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Abstract

Immigration, as a source of population growth, is traditionally associated with negative output and growth effects for the host economy in per capita terms. This paper explores how different these effects can be when the human capital brought in by immigrants upon arrival is explicitly taken into account. Descriptive evidence, based on education data, on the human capital content of international migration flows is provided for nine receiving countries suggesting that the immigrants' human capital may indeed be fairly high and similar to the natives' one. To provide a framework for the econometric analysis, the implication of these findings are then analysed within a Solow growth model augmented by migration, in which the negative output and growth effects of immigration are shown to become less important the higher the immigrants human capital. In the presence of both physical and human capital, however, the human capital of immigrants has to be much higher than that of natives in order to eliminate the negative impact of migration inflows. These conclusions are shown to be supported by an econometric analysis based on both a cross-section and a pooled country dataset consisting of 23 OECD economies for the period 1960-1985. Econometric estimates of the human capital content of migration inflows relative to natives, appear to be in line with the descriptive evidence based on education data.

Introduction

Population growth is traditionally associated, by neo-classical theory, with negative effects in per capita terms on output and growth, the reason being the undisputed assumption of decreasing returns to labour in the production function. Immigration, as a source of population growth, has therefore understandably shared the same presumption of negative per capita effects. However, immigrants are not like new-born babies: when they enter the host country they bring with themselves the human capital accumulated in the country of origin and after arrival they contribute to the human capital accumulation in the host economy in a way which may be different from that of native new-borns.

The traditional production function in which output is produced with physical capital and labour does not leave too much room for a positive immigrants' contribution to output and growth via the human capital they bring in with themselves or via their capacity to accumulate skills in the host economy. Yet the most recent growth literature has highlighted the importance of considering explicitly human capital as one of the reproducible factors of production. For the "endogenous growth" literature, the introduction of human capital in the production function has represented one way to justify the existence of constant returns to the reproducible factor, thereby allowing for a steady state constant growth without convergence.[1] More recently Mankiw, Romer and Weil [1992] (MRW hereafter) have shown that, without the assumption of a constant return to the reproducible factor, "an augmented Solow model that includes accumulation of human as well as physical capital provides an excellent description of cross-country data", and that "holding population growth and capital accumulation constant, countries converge at about the rate the augmented Solow model predicts."

These recent developments of the growth literature invite an explicit consideration of the human capital contributions of immigrants to the host economy. As already anticipated above, there are two ways in which immigrants can contribute to the human capital accumulation in the receiving country: first, they bring with themselves the skills

1 See Lucas [1988], Rebelo [1991] and the extremely clear and useful survey of endogenous growth models contained in Sala-i-Martin [1990].

they have acquired before arrival, and, second, after arrival, they accumulate human capital differently than natives or they can influence the natives accumulation of knowledge.

Starting with this second effect, the migration literature has seen in the "assimilation process" a major mechanism driving the immigrants' accumulation of human capital after arrival. The estimation of cross section earning functions for the US shows that the age-earnings profile of immigrants is steeper than the age-earnings profile of natives, and that the immigrants' profile crosses the native profile at ten to fifteen years after arrival.[2] The simplest interpretation of these results is that upon arrival immigrants are not only low skilled but they also lack the country specific skills necessary to perform well in the host country. Examples of such skills are knowledge of the language, knowledge of the rules of behavior at the workplace and having a supporting network of friends and relatives who are able to indicate job openings. During the assimilation process they acquire both general and country specific skills increasing their human capital and their earnings. Chiswick [1979], argues, more generally that immigrants are self selected from the individuals that have "higher innate ability, greater motivation and greater willingness to sacrifice current consumption for human capital investments". Chiswick [1980] further suggests that the incentive to invest in the host country specific human capital is more pronounced the larger is the cost of migration and the lower is the probability of return in the country of origin.

It should, however, be noted that the cross section earning functions results quoted above are compatible with this interpretation but do not prove it. In fact, as suggested by Borjas[1985] and [1990], snap-shot cross sectional results confound vintage and cohort effects. Even in the absence of human capital accumulation, if the quality of subsequent immigrants' cohorts decline, as Borjas claims is the case for the U.S., the time from arrival would be positively correlated with earnings. Also the conclusion that immigrants are positively self selected from the original population cannot be taken for granted. The relative inequality of the income distribution in the country of origin and in the host

2 See Chiswick [1978].

country is found by Borjas [1987] to be an important determinant of the selection process. If the income distribution is more unequal in the sending country, the workers with the lowest potential skills may find more convenient to migrate while the workers with the highest skills will have stronger incentives to stay. Recent evidence suggests that even when the within cohort immigrants' experience is considered there may not be evidence of a significant assimilation process. For example, Baker and Benjamin [1992] argue that "(A)dditional years in Canada do not appreciably increase immigrants earnings relative to natives, and, indeed, we might characterize their experience as one of dissimilation."

Independently from the position taken in this debate, human capital accumulation among immigrants of the same cohort has at least the potential for being an important factor. Indeed, if the native economy is shocked by the inflow of foreign working groups with individual learning patterns that differ from the native ones, it is possible that the rate of aggregate human capital accumulation for the native economy is going to change. Furthermore, the change is likely to be positive if the average immigrants accumulation profile is steeper than the average native one, and viceversa. As a consequence, the growth rate of the host economy is likely to be affected in possibly interesting and sizeable ways, both within traditional Solow models or within endogenous growth models in which human capital plays a role.

As mentioned above, not only immigrants may accumulate human capital differently than natives after arrival, but they may also influence the native accumulation process, as for example recently suggested by Cartiglia [1990]. In his two sector model, growth takes place because of external learning by doing generated by the production of high tech goods. Skilled workers may be employed in the high tech sector or as teachers. An inflow of foreign skilled workers increases the production of high tech goods, reduces the wage of high skilled workers in that sector and increases the supply of teachers; this mechanism "lowers the cost of education, prompting in the following period an increase in the supply of native skilled workers" (i.e. a larger native accumulation of human capital).

Despite the likely importance of the immigrants propensity to accumulate human capital or of their capacity to influence the native accumulation, in this paper we will not focus on these types of effects, mostly because we have not yet found a framework in which to consider the issue in a way suitable of empirical verification[3].

Here, instead, we focus on the other type of immigrants' contribution to the host country human capital mentioned above: i.e. the stock of already accumulated skills that immigrants bring with themselves when they enter the country. The issue is obviously not new in the literature[4], but the implications for output and growth in the host economy have been relatively less explored explicitly. Burda and Wyplosz [1991a] and [1991b] have recently openly addressed this issue in order to evaluate, at a theoretical level, the output and growth effects of migration from eastern to western Europe. Being likely that the composition of migrants will tend to reflect more highly educated workers, their analysis suggests the possibility of "deleterious effects on the economies left behind" while even "receiving countries may ... suffer negative effects, at least in the short run". More generally, they conclude that "the impact of several million future migrants on the economic development of eastern Europe should bring new evidence to bear on the role of external human capital in the production function."

As a contribution to prepare ourselves to that impact, in this paper we explore the dimension and the role of the human capital brought in by immigrants for the output level and the growth rate of the receiving economies. Section I, provides descriptive evidence, based on education data, on the human capital content of international migration flows for nine major receiving countries for which we could get quality data on immigration sources and suggests that such human capital content may indeed be fairly high and similar to the native one. To provide a framework for the econometric analysis, Section II analyses the implication of these findings within a one-type-of-capital Solow growth model augmented by migration, in which the negative output and growth effects of immigration are shown

3 The literature already offers models in which the immigrants accumulation of human capital can be (and has been) explored with individual data (see the previously quoted works by Chiswick and Borjas and the surveys by Grenwood -Mc Dougal [1986], and Ichino A. [1992]): it also offers aggregate growth models that stress the importance of human capital accumulation for growth and tests it with aggregate data (see for example the literature already quoted in footnote 1 and Mankiw, Romer and Weil [1992]). The problem, in our opinion, is to bridge theoretically and, in particular, empirically the two types of models

4 See again Chiswick [1978], Borjas [1990], Grenwood and McDougal [1986] and also Simon[1989] and Stark[1991].

to become less important the higher the immigrants' human capital. Section III extends the analysis to two types of capital showing that, in this case, the human capital of immigrants has to be much higher than that of native in order to eliminate the negative effects of migration inflows. In Section IV the conclusions of the theoretical sections are shown to be supported by an econometric analysis based on both a cross-section and a pooled country dataset consisting of 23 OECD economies for the period 1960-1985. Furthermore, econometric estimates of the human capital content of migration inflows relative to natives are shown to be in line with the descriptive evidence based on education data presented in Section I. Concluding remarks follow.

I Descriptive evidence on the human capital content of migration flows

Before exploring the output and growth effects of immigration when human capital is taken into account, we want to provide some descriptive evidence on the skills content of migration flows. Given the well known lack of good data on international migration, the scope of this section is necessarily limited. No evidence based on individual data will be provided, but just some measures of the average human capital of immigrants based on aggregate information. These measures represent an admittedly imperfect estimate of the actual economic variables that we would like to document. Nevertheless they are the most informative measures we could construct with the available data and we hope that, despite their many weaknesses, something can be learned from them.

The methodology that we have followed is based on figures on the number of immigrants by country of origin and on education data.[5] The number of immigrants by country of origin was obtained, from a United Nation source[6], for the following nine major receiving countries: Australia. Belgium, Canada, Germany, Netherlands, Sweden, Switzerland, United Kingdom, and United States. For most of these countries the time series covered the 1960-1987 period, but for some of them the period was significantly shorter. The reader should also keep in mind that these are official figures on legal entries

[5] A more detailed description of this methodology is provided in the Data Appendix. Here we just sketch and discuss the main steps for the construction of our human capital measures.

[6] See Zlotnick [1991] and [1990]

in the receiving country and that not for all countries the list of origins is very detailed: for example, we go from almost 220 countries of origin for the case of Canada to 5 for Switzerland.[7]

Table 1 provides some evidence on the size of these migration inflows in comparison with population growth. On average immigrants appear to be a very important source of population growth for these countries. This is even more true in the 70s and 80s, in which the effects of the "baby boom" appear to be over. If on average, the population growth due to immigrants was 56% of the total population growth in the 60s, this percentage becomes 91% in the 70s and it climbs up to 111% in the 80s.[8]

TABLE 1: Population growth and immigration rate

Host countries	% Population growth			% Immigration rate		
	60/69	70/79	80/87	60/69	70/79	80/87
Australia	1.99	1.70	1.42	1.22	0.73	0.67
Belgium	0.59	0.23	0.03	0.75	0.63	0.49
Canada	1.80	1.22	1.07	0.72	0.65	0.46
Germany	0.90	0.21	-0.04	1.12	1.14	0.85
Netherlands	1.28	0.87	0.54	0.55	0.69	0.58
Sweden	0.70	0.40	0.09	0.50	0.52	0.43
Switzerland	1.51	0.36	0.35		0.81	1.05
United Kingdom	0.58	0.16	0.14	0.37	0.35	0.36
United States	1.29	1.05	1.00	0.17	0.20	0.25
Countries' average	1.18	0.69	0.51	0.67	0.64	0.57
Standard dev. of logs	0.47	0.86	1.31	0.62	0.51	0.44

Having established that immigration may represent a significant source of

7 More information on the characteristics of these immigration data is provided in the Data Appendix and in Zlotnick[1990].

8 Obviously this percentage may exceed 100% because of emigrants out of the host economy. Table 1 suggests that, for some of these countries, population outflows have represented a significant phenomenon.

population growth, it is important to notice that there is a substantial difference between the growth due to immigrants and the growth due to new-borns: immigrants, as opposed to babies, enter the host country with some (possibly large) human capital. Therefore, from the perspective of growth in the host economy, an inflow of immigrants cannot be considered equivalent to an increase of new-borns even if they represent equivalent percentage variations of total population. Hence, measuring the human capital contribution of immigrants is important in order to understand if these sources of population growth may have different output and growth effects.

In the absence of more detailed information, in order to ascertain the human capital content of migration flows we have looked for yearly measures of schooling in the countries from which these flows were originated. We found three sources of relevant information on education: first, the data on secondary school enrolment from the World Bank; second, the series of school attainment constructed by Kyriacou [1991] and third, the series of school attainment constructed by Barro and Lee [1992]. The World Bank secondary school enrolment rate is defined as the percentage of people enrolled in secondary school in relation to the population in the relevant age bracket. The figures on school attainment measure, instead, the average number of completed years of schooling in the population. These series have been constructed with slightly different methodologies by Kyriacou [1991] and by Barro and Lee [1992], extrapolating from point information on school attainment and school enrolment rates.[9] Notice that the first measure can be thought as an indicator of investment in human capital, while the two latter are to be considered as stock measures.

For each host country and for each of the three human capital measures, we have constructed an indicator of the immigrants' human capital equal to the weighted average of the human capital measures of the original countries using the numbers of immigrants from each origin as the weights. Assuming that immigrants are randomly chosen from the original population, the World Bank data provide in this way an index of the average

[9] More on the nature of these series in the Data Appendix and in the original papers in which they were constructed (Kyriacou [1991] and Barro and Lee [1992]).

enrolment rate among the immigrants upon departure from the country of origin; similarly, using the school attainment indexes, the average number of completed years of schooling among immigrants upon departure from the country of origin can be obtained.

The hypothesis that immigrants are randomly chosen from the original population can clearly be disputed. As already mentioned in the introduction, a traditional view in the migration literature[10] holds that immigrants are likely to be the most skilled in the country of origin. However, Borjas [1987] has convincingly shown that immigrants are self selected from the original population in possibly very different ways according to the characteristics of the host and sending countries. In particular, it is possible that the least skilled are those who emigrate from the sending country if, for example, the income distribution is more compressed in the host country than in the sending one. In the light of these different possibilities, we believe that a human capital measure like the one constructed in this paper may represent a satisfactory first order approximation to the real variable we would like to document. Indeed, there are good theoretical reasons to think that our measures could represent either a lower or an upper bound for the true measure.

Unfortunately, our immigrants' human capital indexes suffers from other weaknesses. Probably, the most important one, from the viewpoint of this paper, is the following: at best these indexes can measure the education of immigrants, but certainly they do not measure other very important components of human capital that are relevant for the production function like, for example, on the job training accumulated in the sending country. We do not see any feasible way to overcome this problem with the available aggregate information on migration flows. However, in the theoretical section we will point out that what is really relevant from the perspective of growth is the ratio between the human capital of immigrants and that of natives. Under the admittedly restrictive assumption that the immigrants/natives ratio for education indexes is similar to the immigrants/natives ratio for on the job training indexes, the first ratio can be used as an approximation to the overall human capital content of migration inflows relative to natives. Indeed, for each education index, the ratio between immigrants and natives will

10 See, for example, Chiswick [1979] and [1980].

be the variable on which we will be mainly focusing. Furthermore, to our defence, we can say that in the empirical growth literature, education has been widely used as a proxy for total human capital.[11]

Letting aside doubts, not because we think they are irrelevant but just because this is "the only game in town" with the available aggregate data, we now describe what these indexes can tell us. The first fairly striking result, in our opinion, is summarised in Graph 1, where, for the three different schooling measures described above, we plot the average human capital ratio of immigrants versus native across the countries considered in this section. This average ratio is never below .7, reaching in some years the value of .9, and these high values are basically confirmed by each of the three indexes. Thus if we are willing to accord some credibility to these measures, the average human capital of immigrants appears to be not too far from the average human capital of natives.

Looking more closely to the different national experiences, Table 2 displays for each country the average relative human capital of immigrants versus natives, in three different sub periods: the 60s, the 70s and the 80s. Looking at these indexes the reader should keep in mind, on the one hand, that cross-countries differences within the same period are just due to changes in the composition of immigrants by country of origin; on the other hand, within-country, cross-time differences are due not only to the compositional changes but also to the time variation of the human capital indicators.

With the exception of the US in the 60s using school enrolment data, for all the other indexes, countries and periods the ratio is always above .5, but there is clearly quite a lot of variation across countries. Some countries even display ratios larger than unity, indicating that immigrants could be more skilled than natives. We carefully checked these numbers and, to the best of our knowledge, they seem to reflect the original educational figures. So, for example, in case of Germany and Switzerland the original figures for the natives' human capital are surprisingly fairly low. On top of that, one should take in mind that in the 60s and 70s a large part of the migration inflow to these countries was

11 See among others, Barro [1991], Barro and Sala-i-Martin[1991] and Mankiw, Romer and Weil [1992].

originated in other European countries, in which the average schooling indicators were fairly high.[12]

For all the three measures in Table 2 and for all the three sub periods, the US appears to be at the lower end of the spectrum. On the contrary, at the upper end, the data do not seem to indicate the existence of countries that do consistently better in attracting skilled immigrants relative to natives. Also inconclusive seems to be the evidence on the within countries time trend across the three sub-periods.

Even if the ratio between immigrants and natives is the crucial variable from a theoretical point of view, it might be interesting to examine the evolution of the numerator of this ratio. This is done in Table 3, where, for each of the three data sets, only the immigrants' human capital indicators are displayed. Here we see, that for all the countries and for all the three measures, the human capital content of migration inflows in the 80s is higher than the in 70s, which in turn is higher than in the 60s. Looking at the countries' averages, school enrolment increases by almost 30% between the 60s and the 80s; the number of completed years of schooling increases instead by more than 9% in the Barro-Lee data set and by almost 25% in the Kyriacou dataset. This is clearly the result of the world wide effort to increase education standards; the lack of trend in the ratios described in Table 2, suggests that on average the increasing diffusion of higher education for host countries has been paralleled by a similar increasing diffusion between sending countries.

Comparing the within-period standard deviations of logs across countries in Table 2 and in Table 3, the percentage variability appears to be higher for the absolute immigrants' human capital indexes than for the immigrants versus natives ratios: this suggests that a significant part of the variability of the ratios is due to the variability of the host countries human capital.

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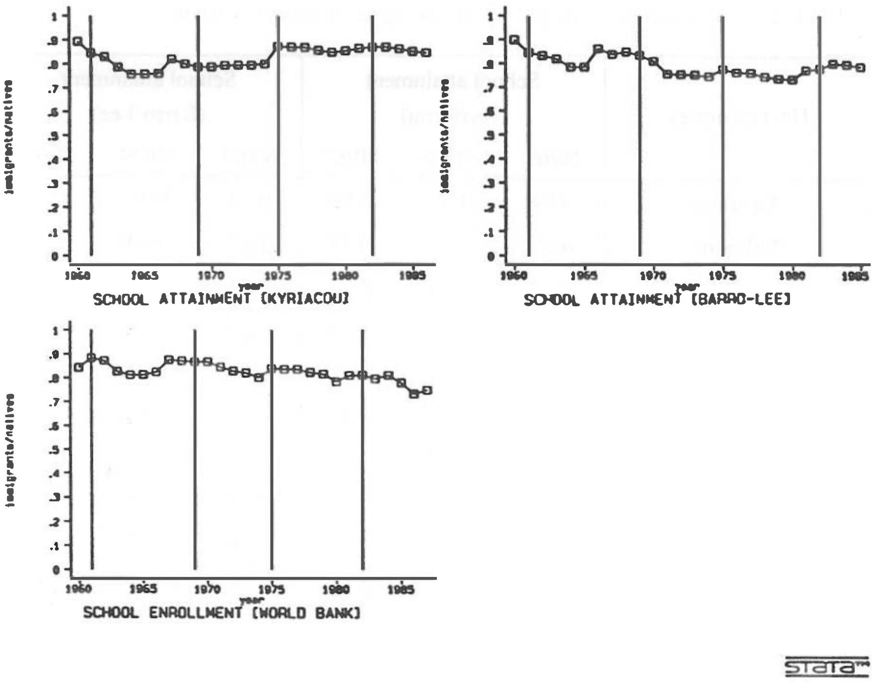
12 At this stage of our analysis we lack of possible justifications for the other numbers greater than unity. The Kyriacou data set seems in general to present less variability, and no ratios larger than 1, with the exception of Switzerland. Currently, we cannot say which feature of the Kyriacou's methodology deliver these more balanced results.



GRAPH.1 : Human capital of immigrants versus natives (averages across selected host countries)*

* Vertical bars denote changes in the number of countries on which the average is computed

TABLE 2: The ratio of immigrants human capital relative to natives

Host countries	School attainment (Kyriacou)			School attainment (Barro-Lee)		
	60/69	70/79	80/87	60/69	70/79	80/85
Australia	0.99	0.92	0.92	0.72	0.73	0.76
Belgium	0.85	0.87	0.87	1.07	0.83	0.86
Canada	0.87	0.78	0.73	0.73	0.65	0.63
Germany	0.64	0.72	0.75	1.14	1.06	1.23
Netherlands	0.79	0.74	0.73	0.73	0.64	0.68
Sweden	0.86	0.90	0.88	0.89	0.88	0.84
Switzerland		1.48	1.34		0.78	0.75
United Kingdom	0.82	0.88	0.93	0.78	0.76	0.78
United States	0.58	0.51	0.56	0.58	0.50	0.50
Countries'average	0.80	0.87	0.86	0.83	0.76	0.78
Standard dev. of logs	0.26	0.28	0.24	0.21	0.22	0.24

Host countries	School enrollment (World Bank)		
	60/69	70/79	80/87
Australia	0.93	0.78	0.77
Belgium	0.72	0.74	0.80
Canada	1.01	0.76	0.61
Germany	1.13	1.41	0.93
Netherlands	0.66	0.59	0.57
Sweden	1.06	0.91	0.89
Switzerland		0.91	0.84
United Kingdom	0.76	0.71	0.79
United States	0.47	0.57	0.60
Countries'average	0.84	0.82	0.76
Standard dev. of logs	0.28	0.27	0.18

TABLE 3: The absolute human capital content of migration inflows

Host countries	School attainment (Kyriacou)			School attainment (Barro-Lee)		
	60/69	70/79	80/87	60/69	70/79	80/85
Australia	6.79	7.15	7.90	7.56	8.11	8.84
Belgium	6.33	7.31	8.05	9.65	8.13	8.94
Canada	6.88	7.18	7.17	7.19	7.19	7.56
Germany	5.87	6.46	7.58	6.46	6.55	8.08
Netherlands	5.93	6.17	6.79	5.38	6.17	6.89
Sweden	5.72	7.17	7.82	8.18	8.50	8.84
Switzerland		8.73	9.55		6.66	7.11
United Kingdom	6.21	6.68	7.72	7.17	7.45	7.96
United States	5.64	5.81	6.71	6.05	5.80	6.39
Countries' average	6.17	6.96	7.70	7.20	7.17	7.85
Standard dev. of logs	0.14	0.12	0.11	0.17	0.13	0.12

Host countries	School enrollment (World Bank)		
	60/69	70/79	80/87
Australia	57.54	66.35	70.35
Belgium	53.04	62.42	74.08
Canada	56.19	61.68	60.87
Germany	47.41	57.76	67.45
Netherlands	40.97	50.29	57.44
Sweden	67.25	74.89	76.82
Switzerland		66.38	77.52
United Kingdom	54.04	57.14	66.95
United States	40.18	48.75	57.22
Countries' average	52.08	60.63	67.63
Standard dev. of logs	0.19	0.14	0.12

Notice also, remaining within Table 3, that for all the three data sets the standard deviations of logs decreases when we move from the 60s to the 80s. This indicates an increasing uniformity of the human capital content of migration inflows around the world.

Since the US are a country with fairly high education indicators, one would have thought that the low immigrants versus natives ratio in Table 2 could be just due to the high natives human capital. Table 3, instead, indicates, that the US have attracted less skilled immigrants not only relative to natives, but also in absolute terms. For almost all the indicators and for all the sub-periods the human capital content of the migration inflow in the US is at the lower end of the countries' spectrum.

This finding may be of some interest for the ongoing debate on the skill content of migration inflows in the US. According to Borjas [1990], who compares the skills and labour market performance of immigrants in the United States with those of immigrants in the two major competing host countries, Australia and Canada, "(T)he empirical evidence is striking and unambiguous. As a result of fundamental changes in immigration policies in all three host countries, the United States began " (in the post war period) "to attract a relatively less skilled immigrant flow than did the other countries." Indeed, immigration policies in Canada (since 1962) and Australia (since 1972) have been based on a points system for the admission of foreign workers; the points were essentially determined by the educational and occupational titles of the potential immigrants. On the contrary the US immigration policy over the post war period has been essentially based on a national-origins-quota system that put less weight on the immigrants skills as a condition for admission.

Without attempting to speculate on the causes (an issue that is beyond the goal of this paper), here we just want to point out that our immigrants' human capital indicators seem to basically support the idea that the US attracted on average less skilled immigrants in comparison to Canada and Australia. To focus on these three countries, Graph 2 plots, for each of the three data sets and for each host economy, the indicators of absolute human capital content of the migration inflows[13]. The circle line, for the US, is always below the

13 These are also the series on which we feel more confident.

lines for the other two countries. Australia (the square line) appears to be the country that overall did better in attracting skilled immigrants, while Canada (the triangle line), from being close to Australian standards at the beginning of the period loses ground with respect the Australia and is reached, in two data sets out of three, by the US in the 80s.

Also the Canadian experience can be interestingly related to previous findings in the literature. The already quoted study by Baker and Benjamin [1992] has recently shown that in Canada "the labour market outcomes of successive arrival cohorts has declined since the 1970's." Borjas [1990] claims that "the labour market performance of recent immigrants is equally poor in the United states and in Canada", while being much better in Australia. Both these studies, however, are focused on the post-arrival labour market performance, holding constant the demographic characteristics of immigrants, among which is previous education. Our indicators refer instead to the immigrants' characteristics before entering the host country labour market, and suggest that despite the different immigration policies, the human capital content of Canadian migration inflows has deteriorated becoming more similar to the US one.[14] Given the nature of our immigrants human capital measures this is likely to be a results of similar changes in the composition of immigrants by country of origins in Canada and the US.

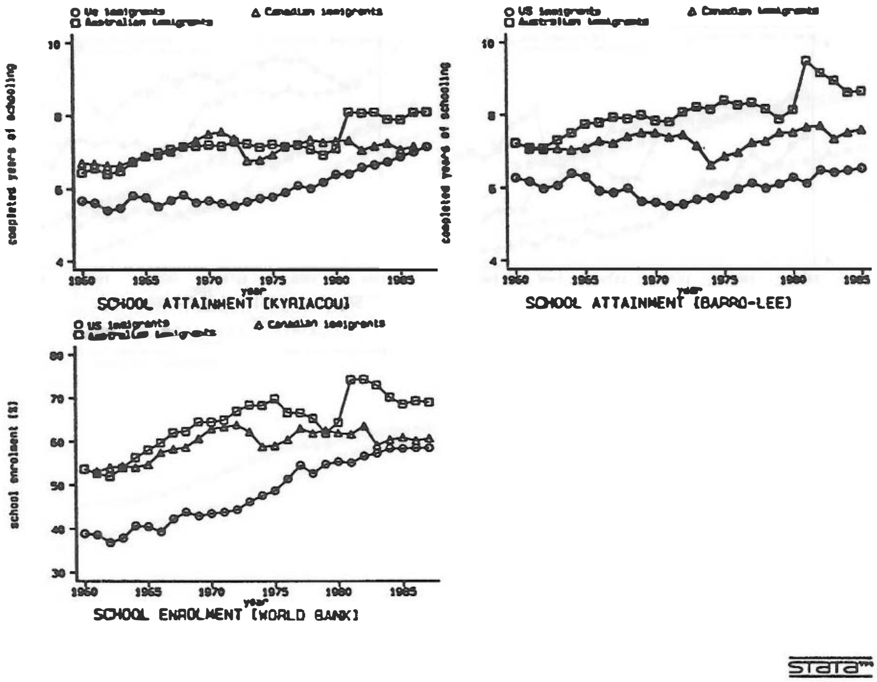
To shed more light on the importance of these compositional changes, Graph 3 describes what the human capital content of the migration inflows would have been if the human capital of the country of origins had remained always equal to the 60s level. Graph 4 shows instead what the human capital content would have been holding constant the composition of the migration inflows at the 60s average.

All the three major receiving countries experienced a deterioration of the migration flow composition, while, holding constant the immigrants composition, the human capital of foreign labour increased more or less similarly in the three countries. It is interesting to notice, in Graph 3, that in the most recent period the compositional deterioration for the US seems to slow down with respect to previous periods. This result seems in line with

[14] Notice that a deterioration, in subsequent cohorts, of the pre-arrival human capital of immigrants is perfectly compatible with a deterioration of the post-arrival labor market performance, holding constant the initial education.

recent evidence by Funkhouser and Trejo [1992] who find, for the US, that "immigrants who came in the late 80s are more skilled than those who arrived earlier in the decade."

Coming back to the main concern of this paper, we want to conclude this section highlighting its most important message: according to our figures the human capital of immigrants is quite significant, and fairly similar to the human capital of natives. In the next section we explore at a theoretical level which are the possible effects of migration inflows when such levels of immigrants' human capital are taken into account.



GRAPH.2 : Human capital of immigrants in Australia, Canada and the US

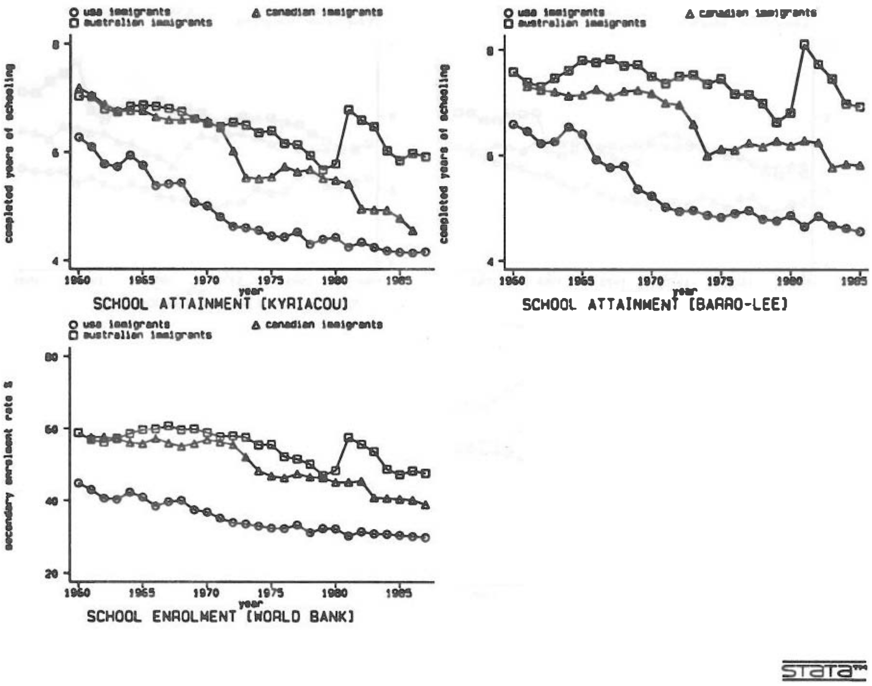


FIG.3 : HUMAN CAPITAL OF IMMIGRANTS IN AUSTRALIA,CANADA AND US HOLDING CONSTANT THE HUMAN CAPITAL IN THE COUNTRIES OF ORIGIN AT THE 60s AVERAGE

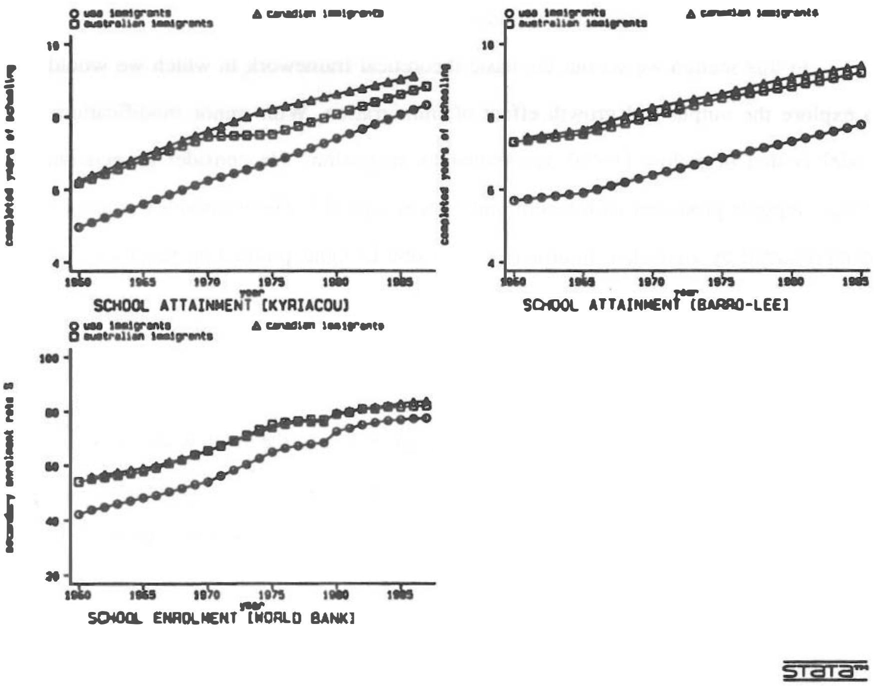


FIG.4 : HUMAN CAPITAL OF IMMIGRANTS IN AUSTRALIA,CANADA AND US HOLDING CONSTANT THE COMPOSITION OF THE MIGRATION INFLOW AT THE 60s AVERAGE

II A Solow growth model with migration

In this section we set out the basic theoretical framework in which we would like to explore the output and growth effect of immigration. With minor modifications, the model is that of Solow [1956] augmented by migration. We consider an economy in which output is produced with labour and human capital[15]. The technology is assumed to be represented by a constant returns to scale Cobb Douglas production function such that (omitting time subscripts)

$$(1) \quad Y = H^{\alpha}(Le^{gt})^{1-\alpha} \qquad 0 < \alpha < 1$$

where Y is the output level, H is human capital and L is the total working population (natives plus new net immigrants) whose productivity grows at an exogenous rate g. Here and in the rest of this paper, natives include immunigrants arrived in previous periods. The working population growth rate is given by

$$(2) \quad \frac{\dot{L}}{L} = n + \frac{M}{L} = n + m$$

where n is the growth rate of the native population, M is the (net) number of new immigrants and therefore $m = \frac{M}{L}$ is the net immigration rate. The number of effective units of labour grows not only because of population growth but also because of the labour embodied technological growth rate g.

Human capital accumulation has three sources: first, a fixed proportion of total output is devoted to increase the stock of H; second, depreciation reduces the existing stock; and, third, new immigrants bring with themselves their own human capital that is added in each period to the human capital of the host country. Therefore, the human capital accumulation equation is given by

$$(3) \quad \dot{H} = sY - \delta H + M\varepsilon\frac{H}{L} = sY - \delta H + .m\varepsilon H$$

15 Limiting the analysis to one reproducible factor greatly simplifies the derivation of our results. In the next section we will see how the conclusions are modified by the consideration of two types of capital.

where s is the fraction of output that is invested, δ is the depreciation rate and ε is the fraction of the existing stock of host country per capita human capital that is brought in by each new immigrant. In other words $\varepsilon \frac{H}{L}$ is the human capital that each new immigrant adds to the host country stock when she/he enters the country. Notice that the right hand side of (3) without $m\varepsilon H$ corresponds to the standard accumulation equation in the Solow's model without migration.

Letting small cases denote variables per effective unit of labour, equations (1) and (2) can be rewritten as:

(4) $y = h^{\alpha}$; $\qquad y = \frac{Y}{Le^{gt}}, \quad h = \frac{H}{Le^{gt}}$;

(5) $\dot{h} = sy - [\delta + g + n + m(1 - \varepsilon)]h = sh^{\alpha} - [D + m(1 - \varepsilon)]h$,

where $D = n + \delta + g$.

Finally, the description of the basic structure of the model is concluded by the following standard migration equation:

(6) $m = \varphi\ln(y) + Z = \varphi\alpha\ln(h) + Z \qquad$ where $\qquad h \gtrless h_m \Longrightarrow m \gtrless 0$.

According to this equation the (net) migration rate depends on the log of per capita income in the host country and on a set of exogenous variables Z that describe the standards of living in the sending countries, the costs of migration and other exogenous characteristics of the host country that may influence the migration flow. We will refer to this variable as to exogenous net migration. Total net migration can in principle be positive or negative depending on h being larger or smaller than h_m. However, in this paper, we will be mainly focused on receiving countries, in which $m > 0$.

Using this framework, we will explore, in what follows, the effects of immigration on the current output level, on the current growth rate, on the steady state towards which the host country is moving and on the speed of adjustment to such steady state.

II.1 Net immigration and the current output level

"The fact that new immigrants are less skilled than the old is responsible for a significant reduction in the potential national income of the United States. If the persons who migrated between 1975 and 1979 had been as skilled as those who came in the early 1960s, national income would be at least \$ 6 billion higher in every single year." (Borjas [1990], p. 20). Taking for granted Borjas' claim on the declining skills of immigrants in the US[16], this conclusion is exactly what our model would qualitatively predict. Indeed, the current output level of the host economy can be written as

$$(7) \qquad y = h^{\alpha} = \left(\frac{H}{L}\right)^{\alpha} = \left(\frac{H_0 + M\varepsilon \frac{H_0}{L_0}}{L_0 + M}\right)^{\alpha}$$

where the subscript (o) denotes variables measured at the beginning of period t. Using this expression we can compute the impact of a migration inflow on the current per capita output level, obtaining the following

RESULT 1: $\frac{\partial y}{\partial M} = \frac{\alpha h^{\alpha-1}}{L^2} H_0(\varepsilon\text{-}1) \gtrless 0 \qquad \text{if} \qquad \varepsilon \gtrless 1$

$$\frac{\partial y}{\partial \varepsilon} = \frac{\alpha h^{\alpha-1}}{L} \frac{MH_0}{L_0} \geq 0 \qquad \text{if} \qquad M \geq 0$$

Thus, for given ε, a higher immigration rate raises (lowers) the current level of output per capita of the host country if ε is larger (smaller) than unity. Similarly for a given positive net migration rate, the higher the human capital of immigrants relative to natives, the higher output per capita.[17]

If in the US the declining skills of immigrants have caused output losses, our result suggests that in other countries the human capital content of migration inflows may have contributed to make the output effects of immigration less negative than expected, or even

16 See, however, opposite evidence for the 80s in Funkhouser and Trejo[1992].

17 Notice that if $M < 0$ (a sending country) output per capita decreases with an increase in ε, since this parameter represent in this case the proportion of natives human capital that emigrants take away when they leave the country.

positive. In particular, given the generally high estimates of the immigrants versus natives human capital described in Section I, the generalised public opinion fear of the impact of immigration on the current output level may very well be excessive, once human capital is taken into account. In this framework, in which human capital is the only reproducible factor, if immigrants are as skilled as natives the negative impact of immigration is totally neutralised. However, as it will be shown in the next section, in the presence of other reproducible factor of which immigrants are not endowed, the human capital content of the migration inflow has to be much higher in order to eliminate the negative impact. Notice also that if immigrants are less skilled than natives larger migration flows from poor to rich countries should imply a decline of the cross-sectional dispersion of per capita income[18].

II.2 The current growth rate and the steady state

The impact of immigration is not likely to be limited to the short run; even more so if immigrants contribute to the host country human capital accumulation. In order to explore the long run effects of migration inflows we first focus on the growth rate γ of human capital in the host economy that is obtained from equations (5) and (6) :

$$(8) \qquad \gamma = \frac{\dot{h}}{h} = sh^{\alpha-1} - [D + (\varphi\alpha \ln(h) + Z)(1 - \varepsilon)].$$

The dynamic behaviour of this economy can be described with the help of Figure 1 which plots (for the more realistic case in which $\varepsilon < 1$) the two terms on the right hand side of the growth equation (8). The vertical distance between the two lines measures the current growth rate, while the steady state is defined by the point in which the two lines cross, i.e., $\gamma = 0$ implies that:

$$(9) \qquad \dot{h} = 0 \qquad \Longrightarrow \qquad sh^{*\alpha-1} = D + m^*(1 - \varepsilon)$$

18 This is what Barro and Sala-i-Martin [1991] (p.112) call σ-converegence as opposed to the conditional convergence on which we will come back below.

$$sh^{*\alpha-1} = D + [\varphi\alpha \ln(h^*) + Z] (1 - \varepsilon)$$

where the superscript (*) denotes steady state values. In the Figure, h_m is the level of human capital at which net migration is zero and h_0 is the current level of human capital.

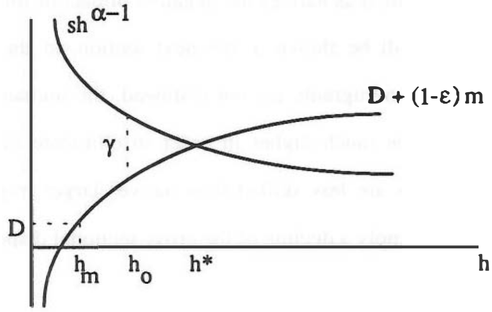


FIG.I: THE GROWTH RATE AND THE STEADY STATE
(if immigrants have less human capital than natives)

The comparative static results concerning the propensity to invest s, and the variables included in D are, in this economy, qualitatively similar to the ones that can be obtained from the basic Solow model without migration. For a given initial condition, a higher propensity to invest shifts upward the $sh^{\alpha-1}$ curve, increasing the steady state level h* and the current growth rate γ. Notice, however, that, quantitatively, if $\varepsilon < 1$ the $D + m^*(1 - \varepsilon)$ curve is upward sloping (instead of flat) and therefore if s increases the steady state increases less than in the model without immigration or in the model in which immigrants are as skilled as natives. This because more immigrants, with a human capital lower that the natives one, are attracted by the host economy. On the other hand, a higher native population growth rate n, a higher technological growth rate g and a higher depreciation rate δ shift upward the $D + m^*(1 - \varepsilon)$ curve decreasing the steady state level h* and the current growth rate γ.

Moving to the main focus of this paper, we now explore the effects of changes in the skills content and in the size of the migration inflow.

Effects of a higher immigrants' human capital

Starting from the human capital of immigrants, as measured by the parameter ε, the effects on the steady state and on the growth rate are described in Figure 2 and summarised in the following comparative static results:

RESULT 2: a) effect of ε on the steady state

$$\frac{\partial h^*}{\partial \varepsilon} = \frac{m^* h^*}{\Delta} > 0 \qquad \text{where } \Delta = (1-\varepsilon)\varphi\alpha + s(1-\alpha)h^{*\alpha-1}$$

b) effect of ε on the current growth rate

$$\frac{\partial \gamma}{\partial \varepsilon} = m \gtrless 0 \qquad \text{if} \qquad m \gtrless 0$$

c) "migration driven endogenous growth"

if $\varepsilon \geq 1 + \frac{D}{m} \Longrightarrow \gamma > 0$ always; the steady state is undefined and the growth rate does not converge to zero.

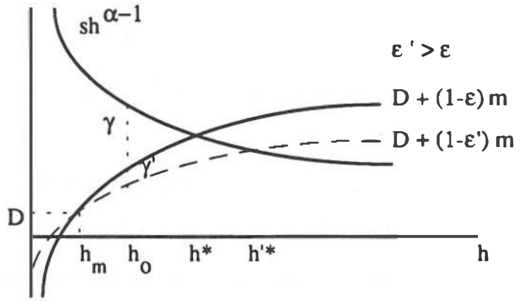


FIG2. : EFFECTS OF A HIGHER IMMIGRANTS' HUMAN CAPITAL
(if immigrants have less human capital than natives)

If the host economy is a net receiver of immigrants ($m > 0$) a higher immigrants' human capital has undoubtedly a positive effects on both the steady state and the current growth rate. If instead the economy is a net sender of immigrants, the outflow of the most skilled labour has a negative effect on growth.

It is also interesting to notice that this model can generate a "migration driven endogenous growth", even in the presence of decreasing returns to the reproducible factor of production. Indeed, if the human capital of immigrants is sufficiently larger than the human capital of natives, the host economy enters into a virtuous circle in which a higher natives' human capital attracts a larger inflow of highly skilled labour that more than offset the decreasing returns to the reproducible factor. The steady state goes to infinity and the growth rate does not converge to zero.

This latter case describes an extreme but perhaps not totally unrealistic situation. Just as a conjecture, based on no empirical information, one example that may provide evidence consistent with this result is suggested by the history of immigration from Europe to the new continent. The early waves of immigration to North and South America were probably characterised by a human capital content larger than the natives' one (i.e. the case in which the "migration driven endogenous growth" may be relevant). Using the country of origin as a proxy for skills and assuming northern Europeans to be more skilled than southern Europeans, one could conjecture that the migration flows to North America, mostly originated in northern Europe, were more skilled than the migration flow to South America, mostly originate in southern Europe. In the light of our result, this immigrants' skill differential might have contributed to determine the long term higher growth rate of the US and Canada.[19]

Leaving aside the extreme case of "migration driven endogenous growth", on a theoretical ground, it seems reasonable to expect that a higher human capital content of the migration inflows may positively contribute to the growth rate and to the steady state of the host economy. Similarly reasonable, is the other face of the story: an increase of the human capital of net migrants out of a sending country decreases its growth rate. In the

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19 Notice, as it will be shown in the next section, that much higher levels of immigrants' human capital would be required, in the presence of other reproducible factors, to generate these results. However, the relative larger importance of human capital with respect to physical capital in the 19th century stage of development, suggests that the one type of reproducible factor model described in this section might be adequate to study the effects of the early migration flows from Europe to the New Continent. Anyway, these are just speculations that we mention only as indications of possible lines of research for the future

light of these results, an increase in the human capital content of migration flows appears to be a factor that reduces the convergence of per capita output level across countries (σ-*convergence* in the terminology of Barro and Sala-i-Martin [1991]). In other words, the brain drain from poor (i.e. low h_0) countries to rich (i.e. high h_0) countries may play an important role in explaining the lack of convergence to similar standard of living across countries.

The effect of a higher net immigration rate

Holding constant the output level in the host country, the net migration rate may increase for two reasons: first, the elasticity φ with respect to the host country output level may increase; second the exogenous net migration inflow Z may become larger. In both cases qualitatively similar negative consequences can be expected for the receiving economy as shown by Figure 3 and by the following comparative statics results:

RESULT 3: a) effect of φ and of Z on the steady state

$$\frac{\partial h^*}{\partial \varphi} = -\frac{(1-\varepsilon)m^*h^*}{\varphi\Delta} \gtrless 0 \qquad \text{if } \varepsilon \gtrless 1$$

$$\frac{\partial h^*}{\partial Z} = -\frac{(1-\varepsilon)h^*}{\Delta} \gtrless 0 \qquad \text{if } \varepsilon \gtrless 1$$

where $\Delta = (1-\varepsilon)\varphi\alpha + s(1-\alpha)h^{*\alpha-1}$

and $\Delta > 0 \Longrightarrow \varepsilon < \dfrac{s(1-\alpha)h^{*\alpha-1}}{\varphi\alpha}$

b) effect of φ and of Z on the current growth rate

$$\frac{\partial \gamma}{\partial \varphi} = -(1-\varepsilon)\alpha\ln(h) \gtrless 0 \qquad \text{if } \varepsilon \gtrless 1$$

$$\frac{\partial \gamma}{\partial Z} = -(1-\varepsilon) \gtrless 0 \qquad \text{if } \varepsilon \gtrless 1$$

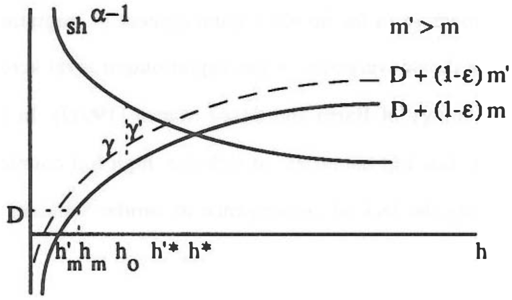

FIG. 3: EFFECTS OF A HIGHER NET IMMIGRATION RATE
(if immigrants have less human capital than natives)

If the immigrants' human capital is lower than the natives one a larger net immigration rate lowers both the current growth rate and the steady state level of capital. This happens independently from the underlining reasons behind a larger net immigration. Opposite results, in terms of growth rate, obtain if immigrants have more human capital than natives. However, ε cannot be too large otherwise the steady state is not defined and we enter into the "migration driven endogenous growth" regime.

The evidence provided in the first section suggests that the case of immigrants being more skilled than natives is certainly the least common. On the other hand, one can suspect the existence of counter examples on which it would be interesting to collect more evidence: our conjecture, without having examined the data, is that one of these examples may be provided by the early history of the country of Israel, in which larger waves of immigrants more skilled than natives may have had positive effects on the host economy growth rate.[20]

Notice that, as for the afore mentioned effect on current output, in the absence of other reproducible factors, if the immigrants' human capital is identical to the natives' one, exogenous increases of the net migration rate have no effect on the steady state and on the

[20] As in the previous footnote, this may be a case in which, given the stage of development, human capital is relatively more important than physical capital in the production function, thereby making the one type of capital model more adequate as a representation of reality. Alternatively, the situation analyzed in the next section, with more than one reproducible factor, would be the relevant one, and a much higher immigrants' human capital, relative to natives, would be necessary to offset the negative impact of the migration inflow.

growth rate. Under the more likely hypothesis of $\varepsilon < 1$, this model suggests that, holding constant the current per capita output levels, larger migration flows from poor to rich countries should decrease the current growth rate of the rich ones and increase the current growth rate of the poor ones. Therefore larger migration flows should cause a decline of the cross-sectional dispersion of per capita income.

II.3 The speed of conditional convergence

If instead of holding constant the initial conditions we hold constant the steady state it is possible to define a second concept of convergence, known in the literature as "conditional convergence".[21] Approximating around the steady state, the growth rate of per capita output in the host economy can be written as

$$(10) \quad \frac{\dot{y}}{y} = \dot{\ln(y)} = \lambda\,[\ln(y^*) - \ln(y_0)].$$

In other words the current growth rate can be written as a fraction, λ, of the percentage distance between the steady state and the current output level. Therefore, λ measures the convergence rate to the steady state, i.e. the speed at which the distance to the steady state is covered.

If countries have identical steady states and λ is positive, convergence to the steady state implies convergence between output levels across countries; furthermore if λ is identical across countries, poor countries grow faster than rich countries. Outside of these extreme cases, as pointed out by MRW, the Solow model predicts that each country converges to its steady state, but does not predict convergence across countries. Therefore the empirical evidence on the lack of convergence across countries does not indicate a failure of the Solow model, but only the existence of differences in the parameters that characterise the steady states. Among these parameters are also the characteristics of migration flows. If steady states are different and the differences are controlled for, the

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21 See: Barro and Sala-i-Martin [1991], Mankiw, Romer and Weil [1992] and Cohen [1992]. Barro and Sala-i-Martin refers to this concept also with term "β - convergence", where β is the speed of convergence (λ in our notation).

Solow model would predict a conditional convergence across countries. Such conditional convergence is faster the larger the parameter λ.

In this economy, the speed of adjustment to the steady state depends in the following way on the variables characterising net migration:

(11) $\lambda = [D + m^*(1-\varepsilon)]\,(1-\alpha) \;+\; \varphi\alpha(1-\varepsilon).$

It is interesting to compare this speed of adjustment with the one that would be obtained in the traditional Solow model without migration ($m^* = \varphi = 0$):

(12) $\lambda_S = D\,(1-\alpha)$

Notice, from (11), that, in the absence of other reproducible factors, if immigrants have the same human capital as natives, migration flows have no effects on the speed of adjustment. Outside of this case, we can first notice that the assumptions generating endogenous growth in the traditional Solow framework, do not yield the same results here. If $\alpha = 1$ the production function takes the Rebelo [1990] "AK" form, which generates a speed of adjustment $\lambda_S = 0$; therefore, the economy grows indefinitely and conditional convergence does not hold. On the other hand, as shown in Figure 4, in the presence of migration the same production function does not necessarily generate this never ending constant growth since the speed of convergence becomes, in this case, $\lambda = \varphi(1-\varepsilon)$. Indeed, if $\varepsilon < 1$, the Rebelo economy would attract an increasing number of immigrants less skilled than natives, thereby progressively reducing (see Result 3b) the growth of per capita human capital that otherwise would remain constant. The Rebelo-type endogenous growth remains a feature of this migration augmented model only if $\varepsilon = 1$, i.e. if immigrants are as skilled as natives and therefore larger immigration rates do not reduce the growth of per capita human capital in the host economy; alternatively, even with constant returns to the reproducible factor, if immigrants are less skilled than natives the economy converges to the steady state.

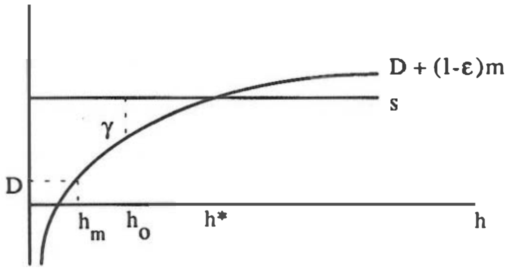

FIG. 4: CONVERGENCE TO THE STEADY STATE UNDER CONSTANT RETURNS TO CAPITAL

Another interesting way in which immigration affects the speed of adjustment relates to the propensity to invest. In the traditional framework, the proportion s of output that goes into investment affects only the steady state but does not affect the speed of adjustment. Here instead, since the speed of adjustment depends on m*, a higher steady state attracts more immigrants and therefore increases λ as shown by the following

RESULT 4: <u>effect of s on the speed of adjustment</u>

$$\frac{\partial \lambda}{\partial s} = (1-\varepsilon)(1-\alpha)\frac{\partial m^*}{\partial h^*}\frac{\partial h^*}{\partial s} \gtrless 0 \qquad \text{if } \varepsilon \lesseqgtr 1$$

Results 5, below, summarises instead how the speed of adjustment is influenced by the human capital content and by the size of the migration inflow. First, the higher the immigrants' human capital the lower the speed of adjustment of the host economy. Remember, however, that both the steady state and the current growth rate are increased by a larger immigrants' human capital (Result 2a and 2b). Therefore, the host economy covers a smaller fraction of a longer distance to the steady state, and altogether grows faster.

Turning to the size of the migration flow, as already shown in the literature,[22] a higher net immigration rate, independently from the underlining reasons (φ or Z), raises the speed of convergence to the steady state if immigrants are less skilled than natives

22 See Barro and Sala-i-Martin [1991].

(Result 5b and 5c). In this case we also know from the above analysis that both the steady state and the growth rate are negatively affected by the larger migration inflow. Therefore, the economy covers a larger fraction of a shorter distance to the steady state and altogether grows less. However, as expected from the above analysis, these negative effects are reduced by a higher immigrants human capital and disappear or become positive, in the absence of other reproducible factors, when immigrants are equally or more skilled than natives.

RESULT 5: a) effect of ε on the speed of adjustment

$$\frac{\partial\lambda}{\partial\varepsilon} = -(1-\alpha)m^* \frac{sA(1-\alpha)k^{*\alpha-1}}{\Delta} - \varphi\alpha < 0$$

b) effect of Z on the speed of adjustment

$$\frac{\partial\lambda}{\partial Z} = (1-\alpha)(1-\varepsilon)\left(1 - (1-\alpha)\frac{(1-\varepsilon)\varphi\alpha}{\Delta}\right) \gtrless 0 \qquad \text{if } \varepsilon \lesseqgtr 1$$

c) effect of φ on the speed of adjustment

$$\frac{\partial\lambda}{\partial\varphi} = \alpha(1-\varepsilon) + m^*(1-\alpha)(1-\varepsilon)\left(\frac{s(1-\alpha)h^{*\alpha-1}}{\Delta\varphi}\right) \gtrless 0 \qquad \text{if } \varepsilon \lesseqgtr 1$$

where $\Delta = (1-\varepsilon)\varphi\alpha + s(1-\alpha)h^{*\alpha-1}$

As shown by Barro and Sala-i-Martin [1991] and by MRW there is a remarkable regularity in the estimates of λ in different sets of countries and regions around the world: using the words of Cohen [1992] it is a "fascinating aspect" of these authors' work the fact that "(A)cross European or US regions or across countries, this coefficient inexorably implies that an economy *converges* towards its *steady state* at a rate of about 2% a year." In the basic Solow model given a (reasonable) value of D (= n + g + δ) equal to .006[23], such a convergence rate implies a return to capital (α) in the production function equal to

23 This is the value assumed by Mankiw, Romer and Weil [1992].

2/3 , i.e. $\lambda_S = (1/3)*.006 = .002$. [24]

Given the same values of D and α, we can get a quantitative feeling of the migration effects on conditional convergence if we compute λ using the migration augmented version (11) for reasonable values of the other parameters. For example, assuming $\varphi = .02$ (which is a value of the migration elasticity with respect to income somewhat lower than the one estimated by Barro and Sala-i-Martin [1991] for the US regions, i.e. 0.026[25]), m = .01 (which is a number in the ballpark of the net migration rates described in Section IV) and $\varepsilon = .5$ (which is a lower bound on the values of ε described in Section I), we get $\lambda = .0283$. This value is 41% larger than the one obtained for the same α and D in the basic Solow model, and implies that half of the distance to the steady state is covered in 24.5 years instead of 34.7 years.

Therefore, with respect to the basic Solow model, the introduction of migration, under reasonable assumptions, may cause a non-insignificant reduction of the convergence period. In Table 4 we explore a wider range of values of the relevant parameters finding that convergence rates in the two models become more similar the lower the return α to the reproducible factor, the lower the net migration rate m, the higher the human capital of immigrants versus natives, and the lower is the elasticity of migration to output in the host economy.

Notice also, in this table, that for the most reasonable higher value of $\alpha = 2/3$, and for $\varepsilon = .75$, doubling the migration rate from .008 to .016 reduces by less than one year the time to cover half the distance to the steady state (from 31.04 to 30.14 years). If ε were equal to .25, the effect would be only slightly bigger (1.7 years, from 25.67 to 23.90). Both these effect would be even smaller if the return to capital α were lower.

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[24] One of the ways to justifie the implied large output share accruing to the reproducible factor (far larger than what implied by national accounts), is to assume that the latter include human capital, so that the share accruing to labor has to be intended just as the payment of raw labor. See below the extended version of the model with two types of capital.

[25] Here we have in mind a process of convergence across countries, that is probably somewhat slower than the convergence across similar regions within a country.

TABLE 4: Speed of convergence to the steady state for different parameter values

Parameter			Solow model with migration		Solow model without migration	
α	m*	ε	λ	years to half the distance to the S.S.	λ_S	years to half the distance to the S.S.
		0.25	4.65	14.91	4.00	17.33
1/3	.008	0.5	4.43	15.63	4.00	17.33
		0.75	4.22	16.44	4.00	17.33
		0.25	5.05	13.73	4.00	17.33
1/3	.016	0.5	4.70	14.75	4.00	17.33
		0.75	4.35	15.93	4.00	17.33
		0.25	2.70	25.67	2.00	34.66
2/3	.008	0.5	2.47	28.10	2.00	34.66
		0.75	2.23	31.04	2.00	34.66
		0.25	2.90	23.90	2.00	34.66
2/3	.016	0.5	2.60	26.66	2.00	34.66
		0.75	2.30	30.14	2.00	34.66

NOTE: $D = 0.06$; $\varphi = 0.01$; λ is expressed in % tenns

Altogether, the comparison between the basic Solow model and the migration augmented model suggests that going from no immigration to some standard size inflow of foreign labour may have non-insignificant effects on the convergence rate. On the other hand, even large variations of an already positive migration rate seem to have relatively small effects.

II.4 A summary of the output and growth effects of immigration

In the following Table 5 we provide a qualitative summary of the theoretical results obtained so far under the more realistic hypothesis of immigrants less skilled than natives: notice that the characterisation of the output and growth effects of immigration amounts to the understanding of the effects on the four tenns in equation (10), i.e.: the current growth rate, the speed of adjustment, the steady state output level and the current output level.

TABLE 5: The output and growth effects of immigration if immigrants have less human capital than natives

	Effects on			
	growth rate	speed of convergence	steady state output level	current output level
ε	+	-	+	+
Z	-	+	-	-
φ	-	+	-	-
s	+	+	+	=
D	-	+	-	=

The basic message of the table can be stated as follows: *ceteris paribus*, a larger size of the migration inflow has negative effects on output an growth, while a higher human capital content of the migration inflow has positive effects. In the econometric section we will complement the qualitative entries of these table with some quantitative estimate of the impact of immigration. Before introducing our econometric framework, however, we need to extend the model described so far to see how the existence of more than one reproducible factor modifies the above results.

III Extension to two types of reproducible factor

In this section we extend the model allowing for the existence of two types of reproducible factors: physical capital and human capital. The extended model (in efficiency units) takes the following form:

$$(13) \quad y = h^{\alpha} k^{\beta} \qquad y = \frac{Y}{Le^{gt}}, \quad h = \frac{H}{Le^{gt}}, \quad k = \frac{K}{Le^{gt}};$$

$$(14) \quad \dot{h} = s_h y - [\delta + g + n + m(1 - \varepsilon)]h = [s_h h^{\alpha-1} k^{\beta} - [D + m(1 - \varepsilon)]\}h.$$

(15) $\dot{k} = s_k y - [\delta + g + n + m]k = [s_k h^{\alpha} k^{\beta-1} - \{D + m\}]k$

where k denotes physical capital and h is now just human capital. Notice that immigrants are assumed to contribute only to the human capital accumulation in the host economy; they do not bring with themselves any physical capital when they enter the country, and this is relevant for a modification of the results obtained in the previous section. The fractions of total output that are invested in human and physical capital are s_h and s_k respectively, while the other symbols maintain the meaning of the one type of capital model.

Under fairly standard conditions the comparative static qualitative results obtained in the simplified model continue to hold here. By equating the marginal returns of human and physical capital (assuming no adjustment or irreversibility costs) we obtain[26]:

(16) $\frac{\partial y}{\partial h} = \frac{\partial y}{\partial k} \implies \frac{h}{k} = \frac{\alpha}{\beta}$

Under these assumptions it is possible to aggregate the two types of capital into one composite reproducible factor C such that

(17) $C = k + h$

and

(18) $y = \Phi C^{\alpha+\beta}$ where: $\Phi = \left(\frac{\alpha}{\alpha+\beta}\right)^{\alpha} \left(\frac{\beta}{\alpha+\beta}\right)^{\beta}$.

The accumulation equation for the composite reproducible factor is easily obtained, from (14) and (15):

26 Notice that this result only holds when the possibility of capital mobility is not considered, as in tha analysis of MRW. As it is well known, the theory suggests that, in the absence of any restriction on the mobility of capital, the speed of convergence should be infinite. Given that this convergence conflicts sharply with the empirical evidence, Barro, Mankiw and Sala-i-Martin [1992] claim that, in practice, the flow of capital is restrained by imperfections in the market. In particular, they assume that the collateral value of human capital is negligible in practice and that the amount of debt is restricted by the collateral value of pysical capital. In this case the process of convergence in a partially open economy resembles that of a closed economy, except that the speed of convergence is faster [$(1-\alpha-\beta)D/(1-\beta)$ instead of $(1-\alpha-\beta)D$, in the no migration case]. Working out this case when labour mobility exists, but is not perfect will be the subject of future analysis in our research agenda.

(19) $\dot{C} = \dot{h} + \dot{k} = (s_h + s_k)\,\Phi\, C^{\alpha+\beta} - [D + m]C + m\,\varepsilon\, h$

Since $h = \dfrac{\alpha}{\alpha+\beta}C$ and $k = \dfrac{\beta}{\alpha+\beta}C$, (19) can be written as

(20) $\dot{C} = (s_h + s_k)\,\Phi\, C^{\alpha+\beta} - \left(D + m(1 - \varepsilon\dfrac{\alpha}{\alpha+\beta})\right)C.$

Finally, given the new production function (18), also the migration equation has to be modified accordingly into the following form:

(21) $m = \varphi\ln(y) + Z = \varphi(\alpha+\beta)\ln(C) + Z + \ln(\Phi).$

Comparing the equations (18), (20) and (21) with the equations (4), (5) and (6), the one type of capital model is clearly isomorphic to the model with two types of capital aggregated into the single reproducible factor C. In the extended model, C takes the place of h; the return to the reproducible factor is $(\alpha+\beta)$ instead of α, the propensity to invest is $(s_h + s_k)$ instead of s and $\varepsilon\dfrac{\alpha}{\alpha+\beta}$ takes the place of ε . Therefore, qualitatively, all the comparative static result obtained for the model described in Section II continue to hold here in terms of the composite reproducible factor C, and will not be repeated.

Yet, from a quantitative point of view, there are important differences that deserve to be highlighted. Immigrants bring with themselves an amount of human capital equal to a fraction ε of the native stock, but the analogous fraction of physical capital that they bring in is assumed to be zero. Thus, the fraction of the native aggregate reproducible factor C carried by immigrants is a weighted average of the fractions of the two types of capital (ε for h and 0 for k) where the weights are the respective rates of returns. Under these assumptions, while in the one type of capital model $\varepsilon \geq 1$ is enough to neutralise the negative impact of a migration inflow, here the relevant threshold is much higher, being given by

(22) $\varepsilon \geq 1 + \dfrac{\beta}{\alpha}.$

Notice in (22) that if the return to physical capital β is equal to zero, the relevant threshold is again unity as in the model of Section II. More generally, the lower the output share of physical capital relative to the output share of human capital, the lower the immigrants' skills have to be, relative to natives, in order to generate null or positive output and growth effects of the migration inflow.

In the light of this modified result, for reasonable values of the output shares, the estimates of the immigrants' human capital described in Section I appear to be far from the relevant threshold as opposed to what was happening in the one type of capital model. Therefore, being forced to exclude the case of no effects or positive effects, it remains to be established if a human capital ratio of immigrants versus natives ranging between .5 and 1 is enough to make the effects of a migration inflow quantitatively different from the effects of a comparable natural population increase. This will be one of the goals of the econometric section.

We move from theory to econometrics applying to our extended model the same methodology followed by MRW. Conditioning on the net migration rate, the steady state levels of physical and human capital are defined, using (14) and (15), by

$$h^* = \left(\frac{s_k^{\beta} \, s_h^{1-\beta} \left(\frac{1}{1-\mu}\right)^{1-\beta}}{D + m^*} \right)^{\left(\frac{1}{1-\alpha-\beta}\right)}$$

(23) $$\text{where:} \quad \mu = \frac{\varepsilon \, m^*}{D + m^*}.$$

$$k^* = \left(\frac{s_k^{1-\alpha} \, s_h^{\alpha} \left(\frac{1}{1-\mu}\right)^{\alpha}}{D + m^*} \right)^{\left(\frac{1}{1-\alpha-\beta}\right)}$$

Substituting these steady state values into the production function (13) and taking logs, gives an equation for income per capita, $\hat{y} = \frac{Y}{L}$, in which we can measure the effects of the size and the human capital content of net migration inflows[27]:

27 In the derivation of (24) we have also used the approximation: $\ln(1-\mu) \cong -\mu$.

$$(24)\ \ln(\hat{y}) = gt + \frac{\beta}{1-\alpha-\beta}\ln(s_k) + \frac{\alpha}{1-\alpha-\beta}\ln(s_h) + \frac{\alpha\,\varepsilon}{1-\alpha-\beta}\left(\frac{m^*}{D+m^*}\right) - \frac{\alpha+\beta}{1-\alpha-\beta}\ln(D+m^*).$$

Notice that in this equation ε can be either considered as an (identified) parameter to be estimated or as a component of one of the regressors. We can therefore use this equation to infer the size of ε implied by the data, in order to compare it with the evidence described in Section 1. Since m* is a function of income per capita, it is an endogenous variable in this equation. We explain in the following section how we deal with this problem.

In order to study the effects of migration on the growth rate and on the speed of adjustment we again proceed as in MRW. The approximation for the growth rate of output per capita, γ_y, described by equation (10) implies that

$$(25)\quad \gamma_y = \ln(\hat{y}) - \ln(\hat{y}_0) = (1 - e^{-\lambda t})\,[\ln(\hat{y}^*) - \ln(\hat{y}_0)]$$

where, in this extended framework with two types of capital, the speed of adjustment is given by

$$(26)\quad \lambda = (1-\alpha-\beta)\left(D + m^*\left(\frac{\beta+\alpha(1-\varepsilon)}{\alpha+\beta}\right)\right) + \varphi[\beta+\alpha(1-\varepsilon)].$$

Substituting the steady state value $\hat{y}^*$ into (25) we obtain an estimable equation for the growth rate in the host economy:

$$(27)\quad \ln(\hat{y}) - \ln(\hat{y}_0) = (1 - e^{-\lambda t})\frac{\beta}{1-\alpha-\beta}\ln(s_k) + (1 - e^{-\lambda t})\frac{\alpha}{1-\alpha-\beta}\ln(s_h) +$$

$$(1 - e^{-\lambda t})\frac{\alpha\,\varepsilon}{1-\alpha-\beta}\left(\frac{m^*}{D+m^*}\right) - (1 - e^{-\lambda t})\frac{\alpha+\beta}{1-\alpha-\beta}\ln(D+m^*) -$$

$$(1 - e^{-\lambda t})\ln(\hat{y}_0)$$

Notice that also in this equation ε can be considered either as an (identified) parameter to be estimated or as a component of one of the regressors. Finally also for this equation the endogeneity of m* will have to be taken into account and dealt with accordingly.

IV Empirical analysis

IV.1 Econometric specification

In this section the empirical counterparts of equations (24) and (27) are estimated. Equation (24) represents the stationary behaviour indicating the relationship between steady state output per worker and the investment (saving) rate in both types of capital (human and physical), the labour force growth rate, the rate of technological progress, the rate of depreciation and, most importantly in this model, the net migration rate. In what follows, we will refer to the estimation of this equation as to the "steady state" regression. Equation (27), instead, embodies the description of the transition to the steady state given by (24). This equation will be instead referred to as the "convergence" equation. Using these equations, the main goal of this section is to obtain an estimate of the parameters α, β, λ, and ε.

To achieve this goal, the availability of information on migration rates is what constraints both the cross-sectional and time dimension of the sample[28]. The set of countries for which we found time series of migration flows consists of 23 OECD countries a list of which is given in Table 9. On the basis of this information, we followed two approaches for the estimation of these equations.

The first approach is to estimate the model using a single cross-section of data corresponding to the set of countries mentioned above (as, for example, in Baumol [1986], Dowrich and Nguyen [1989], Barro [1991] and MRW). In the current context, one would use (log) output per worker in any given year as the dependent variable in equation (24). Averages for all the preceding years in the sample would serve as empirical proxies for the right hand side variables. Thus, one would estimate the (non linear) relationship between, say, 1985 labour productivity ($\hat{y}$) and the average rates of s_k, s_h, $(n+\delta+g)$ and m between, say, 1960 and 1985. Similarly, equation (27) could be estimated using the average productivity growth between 1960 and 1985 as the dependent variable, with the averages of the explanatory variables and (log) productivity in 1960 (the initial condition) as regressors. .

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[28] See, below, for a description of the variables used in the regression.

The second approach consists, instead, in the construction of such regressions for each year in the sample, using the panel structure of the data to exploit the information in all years of the sample via a pooling regression with fixed effects for each country in the sample. One possible objection to this approach is that annual observations of output per worker do not correspond to steady state behaviour. To overcome this problem, we decided to smooth out some of the individual time varying effects by taking 5 years averages for the period 1960-85 which is the sample period used in the paper . Thus, following this approach, equations (24) and (27) are estimated using 5 half decades for each country, making a total of 115 (23 times 5) observations. In these regressions, $\hat{y}_{it}$ and $(\hat{y}_{it} - \hat{y}_0)$ are productivity and changes in productivity for country i in the half-decade t (i.e. productivity in the last year of t and productivity growth during t) respectively. Similarly, the rest of the variables are measured as the averages in the country i between the start of the sample (1960) and half-decade t. For example, s_{kit} is the average physical capital investment rate in country i between 1960 and period t, etc.

For both approaches, estimation is done via non-linear least squares, with the reported t-statistics being computed from White [1980] heteroskedasticity robust standard errors. One possible objection to using least squares is the potential endogeneity of most of the regressors and in particular of the net migration rate, given the analysis in previous sections. This would require instrumental variables estimation methods. However, as noted by many authors, finding instruments in these types of models might be a formidable task, especially in the cross section regressions. Our approach, to circumvent partially this issue, has been to estimate steady state and convergence regressions using information for the sample in the 1970-1985 period, with the averages of the relevant variables during the 1960-1970 period acting as lagged instrumental variables. Apart from these lagged variables, we used a population density index (thousands of people per square meter) and its square during the 1960-1970 period as additional instruments for net migration. The total number of instruments is, therefore, 5 (one lag of s_k, s_h and m, plus the two density variables) whose validity is tested with Sargan's [1958] overidentifying restrictions test. A similar approach is used in the panel regressions where the sample size now reduces from 115 to 92 (23 times 4).

IV.2 Data

The data that we use mirror that used in the empirical analysis of MRW, except that our data base has been updated using the latest version of Summers and Heston [1991] "Real National Accounts for 138 countries". As previously mentioned, the availability of data on net migration has constrained the choice of countries to 23 OECD nations with population greater than one million (except Luxembourg). This sample more or less corresponds to the third sample used in MRW, a fact that we will use for comparison purposes

Labour productivity $\hat{y}$ for each country is measured as real GDP divided by the implicit adult population (working age population) in that year. The two investment rates are measured as follows. The rate s_k corresponds to the share of total real investment (private and public) in real GDP. The rate s_h has been constructed as in MRW, measuring approximately the percentage of the working population that is in secondary school. The population growth rate n has been measured as the implicit adult (working-age) population growth rate, and the sum of $(g+\delta)$, again following MRW, as been assumed equal to 0.05.[29]

Finally, the data on net migration has been elaborated by us using the sources described in the Data Appendix. For six[30] countries infonnation was only available for some years (1979 to 1985 in most cases). To construct data sets for the 5 half decade periods, we first interpolated the 1960-1985 averages for the six incomplete data countries, using a simple migration equation for the 17 countries for which the whole data set was available.[31] Assuming this relation constant across countries, the averages for the

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29 See the Data appendix for more infonnation on the constructionof these variables.

30 Japan, Austria, Finland, Norway, Sweden and Switzerland.

31 The estimation of this migration equation gave the following results:

$$m_i = \underset{(0.59)}{-0.035} + \underset{(11.6)}{0.007}\ln\left(\frac{\hat{y}_i}{\hat{y}_w}\right) + \underset{(6.72)}{0.002}\ln(s - s_w)) - \underset{(2.06)}{0.086}conc + \underset{(1.4)}{0.0021}conc^2 \quad \bar{R}^2 = 0.91;\ i = 1, ...17;$$

where: $s = s_k + s_h$; $\hat{y}_w$ is the world income (average 1960-1985); s_w is the world total saving (average eight remaining countries were constructed using the fitted values of the regression, since the regressors were available for all countries. Next, the time dimension interpolation was done using a version of Denton's (1971) approach where the chosen indicator was the time series of the average absolute values of net migration for the 16 countries where data existed. Sample statistics are shown in Table 6.

TABLE 6: Sample statistics

Variable	Δy^{av} (1)	y_{60}	s_k	s_h	m (2)	m>0 (3)	m>0 (4)
Mean	2.85	6121	25.8	9-0	1.35	2.42	-1.11
Standard dev.	0.95	2671	4.9	2.2	2.25	1.66	0.52

Note:
(1) Δy^{av} is the average growth rate of output per adult between 1960 and 1985.
(2) Average, unweighted, net migration rate per thousand; the correspondent weighted rate is 3.4 %
(3) Average, unweighted, net migration rate per thousand for the 16 countries in which m is positive.
(4) Average, unweighted, net migration rate per thousand for the 7 countries in which m is negative.

IV.3 Results

The estimated results for the cross-section regressions are presented in Table 7. Besides the parameters of interest (α, β, ε and λ), the p-values of the relevant tests are given. Test 1 refers to a test of the restrictions entailed in (24) and (27), i.e. that the coefficient of $\ln(D + m^*)$ should be equal with opposite sign to the sum of the coefficients of $\ln(s_k)$ and $\ln(s_h)$. Test 2 is an F-test of the exclusion restrictions pertaining to a set of dummy variables, more or less corresponding to continent and degree of development.[32] As mentioned below, this set of country specific dummies turns out to be very significant in the panel regressions (see test 2 in Table 8) and the estimated signs and sizes suggested

1960-1985); and conc is the population density (1000 of people per square meter).

32 These dummies have the following definitions:
DEU (dummy Europe): Austria, Belgium, Denmark, Finland, France, Germany, Italy, Luxembourg, Netherland, Norway, Sweden, United Kingdom, Switzerland;
DDE (dummy Development): Greece, Ireland, Spain, Portugal;
DPA (dummy Pacific): Australia, Japan, New Zealand;
DAM (dummy America): Canada, US (excluded dummy).
In the panel regression reported below, an F test for the restriction that the 23 country specific dummies can be assembled in these four dummies is $F_{(19,88)} = 0.86$ (p-value: 0.47)

the groupings. We were therefore induced to control for them also in the cross-section regressions. Given the potential homogeneity of the OECD economies chosen in the sample, it is interesting to examine whether the variation in country specific effects is likely to be small. Finally Test 3 refers to Sargan's [1958] test of overidentifying restrictions in the regressions.

Consider first, in columns (1) and (2) of Table 7, the estimates of the steady state equation (24), without and with migration respectively. The basic model (without migration) offers results that are similar to those found in Table II of MRW, except that the model's restrictions are marginally rejected when the continent dununies are included. Note that these dummies turn out to be significant at the 10% level. When the dummies are excluded, the fit falls drastically ($\bar{R}^2 = 0.30$) and the model's restrictions is not rejected (p-value = 0.66). Thus, MRW's conjecture that country specific effects are likely to be small does not seem to hold in our sample. However, as shown in column (2), migration seems to play a crucial role, first in making the continent dummies insignificant and, second, in increasing the $\bar{R}^2$ from 0.42 to 0.81, .

To see whether these results are only an outcome of the endogeneity problem, columns (3) displays instrumental variables estimates with similar results, except that β (α) tends to be higher (lower) than in the OLS case. The fit is much worse ($\bar{R}^2 = 0.67$) but still much higher than in the basic model without migration. Note that, according to Test (3), the overidentifying restrictions are not rejected. Both α (= 0.32) and β (= 0.20) are statistically significant and within the range of values estimated in the recent growth literature[33], suggesting, in agreement with such literature, that both physical and human capital enter the production function in a more or less symmetric function. Similarly reasonable are the estimates of ε that range from 0.53 to 0.72, and are significant in both the OLS and the IV regressions. These values are in agreement with the evidence presented in Section 1 for the 9 countries of which information on the human capital of immigrants is available.

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33 See, in particular MRW which get $\alpha = 0.37$ and $\beta = 0.14$ in their preferred specification.

TABLE 7 Cross-section regressions for the steady state and for convergence.

Estimated parameters	Steady state [equation (24)]			Convergence [equation (27)]		
	(1) Basic NLS	(2) Augmented NLS	(3) Augmented NLS2SLS	(4) Basic NLS	(5) Augmented NLS	(6) Augmented NLS2SLS
α	0.30 (2.46)	0.25 (3.79)	0.20 (3.21)	0.24 (2.57)	0.22 (2.85)	0.27 (2.16)
β	0.14 (0.85)	0.24 (2.44)	0.32 (2.02)	0.37 (3.25)	0.32 (3.54)	0.31 (2.63)
ε	-	0.72 (2.98)	0.53 (2.56)	-	0.63 (2.36)	0.54 (1.93)
λ	-	-	-	0.021 (4.06)	0.034 (3.55)	0.031 (4.23)
$\bar{R}^2$	0.42	0.81	0.67	0.64	0.73	0.69
$\hat{\sigma}$	0.29	0.17	0.20	0.14	0.12	0.11
N	23	23	23	23	23	23
Test (1) p-value	0.08	0.36	0.54	0.36	0.42	0.48
Test (2) p-value	0.03	0.47	0.63	0.82	0.76	0.56
Test (3) p-value	-	-	0.19	-	-	0.13

Note: The figures in brackets are the t-ratios. $\bar{R}^2$ is the coefficient of multiple correlation (corrected by d.f.); $\hat{\sigma}$ is the standard error of residuals. N is the number of observations.
Test (1) is a test for the restriction that the coefficient of ln(D+m*) should be equal with opposite sign to the sum of the coefficients of $\ln(s_k)$ and $\ln(s_h)$ in equations (24) and (27).
Test (2) is an F-test on the exclusion restrictions pertaining to a set of continent and grade of development dummies:
Test (3) is Sargan's test of overidentifying restrictions concerning the following 5 instruments: one lag of s_k, s_h and m, density and square density.

To investigate the transition process, the cross-section estimates of the convergence regression are reported in columns (4) to (6) of Table 7. The comments are very much as before, with the augmented regression having a better fit than the basic one. It is interesting to notice that the estimated speed of convergence λ rises in the augmented regression, in agreement with the theoretical implications of the model (see Table 5). In fact, taking at face value the estimates of α and β equal to 0.3 and assuming, in line with the sample statistics and with our estimates, that D = 0.06, m* = 0.01, ε = 0.5, and φ = 0.01, the values of λ computed with equation (25), are 0.024 for the case of no migration and 0.0295 for the case of positive net migration. These values are very similar to the estimates of λ in columns (4) and (6) of Table 7 (0.021 and 0.031, respectively).

TABLE 8: Panel regressions for the steady state and for convergence.

Estimated parameters	Steady state [equation (24)]			Convergence [equation (27)]		
	(1) Basic NLS	(2) Augmented NLS	(3) Augmented NLS2SLS	(4) Basic NLS	(5) Augmented NLS	(6) Augmented NLS2SLS
α	0.33 (2.66)	0.26 (2.93)	0.26 (2.46)	0.35 (8.61)	0.28 (5.83)	0.31 (3.32)
β	0.11 (1.77)	0.17 (1.88)	0.22 (2.15)	0.27 (5.64)	0.27 (5.52)	0.25 (4.16)
ε	-	0.42 (2.26)	0.56 (2.53)	-	0.54 (3.79)	0.63 (2.08)
λ	-	-	-	0.022 (12.42)	0.030 (13.62)	0.033 (11.22)
$\bar{R}^2$	0.77	0.80	0.65	0.69	0.73	0.75
$\hat{\sigma}$	0.20	0.19	0.22	0.05	0.04	0.03
NT	115	115	92	115	115	92
Test (1) p-value	0.35	0.62	0.33	0.25	0.53	0.67
Test (2) p-value	0.02	0.02	0.05	0.00	0.01	0.02
Test (3) p-value	-	-	0.09	-	-	0.13

Note: The figures in brackets are the t-ratios. $\bar{R}^2$ is the coefficient of multiple correlation (corrected by d.f.); $\hat{\sigma}$ is the standard error of residuals. NT is the number of observations.
Test (1) is a test for the restriction that the coefficient of ln(D+m*) should be equal with opposite sign to the sum of the coefficients of $\ln(s_k)$ and $\ln(s_h)$ in equations (24) and (27).
Test (2) is an F-test on the exclusion restrictions pertaining to a set of continent and grade of development dummies:
Test (3) is Sargan's test of overidentifying restrictions concerning the following 5 instruments: one lag of s_k, s_h and m, density and square density.

Turning to Table 8, the panel regression results are somehow similar, except that the continent effects are very significant in all cases. This significance probably reflects the fact that the choice of half decades is a too short period to wash out potentially large cross-country variation in productivity stemming from different sectoral compositions, factor endowments etc. In other words, by taking half decades, the variation in omitted country specific factors is likely to be non negligible. The fact that migration captures the explanatory power of the dummies in the cross-section regressions, probably reflects the possibility that, over long periods (25 years), these differences are an important argument behind migration decisions.

When the continent dummies are excluded from the panel regressions the coefficients β and ε do not change much but α goes down to 0.2 . Similarly λ goes down to 0.0224. Both values are in the neighbourhood of the estimates presented by MRW in Table IV. Their equation, however, does not fully control for any country specific effects and it is tempting to speculate that given the significance of the dummies in the basic cross-section model (that is identical to their model), the exclusion of such factors reduces their estimate as well.

We also allowed the coefficients on initial income (λ), and on both investments (α and β) to differ across countries. However, the null hypothesis that the coefficient were equal in magnitude could not be rejected.[34]

A significant value added of the panel regressions, is that they offer the possibility to estimate, for each country, the ratio of the immigrants versus natives human capital. These estimated ratios are presented in Table 9, together with the countries' mean net migration rates. With the exception of France, the estimates for ε are not significant at the 5% level. This is not surprising given the limited time dimension of the sample. Nevertheless, the point estimates appear to be strikingly similar to the school measures constructed in Section 1 for nine of the countries. Notice, that the ranking between the three main immigration countries is preserved, with Australia appearing to be the country that attract the most skilled immigrants relative to natives, while Canada occupies an intermediate position and the US do worse.

[34] $F_{\alpha(22.85)} = 1.51$ (p-value: 0.09); $F_{\beta(22,85)} = 0.74$ (p-value: 0.46); $F_{\lambda(22,85)} = 1.55$ (p-value: 0.08)

TABLE 9: Net migration rates and estimated ratios of the immigrants versus native human capital. (A * denotes the countries described in Section I)

Country	Net migration rate (per thousand) m	Human capital of immigrants versus natives ε		
		school mesure	NLS estimate	t-ratio
Australia*	7.3	0.84	0.86	1.72
Austria	0.7		0.36	0.61
Belgium*	0.9	0.85	0.45	0.12
Canada*	3.5	0.76	0.79	0.07
Denmark	0.5		0.48	0.63
Finland	1.6		0.43	0.63
France	2.3		0.26	3.62
Germany*	3.0	1.01	0.89	1.94
Greece	-0.6		0.65	1.83
Ireland	-1.7		0.75	0.30
Italy	-0.6		0.71	0.28
Japan	1.8		0.75	0.30
Luxembourg	4.9		1.03	1.38
Netherlands*	1.5	0.69	0.69	1.46
New Zealand	0.9		0.70	1.58
Norway	2.8		0.77	0.65
Portugal	-2.1		0.63	0.16
Spain	-0.7		0.46	1.01
Sweden*	1.6	0.91	0.91	0.18
Switzerland*	3.6	1.02	0.91	1.28
Turkey	-2.0		034	0.82
United Kingdom*	-0.2	0.80	0.85	1.60
United States*	1.9	0.54	0.53	1.08
Average	1.35		0.66	
Restricted ε (see Table 2)			0.54	3.79
Test for equality of ε across countries		$F_{(22,85)} = 0.46$ p- value = 0.73		

It has to be noticed, however, that the model estimates the relative human capital content of the net migration, while the figures described in section 1 are indicators of the human capital of immigrants only (without taking into accounts emigrants). Thus, for the countries for which the net migration rate is negative, the estimate for ε in Table 9 has to be interpreted as the average human capital (relative to natives) of the net migration flow out of the country. For example, for Turkey, where the number of emigrants prevail over the number of immigrants, the fairly low estimate of ε seem to indicate that particularly low skilled workers leave the country. Relatively more skilled emigrants seem instead to leave Italy, another country in which the net migration rate is negative. [35]

All in all, the characteristics of our estimated models appear to make sense. The estimates of α and β are in the range of the values estimated in the literature, and they are significant in most cases. As for the convergence behaviour, when net migration is taken into account, the estimated speed of adjustment increases approximately from 0.02 to 0.03 with an implied 35% reduction of the number of years to cover half the distance to the steady state (from 34 to 23 years). This suggests that even with the relatively low net migration rate of our sample, the adjustment is somewhat faster. Therefore, in environments in which labour mobility were higher (regions within a country) the convergence rate could be considerably accelerated by larger migration flows

As a conclusion to this section, given the fairly satisfactory performance of our models, we proceed in attempting an evaluation of the overall output and growth effect of immigration using the parameters estimates that we obtained. In the two types of capital model, the effects on the steady state output per capita, the current output per capita and the current growth rate are given by the following expressions (generalised from Result 3):

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[35] If the data were available, our estimation techniques applied to more countries in which the net migration rate were negative (particularly the eastern countries), could provide indirect evidence for the ongoing debate on the relative skills of emigrants. However, taking at face values the figures in Table 8, there seems to be evidence that, for the set of eight countries with negative net migration, those who migrate have lower skills those who stay.

(28) $$\frac{\partial \ln(\hat{y}^*)}{\partial Z} = \frac{-(\alpha+\beta)\left(1-\frac{\alpha\varepsilon}{\alpha+\beta}\right)}{\left(1-\frac{\alpha\varepsilon}{\alpha+\beta}\right)\varphi\,(\alpha+\beta)+(1-\alpha-\beta)\left(D+m^*\left(1-\frac{\alpha\varepsilon}{\alpha+\beta}\right)\right)}$$

(29) $$\frac{\partial \ln(\hat{y})}{\partial Z} = (1-e^{-\lambda t})\frac{\partial \ln(\hat{y}^*)}{\partial Z}$$

(30) $$\frac{\partial \gamma_y}{\partial Z} = \beta + \alpha(1-\varepsilon)$$

where $\hat{y}^*$ is output per capita in steady state, $\hat{y}$ is the current output per capita, γ_y is the growth rate of output per capita, and Z is exogenous net migration. These three derivatives are what our two estimated equations allow us to compute. Using the point estimates described in Table 2, and assuming $D = .05$, $\varphi = .01$ and $m^* = .0034$ (the population weighted average in our sample), on the basis of (28) a one per thousand increase of net migration reduces output per capita in the steady state by 1.3 percent and current output per capita by 0.044 percent. The same increase of net migration reduces instead the growth rate of output per capita by 0.036 percentage points. Of course, the very low size of these two last effects stems from the low convergence rate, i.e. 3% per year. So, even if the long run effects are sizeable, the short run effects of migration are almost negligible.

As for the effects of a change in the immigrants versus natives human capital ratio, starting from $\varepsilon = 0.63$, a 0.1 increase of this parameter increases output per capita in steady state by 0.3% and the growth rate by 0.034 percentage points. Notice that if ε were equal to $1 + \frac{\beta}{\alpha}$ the effects of a higher net migration rate would be null. However, the evidence described in Section 1 and the estimates in Table 9 suggest that immigrants do not have such a high level of human capital relative to natives. The observed level of immigrants human capital is clearly too low to deliver no output and growth effects, but it may still be large enough to substantially differentiate the effects of immigration from the effects of a comparable natural population increase. Indeed, the impact of natural population growth on current output per capita is given by

$$(31) \quad \frac{\partial \ln(\hat{y})}{\partial n} = \frac{-1}{\left(1-\frac{\alpha\varepsilon}{\alpha+\beta}\right)\varphi\,(\alpha+\beta) + (1-\alpha-\beta)\left(D + m^*\left(1-\frac{\alpha\varepsilon}{\alpha+\beta}\right)\right)}$$

$$= \frac{\partial \ln(\hat{y}^*)}{\partial Z}\left(\frac{1}{\beta+\alpha(1-\varepsilon)}\right)$$

On the basis of the parameter values described above, (31) suggests that if the native population grows by one per thousand, the current output per capita decreases by more than 3 percentage points. Therefore, because of its human capital content, a migration inflow has half the negative impact of a comparable natural population increase.

Conclusions

In this paper we have analysed the effects of migration in an augmented Solow growth model without capital mobility. This is a first step towards the analysis of a fully fledged model which considers not only labor but also capital mobility. The basic message that we draw from the above analysis can be summarised as follows. Although immigration represents a source of population growth, it cannot be assumed to share, quantitatively, the same negative output and growth effects, per capita, of a natural increase in native population. The reason is the stock of human capital that immigrants bring with themselves when they enter the country. Yet, in the presence of other reproducible factors of which immigrants are not endowed, the human capital content of a migration inflow would have to be extremely high (twice as much as that of natives, under reasonable parameters values) in order to neutralise the negative output and growth effects of immigration in per capita terms.

Evidence based on education data suggests that the human capital content of international migration flows is indeed fairly high, making immigrants look, on average, almost as skilled as natives. The econometric results show that this is enough to halve the negative impact of immigration with respect to a comparable natural increase of the host country population. It is also enough to cause fairly limited effects on current output and growth, but it leaves room for sizeable long run effects on the steady state output level, which is reduced, and on the speed of adjustment, which is increased. These two opposite effects almost neutralise each other thereby making the overall effect on current growth fairly small.

It should be noticed that these conclusions are reached in a framework in which immigrants contribute to the host country human capital accumulation only with the skills that they have accumulated in the country of origin. However, after arrival in the host country, immigrants may also accumulate human capital differently than natives thereby influencing, during the assimilation process, the host country accumulation of reproducible factors. Leaving for future research an explicit analysis of the sign and size of these effects, we conjecture here that they may make the overall impact of immigration less dramatic than usually thought.

From the viewpoint of the European Monetary Union, waiting, up to the end of the century, for more than 12 millions of potential non EC immigrants from the South and from the East (SOPEMI/OECD [1992]), this is mixed news. The possibility of negative long run effects can hardly be denied on the basis of our results, although in the short run the effects would probably be limited. Yet the human capital of these potential immigrants, particularly of those coming from the Eastern Countries, may be fairly high, allowing us to expect less dramatic consequences than those of a comparable natural population increase.

In conclusion, an obvious policy indication of our paper concerns the opportunity that European immigration policies become more clearly geared toward the selection of the most skilled potential immigrants This is a goal that the current administrative controls, mainly aimed at limiting the size of migration inflows, are far from achieving. However, such an objective is desirable only from the point of view of the host countries. Once the output and growth effects of both the sending and the receiving countries, together with capital mobility, are taken into account, policy indications become definitely less clear cut. One possible conjecture would be to combine the aforementioned selection policies for immigrants with sizeable flows of direct investment in the sending countries, in order to generate employment in situ and set in place an occupational training system with a twofold goal: to provide skilled foreign labor for the host country when necessary and to train labor to work with the technology of the host country firms established in the sending country.

In any case, we hope that our quantitative effort, aimed at measuring the size of these effects, may help to define an international migration policy from which both sending and receiving countries could profit.

Data appendix

1. The Human Capital Index

The human capital index is based on educational data from the countries of origin and the host countries of immigration.We use in our analysis the human capital of immigrants, the human capital of natives and their ratio referring to nine selected host countries, over a maximum 28 years period. The measure of the human capital of immigrants is given by schooling rates or levels associated with the immigrants' flows. Referring to each host country it is computed as the weighted average of the human capital of the countries of origin using the numbers of immigrants from each origin as the weights. Where only immigration data by regional groups were available, the schooling data used are the average of the schooling data for the countries within that region for which data were available.

The data and the methodology adopted to measure immigration flows and educational data are described in the following sections.

1.1 Migration data

The data source for migration inflows is a U.N. source[36]. A regional composition of migration inflows, classified by countries of origin, was available for nine receiving countries: the three major countries of immigration, i.e. Australia, Canada and the US, and six European countries, i.e. Belgium, the Federal Republic of Germany, the Netherlands, Sweden, Switzerland and the United Kingdom. Table A1 shows for each host country the number of individual and regional countries of origin of migration inflows available to be used in the human capital computation. Migration flows from each country of origin have been used when corresponding schooling data were available. Therefore the number of the countries of origin of migration inflows in the selected host countries varies in relation to the schooling data set used. Table A1 also shows the length of the period over which single years data on the composition of migration inflows for each host country were provided.

Table A1

Host country	Countries'of origin #	Time series
Australia	76	1960-1988*
Belgium	34	1960-1987
Canada	220	1961-1987
Germany	58	1961-1987
Netherlands	23	1960-1988
Sweden	19	1960-1981
Switzerland	5	1975-1988
United Kingdom	12	1969-1987
USA	124	1960-1988

*Note: In Australia the representative single year for migration inflows, originally gathering data from the 1st of July until the 31st of June of the following year, has been expressed assumig the following year as exhaustive.

The criteria used to identify immigrants vary across the host countries: Canada

[36] See H.Zlotnick[1991]

and the United States gather data only on persons admitted as permanent residents, and Australia on broadly defined "settlers". The origin of the immigrants in the three countries is classified by country of birth.

The European countries provide information on the number of immigrants including citizens returning . The criteria adopted to classify immigrants differ among the European countries considered as follows: Belgium and the Netherlands classify migrants by citizenship; the Federal Republic of Germany, Sweden and the United Kingdom by country of previous residence; whereas Switzerland does so by nationality and class, distinguishing between immigrants with annual and permanent permits. In this context the permanent permit classification has been adopted.

1.2 Schooling data

The schooling data used to measure the natives' and immigrants' human capital originate from three different sources :

- Secondary school enrollment data , provided by the World Bank
- Educational Attainment data provided by Barro and Lee [1992][37]
- Educational attainment data provided by Kyriacou [1991][38]

The World Bank secondary school enrollment data express the number of pupils enrolled in secondary school, given by the gross ratio of total pupils to the population of school-age children. Although the definition of secondary school age differs among countries, it is most commonly considered to be 12 to 17 years. Since some pupils are younger or older than the country's standard secondary school-age, the gross enrollment ratios for a few countries exceed 100 percent.

The data were available for 118 countries, with a maximum availability for five-year period observations, between 1960 and 1987. Yearly estimates for intervening years and future projections have been linearly extrapolated.[39]

The Barro and Lee's educational attainment measure expresses the years of completed schooling for persons aged 25 and over. Within the 25 and over years category, the education figures are constructed at four levels: no schooling, some primary schooling, some secondary schooling, and some amount of higher education. Those categories are broken down into completed and incompleted schooling, and missing observations are then filled in by adopting an estimation method that exploits the available data on school-enrollment rates and population by age.

The data set has been originally constructed for 113 contries over five-year periods from 1965 to 1985. We linearly extrapolated the estimates for the intervening years.

The Kyriacou's educational attainment measure indicates the estimated years of schooling in the labor force. The estimation procedure is as follows: 42 countries' data on the average years of schooling in the labor force in 1975 are heuristically found to be strongly related with lagged enrollment ratios in primary, secondary and higher education. Assuming this relationship to be more or less constant over time and across countries, it is then used to estimate the average years of schooling in the labor force for several years and many countries.

[37] Highly recommended for a detailed analysis of the educational data

[38] Highly recommended for a detailed analysis

[39] Data estimates for Switzerland, from 1965 onwards, have been extrapolated assuming a trend similar to the Spanish one, since in 1965 (our last observation for Switzerland) the two countries show equal schooling rates.

The data set has been originally constructed for 121 countries over five-year periods from 1965 to 1985. We did linearly extrapolate the estimates for the intervening years.

2. Net migration and immigration in the OECD Countries

Data on net migration flows used to estimate the ratio between the immigrants' and natives' human capital referring to the OECD Countries originate from three sources: Eurostat, H. Zlotnick , UN (1989 Annual Statistical Yearbook).

The Eurostat data on net migration identify migrants by country of origin, referring to their citizenship, and by class, according to the residence criterion. The data are provided for the European Countries over the 1960- 1989 period.

The H.Zlotnick data on emigration and net migration reflect the criteria previously described (section 1.1) to identify immigrants by country of origin and class. Emigration data within the major group of receiving countries are assessed only for Australia, whereas they are provided for all the European Countries considered above, albeit over a shorter time series.

The UN data selected identify incoming and outgoing flows with "long-term" migrants. Countries of origin are defined by migrants' nationality. The net migration data are provided for some OECD Countries from 1979 onwards.

To select the data source a ranking order has been assessed: priority has been given to the Eurostat source, then the Zlotnick source and finally the UN source have been adopted, according to the availability of data.

Since net migration data were not available for the US, migration inflows have been used instead.

Immigration data, originating from the Zlotnick and the UN source, have been selected following the same ranking criterion, giving priority to the Zlotnick data set.

3. Other variables used in the econometric analysis

The data are from the Summers and Heston data base [1991], which covers the 1960-1988 period for 138 countries. We used the data for 23 OECD Countries, listed in Table 9 in the text.

The real income measure adopted is the real GDP per capita in constant dollars, using Chain, at 1985 international prices.

The implicit working-age population has been computed by weighting the total Real GDP by the Real GDP per Equivalent Adult, both measures being taken at 1985 international prices.

The rate of human capital accumulation (s_h), due to difficulties in gathering yearly data for the age-population distribution, has been constructed using the School variable computed by Mankiw, Romer and Weil [1992], augmented by the total population in each year, weighted by the average population over the 1965-1980 period for each reference country.

The rate of physical capital accumulation (s_k) is measured as the Investment share of GDP, in percentage terms, at 1985 international prices.

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