] we assume that the convergence parameter λ is constant over time and across countries. The term $A(0)$ represents all unobserved elements (e.g., initial level of technology, resource endowments, climate, institutions). It suggests the presence of a country-specific effect, which may be correlated with the other explanatory variables considered in the model.

The model used to estimate the effect of immigration on GDP per worker for a given country i is a more general form of Eq.(9):

$$\begin{aligned}
\ln \widehat{y}_{i,t} =\ & \beta_1 + \beta_2 \ln \widehat{y}_{i,t-1} + \beta_3 \ln s_{K_{i,t}} + \beta_4 \ln s_{H_{i,t}} + \beta_5 \ln\left(\delta + g_A + n_{i,t}\right) \\
& + \beta_6 \frac{m_{i,t}\kappa^M_{i,t}}{\delta + g_A + n_{i,t}} + \beta_7 \frac{e_{i,t}\kappa^E_{i,t}}{\delta + g_A + n_{i,t}} + \mu_i + \gamma_t + v_{i,t}
\end{aligned} \tag{10}$$

where μ_i and γ_t represent country- and time-specific effects and β_1, ..., β_7 are parameters to be estimated.

4.2 Data

We consider a panel of 22 OECD countries between 1986 and 2006. To reduce the influence of short-run variation, we split the sample period into five sub-periods. Because data are missing for some periods, our panel is unbalanced with between 3 and 5 data points for each country. The list of countries, periods, and data sources for the migration variables are presented in Appendix Table B.1.

[4] Benhabib and Spiegel (1994), Islam (1995), and Cohen and Soto (2007)

To assess the human capital content of migration flows, we compile a unique data set of net migration flows that includes place of birth and educational attainment. Data on international migration in OECD countries are relatively scarce. Most available data are related to the characteristics of the stock of immigrants, whereas we require data on the characteristics of immigrant flows to estimate Eq.(10). Indeed, the main sources of data on international migration are the population censuses, which provide comparable migration stock data for recent census years. For example, Artuc *et al.* (2013) provide information on gender, country of origin, and educational level of foreign-born populations in 1990 and 2000. These data were extended by Brücker *et al.* (2013) for 20 OECD countries for two additional census years, 1980 and 2010. Moreover, they impute missing information to compile data on the foreign-born population from 1980 to 2010 at 5-year intervals. Furthermore, the OECD (2008) database on immigrants (DIOC) includes additional information on labour market outcomes and the duration of stay for immigrants living in OECD countries using the 2000 round of population censuses. Note that these data do not indicate where the tertiary diploma was obtained nor do they account for differences in skills, including language proficiency.
Additional sources of information on immigrants include the OECD International Migration Database and the UN International Migration Flows Database. However, these data are not harmonized and are not comparable across countries. Moreover, outflows are generally unregulated and pose more measurement problems than inflows. Therefore, it is not possible to reconstruct comparable measures of net migration flows. Furthermore, data on immigrant flows concern only non-nationals (foreigners) while migration also involves nationals (citizens). Note that, unlike country of birth, citizenship changes over time with naturalization, which may compromise the comparison across countries at different time periods. Finally, statistics available on migration flows usually do not distinguish education levels.

Consequently, an important part of the background work for this study has been to gather and produce comparable data on net migration by country of birth and educational attainment.
Data on net migration flows by place of birth are directly available from the border statistics for Australia, New Zealand, and the United Kingdom and from population registers for Germany, the Netherlands, and Switzerland. For the 16 other countries, net migration flows of the native-born (E) are computed as a residual using a basic demographic equation (Appendix B)[5]. Data on the native-born population are mainly collected from population censuses. We impute missing information on the native-born population between census years following the United Nations (2009) methodology. Data on births, deaths and total net migration flows come from the OECD Population and Vital Statistics data set. Note that net migration data (for both nationals and non-nationals) has fewer comparability problems than the available data on inflows and outflows of foreign citizens cited above. Finally, foreign-born net migration (M) is calculated as the difference between total net migration obtained from the OECD database

[5]For the countries for which data on native-born net migration are directly available, there is a strong correlation between data computed from population censuses and published data on native-born net migration.

and native-born net migration computed from the native population.

Although data on the educational attainment of the immigrant population in OECD countries are accessible, for example from Brücker *et al.* (2013), to the best of our knowledge no data on the education level of immigrant flows are available. Because the education or skill level of immigrants, regardless of their date of arrival, does not account for the changes in their education and skill level over time, we compile data on the educational attainment of recent immigrants. More precisely, we use the share of recent foreign-born migrants (i.e., those who have been in the host country for fewer than 5 years) who have completed their tertiary education[6] as a measure of the (average) human capital that each foreign-born immigrant brings to the host country (h^M). This share is then compared to the corresponding figure for the total resident population at the beginning of the period to compute κ^M. The data come from labour force survey data for European countries and the United States and from population censuses for other OECD countries. Note that these data provide information only on immigrants who still reside in the host country at the end of the observation period. No data are available on the skill composition of immigrants who left the host country during the period.

To calculate κ^E, we take advantage of the DIOC, which provides data for people born in the OECD and living in another country circa 2000 including educational attainment, age, and duration of stay. The educational structure of native-born expatriates is directly observed from this data source for those who emigrated between 1990–1994 and 1998–2002. The former is approximated by OECD expatriates with 5 to 10 years of residence abroad in 2000 and the latter by OECD expatriates with fewer than 5 years of residence abroad in 2000. Data are then linearly extrapolated for other periods (1986–1990, 1994–1998, and 2002–2006). Note that data on the education structure of the resident population come from Lutz *et al.* (2007).

The data clearly show that net migration of the native-born tends to be negative in most OECD countries over the period considered while the reverse is true for the foreign-born (Appendix Table B.2). Furthermore, net migration of the native-born is non-negligible, and OECD expatriates are, on average, significantly more qualified than both foreign-born migrants (Appendix Table B.3) and the resident population. The capacity to distinguish between net migration of the foreign-born and that of the native-born is therefore essential to estimating the full impact of migration on host countries. Note that recent immigrants to OECD countries are, on average, better educated than the resident population (Appendix Table B.4), which is in line with the findings of Manacorda *et al.* (2012) and Dustmann *et al.* (2012) on migrant stocks. The notable exception is the United States where recent immigrants are slightly less educated, on average, than the resident population.

Data on GDP and the working age population (foreign- and native-born) come from

[6] People who have completed 5 to 6 ISCED education levels.

the OECD database. Real GDP (constant prices, constant PPP, reference year 2000) is used to measure output. The labour force is measured by the population aged 15–64 at the beginning of each period. The savings rate is approximated by the average share of investment of real GDP over each period. These data come from the Penn World Table version 7.1 (Heston et *al*, 2012). We use tertiary school enrolment as a proxy for the rate of investment in human capital. Most previous studies have used the secondary enrolment rate as the measure of educational input. However, tertiary education is identified as being important for the development, acquisition or adoption of innovative research. Gemmell (1996) finds that, other things equal, tertiary education appears to be more important for economic growth in OECD countries. Thus, for our sample of OECD countries, tertiary school enrolment is more relevant than secondary school enrolment. These data come from the World Development Indicators (World Bank, 2013). Sample descriptive statistics are shown in Table 1.

Table 1: Sample statistics

Variables	Mean	Standard deviation	Min	Max
$\widehat{y}_t$	39768	(11.331)	20027	92994
$\widehat{y}_{t-1}$	36575	(9.826)	15972	83280
s_K	0.204	(0.028)	0.147	0.289
s_H	0.483	(0.190)	0.025	0.919
n	0.031	(0.031)	-0.008	0.255
m	0.021	(0.015)	-0.006	0.071
e	-0.005	(0.009)	-0.043	0.011
κ^M	1.758	(0.672)	0.577	4.221
κ^E	2.522	(0.843)	0.694	4.545

Note: n denotes the population growth rate over a 5-year period. m and e denote the net migration of the foreign- and native-born, respectively, over a 5-year period.

4.3 Methodological Considerations

The residuals of Eq.(10) are autocorrelated because of the presence of the lagged dependent variable; this prevents us from implementing the usual econometric methods, such as ordinary least squares (OLS), Between, or Within estimators. Specifically, as reported by Nickell (1981), the least squares dummy variables estimator, for example, has a non-vanishing bias for small T and large N. Moreover, the coefficient estimates of Eq.(10) obtained via standard econometric methods are likely to be biased for various reasons, including measurement error and omitted variable bias. To address some of these issues, one may consider using fixed-effects instrumental variables (IV) regressions (e.g., two-stage least squares (2SLS)). The problem is that the first-stage statistics of a 2SLS regression often has many weak instruments (see Arellano and Bover, 1995). Moreover, when this is the case, the fixed-effects IV estimators may be biased in the same way as the OLS estimators (see, for example, Roodman, 2006). For this reason, different econometric techniques were developed to estimate dynamic panel data models with short time dimensions in which lagged values of the explanatory endogenous variables are used as instruments. These methods control for endogeneity and measurement error for the lag of $\widehat{y}_t$ and other explanatory variables.

In our study, we use SYS-GMM, as proposed by Arellano and Bover (1995), which combines a regression in differences with one in levels. Blundell and Bond (1998) report Monte Carlo evidence that the inclusion of a level regression in the estimation leads to a reduction of the potential bias in small samples and asymptotic inaccuracy in the difference estimator.[7] The consistency of the GMM estimator relies on the validity of the instruments introduced in the model and the assumption that the error terms are uncorrelated[8]. To obtain valid instruments, we followed some of the recommendations provided by Roodman (2009) and Bazzi and Clement (2013); the former address the problem of too many instruments,[9] and the latter address the fact that common instrumental variable approaches can lead to opaquely weak or opaquely invalid instruments. One of them is to limit the lag depth; the other is 'collapsing' the instrument set (see Roodman, 2009). The former implies a selection of lags to be included in the instrument set, making the instrument count linear in T. The latter embodies a different belief about the orthogonality condition: it no longer needs to be valid for any one time period but still for each lag, again making the instrument count linear in T. A combination of both techniques makes the instrument count invariant to T. In our case, we use collapsed two-period lags from all variables included in the estimation as the (internal) instrument sets.[10] Moreover, following Bazzi and Clement (2013), internal instruments may not be sufficient in dynamic models estimated by SYS-GMM techniques; thus, we also include an external instrument[11] that has already been used in other published

[7]The first-differenced GMM estimator is based on writing the equation at hand as a dynamic panel data model, taking first-differences to remove the unobserved time-invariant country-specific effects and then instrumenting the right-hand-side variables in the first-differenced equations using levels of the series lagged two periods or more. This is performed under the assumption that the time-varying disturbances in the original level equations are not serially correlated.

[8]Note that we are aware that there exist doubts in the literature about the consistency of the SYS-GMM estimator when used with macroeconomic data. For instance, compared to the first-differenced GMM estimator, when implementing the SYS-GMM estimator, an additional assumption must be made to ensure the validity of the additional instrumental variables used in the level equation; indeed, the country fixed effects are assumed to be uncorrelated with lagged differences in the dependent variable, an assumption that is actually quite complicated to assess in an empirical study. We acknowledge these drawbacks as limitations of the paper; however, as accurately noted by a referee, the SYS-GMM estimator is the best available estimator in this context (compared to other estimation methods). Besides, notice also that it is now recognized in the literature that for the coefficient on the lagged-dependent variable, OLS estimations are upward biased, while FE estimations are downward biased, and that SYS-GMM estimations are in between (see Tables 2 and 3).

[9]The main small-sample problem associated with numerous instruments is that a large instrument collection overfits endogenous variables even as it weakens the Hansen test of the instruments' joint validity. Specifically, as Roodman (2009) states, "if for instance $T = 3$, the SYS-GMM generates only two instruments per instrumenting variable. However, as T rises, the instrument count can easily grow largely relative to the sample size, making some asymptotic results about the estimators and related specification tests misleading." See the paper for a more complete discussion of this issue.

[10]Note that similar results are obtained with the collapsed three-period lags from all variables included in the estimation as the instruments sets.

[11]We also use the collapsed two-period lags from past immigrant concentrations as external instrument

work (Card, 2001; Dustmann *et al.*, 2005). This procedure is typically implemented by using the share of immigrants in the population at the beginning of the period as an instrumental variable for immigrant inflows during the period. Indeed, immigrants tend to settle where networks exist (Bartel, 1989; Jaeger, 2007), and past immigration concentrations are unlikely to be related to current economic shocks. Here, the stock of high-skilled immigrants already residing in a country from Brücker *et al.* (2013) is used as an instrument for the inflows of highly skilled immigrants. Indeed, an OECD country with a larger high-skilled immigrant population attracts larger flows of highly skilled immigrants.

Finally, we consider three specification tests to address the consistency of the SYS-GMM estimator. The first is a serial correlation test, which tests the null hypothesis of no first-order serial correlation and no second-order serial correlation in the residuals of the first-differenced equation. The second is a Hansen test (or J test) of overidentifying restrictions, which examines the overall validity of the instruments by comparing the moment conditions to their sample analogue. A finite sample correction is made to the two-step covariance matrix using Windmeijer's (2005) method. The third is a difference-in-Hansen-test, denoted as Diff-Hansen, proposed by Blundell and Bond (1998), which examines the null hypothesis of mean stationarity for the SYS-GMM estimator. These statistics, called incremental Hansen test statistics, are the difference between the Hansen statistics for first-differenced GMM and SYS-GMM. It is asymptotically χ^2 distributed with k degrees of freedom, where k is the number of additional moment conditions.

4.4 Econometric Results

Before turning to the regression equations, we first consider the pooling restrictions implicit in Eq.(10) and test whether key parameters are equal across countries (i.e., $\beta_{ij} = \beta_i, \forall i = [1, 7], j = [1, 22]$), which would imply that pooling time series and cross-sectional data are valid in our growth regression context. Specifically, we employ a multi-step procedure to test pooling restrictions in our system of 22 OECD members; hypotheses of interest are tested by means of a likelihood-ratio statistic. This procedure is in the spirit of the approach of Hsiao (1986). Our results (available upon request) provide evidence that common coefficients can be assumed across countries, and consequently, pooling time series and cross sectional data appears to be reasonable in this context. However, the additional restriction that $\mu_j = \mu, \forall j = [1, 22]$ was strongly rejected by the data, implying that Eq.(10) includes individual country effects. Furthermore, the fixed effect specification is more appropriate in our growth equation framework.

We then estimate Eq.(10) using data for 22 OECD countries from 1986–2006. The results for the SYS-GMM estimation are reported in Table 2[12]. Two types of specifications are considered. The first is the standard augmented Solow model, which serves as

sets. Similar results are obtained with the collapsed three-period lags.

[12]The estimation results using pooled OLS and FE estimators are presented in Table 3.

a benchmark. The results for this specification are presented in column 1. The second includes the human capital content of the net migration variables as specified in Eq.(10). These results are presented in the second column.

Before commenting on our results, it is important to note that our GMM model specification passes all the standard diagnostic tests, the p-values of which are listed in the last three lines of Table 2. In particular, there is no evidence of residual first- or second-order autocorrelation, and the validity of the instruments is confirmed by Hansen-Sargan's test. The results in Table 2 show that most estimated coefficients have a sign that is consistent with the prediction of the empirical and theoretical literature. This is true for all specifications considered. The only exceptions are the estimated coefficients of the rate of human capital accumulation, which are statistically insignificant.
The estimation of the benchmark model in column 1 shows a highly significant nega-

Table 2: Estimation results
Dependent variable: $ln\widehat{y}_t$

	(1)	(2)
$\ln \widehat{y}_{i,t-1}$	0.815^{***}	0.857^{***}
	(0.147)	(0.080)
$\ln(s_{K_{i,t}})$	0.344^{**}	0.279^{***}
	(0.155)	(0.071)
$\ln(s_{H_{i,t}})$	0.037	-0.011
	(0.059)	(0.021)
$\ln(g_A + \delta + n_{i,t})$	-0.405^{*}	-0.381^{***}
	(0.214)	(0.156)
$m_{i,t}\kappa^M_{i,t}/g_A + \delta + n_{i,t}$		0.390^{**}
		(0.189)
$e_{i,t}\kappa^E_{i,t}/g_A + \delta + n_{i,t}$		0.326^{*}
		(0.164)
Implied λ	0.051	0.038
	(0.045)	(0.023)
P-value Arellano-Bond test for AR(1)	0.016	0.005
P-value Arellano-Bond test for AR(2)	0.846	0.202
P-value Hansen test	0.169	0.546

Notes: 1) Two-step GMM robust standard errors for a finite sample computed using the correction defined by Windmeijer (2005) are in parentheses. 2) *, **, and *** denote significance at the 10%, 5%, and 1% levels. 3) The null of the Arellano-Bond test for AR(1) is the absence of residual autocorrelation of order 1. 4) The null of the Arellano-Bond test for AR(2) is the absence of residual autocorrelation of order 2. 5) The null of the Hansen-Sargan test is the validity of instruments.

tive coefficient for initial per capita income but yields an implicit convergence rate, λ, of 5% per year, which is higher than the 2% value usually reported in the literature. Working-age population growth has a significantly negative effect on GDP per worker. The coefficient of the physical capital investment rate is positive and significant. However, the estimated coefficient for human capital investment is insignificant.
The second column of Table 2 presents the estimates for the augmented Solow model, taking into account the human capital content of net migration, from Eq.(10). The results show that the coefficient on initial income has the expected negative sign and

is strongly significant. It implies a conditional convergence speed of approximately 3% per year. The estimated coefficient for human capital investment remains insignificant. The coefficient for the growth rate of the labour force has the expected negative sign and is strongly significant. The human capital contribution of foreign-born immigrants has a positive and significant effect on GDP per worker. A similar impact is found for native-born migration, although it is only significant at the 10% level.

Overall, the model appears to perform well. First, most coefficients are significant and have the expected signs. Second, the coefficients that measure the human capital content of the net migration are positive and strongly significant, which shows the important role played by the skills of immigrants on the growth of OECD countries. However, there is some indication that the schooling measure may not have a significant effect on GDP per worker in OECD countries. This is a common result in the empirical literature on the growth effects of human capital investment (Benhabib and Spiegel, 1994; Islam, 1995). One possible explanation is that school enrolment affects GDP per worker through the rate of investment (Bond *et al.*, 2001). Moreover, Hauk and Wacziarg (2009) conduct various Monte Carlo simulations to evaluate the econometric methods commonly used to estimate growth regressions derived from the Solow model. They show that the SYS-GMM estimator is likely to suffer from a violation of some of its moment conditions, which could lead to an upwards bias in the estimation of the slope of the human and physical capital accumulation variables. They also note that the other usual estimators such as the fixed-effects and the first-differenced GMM estimator are likely to overstate the speed of convergence, while the between estimator may understate it.

Table 3:
Dependent variable: $ln\widehat{y}_t$

	OLS		FE	
	(1)	(2)	(1)	(2)
$\ln\widehat{y}_{i,t-1}$	0.961***	0.942***	0.636***	0.540
	(0.028)	(0.031)	(0.135)	(0.100)
$\ln(s_{K_{i,t}})$	0.027	0.010	0.041	0.029
	(0.035)	(0.036)	(0.068)	(0.067)
$\ln(s_{H_{i,t}})$	−0.035***	−0.033**	0.043	0.032
	(0.012)	(0.013)	(0.030)	(0.029)
$\ln(g_A+\delta+n_{i,t})$	-0.048	-0.055	-0.055	−0.078**
	(0.084)	(0.093)	(0.058)	(0.036)
$m_{i,t}\kappa^M_{i,t}/g_A+\delta+n_{i,t}$		0.041		0.082
		(0.087)		(0.057)
$e_{i,t}\kappa^E_{i,t}/g_A+\delta+n_{i,t}$		-0.031		0.145**
		(0.063)		(0.049)
Implied λ	0.010	0.015	0.113	0.154
	(0.007)	(0.008)	(0.053)	(0.047)

Notes: *, **, and *** denote significance at the 10%, 5%, and 1% levels.

5 The impact of immigration on economic growth

The theoretical model described in Section 3 suggests that the impact of migration on GDP per worker is ambiguous and depends on (*i*) foreign- and native-born migrants' relative human capital endowments, (*ii*) the scope of migration, and (*iii*) production parameters. The results of the econometric investigation of Section 4 allow us to assess the overall effect of foreign-born immigrants on economic growth.

Based on the estimation results outlined in Table 2, we evaluate the effect of a permanent increase in the flows of foreign-born migrants on GDP per worker for each country included in our sample using the average variables for the total period 1986-2006. We consider a 50% rise of the average net migration rate for each country. We perform the same analysis for a 10% increase in the relative human capital of foreign-born migrants (cf. Appendix C). The results are reported in the Table 4.

Table 4: Impacts of increases in net migration

	Key structural variables			on GDP per worker in % per year			
				Short-term		Long-term	
Country	m	h^M	κ^M	50% increase in m	10% increase in κ^M	50% increase in m	10% increase in κ^M
Austria	0.47	18.9	2.20	0.45	0.18	3.15	1.23
Australia	0.56	36.6	1.73	0.26	0.14	1.83	0.99
Belgium	0.44	33.6	1.77	0.26	0.13	1.84	0.94
Canada	0.76	49.5	1.67	0.29	0.19	2.07	1.33
Switzerland	0.97	34.2	1.87	0.57	0.29	3.99	2.07
Germany	0.58	20.3	1.12	0.03	0.09	0.20	0.66
Denmark	0.33	28.4	1.33	0.09	0.08	0.66	0.54
Spain	0.56	24.1	1.52	0.16	0.13	1.13	0.92
Finland	0.17	24.0	1.39	0.06	0.04	0.40	0.29
France	0.32	27.8	1.91	0.24	0.10	1.65	0.71
Greece	0.32	13.5	1.01	-0.03	0.05	-0.23	0.37
Ireland	0.81	43.6	2.87	0.97	0.32	6.80	2.28
Iceland	0.55	34.7	2.26	0.62	0.21	4.36	1.47
Italy	0.29	10.9	1.77	0.20	0.09	1.40	0.66
Luxembourg	1.24	35.5	2.07	0.70	0.39	4.93	2.74
Netherlands	0.35	22.8	1.33	0.09	0.08	0.65	0.54
Norway	0.36	29.4	1.33	0.09	0.08	0.60	0.54
New Zealand	0.79	35.2	1.85	0.43	0.21	3.00	1.49
Portugal	0.09	18.3	2.51	0.11	0.04	0.80	0.27
Sweden	0.50	36.6	1.63	0.22	0.13	1.56	0.94
United Kingdom	0.37	39.6	2.08	0.32	0.13	2.23	0.90
United States	0.51	26.7	0.97	-0.04	0.07	-0.25	0.52
OECD 22	0.52	29.3	1.75	0.28	0.15	1.98	1.03

Note: m is the average annual net migration rate %, h^M is the share of those with tertiary educations among recent foreign-born migrants averaged over the 1986-2006 period %. κ^M is the relative human capital of foreign-born migrants compared to the average human capital per worker in the host economy averaged over the 1986-2006 period.

The results show that in the short-run, taking into account the skill composition of foreign-born migrants, a 50% increase in the net migration rate of foreign-born would increase GDP per worker by three-tenth of a percentage-point per year (column 4, Table 4). The long-run effect of foreign-born migration on GDP per worker is, on average, two percent per year (column 6, Table 4). Thus, the migration growth effect is high for all countries except Finland and Germany, where the increase in the level of GDP per worker is less than five-tenth of a percentage-point per year in the long-run. A negative effect is observed for Greece and the United States. In these countries, recent immigrants are as skilled as the resident population, so the human capital they contribute is nearly sufficient to offset the capital dilution effect. Note that the small negative effect of foreign-born migration on GDP per worker in Greece and the United States represents only one-tenth of the negative impact of a comparable increase in the natural population growth rate, $\widetilde{n}$.

To compare our results with regard to recent empirical literature, we should look at the effect on the demographic ratio of working age to total population (Appendix D) –in addition to the effect on GDP per worker outlined in Table 4. Foreign-born migration flows improved this ratio in all OECD countries. In Greece and the United States, the positive demographic effect compensates for the small negative effect on GDP per worker. Thus, foreign-born, permanent migration flows increase GDP per capita in all of the OECD countries considered (Appendix Table D.1). These results are in line with the findings of recent empirical studies based on migration stock data. For instance, the results of Felbermayr *et al.* (2010) indicate that a 10% increase in the migration stock leads to a per capita income gain of 2.2%. Ortega and Peri (2014) also find "'a qualitatively large effect: a 10 percentage-point difference in the share of foreign born in the population"' seems to be "'associated with differences in income per person by a factor close to 2"'.

Moreover, in this framework, adopting more selective migration policies has a systematically positive impact on GDP per worker. A 10% increase in the relative share of immigrants with tertiary educations compared to the resident population generates, on average, a short-run increase in GDP per worker of less than two-tenth percent and in the long run a one percent increase. It is also worth noting that increasing the education level of new immigrants will have a positive impact on GDP per worker in countries such as Germany, Greece, and the United States, where foreign-born immigrants are as educated as the resident population. For the remaining countries, immigrants are highly educated compared to the resident population, and given the skill level of recent immigrants, selective policies don't seem to have a more sizable impact on GDP per worker than increasing net migration.

6 Conclusion

By estimating a structural model, this paper has sought to re-examine the effects of permanent migration flows by country of origin and skill level on economic growth. Our empirical results support the theoretical model and demonstrate a positive impact from migrants' human capital on GDP per worker. Besides, the contribution of immigrants to human capital accumulation tends to dominate the capital dilution effect. Moreover, the growth impact of immigration is high even in countries that have non-selective migration policies. Indeed, a 50% increase in net migration of the foreign-born generates, on average, an increase of three-tenths of a percentage-point in per worker GDP per year in OECD countries. The long-run effect is on average about two percent. Increasing the selectivity of migration policies does not appear to have a more marked effect on GDP per worker, except perhaps in countries where recent immigrants are somewhat less educated than the resident population.

Obviously, one could argue that our model only partially captures the effects of migration on economic growth. For example, migration changes the domestic age structure of host countries because migrants tend to be concentrated in more active age groups compared to natives, and thereby reducing dependency ratios. There is also some evidence that immigrants tend to be complementary to natives, as they may allow some native workers to devote time to more productive jobs. Further, immigrants may bring some assets with them, thereby contributing to physical capital accumulation in the host country. Moreover, skilled immigrants may contribute to research and boost innovation and technological progress. Further research is needed to account for these effects before one can definitively state the full impact of migration on economic growth. That said, our results provide evidence that one should not expect large gains (or significant loses) in terms of productivity from migration.

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Appendix A The theoretical model

Appendix A.1 The speed of convergence

From the intensive form production function given by Eq.(4), the rate of growth of income per effective worker is given by:

$$\frac{\dot{y}}{y} = \alpha\frac{\dot{k}}{k} + \beta\frac{\dot{h}}{h} \tag{A.1}$$

We substitute Eq.(5) into Eq.(A.1) to get:

$$\begin{aligned}\frac{\dot{y}}{y} &= \alpha\left(s_K\ \frac{y}{k} - (\delta + g_A + n)\right) \\ &\quad +\beta\left(s_H\ \frac{y}{h} - \left(\delta + g_A + n - \left(m\ \kappa^M + e\ \kappa^E\right)\right)\right)\end{aligned} \tag{A.2}$$

The economy converges to a steady state defined by :

$$\begin{aligned}k^* &= \left(\frac{s_K}{\delta + g_A + n}\right)^{\frac{1-\beta}{1-\alpha-\beta}}\left(\frac{s_H}{\delta + g_A + n - (m\kappa^M + e\kappa^E)}\right)^{\frac{\beta}{1-\alpha-\beta}} \\ h^* &= \left(\frac{s_K}{\delta + g_A + n}\right)^{\frac{\alpha}{1-\alpha-\beta}}\left(\frac{s_H}{\delta + g_A + n - (m\kappa^M + e\kappa^E)}\right)^{\frac{1-\alpha}{1-\alpha-\beta}}\end{aligned} \tag{A.3}$$

Note that at the steady state, using Eq.(A.3) we have:

$$\begin{aligned}s_K\ \frac{y*}{k*} &= (\delta + g_A + n) \\ s_H\ \frac{y*}{h*} &= \delta + g_A + n - \left(m\ \kappa^M + e\kappa^E\right)\end{aligned} \tag{A.4}$$

Substituting Eq.(A.4) into Eq.(A.2) results in:

$$\frac{\dot{y}}{y} = \alpha\left(s_K\ \frac{y}{k} - s_K\ \frac{y*}{k*}\right) + \beta\left(s_H\ \frac{y}{h} - s_H\ \frac{y*}{h*}\right)$$

Therefore:

$$\begin{aligned}\frac{\dot{y}}{y} &= \alpha s_K\frac{y*}{k*}\left(\left(\frac{k}{k*}\right)^{\alpha-1}\left(\frac{h}{h*}\right)^{\beta} - 1\right) \\ &\quad +\beta s_H\frac{y*}{h*}\left(\left(\frac{k}{k*}\right)^{\alpha}\left(\frac{h}{h*}\right)^{\beta-1} - 1\right)\end{aligned}$$

(A.5)

Note that:

$$\left(\frac{k}{k*}\right)^{\alpha-1}\left(\frac{h}{h*}\right)^{\beta}-1=\exp\left((\alpha-1)\ln\left(\frac{k}{k*}\right)+\beta\ln\left(\frac{h}{h*}\right)\right)-1.$$

Around the steady state $(\alpha-1)\ln\left(\frac{k}{k*}\right)+\beta\ln\left(\frac{h}{h*}\right)$ is small, so we can use the exponential approximation $e^x=1+x$ to obtain:

$$\begin{aligned}\left(\frac{k}{k*}\right)^{\alpha-1}\left(\frac{h}{h*}\right)^{\beta}-1 &= (\alpha-1)\ln\left(\frac{k}{k*}\right)+\beta\ln\left(\frac{h}{h*}\right)\\ \left(\frac{k}{k*}\right)^{\alpha}\left(\frac{h}{h*}\right)^{\beta-1}-1 &= \alpha\ln\left(\frac{k}{k*}\right)+(\beta-1)\ln\left(\frac{h}{h*}\right)\end{aligned}\tag{A.6}$$

Substituting Eq.(A.4) and Eq.(A.6) into Eq.(A.5), we have:

$$\begin{aligned}\frac{\dot{y}}{y} &= \alpha\left(\delta+g_A+n\right)\left((\alpha-1)\ln\left(\frac{k}{k*}\right)+\beta\ln\left(\frac{h}{h*}\right)\right)\\ &\quad+\beta\left(\delta+g_A+n-\left(m\ \kappa^M-e\ \kappa^E\right)\right)\left(\alpha\ln\left(\frac{k}{k*}\right)+(\beta-1)\ln\left(\frac{h}{h*}\right)\right)\end{aligned}$$

Then:

$$\frac{\dot{y}}{y} = -\left(\delta+g_A+n\right)\left[(1-\alpha-\beta)\ln\left(\frac{y}{y*}\right)+\beta\ \frac{m\ \kappa^M+e\ \kappa^E}{\delta+g_A+n}\left(\ln\left(\frac{y}{y*}\right)-\ln\left(\frac{h}{h*}\right)\right)\right]$$

For small $\frac{m\ \kappa^M+e\ \kappa^E}{\delta+g_A+n}$, $\beta\frac{m\ \kappa^M+e\ \kappa^E}{\delta+g_A+n}\left(\ln\left(\frac{y}{y*}\right)-\ln\left(\frac{h}{h*}\right)\right)$ can be neglected. So, the growth rate as the economy converges to the steady state is:

$$\begin{aligned}\frac{\dot{y}}{y} &= -\left(\delta+g_A+n\right)(1-\alpha-\beta)\ln\frac{y}{y*}\\ &= -\left(\delta+g_A+n\right)(1-\alpha-\beta)\left(\ln y-\ln y*\right)\\ &= -\lambda\ \left(\ln y-\ln y^*\right),\end{aligned}\tag{A.7}$$

and thus the rate of convergence is given by:

$$\lambda=(1-\alpha-\beta)\left(\delta+g_A+n\right)$$

The rate of growth as the economy converges to the steady state can be approximated by:

$$\frac{\dot{y}}{y}=\frac{\partial\ln y}{\partial t}\simeq-\lambda\left(\ln y\left(t\right)-\ln y^*\right)$$

This yields to :

$$\ln y\left(t\right)-\ln y^*\cong e^{-\lambda t}\left(\ln y\left(0\right)-\ln y^*\right)\tag{A.8}$$

where $y(0)$ is income per effective worker at some initial date. Note that, assuming a constant rate of convergence λ over time, Eq.(A.8) also holds between dates t and $t-1$. We obtain Eq.(7).

Appendix A.2 The effect of migration on GDP per worker

The output per worker, $\widehat{y}(t)$, is given by :

$$\ln \widehat{y}(t) = g_A t - e^{-\lambda}\left(g_A(t-1) + \ln \widehat{y}(t-1)\right) + (1-e^{-\lambda})\left(\ln A(0) + \ln y^*\right)$$

Foreign-born migrants' impact on GDP per worker is given by:

$$\begin{aligned}\frac{\partial(\ln \widehat{y}(t))}{\partial m} &= -\left(g_A(t-1) + \ln \widehat{y}(t-1)\right)\frac{\partial(e^{-\lambda})}{\partial m} + \frac{\partial\left(1-e^{-\lambda}\right)}{\partial m}\left(\ln A(0) - \ln y^*\right) \\ &\quad + \left(1-e^{-\lambda}\right)\frac{\partial \ln y^*}{\partial m}\end{aligned}$$

Countries are assumed to be growing near their steady state so we can neglect the effect of m on the convergence rate. The impact on GDP per worker of foreign-born migration is determined by the partial derivative of $\ln y^*$ given by Eq.(6) with respect to the foreign-born immigration rate, m:

$$\begin{aligned}\frac{\partial(\ln \widehat{y}(t))}{\partial m} &= \left(1-e^{-\lambda t}\right)\frac{\partial \ln y^*}{\partial m} \\ &= \frac{\left(1-e^{-\lambda t}\right)\ \left(\beta\kappa^M - (\alpha+\beta)\right)\ (g_A+\delta+n) + \alpha\left(m\kappa^M + e\kappa^E\right)}{(1-\alpha-\beta)\ (g_A+\delta+n)\ (g_A+\delta+n-(m\kappa^M+e\kappa^E))}\end{aligned}$$

Note that $(1-\alpha-\beta)(g_A+\delta+n)\left(g_A+\delta+n-\left(m\kappa^M+e\kappa^E\right)\right) \geq 0$. Provided there is not a net outflow of human capital (i.e. $m\kappa^M + e\kappa^E \geq 0$), the inflow of foreign workers has a positive impact on GDP per worker if $\kappa^M \geq (\alpha+\beta)/\beta$.

The relative human capital of foreign born migrants (compared to the average human capital per worker in the receiving country, κ^M, always has a positive impact on GDP per worker:

$$\begin{aligned}\frac{\partial(\ln \widehat{y}(t))}{\partial \kappa^M} &= \left(1-e^{-\lambda t}\right)\frac{\partial \ln y^*}{\partial \kappa^M} \\ &= \frac{\left(1-e^{-\lambda t}\right)\ \beta\ m}{(1-\alpha-\beta)\left(g_A+\delta+n-(m\kappa^M+e\kappa^E)\right)}\end{aligned}$$

Appendix A.3 Derivation of Eq.(9)

In Eq.(8), note that :

$$\begin{aligned}\ln\left(g_A+\delta+n-\left(m\kappa^M+e\kappa^E\right)\right) &= \ln\left((g_A+\delta+n)\,(1-\frac{m\kappa^M+e\kappa^E}{g_A+\delta+n})\right) \\ &= \ln(g_A+\delta+n) + \ln(1-\frac{m\kappa^M+e\kappa^E}{g_A+\delta+n})\end{aligned} \tag{A.9}$$

One can expect that $\frac{m\kappa^M+e\kappa^E}{g_A+\delta+n}$ is small.[13] Using the approximation $\ln(1-x) \cong -x$ yields the Eq.(9).

[13] The relative human capital content of migration flows is small compared to the sum of the rate of technical progress, the depreciation rate, and the overall labour force growth rate. The data set, presented in Section 4.2, indicates that $\frac{m\kappa^M+e\kappa^E}{g_A+\delta+n}$ has a mean value of 0.095 and a standard error of 0.14.

Appendix B Data

This section presents the methodology used to estimate net migration by country of birth (see Table B.1).

According to the basic demographic equation, the native-born population (NBP)[14] at any point in time is equal to the native population at the previous point in time plus the net migration of the native-born (NBM) and the natural increase in the population (number of births, B, in the country minus deaths of the native-born, NBD):

$$NBP_{t+1} = NBP_t + B_{t-t+1} - NBD_{t-t+1} + NBM_{t-t+1}$$

Note that all births are by definition native, but deaths also include the foreign-born. In order to calculate the deaths of the native-born, we use the share of native-born in the total population, corrected their age structure and mortality rates by age. Data on deaths, births, and net migration are from the OECD database. Deaths by age group come from the World Health Organisation Mortality Database.

Native-born net migration is then given by:

$$NBM_{t-t+1} = NBP_{t+1} - NBP_t - (B_{t-t+1} - NBD_{t-t+1})$$

Foreign-born net migration is given by the difference between total net migration and the net migration of the native-born as estimated above. When census data are used, the statistical adjustment was added to net migration of the foreign-born, except for France between 1990 and 1999 (to the native-born) and Italy (not included). Note that the majority of immigrants are of working age. We assume that 80% of the estimated net migration as working age immigrants for the foreign- and native-born.

[14]In order to evaluate the stock of the native-born between census dates, we use an interpolation technique. This methodology is used by the United Nation Population Division to estimate the migrant stock in the Global Migration Database United Nations (2009).

Table B.1: Main data sources for net migration data and the educational attainment of recent foreign-born migrants.

Country	Country Code	Period	Foreign-born and native-born net migration	Education of recent foreign-born migrants
Austria	**AT**	1994-2006	LFS	LFS
Australia	**AU**	1986-2006	Department of Immigration and Citizenship	Census
Belgium	**BE**	1986-1990	Census	LFS
		1990-2006	Register	LFS
Canada	**CA**	1986-2006	Census	Census
Switzerland	**CH**	1986-1998	Census	LFS
		1998-2006	Federal Statistical Office (FSO).	LFS
Germany	**DE**	1986-2006	Federal Statistical Office (Destatis)	LFS
Denmark	**DK**	1986-1990	Census	LFS
		1990-2006	Register	LFS
Spain	**ES**	1986-2002	Census	LFS
		2002-2006	Register	LFS
Finland	**FI**	1986-1990	Census	LFS
		1990-2006	Register	LFS
France	**FR**	1986-2006	Census	LFS
Greece	**GR**	1994-2006	LFS	LFS
Ireland	**IE**	1986-2006	Census	LFS
Iceland	**IS**	1986-2006	Register	LFS
Italy	**IT**	1986-2002	Census	LFS
Luxembourg	**LU**	1986-2002	Census	LFS
		2002-2006	LFS	LFS
Netherlands	**NL**	1986-2006	CBS	LFS
Norway	**NO**	1986-2006	Register	LFS
New Zealand	**NZ**	1986-2006	Statistics New Zealand	Census
Portugal	**PT**	1986-2002	Census	LFS
		2002-2006	LFS	LFS
Sweden	**SE**	1986-1990	Census	LFS
		1990-2002	Register	LFS
		2002-2006	Statistics Sweden	LFS
United Kingdom	**UK**	1986-1990	Census	DIOC
		1990-2006	Office for National Statistics	LFS
United States of America	**USA**	1986-2006	Census	LFS

LFS : Labour Force Survey Eurostat for European countries and Current population survey for the United States.

DIOC: Database on immigrants in OECD countries

Table B.2: Net migration of the native- and foreign-borns in selected OECD countries, 1986–2006.

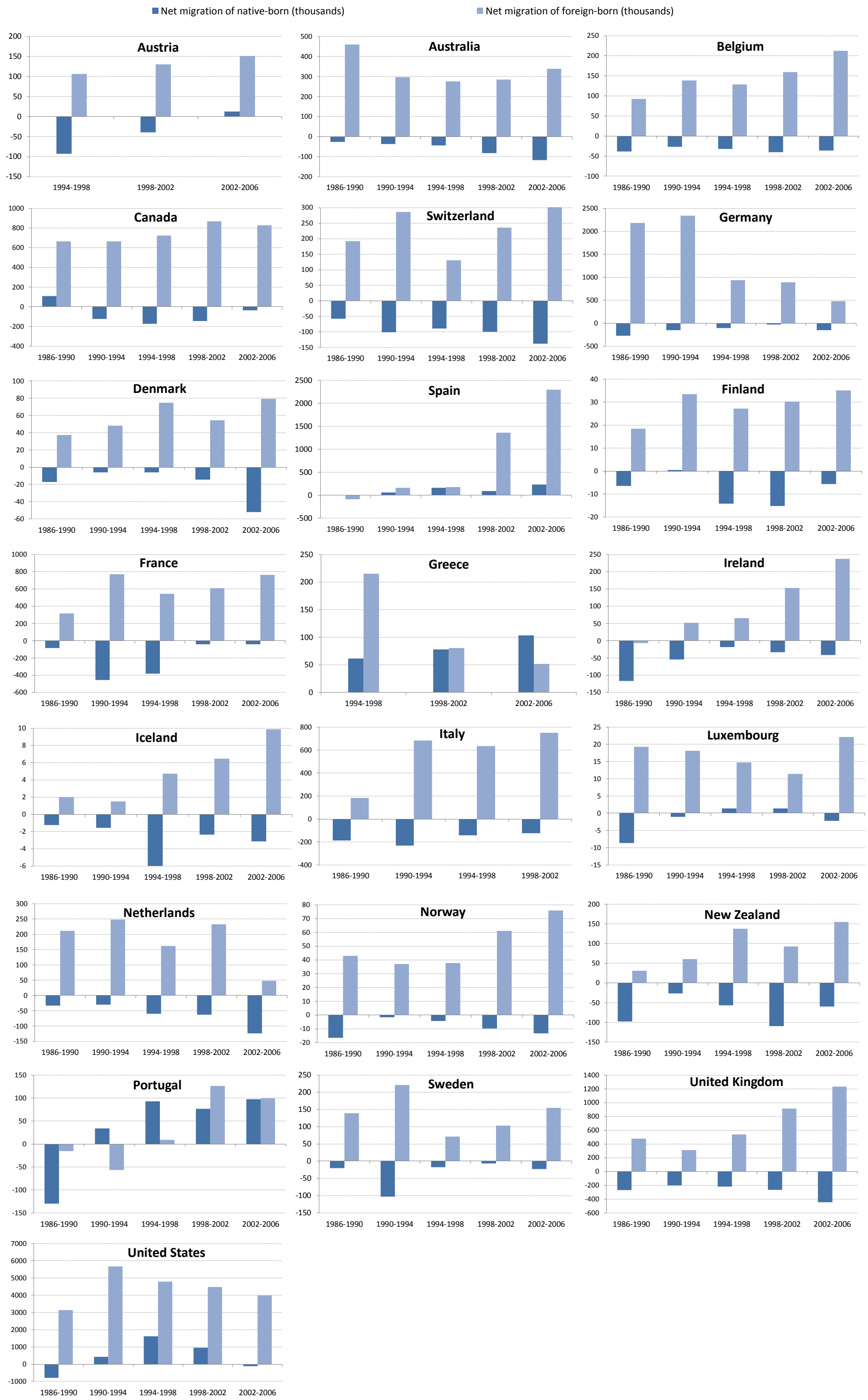

Table B.3: Share of native-born emigrants and recent foreign-born migrants that has completed tertiary educations in selected OECD countries, 1986–2006.

Table B.4: Share of recent foreign-born migrants and host country resident population that has completed tertiary educations in selected OECD countries, 1986–2006.

Appendix C Impact of foreign-born net migration on GDP per worker

The impact on growth due to foreign-born migrants given in Table 4 is evaluated from the estimation of the econometric model, given by Eq.(10):

$$\begin{aligned}\ln \widehat{y}_{i,t} &= \hat{\beta}_1 + \hat{\beta}_2 \ln \widehat{y}_{i,t-1} + \hat{\beta}_3 \ln s_{K_{i,t}} + \hat{\beta}_4 \ln s_{H_{i,t}} \\ &\quad + \hat{\beta}_5 \ln (\delta + g_A + n_{i,t}) + \hat{\beta}_6 \, \frac{m_{i,t}\kappa_{i,t}^M}{\delta + g_A + n_{i,t}} + \hat{\beta}_7 \, \frac{e_{i,t}\kappa_{i,t}^E}{\delta + g_A + n_{i,t}}\end{aligned}$$

where $n_{i,t} = \tilde{n}_{i,t} + m_{i,t} + e_{i,t}$.
Noting that we consider four year time intervals, the short-run effect of increasing net migration of the foreign-born is approximated, for each country, by $\frac{\partial \ln \widehat{y}_t}{\partial m_t}$ with :

$$\frac{\partial \ln \widehat{y}_t}{\partial m_t} = \hat{\beta}_5 \frac{\partial \ln (\delta + g_A + n_t)}{\partial m_t} + \hat{\beta}_6 \frac{\partial \left(m_t \kappa_t^M / \delta + g_A + n_t\right)}{\partial m_t} + \hat{\beta}_7 \frac{\partial \left(e_t \kappa_t^E / \delta + g_A + n_t\right)}{\partial m_t}$$

$$\frac{\partial \ln \widehat{y}_t}{\partial m_t} = \frac{\left(\hat{\beta}_5 + \hat{\beta}_6 \kappa_t^M\right)(\delta + g_A + n_t) - \hat{\beta}_6 m_t \kappa_t^M - \hat{\beta}_7 e_t \kappa_t^E}{(\delta + g_A + n_t)^2} \tag{C.1}$$

The short-run effect of increasing the immigrants' skill composition, κ^M, on GDP per worker can be assessed by $\frac{\partial \ln \widehat{y}_t}{\partial \kappa_t^M}$:

$$\frac{\partial \ln \widehat{y}_t}{\partial \kappa_t^M} = \hat{\beta}_6 \frac{m_t}{(\delta + g_A + n_t)} \tag{C.2}$$

We use the estimated coefficients provided in Table 2 and apply the time-averaged measures for each country.

In the long-run, $\ln \widehat{y}_{i,t} = \ln \widehat{y}_{i,t-1} = \ln \widehat{y}_i$. The long-run effect of immigration is approximated, for each country, by $\frac{\partial \ln \widehat{y}}{\partial m} = \frac{1}{1-\hat{\beta}_2} \frac{\partial \ln \widehat{y}_t}{\partial m_t}$. In the same way, the long-run effect of the immigrants' skill composition is evaluated by $\frac{\partial \ln \widehat{y}}{\partial \kappa^M} = \frac{1}{1-\hat{\beta}_2} \frac{\partial \ln \widehat{y}_t}{\partial \kappa_t^M}$.

Appendix D Impact of foreign-born net migration on per capita GDP

Let $\tilde{y}_{i,t}$ denote GDP per capita of country i during the period t, $P_{i,t}$ the total population, $L_{i,t}$ the working age population, and $d_{i,t} = \frac{L_{i,t}}{P_{i,t}}$ the demographic ratio. Noting that $\widehat{y}_{i,t}$ refers to GDP per working age population, we have:

$$\tilde{y}_{i,t} = \frac{Y_{i,t}}{P_{i,t}} = \frac{Y_{i,t}}{L_{i,t}} \cdot \frac{L_{i,t}}{P_{i,t}}$$
$$\ln \tilde{y}_{i,t} = \ln \widehat{y}_{i,t} + \ln d_{i,t}$$

The effect of increasing net migration on GDP per capita is approximated, for each country, by $\frac{\partial \ln \tilde{y}_t}{\partial m_t}$:

$$\frac{\partial \ln \tilde{y}_t}{\partial m_t} = \frac{\partial \ln \widehat{y}_t}{\partial m_t} + \frac{\partial \ln d_t}{\partial m_t}$$

From the estimated model given by Eq.(10), the impact of foreign-born net migration is given by (cf. Eq (A1) in Appendix A.2):

$$\frac{\partial \ln \widehat{y}_t}{\partial m_t} = \frac{\left(\hat{\beta}_5 + \hat{\beta}_6 \kappa_t^M\right)(\delta + g_A + n_t) - \hat{\beta}_6 m_t \kappa_t^M - \hat{\beta}_7 e_t \kappa_t^E}{(\delta + g_A + n_t)^2}$$

To evaluate the impact of net migration on demographic ratio for each country, note that: $\ln d_t = \ln L_t - \ln P_t$

$$\frac{\partial \ln d_t}{\partial m_t} = \frac{\partial \ln L_t}{\partial m_t} - \frac{\partial \ln P_t}{\partial m_t}$$

An increase in the net migration rate of working-age, foreign-born persons (m_t) affects the working age population, L_t (since $L_t = (\tilde{n}_t + m_t + e_t)\, L_{t-1}$), and hence total population P_t (since $P_t = L_t + P_t^{65+} + P_t^{00-14}$), where P_t^{00-14} is population aged 0 to 14 years and P_t^{65+} is population aged 65 years and older. So, the effect of changes in m on the demography ratio d is given by:

$$\frac{\partial \ln d_t}{\partial m_t} = \frac{L_{t-1}}{L_t} - \frac{L_{t-1}}{P_t}$$

We use the estimated coefficients provided in Table 2 and apply the time-averaged measures for each country.

Table D.1: Impacts of 50% increases in foreign-born net migration rate

	on GDP per worker in % per year		on GDP per capita growth in % per year	
Country	Short-term	Long-term	Short-term	Long-term
Austria	0.45	3.15	0.52	3.68
Australia	0.26	1.83	0.35	2.45
Belgium	0.26	1.84	0.34	2.36
Canada	0.29	2.07	0.41	2.88
Switzerland	0.57	3.99	0.72.	5.06
Germany	0.03	0.20	0.12	0.83
Denmark	0.09	0.66	0.15	1.05
Spain	0.16	1.13	0.25	1.74
Finland	0.06	0.40	0.08	0.60
France	0.24	1.65	0.29	2.03
Greece	-0.03	-0.23	0.02	0.13
Ireland	0.97	6.80	1.10	7.72
Iceland	0.62	4.36	0.71	5.00
Italy	0.20	1.40	0.25	1.72
Luxembourg	0.70	4.93	0.89	6.28
Netherlands	0.09	0.65	0.15	1.03
Norway	0.09	0.60	0.15	1.03
New Zealand	0.43	3.00	0.55	3.90
Portugal	0.11	0.80	0.13	0.90
Sweden	0.22	1.56	0.31	2.17
United Kingdom	0.32	2.23	0.38	2.67
United States	-0.04	-0.25	0.05	0.33
OECD 22	0.28	1.98	0.37	2.57