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ABSTRACT

Immigration and Economic Growth in the OECD Countries, 1986-2006*

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-born and foreign-born 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 deal with the risk of an endogeneity bias of the migration variables. Two important findings emerge from our analysis. First, there exists a positive impact of migrants' human capital on economic growth. And second, the contribution of immigrants to human capital accumulation tends to dominate the mechanical dilution effect while the net effect is fairly small. This conclusion holds even in countries with highly selective migration policies.

JEL Classification: C23, F22, J24, J61, O41, O47

Keywords: immigration, growth, human capital, generalized methods of moments

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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 aging can already be felt in the working age population as baby boomers begin to retire in large numbers while younger cohorts are too small to replace them. In this context, labour migration will continue to play a significant role in 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 system to make it more selective vis-à-vis skills and education. Traditional settlement countries (Australia, Canada, New Zealand, and the United States) have implemented 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 reformed their migration system to give more priority to highly educated migrants through a point-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 having their own system of national residence permits for highly skilled migrants, but such national permits cannot grant the right of residence in other EU Member States that 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 point-based immigration scheme-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. Also, the United Kingdom changed its point system in 2011 towards greater selectivity. The Highly skilled migrant programme has been replaced by an 'Exceptional Talent' visa for applicants who are 'internationally recognised leader or emerging leader' in their field. This trend is most likely to continue, and could 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 likely to influence public opinion on migration, namely the labour market impact of immigrants (Borjas, 2003, 2009; Angrist and Kugler, 2003; Lubotsky, 2007; Ottaviano and Peri, 2008)[1] and the fiscal impact of immigration (Auerbach and Oreopoulos, 1999; Storesletten, 2000, 2003; Hansen and Lofstrom, 2003).[2] However, the debate is relatively quiet on a third major area of interest: the impact of migration on economic growth. This is precisely the question addressed by this paper.

[1]See, for instance, Longhi *et al.* (2005, 2008) for recent meta-analyses.

[2]See, for instance, Rowthorn (2008) or Leibfritz *et al.* (2003) for a review.

Though there are few doubts about the impact of a labour shock due to migration on aggregate GDP growth, the effect is not so obvious with regard to per capita GDP growth. Indeed, in the standard augmented neoclassical growth model developed by Mankiw *et al.* (1992), an increase in permanent migration flows has a negative impact on long-term economic growth 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 or not migration positively effects per capita GDP growth 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 tried to estimate the impact of permanent immigrant flows on economic growth while accounting for educational attainment. The closest 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 level and use 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. In the past two decades the characteristics of international migration has evolved considerably and its impact therefore needs to be reconsidered. This is the purpose of this paper.

This paper is also related to the recent studies that analyse the effects of economic openness and diversity on GDP per capita. 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, 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 of 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 productivity growth. We focus on permanent migration—movements that the receiving country considers are for the long term. We exclude temporary visitors (i.e. tourists and businessmen) 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 has changed over time and flows better reflect these changes 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 between 1986–2006. Moreover, specific attention is devoted to producing robust measures of the educational attainment of recent immigrants as well as native-born expatriates who return to their home country. Second, our estimations are based on the SYS-GMM for dynamic panel data models developed by Arellano and Bover (1995) and Blundell and Bond (1998) that permit one to deal with 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 think that this way of proceeding is a useful complement to standard specification tests for getting valid instruments and obtaining robust econometric results.

Our econometric investigation provides evidence showing that, over the period considered, the impact of migration on productivity growth via human capital accumulation and capital dilution is significant with the expected signs (i.e. respectively positive and negative). Furthermore, in almost all OECD countries, the former dominates the latter. Therefore migration flows tend to have a positive (though small) impact on economic growth, even in countries which have highly selective migration policies. Moreover, simulations based on these results indicate that, all else equal, a one percentage-point increase in foreign-born net migration would have increased productivity growth by three-tenths of a percentage-point per year on average for the 22 OECD countries considered.

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 and the data, and presents the empirical results. Section 5 discusses the implications of the results. Finally, Section 6 offers some concluding remarks. Technical details of the theoretical model and data sources are contained in the appendix.

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

International migration potentially has direct and indirect effects on economic growth. Firstly, 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 where all per capita variables are nonetheless stable. Even in this framework however, migration affects the age structure of the population of the destination country 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,[3] which finally could result in higher total factor productivity (TFP) growth.[4] Yet, this transmission channel has not been directly considered in the literature.

Secondly, migrants arrive with their skills and abilities, which supplement the stock of human 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) 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 immigrants have on technological progress, notably their contribution to innovation.[5] Walz (1995), for instance, introduces migration in a two country endogenous growth model based on Lucas (1998). 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 developed by Grossman and Helpman (1991). They find that free migration would stimulate growth, especially if it responds to differences in labour force endowments. Similarly, in an expansion-in-variety framework, Bretschger (2001) shows that skilled migration can promote growth by decreasing the costs of research and development and also by raising 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 doesn't have a significant effect on TFP. Since immigration shocks lead to an increase in total employment and a proportional response in production, output per capita is not effected by inflows of migrants. However, this study does not take into

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

[4]There is increasing evidence of the impact of changes in age structure of the population on productivity (Sarel, 1995; Lindh and Malmberg, 1999; Kögel, 2005; Feyrer, 2007).

[5]Hunt and Gauthier-Loiselle (2008) provide recent evidence on the impact of highly skilled migration in the United States on innovation. They find that a one percentage-point rise in the share of immigrant college graduates in the population increases patents per capita by 6%.

account the human capital of migrants,[6] or their diversity by 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 by 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 diversity of immigration population by country of birth and education on growth.

Another approach is to use time-series analysis. Morley (2006), for instance, analyses the causality between migration and economic growth on 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 such 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 harmonised 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 productivity growth, controlling for the skill composition of recent immigrants, through a clear theoretical framework which 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:

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

where A is the 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 between 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 the skill composition of these two migration streams are quite dissimilar. Note that net migration is the

[6] Orefice (2010) estimates the impact of migration on economic growth in a gravity model using OECD data on gross migration flows for 24 countries between 1998 and 2007 and uses a proxy for education based on migrant stocks in 2000. The author finds a negative impact of migration on economic growth.

difference between immigration into and emigration from the country during the period. Labour force growth is therefore given by (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 notably). 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 their human capital (skills and abilities) that supplements the domestic stock of human capital.[7] Inversely, those who leave the country, take with them their human capital. This is the second channel through which migration impacts production factor endowments in this basic model. We denote by h^M the average quantity of human capital that each foreign-born migrant brings along, h^E the average human capital of native-born migrants, and $\hat{h}$ 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, $\kappa^M = h^M/\hat{h}$ ($\kappa^E = h^E/\hat{h}$) 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:[8]

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

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:

$$\dot{k} = s_K\ y - (\delta + g_A + n)\, k \tag{5}$$

$$\dot{h} = s_H\ y - \left(\delta + g_A + n - \left(m\ \kappa^M + e\kappa^E\right)\right) h \tag{6}$$

[7]Migrants are not supposed to bring significant amounts of physical capital to the economy of the host country.

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

The economy converges to a steady state defined by:

$$k^* = \left(\frac{s_K}{\delta + g_A + n}\right)^{\frac{1-\beta}{1-\alpha-\beta}} \left(\frac{s_H}{\delta + g_A + n - (m\kappa^M + e\kappa^E)}\right)^{\frac{\beta}{1-\alpha-\beta}} \tag{7}$$

$$h^* = \left(\frac{s_K}{\delta + g_A + n}\right)^{\frac{\alpha}{1-\alpha-\beta}} \left(\frac{s_H}{\delta + g_A + n - (m\kappa^M + e\kappa^E)}\right)^{\frac{1-\alpha}{1-\alpha-\beta}} \tag{8}$$

Substituting (7) and (8) into the production function and taking logarithms, the steady state income per effective worker is:

$$\begin{aligned} \ln y^* &= \frac{\alpha}{1-\alpha-\beta} \ln s_K + \frac{\beta}{1-\alpha-\beta} \ln s_H \\ &\quad - \frac{\alpha}{1-\alpha-\beta} \ln (\delta + g_A + n) \\ &\quad - \frac{\beta}{1-\alpha-\beta} \ln \left(\delta + g_A + n - \left(m\kappa^M + e\kappa^E\right)\right) \end{aligned} \tag{9}$$

Assuming that all countries are in their steady state, this equation could be used for empirical analysis. Rather, we suppose that countries are growing near their steady state. The rate of growth as the economy converges to the steady state can be approximated by:

$$\frac{\dot{y}}{y} = \frac{\partial \ln y}{\partial t} \simeq -\lambda \left(\ln y\left(t\right) - \ln y^*\right) \tag{10}$$

where $\lambda = (1 - \alpha - \beta)(g_A + \delta + n)$ (Cf. appendix A.1). This yields:

$$\ln y\left(t\right) - \ln y^* \cong e^{-\lambda t} \left(\ln y\left(0\right) - \ln y^*\right) \tag{11}$$

where $y(0)$ is income per effective worker at some initial date. Note that, assuming a constant rate of convergence λ over time, Equation (11) also holds between dates t and $t-1$:

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

For estimation purposes, we need an expression in terms of income per worker, $\widehat{y}$, rather than income per effective worker, y. Since y can be expressed in term of $\widehat{y}$ ($\widehat{y} \equiv Y/L$), $\ln y\left(t\right) = \ln \widehat{y}(t) - \ln A(0) - g_A t$ and, using Equation (9), we finally obtain the productivity growth rate:

$$\begin{aligned} \ln \widehat{y}(t) - \ln \widehat{y}\left(t-1\right) &\cong g_A \left(t - e^{-\lambda}(t-1)\right) + (1 - e^{-\lambda}) \ln A(0) \\ &\quad -(1 - e^{-\lambda}) \ln \widehat{y}\left(t-1\right) \\ &\quad +(1 - e^{-\lambda}) \frac{\alpha}{1-\alpha-\beta} \left(\ln s_K - \ln\left(\delta + g_A + n\right)\right) \\ &\quad +(1 - e^{-\lambda}) \frac{\beta}{1-\alpha-\beta} \ln s_H \\ &\quad -(1 - e^{-\lambda}) \frac{\beta}{1-\alpha-\beta} \ln \left(g_A + \delta + n - \left(m\kappa^M + e\kappa^E\right)\right) \end{aligned} \tag{12}$$

Equation (12) shows that for a given α, β, δ, λ, and g_A, the rate of growth of productivity 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 $\left(m\kappa^M + e\kappa^E\right)$. The net effect of migration on productivity growth is therefore ambiguous and depends on the relative human capital contribution of foreign- and native-born migrants (κ^M and κ^E), on the net migration rates (m and e) and on the parameters of the production function (α and β).

In this framework, *ceteris paribus*, the inflow of foreign workers will have a positive impact on productivity growth only if new migrants are more qualified than the resident population ($\kappa^M > 1$) on average. However, this is not a sufficient condition as the human capital brought by migrants should also offset the capital dilution effect. Indeed, appendix $B.1$ shows 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 productivity growth. Below that threshold the impact will however depend on other parameters of the model.

The fact that migration has a positive impact on productivity growth 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 in which one 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

Equation (12) suggests a useful specification for the model that can be used to evaluate the impact of immigration on economic growth in receiving countries. Note that:

$$\begin{aligned} \ln\left(g_A + \delta + n - \left(m\kappa^M + e\kappa^E\right)\right) = &\quad \ln\left((g_A + \delta + n)(1 - \frac{m\kappa^M + e\kappa^E}{g_A + \delta + n})\right) \\ = &\quad \ln(g_A + \delta + n) + \ln(1 - \frac{m\kappa^M + e\kappa^E}{g_A + \delta + n}) \end{aligned} \tag{13}$$

One can expect that $\frac{m\kappa^M + e\kappa^E}{g_A + \delta + n}$ is small.[9] Using the approximation $\ln(1 - x) \cong -x$ yields the following equation for the growth rate per worker:

[9] 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 the next section, 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.

$$
\begin{aligned}
\ln \widehat{y}_{i,t} - \ln \widehat{y}_{i,t-1} \cong\ & g_A \left(t - (t-1)e^{-\lambda}\right) + \left(1 - e^{-\lambda t}\right) \ln A\,(0) \\
& - \left(1 - e^{-\lambda}\right) \ln \widehat{y}_{i,t-1} \\
& + \left(1 - e^{-\lambda}\right) \frac{\alpha}{1-\alpha-\beta} \ln s_{K_{i,t}} \\
& + \left(1 - e^{-\lambda}\right) \frac{\beta}{1-\alpha-\beta} \ln s_{H_{i,t}} \\
& - \left(1 - e^{-\lambda}\right) \frac{\alpha+\beta}{1-\alpha-\beta} \ln \left(g_A + \delta + n_{i,t}\right) \\
& + \left(1 - e^{-\lambda}\right) \frac{\beta}{1-\alpha-\beta} \frac{m_{i,t}\kappa^M_{i,t} + e_{i,t}\kappa^E_{i,t}}{g_A + \delta + n_{i,t}}
\end{aligned} \tag{14}
$$

The human capital effect of net migration is captured by $\frac{m_{i,t}\kappa^M_{i,t}+e_{i,t}\kappa^E_{i,t}}{g_A+\delta+n_{i,t}}$.

Following standard practice in the literature,[10] we assume that the convergence parameter λ is constant over time and across countries. The term $A\,(0)$ represents all unobserved elements (e.g. the initial level of technology, resource endowments, climate, institutions, etc.). 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 productivity growth for a given country i is a more general form of Equation (14):

$$
\begin{aligned}
\ln \widehat{y}_{i,t} =\ & \beta_1 + \beta_2 \ln \widehat{y}_{i,t-1} + \beta_3 \ln s_{K_{i,t}} + \beta_4 \ln s_{H_{i,t}} + \beta_5 \ln \left(\delta + g_A + n_{i,t}\right) \\
& + \beta_6 \frac{m_{i,t}\kappa^M_{i,t}}{\delta + g_A + n_{i,t}} + \beta_7 \frac{e_{i,t}\kappa^E_{i,t}}{\delta + g_A + n_{i,t}} + \mu_i + \gamma_t + v_{i,t}
\end{aligned} \tag{15}
$$

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

4.2 Data

We consider a panel of 22 OECD countries between 1986 and 2006. In order to reduce the influence of short-run variation, we split the sample period into five sub-periods. Since 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 of the migration variables are presented in Table C.1.

To assess the human capital content of migration flows, we compile a unique data set on net migration flows that includes data on place of birth and educational attainment. Data on international migration in OECD countries are relatively scarce. Most

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

available data are related to the characteristics of the stock of immigrants whereas we need data on the characteristics of immigrant flows to estimate equation (15). Indeed, the main source of data on international migration is the population census, which provides comparable migration stock data for recent census years. Artuc *et al.* (2013), the last update of the Docquier and Marfouk (2006), data provide information on gender, country of origin, and educational level of the foreign-born population in 1990 and 2000. These data were extended by Brücker *et al.* (2013) for 20 OECD countries to two additional census years, 1980 and 2010. Moreover, they impute missing information in order 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 of immigrants living in OECD countries using the 2000 round of population censuses. Note that these data do not show where the tertiary diploma was obtained nor do they account for differences in skills, including language proficiency.

An additional source of information on immigrants is data on migration flows available from the OECD International Migration Database and the UN International Migration Flows Database. However, these data are not harmonised 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 are usually not broken down by education level.

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 by educational attainment.

Data on net migration flows by place of birth are directly available from 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 the basic demographic equation (Appendix C).[11] Data on the native-born population are mainly collected from population censuses (see Table C.1 for details on data sources). 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 problems of comparability than the available data on inflows and outflows of foreign citizens cited above. Finally, foreign-born net migration (M) is given by the difference between total

[11] For the countries where 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.

net migration from the OECD database and native-born net migration, computed from the native population.

Though 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. Since 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 less than 5 years) who have completed their tertiary education[12] 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 Database on Immigrants in OECD Countries (DIOC) which provides data for people born in the OECD and living in another country circa 2000 on educational attainment, age, and duration of stay. The education 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 looking at OECD expatriates with 5 to 10 years of residence in 2000 and the later by looking at those OECD expatriates with less than 5 years of residence 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 (Table C.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 (Table C.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 for 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 (Table C.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

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

from the OECD database. Real GDP (constant prices, constant PPPs, 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 share of investment in real GDP, taken as an average over each period. Data come from the Penn World Table version 7.1 (Heston et *al*, 2012). We use tertiary school enrollment as a proxy for the rate of investment in human capital. Almost all previous studies have used the secondary enrollment rate as the measure of educational input. However, tertiary education is identified as important for the development of innovative research and the ability to acquire and adopt it. Gemmell (1996) finds that, other things equal, tertiary education seems to be more important for economic growth in OECD countries. So, for our sample of OECD countries, the use of tertiary school enrollment is more relevant than secondary school enrollment. The data come from the World Development Indicators (World Bank, 2013). Sample 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

4.3 Methodological Considerations

The residuals of Equation (15) are autocorrelated because of the presence of the lagged dependent variable which 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 equation (15) obtained via standard econometric methods are likely to be biased for various reasons, including measurement error and omitted variable bias. To deal with 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). And, 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). That's why 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 enable one to 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 showing 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.[13] 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. To obtain valid instruments, we followed some of the recommendations given by Roodman (2009) and Bazzi and Clement (2013), the former addressing the problem of too many instruments,[14] and the latter the fact that common instrumental variable approaches can lead to opaquely weak or opaquely invalid instruments. One of them is limiting the lag depth, the other one 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 the collapsed two-period lags from all variables included in the estimation as the (internal) instrument sets.[15] Moreover, following Bazzi and Clement (2013), since internal instruments may not be sufficient in dynamic models estimated by SYS-GMM techniques, we also include an external instrument[16] which has already been used in other published works (Altonji and Card, 1991; 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 there are existing networks (Bartel, 1989; Jaeger, 2007) and past immigration concentrations are unlikely to be related to current economic shocks.

Finally, we consider three specification tests to deal with the consistency of the SYS-GMM estimator. The first one 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

[13] The first-differenced GMM estimator is based on the idea of 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 done under the assumption that the time-varying disturbances in the original level equations are not serially correlated.

[14] 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. But 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.

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

[16] We also use the collapsed two-period lags from past immigrant concentrations as external instrument sets. Similar results are obtained with the collapsed three-period lags.

of the first-differenced equation. The second one is a Sargan 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 one is a difference Sargan test, denoted by Diff-Sargan, proposed by Blundell and Bond (1998), which examines the null hypothesis of mean stationarity for the SYS-GMM estimator. These statistics, called incremental Sargan test statistics, are the difference between the Sargan 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 moving to regression equations, we first consider the pooling restrictions implicit in equation (15) 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 is valid in our growth regression context. Specifically, we employ a multi-step procedure to test pooling restrictions in our system of 22 OECD members where hypotheses of interest are tested by means of a likelihood-ratio statistic. This procedure is in the same spirit as the approach of Hsiao (1986). Our results (available upon request) provide evidence showing that common coefficients can be assumed across countries and consequently pooling time series and cross sectional data seems 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 equation (15) includes individual country effects. What is more, the fixed effect specification turns out to be the more appropriate in our growth equation framework.

We then estimate equation (15) on data for 22 OECD countries from 1986–2006. The results for the SYS-GMM estimation are reported in Table 2. Two types of specifications are considered. The first is the standard augmented Solow model, which serves as a benchmark. Results for this specification are presented in column 1. The second is the human capital content of net migration in the augmented Solow model as specified in equation (15). Results are presented in the second column.

Before commenting on our results, it is important to point out that our GMM model specification passes all the standard diagnostic tests, the p-values of which are given 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 from Table 2 show that most estimated coefficients have a sign that accords with what is predicted by 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.[17] Estimation of the benchmark model in column 1 shows a highly signifi-

[17]This result is identical to that reported by many authors (Benhabib and Spiegel, 1994; Islam, 1995, Bond *et al.*, 2001).

Table 2: Productivity growth
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)
$\ln(g_A + \delta + n_{i,t})$	-0.404*	-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-Sargan 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 parenthesis. 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.

cant negative 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 found in the literature. Working-age population growth has a significantly negative effect on productivity growth. The coefficient of the physical capital investment rate is positive and significant. However, the estimated coefficient for human capital investment is insignificant. This is a common result in the empirical literature on the growth effects of human capital investment.[18]

The second column of Table 2 presents estimates for the augmented Solow model taking into account the human capital content of net migration, equation (15). 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 about 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 productivity growth. A similar impact is found for native-born migration, although it is only significant at the 10% level.

Overall, the model seems to perform well. First, most coefficients are significant and have the expected signs. Schooling measure is the only variable which is not significant, but other studies have found similar or even negative effects. Second, the human capital

[18] Benhabib and Spiegel (1994, p.149-50) also find that the investment in human capital between 1965 and 1985 has an insignificant effect on per capita output growth.

content of the net migration coefficients is positive and strongly significant, which shows the importance of the role played by the skills of immigrants on the growth of OECD countries.

5 The impact of immigration on productivity growth

The theoretical model described in Section 3 suggests that the impact of migration on productivity growth is ambiguous and depends on (*i*) foreign-born 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 GDP growth per worker.

Based on the estimation results for outlined in Table 2 and applying the average variables for the total period 1986-2006, we estimate the effect of an increase in the net migration rate of the foreign-born on productivity growth for each country included in our sample. We do the same for an increase in the skill composition of net migration flows (Cf. Appendix $B.2$). Results are reported in the Table 3.

Table 3: Impacts of increases in net migration

	Key structural variables			Impact on productivity growth in % per year		
Country	m	h^M	κ^M	+1 % point in m	50% increase in m	10% in κ^M
Austria	0.47	18.9	2.20	0.47	0.45	0.18
Australia	0.56	36.6	1.73	0.23	0.26	0.14
Belgium	0.44	33.6	1.77	0.30	0.26	0.13
Canada	0.76	49.5	1.67	0.19	0.29	0.19
Switzerland	0.97	34.2	1.87	0.29	0.56	0.29
Germany	0.58	20.3	1.12	0.02	0.03	0.09
Denmark	0.33	28.4	1.33	0.14	0.09	0.08
Spain	0.56	24.1	1.52	0.14	0.16	0.13
Finland	0.17	24.0	1.39	0.17	0.06	0.04
France	0.32	27.8	1.91	0.37	0.23	0.10
Greece	0.32	13.5	1.01	-0.05	-0.03	0.05
Ireland	0.81	43.6	2.87	0.60	0.96	0.32
Iceland	0.55	34.7	2.26	0.56	0.62	0.21
Italy	0.29	10.9	1.77	0.34	0.20	0.09
Luxembourg	1.24	35.5	2.07	0.28	0.70	0.39
Netherlands	0.35	22.8	1.33	0.13	0.09	0.08
Norway	0.36	29.4	1.33	0.12	0.08	0.08
New Zealand	0.79	35.2	1.85	0.27	0.43	0.21
Portugal	0.09	18.3	2.51	0.62	0.11	0.04
Sweden	0.50	36.6	1.63	0.22	0.22	0.13
United Kingdom	0.37	39.6	2.08	0.44	0.32	0.13
United States	0.51	26.7	0.97	-0.03	-0.04	0.07
OECD 22	0.52	29.3	1.75	0.27	0.28	0.14

Note: m is the average annual net migration rate %, h^M is the share of tertiary educated among recent foreign-born migrants %, average 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, average over the 1986-2006 period.

Results show that in most OECD countries, taking into account the skill composition of foreign-born migrants, increasing permanent migration of foreign-born workers by 1 percentage-point would increase productivity growth by between one- and six-tenths of a percentage-point per year (Column 4, Table 3). Practically no effect is observed for Germany, Greece, and the United States. In these countries recent immigrants are as skilled as the resident population so the human capital they contribute is almost enough to offset the capital dilution effect. Note that the very small negative effect of foreign-born migration on productivity growth in Greece and the United States represents only one-tenth of the negative impact of a comparable increase in the natural population growth rate, $\widetilde{n}$.

A one percentage-point increase in net migration is not necessarily comparable across countries as it represents quite distinct shocks on migration. If we consider a 50% increase in the net migration rate of the foreign-born, everything else being equal, we find in all but two countries that the change in productivity growth is positive (column 5, Table 3). Still, the migration growth effect is small for all countries except Ireland, Iceland, and Luxembourg where the increase in productivity growth is more than six-tenths of a percentage-point per year.
In order to compare our results with regard to recent empirical literature, we should look at -in addition to the effect on GDP per worker outlined in Table 3- the effect on the demographic ratio of working age to total population (Appendix D). Foreign-born migration flows improved this ratio in all OECD countries. In Greece and the United States, the positive demographic effect compensates the small negative effect on productivity growth. Thus, foreign-born permanent migration flows increase GDP per capita in all OECD countries considered (Table D.1). These results are in line with the findings of recent empirical studies based on migration stock data, although the positive effect of foreign-born migration we find seems smaller in magnitude. 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) 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 productivity growth (Cf. Appendix B.2). Column 6 shows that a 10% increase in the relative share of tertiary-educated immigrants compared to the resident population adds between one- and four-tenths of a percentage-point to the productivity growth rate. It is also worth noting that raising the education level of new immigrants will have a positive impact on productivity growth 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, increasing net migration seems to have a more sizable impact on productivity growth than adopting a more selective policy.

6 Conclusion

By estimating a structural model, this paper has sought to provide a new look at the effect of permanent migration flows by country of origin and skill level on economic growth. To this end, we have first compiled an original data set on the net migration of the native- and foreign-born containing educational attainment information from various data sources for 22 OECD countries between 1986 and 2006. Moreover, in the theoretical model, on which our econometric investigation is based, we account for the impact of migration on capital dilution and human capital accumulation. Depending on the relative skill endowment of migrants compared to the resident population, the permanent migration flow may positively impact productivity growth.

In contrast to previous studies and following the recommendations of both Roodman (2009) and Bazzi and Clement (2013), we deal with the potential endogeneity of the migration variables by choosing appropriate (internal and external) instruments, estimating our model using SYS-GMM. The results support the theoretical model and demonstrate a positive impact of the human capital brought by migrants on economic growth. The contribution of immigrants to human capital accumulation tends to dominate the mechanical dilution effect. The net effect is fairly small, even in countries that have highly selective migration policies. A 50% increase in net migration of the foreign-born generates, on average, an increase of three-tenths of a percentage-point in productivity growth per year in OECD countries. Increasing the selectivity of migration policies does not appear to have a more marked effect on productivity growth, except perhaps in countries where recent immigrants are somewhat less educated than 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 as migrants tend to be concentrated in the more active age groups compared to natives and thereby reduce dependency ratios. There is also some evidence that immigrants tend to be complementary to natives as they may free 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 could boost innovation and technological progress. Therefore, 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 speed of convergence

From the intensive form production function given by equation (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 (5) and (6) into $(A.1)$ to get:

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

Note that at the steady state, using (7) and (8), we have:

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

Substituting $(A.3)$ into $(A.2)$ 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:

$$\begin{aligned} \frac{\dot{y}}{y} &= \alpha s_K \frac{y*}{k*}\left(\left(\frac{k}{k*}\right)^{\alpha-1}\left(\frac{h}{h*}\right)^{\beta} - 1\right) \\ &\quad + \beta s_H \frac{y*}{h*}\left(\left(\frac{k}{k*}\right)^{\alpha}\left(\frac{h}{h*}\right)^{\beta-1} - 1\right). \end{aligned} \tag{A.4}$$

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:

$$\begin{aligned} \left(\frac{k}{k*}\right)^{\alpha-1}\left(\frac{h}{h*}\right)^{\beta} - 1 &= (\alpha-1)\ln\left(\frac{k}{k*}\right) + \beta\ln\left(\frac{h}{h*}\right) \\ \left(\frac{k}{k*}\right)^{\alpha}\left(\frac{h}{h*}\right)^{\beta-1} - 1 &= \alpha\ln\left(\frac{k}{k*}\right) + (\beta-1)\ln\left(\frac{h}{h*}\right). \end{aligned} \tag{A.5}$$

Substituting $(A.3)$ and $(A.5)$ into $(A.4)$, we have:

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

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:

$$\begin{aligned}\frac{\dot{y}}{y} &= -\left(\delta+g_A+n\right)\left(1-\alpha-\beta\right)\ln\frac{y}{y*} \\ &= -\left(\delta+g_A+n\right)\left(1-\alpha-\beta\right)\left(\ln y-\ln y*\right) \\ &= -\lambda\ \left(\ln y-\ln y^*\right),\end{aligned} \tag{A.6}$$

and thus the rate of convergence is given by:

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

This leads to:

$$\ln y\left(t\right)-\ln y^* = e^{-\lambda t}\left(\ln y\left(0\right)-\ln y^*\right). \tag{A.7}$$

Appendix B The growth effect of migration

Appendix B.1 The theoretical model

The annual growth rate of output per worker, $g_{\hat{y}}$, is given by Equation (12):

$$tg_{\hat{y}} \equiv \ln\widehat{y}\left(t\right)-\ln\widehat{y}\left(0\right) = g_At+\left(1-e^{-\lambda t}\right)\left(\ln A\left(0\right)-\ln\widehat{y}\left(0\right)+\ln y^*\right).$$

Foreign-born migrants' impact on growth is given by:

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

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 growth of foreign-born immigrants is determined by the partial derivative of $\ln y^*$ given by Equation (9) with respect to the foreign-born immigration rate, m:

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

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. $m\kappa^M + e\kappa^E \geq 0$), an increase in the inflow of foreign workers has a positive impact on productivity growth if $\kappa^M \geq (\alpha + \beta)/\beta$.

The increase in the skill composition of foreign born immigrants, κ^M, always has a positive impact on productivity growth:

$$\begin{aligned}
t\frac{\partial g_{\hat{y}}}{\partial \kappa^M} &= \frac{\partial \left(\ln \widehat{y}(t) - \ln \widehat{y}(0)\right)}{\partial \kappa^M} \\
&= \left(1 - e^{-\lambda t}\right) \frac{\partial \ln y^*}{\partial \kappa^M} \\
&= \frac{\left(1 - e^{-\lambda t}\right) \ \beta \ m}{(1 - \alpha - \beta)\left(g_A + \delta + n - (m\ \kappa^M - e\ \kappa^E)\right)}.
\end{aligned}$$

Appendix B.2 Empirical analysis

The impact on growth due to foreign-born migrants given in Table 3 is evaluated from the estimation of the econometric model, given by equation (15):

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

where $n_{i,t} = \tilde{n}_{i,t} + m_{i,t} + e_{i,t}$.

The effect of increasing net migration of the foreign-born by 1 percentage-point is approximated, for each country, by $\frac{\partial g_{\hat{y}}}{\partial m}$:

$$\begin{aligned}
t\frac{\partial g_{\hat{y}}}{\partial m} &= \hat{\beta}_5 \frac{\partial \ln\left(\delta + g_A + n\right)}{\partial m} + \hat{\beta}_6 \frac{\partial \left(m\kappa^M/\delta + g_A + n\right)}{\partial m} + \hat{\beta}_7 \frac{\partial \left(e\kappa^E/\delta + g_A + n\right)}{\partial m} \\
&= \frac{\left(\hat{\beta}_5 + \hat{\beta}_6 \kappa^M\right)(\delta + g_A + n) - \hat{\beta}_6 m\kappa^M - \hat{\beta}_7 e\kappa^E}{\left(\delta + g_A + n\right)^2}. \qquad \text{(B.1)}
\end{aligned}$$

We use the estimated coefficients provided in Table (3) and apply the time-averaged measures for each country. Note that we consider four year time intervals so $t = 4$. The growth impact of the immigrants' skill composition, κ^M, can be assessed by:

$$t\frac{\partial g_{\hat{y}}}{\partial \kappa^M} = \hat{\beta}_6 \frac{m}{\delta + g_A + n}. \qquad \text{(B.2)}$$

We use estimated coefficients (3) and time-averaged measures for each country.

Appendix C Data

Appendix C.1 Estimation of net migration by country of birth

This section presents the methodology used to estimate net migration by country of birth. The data mainly come from national population censuses held between 1980 and 2006, population registers, and the European Labour Force Survey. Table C.1 summarizes data sources for each country. Data on deaths, births, and net migration are from the OECD database. Deaths by age group come from the World Health Organisation Mortality Database (WHO).

According to the basic demographic equation, the native-born population (NBP)[19] 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.

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.

[19] 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 C.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 C.2: Net migration rates of the native- and foreign-born in selected OECD countries, 1986–2006.

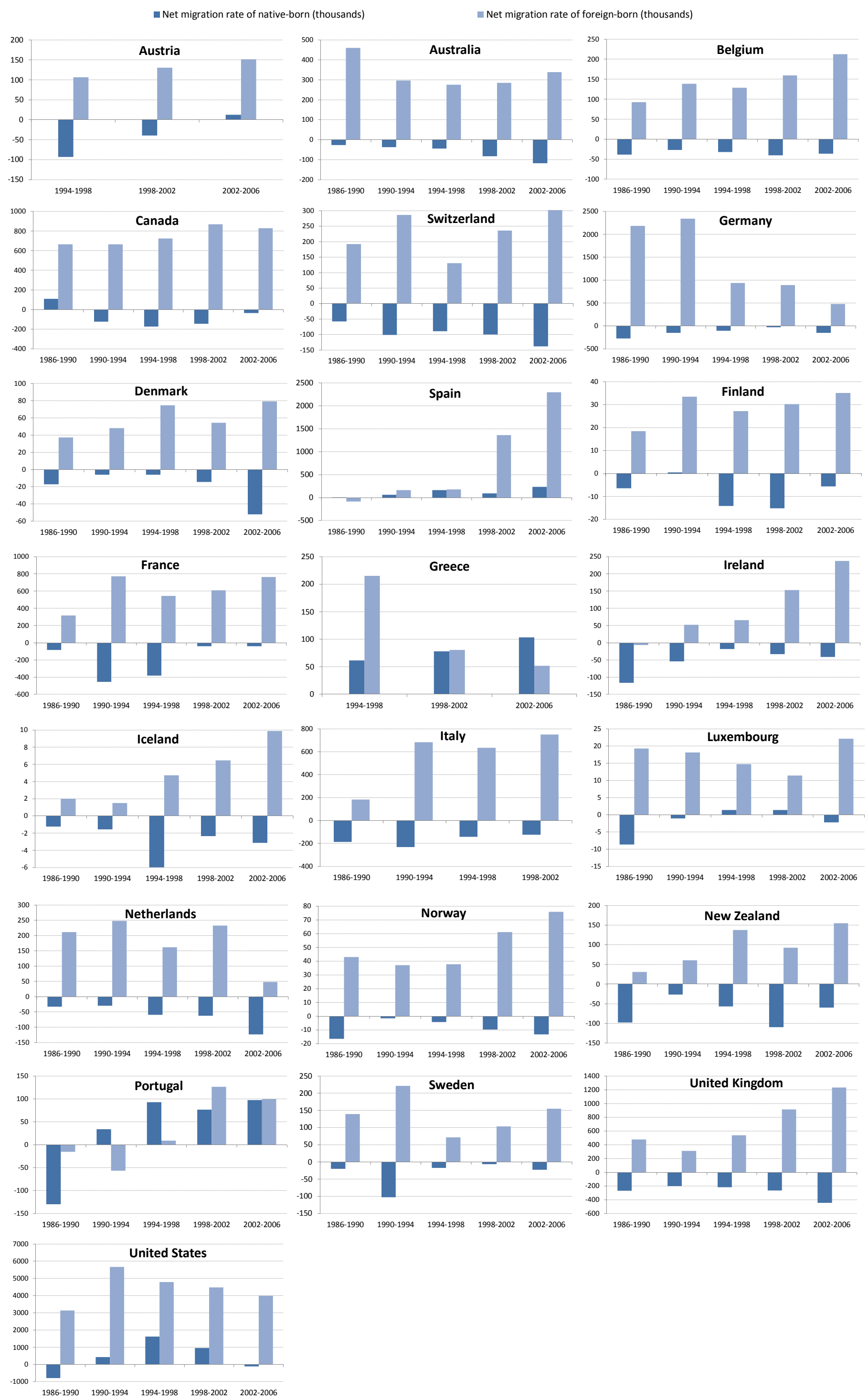

Table C.3: Share of native-born emigrants and recent foreign-born migrants that has completed tertiary education in selected OECD countries, 1986–2006.

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

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

Let $\tilde{y}$ denote GDP per capita, P the total population, L the working age population, and $d = \frac{L}{P}$ the demographic ratio. Then, we have:

$$\tilde{y} = \frac{Y}{P} = \frac{Y}{L} \cdot \frac{L}{P}.$$

The growth rate of per capita GDP is given by:

$$\ln \tilde{y}(t) - \ln \tilde{y}(0) = \ln \widehat{y}(t) - \ln \widehat{y}(0) + \ln d(t) - \ln d(0).$$

We let $g_{\tilde{y}}$ be the annual growth rate of GDP and g_d the annual growth rate of the demographic ratio. Then, we get:

$$tg_{\tilde{y}} = tg_{\hat{y}} + tg_d.$$

The effect of m on the growth of per capita GDP is:

$$\begin{aligned}
\frac{\partial\left(\ln \tilde{y}(t) - \ln \tilde{y}(0)\right)}{\partial m} &= \frac{\partial\left(\ln \widehat{y}(t) - \ln \widehat{y}(0)\right)}{\partial m} + \frac{\partial\left(\ln d(t) - \ln d(0)\right)}{\partial m} \\
t\frac{\partial g_{\tilde{y}}}{\partial m} &= t\frac{\partial g_{\hat{y}}}{\partial m} + t\frac{\partial g_d}{\partial m}.
\end{aligned}$$

From the estimated model given by Equation (15), the impact of foreign-born net migration is given by (Cf. Appendix B.2):

$$\frac{\partial g_{\hat{y}}}{\partial m} = \frac{\left(\hat{\beta}_5 + \hat{\beta}_6 \kappa^M\right)(\delta + g_A + n) - \hat{\beta}_6 m \kappa^M - \hat{\beta}_7 e \kappa^E}{(\delta + g_A + n)^2}.$$

To evaluate the impact of m on demographic ratio d, note that:

$$\ln d(t) - \ln d(0) = \ln \frac{d(t)}{d(0)} = \ln \frac{L_t}{P_t}\frac{P_0}{L_0} = \ln \frac{L_t}{L_0} - \ln \frac{P_t}{P_0}.$$

An increase in the net migration rate of working-age, foreign-born persons (m) affects the working age population, L_t (since $L_t = (\tilde{n} + m_t + e_t) L_0$), 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 to 0 to 14 years and P_t^{65+} is population aged 65 and older. Note that:

$$\begin{aligned}
\frac{P_t}{P_0} = \frac{L_t + P_t^{65+} + P_t^{00-14}}{P_0} &= \frac{L_t}{L_0}\frac{L_0}{P_0} + \frac{P_t^{65+} + P_t^{00-14}}{P_0} \\
&= (\tilde{n} + m_t + e_t)\frac{L_0}{P_0} + \frac{P_t^{65+} + P_t^{00-14}}{P_0}.
\end{aligned}$$

The effect of changes in m on the demography ratio d is given by:

$$\begin{aligned}
\frac{\partial\left(\ln d(t) - \ln d(0)\right)}{\partial m} &= \frac{\partial\left(\ln \frac{L_t}{L_0}\right)}{\partial m} - \frac{\partial\left(\ln \frac{P_t}{P_0}\right)}{\partial m} \\
&= \frac{L_0}{L_t} - \frac{L_0}{P_t}.
\end{aligned}$$

Table D.1: Impacts of increases in net migration

	Impact on productivity growth in % per year		Impact on per capita growth in % per year	
Country	+1 % point in m	50% increase in m	+1 % point in m	50% increase in m
Austria	0.47	0.45	0.55	0.52
Australia	0.23	0.26	0.31	0.35
Belgium	0.30	0.26	0.39	0.34
Canada	0.19	0.29	0.27	0.41
Switzerland	0.29	0.56	0.37	0.72
Germany	0.02	0.03	0.10	0.12
Denmark	0.14	0.09	0.22	0.15
Spain	0.14	0.16	0.22	0.25
Finland	0.17	0.06	0.25	0.08
France	0.37	0.23	0.46	0.29
Greece	-0.05	-0.03	0.03	0.02
Ireland	0.60	0.96	0.68	1.10
Iceland	0.56	0.62	0.64	0.71
Italy	0.34	0.20	0.42	0.25
Luxembourg	0.28	0.70	0.36	0.89
Netherlands	0.13	0.09	0.21	0.15
Norway	0.12	0.08	0.20	0.15
New Zealand	0.62	0.43	0.35	0.55
Portugal	0.22	0.11	0.70	0.13
Sweden	0.44	0.22	0.31	0.31
United Kingdom	-0.04	0.32	0.52	0.38
United States	0.51	-0.04	0.05	0.05
OECD 22	0.27	0.28	0.35	0.08