# Age-Specific Education Inequality, Education Mobility and Income Growth*

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**Abstract**

We construct a new dataset of inequality in educational attainment by age and sex at the global level. The comparison of education inequality measures across age groups allows us to assess the effect of inter-generational education attainment trends on economic growth. Our results indicate that countries which are able to reduce the inequality of educational attainment of young cohorts over time tend to have higher growth rates of income per capita. This effect is additional to that implied by the accumulation of human capital and implies that policies aiming at providing broad-based access to schooling have returns in terms of economic growth that go beyond those achieved by increasing average educational attainment.

**Keywords:** Human capital, education inequality, age structure, economic growth

**JEL codes:** I24, I25, O50

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# 1 Introduction

The term *human capital* comprises aspects inherent in humans, which are either given - as in the case of congenital abilities, skills and talent - or can be acquired - as in the case of education or experience. In this context, formal education takes on an essential role in linking those two components of human capital. On the one hand, education is able to compensate for congenital differences as well as educational gaps arising in early childhood. On the other hand, education constitutes the foundation of personal professional careers and affects lifetime income and health over the whole life-cycle. Its central role as a determinant of individual well-being and income has lead formal education to play a particularly important role in development policy paradigms (see for example Lutz (2009) for a broad discussion of the role of education on development).

At the aggregate level, the empirical analysis of the effects of investments of education on economic outcomes has been traditionally based on measurements of average educational attainment of societies. Variables such as the mean years of schooling of a person in the working age population or the proportion of population with some specific formal educational attainment level are often used in the framework of cross-country or panel data regressions to assess the role played by human capital as a determinant of socio-economic outcomes (see for example Mankiw, Romer, and Weil (1992), Barro and Lee (1993), de la Fuente and Doménech (2006), Cohen and Soto (2007), just to name a few).

The literature on the linkage between human capital and economic outcomes has concentrated on relating these to the first moment of the distribution of educational attainment, although in the last decades some effort has been invested in analysing the distributional dimension of human capital measures. The standard deviation of schooling measures and Gini indices of educational attainment levels are the two statistics that have primarily been used in the literature in order to investigate the aggregate distributional characteristics of educational attainment across individuals. The impact of the distribution of education on income growth, income distribution and poverty reduction has been explored making use of the standard deviation of school attainment (see Birdsall and Londono (1997), López, Thomas, and Wang (1998), Lam and Levison (1991) or Inter-American Development Bank (1999)). Such a measure of dispersion in the distribution of educational outcomes has been used for testing the existence of an Education Kuznets Curve (an inverted U-shaped relationship between the dispersion and the average level of schooling) by Fan, Thomas, and Wang (2002), who confirm the findings of Londono (1990) and Ram (1990) concerning the fact that education inequality first increases as the average level of schooling rises, and, after reaching a peak, starts to decline.

Since the standard deviation of the distribution of education variables is only a measure of absolute dispersion, it does not provide a consistent picture of the distribution of education outcomes across individuals, especially for countries with very low and high levels of average schooling. The use of the education Gini coefficient as a measure of inequality is thus more widespread in the recent literature. Earlier studies used Gini indices computed using school enrollment or education finance data (Maas and Criel (1982), Rosthal (1978) and Sheret (1988)) for relatively small samples of developing economies. To the extent that enrolment ratios are flow variables and as such constitute indicators of access to education, they do not capture the degree of inequality in educational outcomes, that is, in the *stock* of human capital. More recent studies calculate the education Gini coefficient based on educational attainment of the population of interest. López, Thomas, and Wang (1998) derive Gini coefficients for 12 countries using attainment data. Fan, Thomas, and Wang (2001) calculate education Gini indices for 85 industrialized and developing countries for the period from 1960 to 1990 and relate them to average educational attainment, educational gender-gaps and real GDP per capita differences. In subsequent work, they further extend the sample to 140 countries spanning the period 1960 to 2000 (see Fan, Thomas, and Wang (2002)). The approach in Fan, Thomas, and Wang (2001) and Fan, Thomas, and Wang (2002) has been utilized for deriving consistent indicators summarizing the distribution of education that can be related to the distribution of income and income growth (see e.g. Checchi (2000)). The results in Checchi (2000) do not support the existence of an education Kuznet's curve, but reveals instead a strong negative relation between the degree of inequality and the average level of educational attainment. Castelló and Doménech (2002) compute Gini coefficients using years of schooling for a broad sample of countries and Castelló-Climent and Doménech (2012) and Sauer and Zagler (2012b) provide an update of the dataset which spans a larger historical period.[1] While the results in Castelló and Doménech (2002) show that uneven distributions of human capital tend to be directly related to lower income per capita growth rates, the evidence of Sauer and Zagler (2012b) reveals that countries that show greater education inequality experience lower macroeconomic returns to education than more equal economies, on average.

Studying the heterogeneity in the distribution of human capital across individuals due to the age structure of societies has gained importance lately. Recent developments in data collection and population back-projections have been able to shed light on the role played by the age structure of educated adults as a determinant of economic development (see Lutz, Crespo-Cuaresma, and Sanderson (2008) or Crespo-Cuaresma and Mishra (2011)). In this contribution we bridge both branches of the literature by constructing a new dataset of inequality measures of educational attainment by age groups and sex for 175 countries during the period 1960-2010. For this purpose, we use the recently developed IIASA/VID (International Institute for Applies Systems Analysis/Vienna Institute of Demography) global dataset of population by age, sex, and levels of education, which enables us to incorporate the demographic dimension into the analysis of education inequality (see KC, Barakat, Goujon, Skirbekk, Sanderson, and Lutz (2010) and Lutz and KC (2011), for example). We are thus able to analyse global trends for subgroups of the population and to distinguish the differential characteristics of distributions of educational attainment across different age groups - which tend to dominate in episodes of educational expansion - from those within age groups.

In addition, the new data allow us to create aggregate measures of intergenerational education mobility based on comparing the distribution of educational attainment among older individuals with that at younger age groups. From a theoretical point of view, Galor and Tsiddon (1997) provide a model that studies the interaction

[1]Fan, Thomas, and Wang (2002) also calculate Theil indices of educational attainment and Castelló and Doménech (2002) additionally report the distribution of education by quintiles.

between the intergenerational mobility of human capital and output growth. In the context of an overlapping generations model, Galor and Tsiddon (1997) hypothesize that the intergenerational transmission of education occurs through two different mechanisms. On the one hand, the prevailing level of human capital of an individual is assumed to depend on the resources invested in education as well as on the level of human capital of their parents. This creates path dependency within dynasties and is thus called the *local home externality*. Second, the level of technology is a nondecreasing function of the parental generation's average human capital in the economy. By increasing the wage rate of each individual by the same amount, thereby creating incentives for human capital accumulation for the skilled and the unskilled, this *global technological externality* creates spillovers across dynasties and generations. The path towards the unique steady state equilibrium in this economy is characterized by intergenerational mobility along with a subsequent decline in the degree of inequality in the distribution of human capital. To the extent that exogenous technological shocks are complementary to human capital, technological progress boosts the returns to skills and increases intergenerational mobility. The model put forward by Galor and Tsiddon (1997) thus predicts a positive relationship between intergenerational education mobility and income growth.

Using panel regressions, we show that countries which reduce the degree of inequality in the distribution of education for younger age groups (and therefore those which increase the degree of intergenerational education mobility) tend to have higher growth rates of income per capita. Our results confirm the theoretical insights of Galor and Tsiddon (1997) and expand some of the results found in the literature. Our estimates indicate that the returns of policy actions aimed at improving intergenerational education mobility in terms of income growth go beyond the direct effect that higher average educational attainment has on economic growth. Our analysis implies that monitoring the distribution of age-structured educational attainment provides policymakers with very valuable information about future economic growth trends and that therefore the use of demographic modelling and projection methods can serve an important function as an instrument to investigate income growth scenarios over long time horizons.

The paper is structured as follows. In section 2 we discuss the database for and the construction of our age and sex-specific education inequality indicator. In section 3 we analyze Global and European trends in the demography of education inequality. The intuition behind our aggregate indicator of intergenerational education mobility is dealt with in section 4, while section 5 brings the inequality and mobility dynamics together and presents projections until 2050. We present and discuss the results of the empirical analysis which addresses the role played by educational inequality and intergenerational education mobility on income growth in section 6. Section 7 summarizes the findings and concludes.

# 2 Constructing Age-Structured Education Gini Coefficients

In this section we present the details about constructing our age and sex-specific education inequality indicator. We demonstrate its overall characteristics and dynamics across and within age groups by presenting results for two selected countries, India and South Korea, which are of interest in their own right.

In line with the respective literature, we follow Fan, Thomas, and Wang (2001) and Fan, Thomas, and Wang (2002) in measuring the degree of inequality in the educational distribution by computing Gini coefficients of educational attainment but extend their approach by accounting for the demographic dimension. In a given country, for the age group $a$ of sex $s$ the measure of inequality in educational attainment is thus given by the Gini coefficient computed over the relevant population group.

$$\text{Gini}_{a,s} = \frac{1}{\bar{y}_{a,s}} \sum_{i=2}^{4} \sum_{j=1}^{i-1} \left| y_{a,s,i} - y_{a,s,j} \right| p_{a,s,i} p_{a,s,j}, \tag{1}$$

where $y_{a,s,i}$ is the cumulative duration of schooling[2] for the level of education $k$ in the age group $a$ with sex $x$ and $p_{a,s,i}$ is the share of the corresponding population with that level of education. $\bar{y}_{a,s}$ denotes the mean value[3] of years of schooling. We consider four educational attainment levels ranging from no formal education ($i = 1$) through primary education ($i = 2$), at least junior secondary education ($k = 3$) and tertiary education ($i = 4$). In relation to its application to income inequality, the education Gini coefficient is a measure of mean standardized deviations between all possible pairs of people. The index always lies in a range between zero and one, indicating perfect equality and perfect inequality respectively.

We are able to assess the full educational attainment distribution for four educational categories by five year age groups for men and women by using a new education dataset. Applying the demographic method of multistate back and forward projection, researchers at the International Institute for Applied Systems Analysis (IIASA) and the Vienna Institute of Demography (VID) have recently constructed population data[4] for 175 countries by age, sex and level of educational attainment spanning the period from 1960 to 2010 at five year intervals. The definitions of formal educational attainment categories are based on UNESCO's International Standard Classification of Education (ISCED) categories and are thus strictly consistent over time and across countries.

The basic structure of the data is nicely visualized by population pyramids for ages above 15. Figure 1 presents these for India and South Korea in the years 1970 and 2000. In each of the four areas, the left and right panels correspond to the male and female population respectively. Each bar relates to one 5-year age group while the distribution therein gives the composition of educational attainment.

In India, on average 55.2% of people aged 20-24 did not have any formal education in 1970. The gender differences in terms of educational attainment have also been very remarkable, with the share of uneducated women being 71.3% and for men 40.1 %. Only a negligible share of individuals attained some tertiary education in this age group. In 2000, the educational attainment of young age groups is comparatively very high. A substantial share of population in younger age groups had primary or secondary education and the share of tertiary educated increased for both, males and females. This having been said, in 2000 still 41.5% of females and 20.2% of

[2]See below and appendix A.1.

[3]Mean years of schooling are given by $\bar{y}_{a,s} = \sum_{i=1}^{n} p_{a,s,i} * y_{a,s,i}$.

[4]See for example Lutz and KC (2011)

males had no formal education. In contrast, the population pyramids for South Korea reveal the country's impressive educational expansion during the last part of the twentieth century. In 2000, among the younger age groups, attaining secondary education is the rule, and the share of individuals with tertiary education is 43% in the age group 25-29. Among the elderly there is still a significant share of uneducated persons and a sizeable gender gap which reflects overall lower educational attainment in preceding decades.

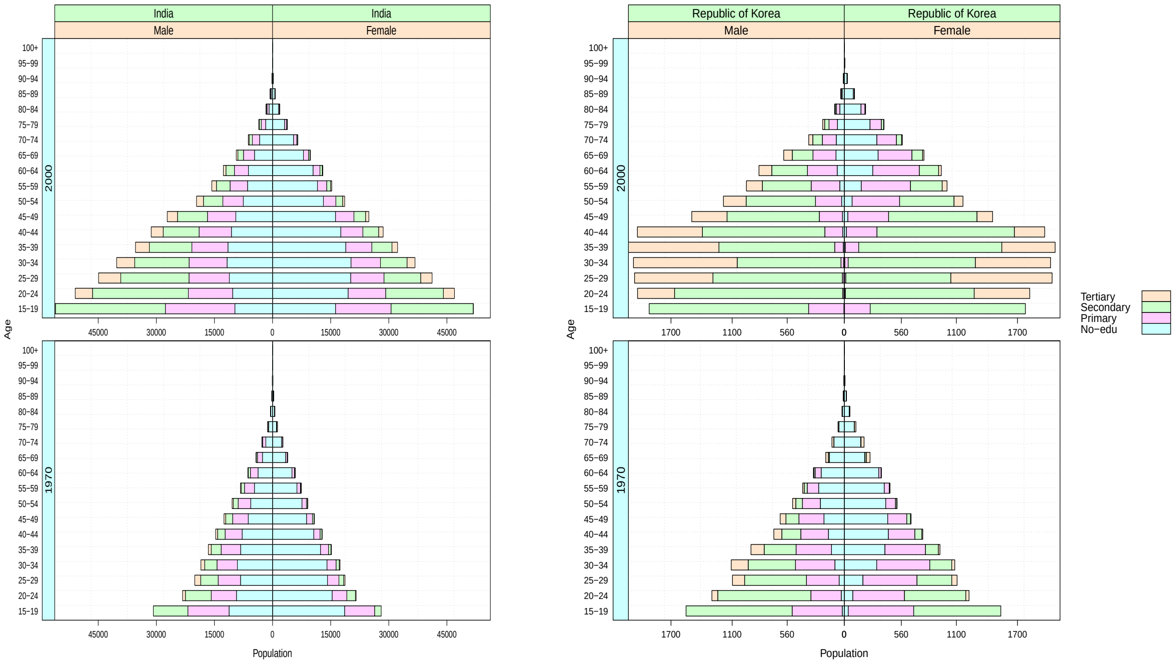


Figure 1: Population pyramids (ages 15+) including educational attainment information: India and South Korea, 1970 and 2000

In order to compute the education Gini coefficient by age group and sex given by (1), we require average duration data for each one of the educational attainment categories. We combine the age-structured education data from the IIASA/VID dataset with country-specific information on duration from the UNESCO Institute for Statistics (UIS). Since the IIASA/VID dataset includes in each one of the four broad categories of educational attainment individuals who did not complete the respective level, using the total duration for completion would overestimate the years that a representative individual spent in school. We therefore follow the method proposed by KC, Barakat, Goujon, Skirbekk, Sanderson, and Lutz (2010) to account for uncompleted attainment levels when computing the *mean* duration of each educational attainment level.[5]

The translation of cohort and gender-specific structures in the distribution of educated individuals to inequality measures are depicted in figures 3 and 2. Figure 2 shows the Gini coefficient for educational attainment in each five-year age group for males and females using data corresponding to the year 2000. In general, the degree of education inequality is lower among younger people than among the elderly. Moreover, the educational attainment level is not only higher but also more equally

[5]See appendix A.1 for a description of the computation of mean durations.

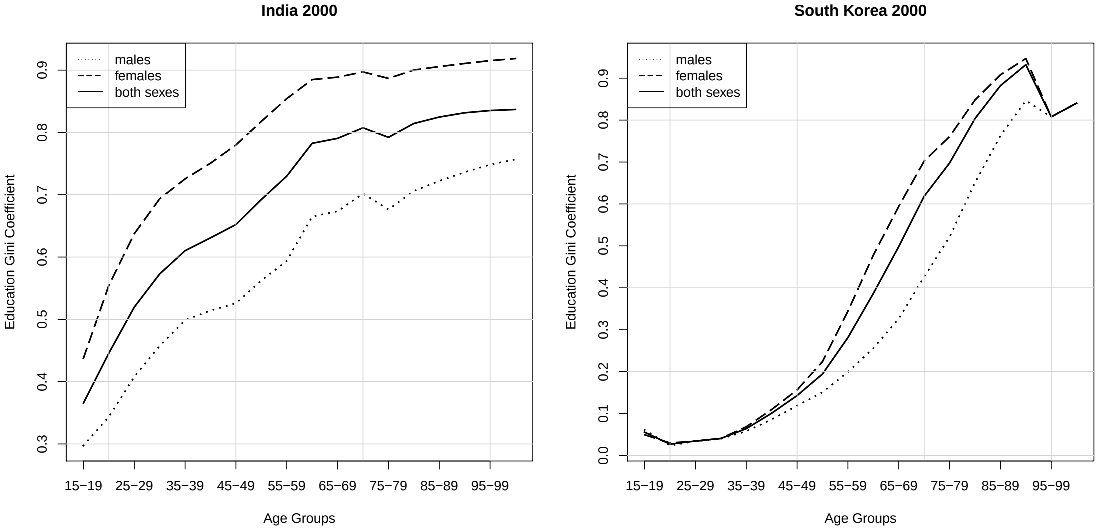


Figure 2: Education Gini coefficients by age group: India and South Korea, 2000

distributed among men than among women. Such a gender gap is particularly pronounced in India as compared to South Korea. While the education Gini coefficient for males ranges between 0.3 in the lowest age group and 0.65 for individuals aged 65 and above, these values are 0.43 and 0.88, respectively, for females. The gender gap in education inequality disappears in young age groups for South Korea, where the education expansion led to an almost perfectly equal distribution of education among younger individuals, with the education Gini coefficient leveling off at 0.03. The steep slope of the curve reveals that education expansion in South Korea was accompanied by a substantial decline in the degree inequality in the distribution of education. Larger differentials in education inequality across sexes appear in South Korea for ages above 45, which correspond to the young age groups depicted in the population pyramid for 1970 in figure 1.

The geometric representation of the Gini coefficient is the Lorenz curve. Formal schooling in the way we are able to measure it is a discrete rather than a continuous variable. The education Lorenz curve is thus a kinked line, with the kinked points corresponding to each of four education categories. Moreover, if a proportion of the population does not attain any education, the function is truncated along the horizontal axis. Figure 3 plots the cumulative population shares against the cumulative shares of years of schooling for selected broader age groups of our two sample countries in 2000. The differences in terms of education inequality between age groups, depicted in the resulting educational attainment Lorenz curves for India and South Korea, stresses the importance of assessing the demographic dimension when analyzing aggregate and distributional aspects of human capital dynamics. In India, the Lorenz curve for the population above 15 years of age presents characteristics which are similar to those in the age group 25-39, while in the case of South Korea the average value for the age group 15+ mimics the distribution observed in the age group 40-54. The average education Gini coefficient for South Korea thus overestimates the overall degree of within-age-group inequality in the distribution of education for most relevant age groups. This phenomenon is particularly relevant for countries which, as South Korea, have experienced a history of strong educa-

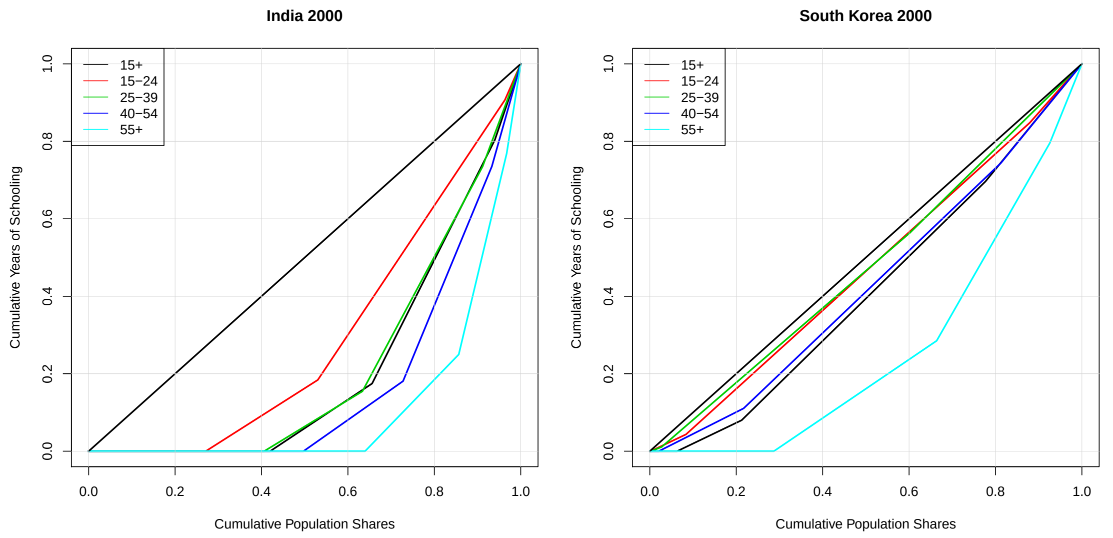


Figure 3: Education Lorenz curves for selected age groups: India and South Korea, 2000

tional improvement and thus present stark differences in attainment levels between old and young individuals.

# 3 The Demography of Education Inequality: Global and European Trends 1960-2010

Figure 4 presents the evolution of the education Gini coefficient computed for the whole population above 15 years of age, as well as for broad age groups, over the period 1960-2010 for the eight world regions defined by the World Bank (Sub-Saharan Africa, South Asia, Middle East & North Africa, East Asia & Pacific, Latin America & the Caribbean, South America, Europe & Central Asia and Advanced Economies). An overall trend towards a more equal distribution of education is observable in all regions and for all age groups. However, marked differences in the dynamics of the Gini coefficients are present both, for the case of the whole adult population and, for the specific age groups.

For all age groups, the highest levels of education inequality are observed in Sub-Saharan Africa and South Asia, where also the trend towards a more equal distribution in educational attainment level has been the slowest in the 50 years depicted in Figure 4. Such an observation is not surprising taking into account that the decline in the share of individuals without education, which has been modest for a large part of the period in these two regions, is one of the main forces driving education inequality reduction (see Castelló-Climent and Doménech, 2012).

The process of educational expansion taking place over time in all regions leads in general to a reduction of the inequality differentials across age groups. Consequently, education Gini coefficients based on the whole adult population tend to be less representative of within-age-group education inequality for less developed economies, which find themselves at early stages of the education expansion phase.

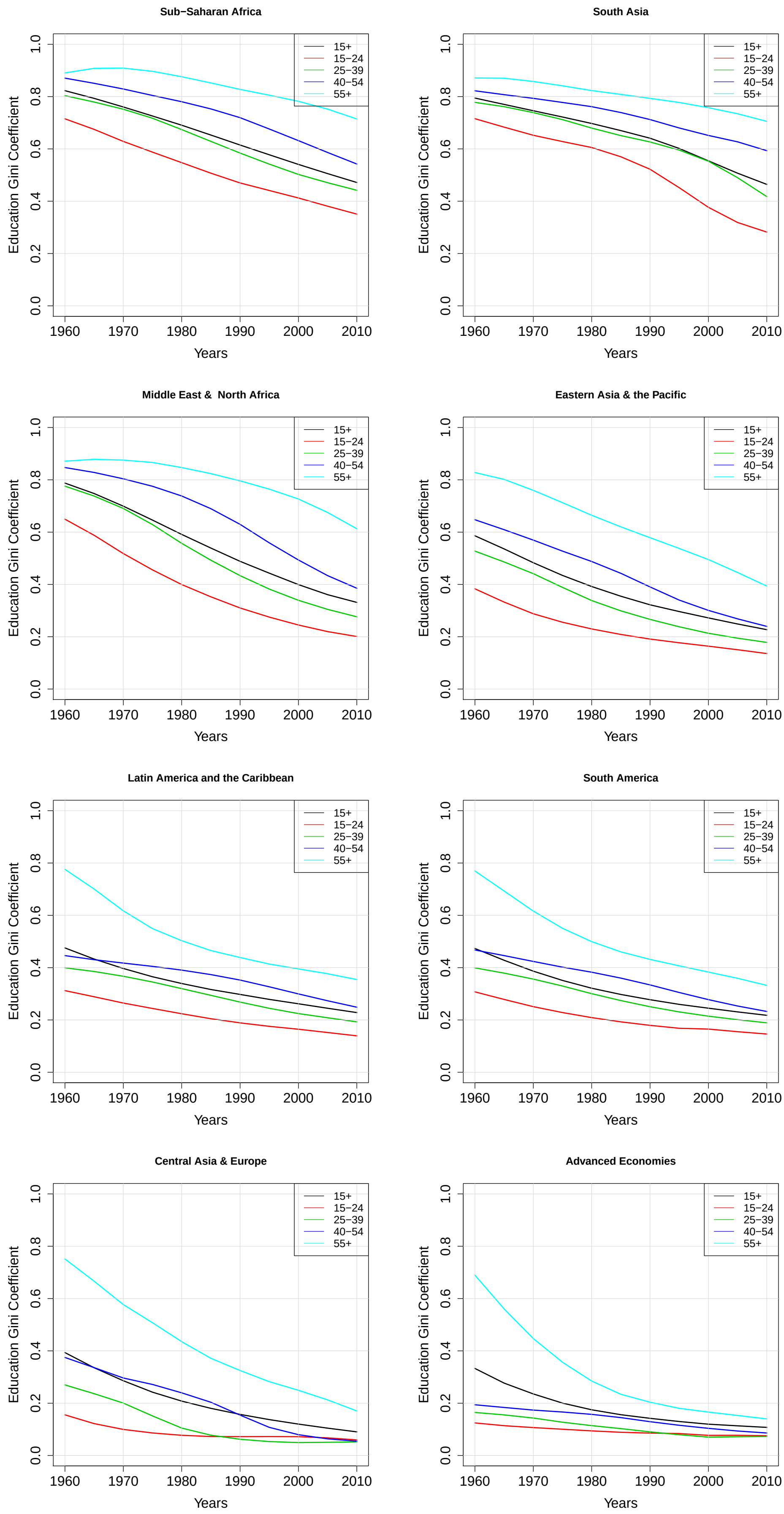


Figure 4: Education Gini coefficients by world region for selected age groups, 1960-2010

The Middle East & North Africa, Eastern Asia & the Pacific and South Asia have experienced large improvements in terms of equalizing the distribution of educational attainment among younger individuals since 1980. The high dynamics in these regions resulted in highly pronounced age-group differentials in educational inequality. As the degree of inequality decreases (see the dynamics in Latin America & the Caribbean and South America as well as in Central Asia & Europe) the potential for further improvement is limited, which leads to more stable dynamics of the education Gini coefficient for economies at a more advanced level of development. The leveling off of the inequality measure takes place at a value of around 0.1 for the group of economies in Europe & Central Asia, as well as for the group of Advanced Economies.

# 4 Measuring Intergenerational Education Mobility

The demographic structure of the education dataset enables to compare the degrees of within-age-group inequality across different cohorts. If we assume that a more equal distribution of education among the youth than among the elderly implies that education has been mobile across generations, we can derive an approach to constructing a simple catch-all measure of intergenerational education mobility at the aggregate level.

Accordingly, we define education mobility as the ratio between the education Gini coefficient of the $25-54$ age group and the education Gini coefficient of the 55+ age group. At a value equal to one, the distribution of the young generation over the four education categories resembles that of the older generation. From an intergenerational point of view, the relationship between the education distribution of the broad age groups is thus consistent with perfectly immobile education levels. The closer the ratio is to zero, the more equally is education distributed among the individuals in the younger age group as compared to the older generations. A value above one, on the other hand, indicates that education is more unequally distributed among the youth than among the elderly.

Figure 5 presents a scatterplot relating the level of educational attainment to the degree of intergenerational mobility for all observations in our sample. On average an overall trend towards a higher degree of intergenerational education mobility is observed as the level of educational attainment increases. The dynamics of the mobility variable are quite different across countries, though. In particular, the recent experience of the economies with the highest average educational attainment levels hint at an U shaped relationship between the two indicators.

A value of the mobility index above one is mainly observed in advanced economies. The increase in education inequality across young individuals observed as societies achieve higher levels of average education is mainly due to increasing shares of tertiary education. For example, in Japan, 48% of the 25-55 age group attained higher education in 2010, while the share was only 18% for individuals aged 55 and over. The education Gini coefficient is thus slightly higher in the former group than in the latter. These dynamics characterize the history of education expansion in Japan

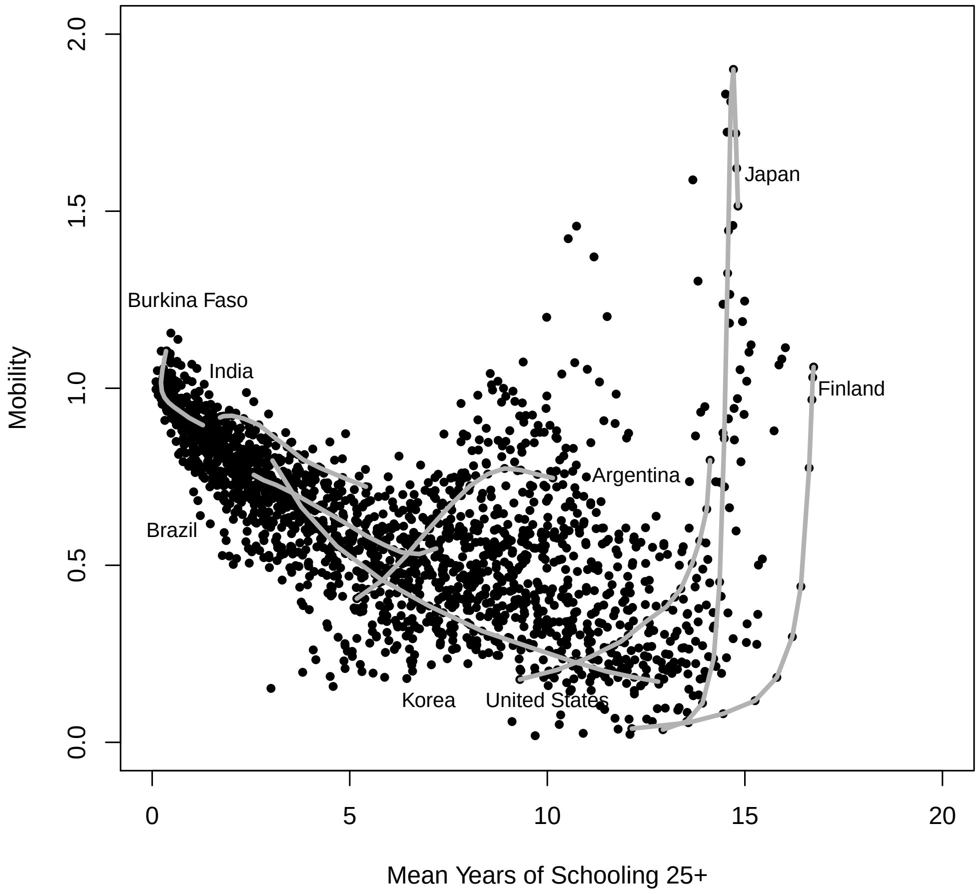


Figure 5: Intergenerational education mobility versus average educational attainment, 1960-2010

over the last ten years, with the education mobility indicator reaching a peak of 1.9 in 2000. On the other hand, in Finland the share of tertiary educated fluctuated around 40% in each one of the age groups considered since 2000, indicating high intergenerational persistence in the educational attainment structure. Figure 6, which depicts the dynamics of our education mobility indicator by world region, demonstrates that these patterns are representative for the region of advanced economies. As societies became highly educated, the pace of further expansion slows down and education becomes increasingly immobile across generations, in the sense captured by our indicator.

Educational attainment levels have remained immobile across generations in South Asian and Sub-Saharan African countries. This is due to the persistently high degree of inequality in the distribution of education along with low levels of average attainment. Besides these extremes, developments have been very different across and within world regions. South Korea accomplished its enormous education expansion not only by increasing the education of the youth but also by consistently decreasing the degree of educational inequality, thereby accelerating mobility between age groups. In Brazil, on the other hand, mobility remained at about 0.5 since 1990 and in Argentina education became increasingly immobile as average attainment approached ten years of schooling.

In general, our findings reveal a pattern of phases of intergenerational mobility alternating with phases of persistence in the educational structure which resembles the theoretical predictions by Galor and Tsiddon (1997). At very low levels of average educational attainment, high mobility allows for education expansions (which in the framework of the model enable to adopt and imitates new technologies). As returns to skill diminish, there is no incentive for additional education investment and the existing composition persists until the next technological impulse. Such dynamics are primary observable in South and Latin American countries.

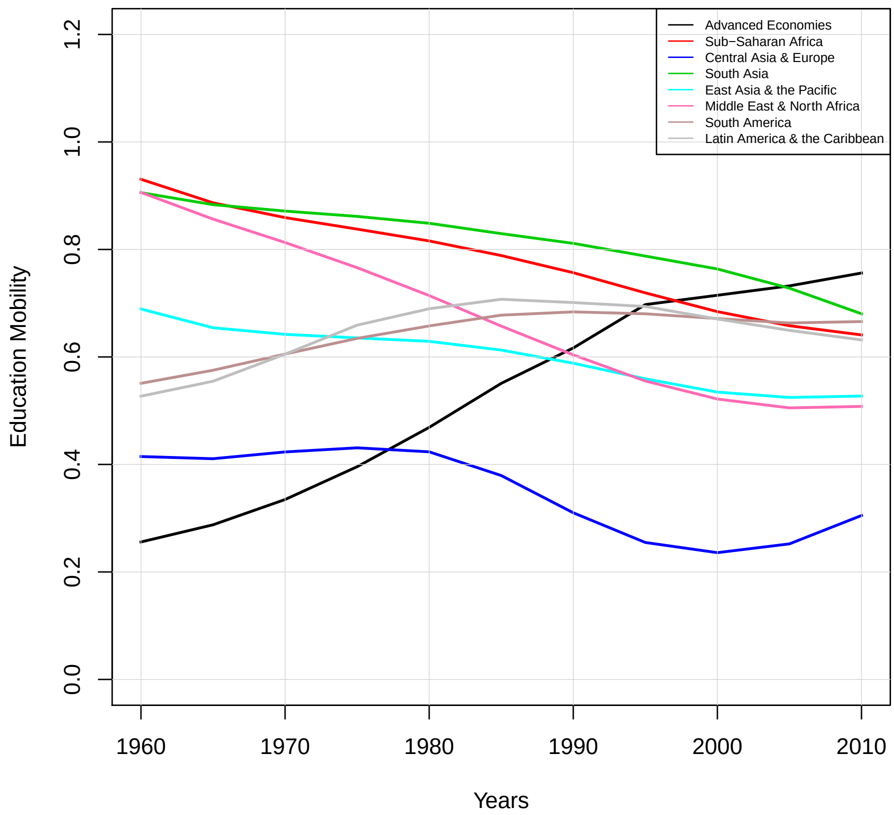


Figure 6: Education mobility by world region, 1960-2010

# 5 Education Inequality and Mobility in Europe: 1960-2050

Our results in section 3 provided indication that Europe[6] is a region where, on average, education is relatively equally distributed. Low levels of education inequality tend to be related to relatively immobile education across generations. However, there exists a quite high degree of heterogeneity within the continent which deserves to be studied in more detail. We therefore consider 41 countries in Europe

[6]Please note that Europe as teated in this section does not coincide with the region of Central Asian & European Economies in section 3 but also includes Advanced Economies.

as defined by the United Nations' macro geographical (continental) region, which is composed of countries belonging to the group of Advanced or Central Asian & European economies. In order to study differential developments within Europe we define 6 subregions: the Anglo-Saxon group (United Kingdom, Ireland), the Continental group (Belgium, France, Germany Luxembourg, Netherlands, Switzerland) the East group (Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Russian Federation, Slovakia, Slovenia, Ukraine), the North group (Denmark, Finland, Iceland, Norway, Sweden) the South group (Cyprus, Greece, Italy, Malta, Portugal, Spain), the South-East group (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Montenegro, Republic of Moldova, Romania, Serbia, TFYR Macedonia, Turkey).

In Figure 7 we present sub-group specific developments of the Gini inequality index for the population aged 25 and above by gender over the 50-years sample period. In 1960, the degree of education inequality and the corresponding gender gap was relatively high in the South-East as well as in the South regions. The former subregion has been able to strongly reduce the degree of education inequality, with the education Gini coefficient of males falling short of that in Anglo-Saxon and Continental countries in 2010. The South-East, in turn, is thus the only subregion with increasing intergenerational education mobility (as measured by our mobility index) throughout the whole period 1960-2010 (see first panel in Figure 8).

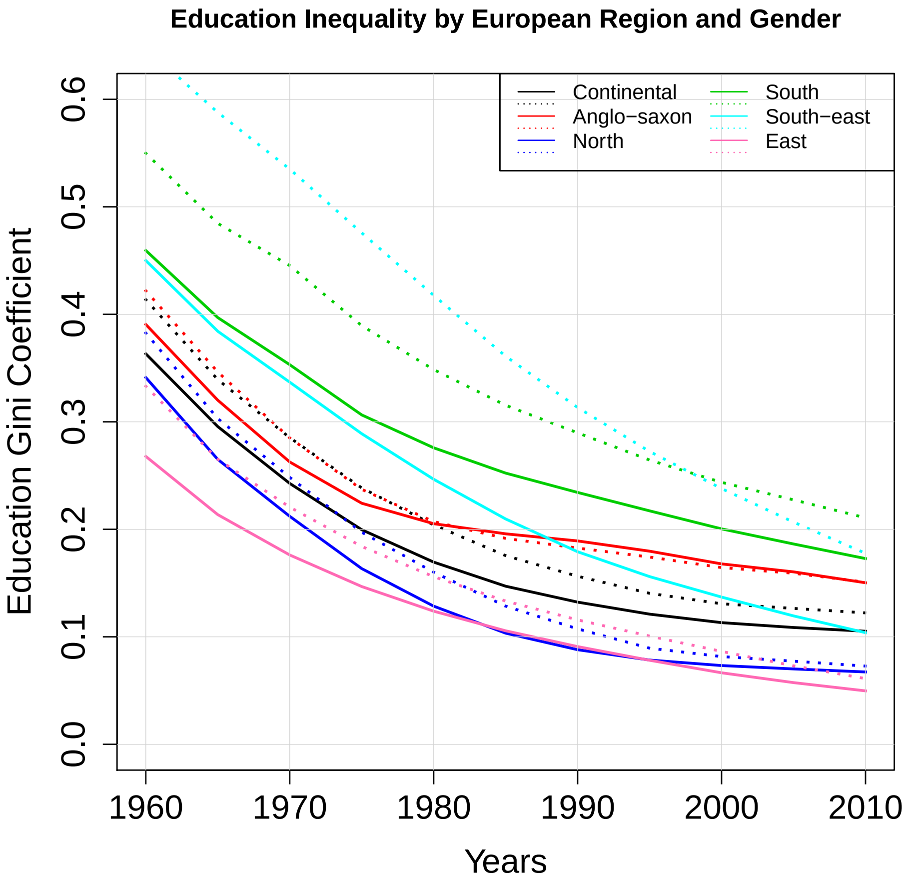


Figure 7: Education inequality by European region and gender, 1960-2010, Total population 25+

When averaged over the total population aged 25 and above, the education Gini is consistently decreasing in all European regions until approximately 1990 and leveling off thereafter. The mobility index, on the other hand, fluctuates also after 1990. This further indicates the importance of considering age-group specific developments in the education distribution to understand the dynamics of educational attainment in European societies. While average education inequality is decreasing in the United Kingdom and Ireland, the inequality in young cohorts, as well as the equality of older cohorts, is increasing. The ratio of young-to-old education Ginis is thus increasing from 0.27 in 1960 to 0.96 in 1985, before consistently decreasing to 0.48 in 2010. Moreover, Northern Europe started out as an economy with a high level of intergenerational education mobility (as measured by our index) in 1960, but in 2010 the education distribution of older age groups resembles that of younger ones. In Denmark, for example, the education Gini of the 55+ age group decreased from 0.43 to 0.021, while that of the 25-54 age group increased from almost zero to 0.03. The increasing persistence in the education distribution across cohorts in Continental and Eastern European countries is also reflected in an increasing aggregate mobility measure. However, this tendency was stronger in Continental Europe.

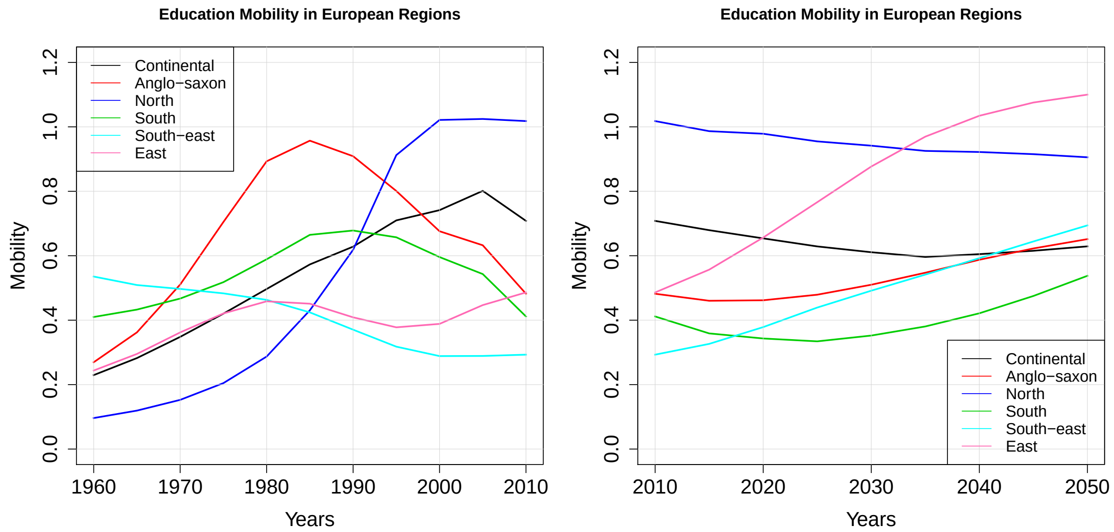


Figure 8: Education mobility by European region

KC, Barakat, Goujon, Skirbekk, Sanderson, and Lutz (2010) provide a series of methods to obtain population projections by age, sex and level of education, which enables us to project the education distribution by age group and compute the corresponding education Gini coefficients up to 2050. We do so using the Global Education Trend (GET) scenario in KC, Barakat, Goujon, Skirbekk, Sanderson, and Lutz (2010), which corresponds to extrapolating the historical trends in educational attainment observed for the world sample of countries. As such, this scenario provides the most realistic population projections among the different settings presented in KC, Barakat, Goujon, Skirbekk, Sanderson, and Lutz (2010).[7]

[7]Notice that, to the extent that overall trend in educational attainment in the world over the last decades has been increasing, this scenario implies improvements in education for practically all economies. The speed of the educational expansion, however, is assumed to depend on the overall level of educational attainment already achieved. Technical details on the assumptions behind the

The education mobility indicator derived for the projection period 2010-2050 is depicted in panel (b) of figure 8. In general, these projections reveal convergence among European regions to a value slightly below one. This is due to the fact that European economies are relatively mature with respect to their average level and the distribution of educational attainment. Since Southern, South-Eastern and Anglo-Saxon economies started out with a relatively low mobility ratio of around 0.4, these countries are projected to gradually close the gap in education inequality between young and old age groups. On the other hand, in Continental and Northern Europe, the degree of inequality in the education distribution is projected to slightly decrease among subsequent young cohorts. After 2030, the education distribution of the youth is predicted to be more unequal than that of the elderly in Eastern Europe. The mobility ratio will therefore increase above one in several Eastern countries.[8]

The observed and the predicted period together show an alternating pattern of intergenerational immobility followed by phases of accelerating mobility, which are fully in line with the theoretical predictions in Galor and Tsiddon (1997).

# 6 Age-Specific Education Inequality and Economic Growth

Existing empirical results confirm that overall education inequality tends to be harmful for economic growth (Castelló and Doménech (2002)). Castelló-Climent (2011) identifies several mechanisms that explain such an effect. In particular, the results by Castelló-Climent (2011) confirm that education inequality increases fertility rates and reduces life expectancy (see also Castelló-Climent and Doménech (2008)), thus affecting further investments in human capital negatively.[9] On the other hand, Sauer and Zagler (2012b) provide evidence that education inequality does not affect income growth directly but abates the macro economic return to education. In this contribution we move a step further by analysing the role played by education inequality within different age groups as a determinant of economic growth and development in a global sample of countries.

We set-up a regression model based on a panel dataset spanning the period 1970-2010 at intervals of five years. Income per capita growth for country $i$ in a given period ($\Delta \ln y_{i,t} = \ln y_{i,t} - \ln y_{i,t-5}$) is assumed to depend on the growth rate of the capital stock ($g^{K}_{i,t}$), population growth ($g^{POP}_{i,t}$), the initial level of income per capita in the period ($\ln y_{i,t-5}$), which captures conditional income convergence dynamics, as well as the overall level of education, measured by the mean years of schooling of the population above 25 years of age ($\text{MYS}^{25+}_{i,t-5}$). We expand the specification by alternatively including measures of aggregate and age-structured education inequality ($\text{EDIN}_{it-5}$). The model we estimate can thus be written as

$$\Delta \ln y_{i,t} = \alpha_i + \beta \ln y_{i,t-5} + \gamma g^{K}_{i,t} + \rho g^{POP}_{i,t} + \theta \text{MYS}^{25+}_{i,t-5} + \eta \text{EDIN}_{it-5} + \lambda_t + \varepsilon_{i,t}, \quad (2)$$

projection model can be found in KC, Barakat, Goujon, Skirbekk, Sanderson, and Lutz (2010).

[8] It has to be noted, however, that the development in Eastern Europe is mainly driven by Belarus and Ukraine (see 2).

[9] In addition, Castelló-Climent (2011) finds that access to credit plays a particularly important role in as a catalyst of such effects. For a survey on the theoretical and empirical literature on the relation between human capital inequality and income growth see Sauer and Zagler (2012a).

where country-specific time-invariant characteristics are captured through country fixed effects ($\alpha_i$) and global income shocks are modelled in the form of fixed period effects ($\lambda_t$). The error term, $\varepsilon_{i,t}$, is assumed to fulfil the standard assumptions of linear regression model disturbances.

Income per capita and total population data are sourced from the Penn World Table 7.1 (Heston, Summers, and Aten (2012)), the capital stock data are obtained from Berlemann and Wesselhoeft (2012) and all the variables based on educational attainment information are sourced from the IIASA/VID dataset (Lutz and KC (2011)). The available sample contains information for 96 countries and spans the period 1970-2010. The list of countries included in the panel regression is presented in appendix A.2. Since income growth is the dependent variable and lagged income per capita one of the covariates, estimation with country fixed effects, OLS estimation methods lead to biased estimates, since the correlation between the error term (which includes a country-specific fixed effect) and the lagged income variable is not explicitly taken into account. Methods based on the generalized method of moments (GMM) estimator have been proposed by to overcome such a problem using lagged values of first differenced and levels of the explained variable as instruments (see Arellano and Bover (1995) and Blundell and Bond (1998)). Given the high persistence of the income variable, we implement the system-GMM estimator by Blundell and Bond (1998) in order to estimate the parameters in (2).

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Initial income | -0.063*** | -0.053*** | -0.058*** | -0.064*** | -0.033 |
| | [0.0168] | [0.0170] | [0.0178] | [0.0184] | [0.0223] |
| Physical capital growth | 0.252*** | 0.257*** | 0.238*** | 0.231*** | 0.231*** |
| | [0.0464] | [0.0503] | [0.0485] | [0.0464] | [0.0470] |
| Population growth | -0.082 | -0.044 | 0.074 | 0.031 | 0.149 |
| | [0.278] | [0.295] | [0.327] | [0.330] | [0.317] |
| Mean years of schooling (25+) | 0.0295*** | 0.0034 | 0.018 | 0.0368*** | 0.0223** |
| | [0.00843] | [0.0205] | [0.0230] | [0.0101] | [0.00948] |
| Education Gini (25+) | | -0.400 | | | |
| | | [0.301] | | | |
| Education Gini (25-54) | | | -0.547** | | |
| | | | [0.219] | | |
| Education Gini (55+) | | | 0.28 | | |
| | | | [0.186] | | |
| Difference Education Gini (55+ and 25-54) | | | | 0.392*** | |
| | | | | [0.132] | |
| Education Mobility index | | | | | -0.186** |
| | | | | | [0.091] |
| Observations | 640 | 640 | 640 | 640 | 640 |
| Number of countries | 96 | 96 | 96 | 96 | 96 |
| AR(1) test (p-value) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| AR(2) test (p-value) | 0.775 | 0.728 | 0.841 | 0.865 | 0.863 |
| Hansen test (p-value) | 0.137 | 0.120 | 0.146 | 0.153 | 0.144 |

The dependent variable is the growth rate of income per capita. All models estimated using system-GMM (Blundell and Bond (1998)). Country and period fixed effects included in all specifications.

Table 1: Estimation results: Economic growth and education inequality

The results of several specifications based on the model presented in (2) are shown in Table 1. In the first column of Table 1, the model is estimated without including any education inequality variable. The parameter estimates indicate that increases in the human capital stock (as measured by the mean years of schooling of the population above 25 years of age) as well as higher physical capital growth tend to be significantly related to higher income per capita growth. The negative parameter estimate associated with the initial level of income per capita gives evidence of conditional income convergence to a country-specific steady state. The inclusion of the education Gini coefficient for the population above 25 years of age (see column 2 in Table 1) does not reveal a statistically significant effect of overall education inequality on income growth. In column 3, we expand the model by including the education Gini coefficient for two broad age groups, one of them covering the population aged 25 to 54 and another one computed for ages 55 and above. The results show that, while education inequality in the older cohorts does not affect income growth significantly, changes in the educational attainment of individuals aged 25-54 that lead towards a more equal distribution of education in this broad age group affect growth positively. Such a result emphasizes the importance of considering the age structure of education inequality and thus moving away from aggregate measures that cover the full population when assessing its effect on income growth.

In addition, a simple F-test cannot reject the hypothesis that the parameter of the education Gini coefficient for the older group is of the same size but opposite sign (p-value = 0.395). This indicates that it is the relative education inequality between the older age groups (ages 55 and above) and the rest of the population that exerts an effect on income growth. Column 4 presents the estimates of the model including the difference in the corresponding education Gini coefficients between both age groups instead of the individual measures of education inequality. For a given degree of education inequality among older cohorts, decreases in education inequality for younger cohorts create positive income growth effects. Such a result indicates that policies oriented towards reducing the intergenerational persistence of educational attainment tend to have income growth returns that are significantly above those implied by the improvement in overall educational attainment. Such a result is also found if the intergenerational persistence measure used is the ratio of both Gini indices, as is presented in column 5 of Table 1. Our results confirm the theoretical insights in Galor and Tsiddon (1997) concerning the role played by changes in the intergenerational distribution of education as an income growth determinant.

# 7 Conclusions

The literature on the relation between human capital and economic outcomes has mainly concentrated on linking these to the first moment of the distribution of educational attainment. More recently, some effort has been invested in allowing for the heterogeneity in the aggregate level of human capital within societies. The distributional and the demographic dimension of educational attainment have, however, been investigated separately. In this contribution we aim at bringing these branches of the literature together. We therefore used the particular structure of the IIASA/VID education dataset, which provides educational attainment by age and sex, in order to construct a new dataset of inequality measures of educational attainment by age groups and sex for 175 countries during the period 1960-2010.

Incorporating the demographic dimension into the analysis of education inequality enables us to analyse global trends for subgroups of the population an to distinguish the differential characteristics of distributions of educational attainment across different age groups from those within age groups. Age-group specific and overall Gini coefficients of educational attainment reveal a general trend towards a more equal distribution of education across individuals. The degree of education inequality varies markedly across age and sex, though. We find education not only to be more equally distributed among men than among women, but also among young people versus older age cohorts. Beyond that, we observe different dynamics over time across regions. Age-group disparities in inequality are relatively high in regions where education is persistently unequally distributed within each generation. Differentials across cohorts also tend to dominate during episodes of educational expansion. As the degree of inequality decreases, the potential for further improvement is limited, which leads to a reduction of the inequality differentials across age groups and to more stable dynamics.

The new data also allows us to create aggregate measures of intergenerational education mobility. Comparing the distribution of educational attainment among older individuals with that at younger age groups leads to an indicator which suggests mobility to be increasing if the education Gini index becomes lower for successive generations. To this effect, we find that more educated societies tend to be characterized by higher mobility across generations. As the aggregate level of formal educational attainment approaches its maximum, however, education tends to converge to a more equal distribution among the youth and among the elderly. This indicates high intergenerational persistence in the educational attainment structure.

The differences in terms of education inequality between and within age groups stresses the importance of assessing the demographic dimension of educational inequality when analysing human capital dynamics. We performed panel data regressions in order to assess the relevance of distributional dynamics in human capital with respect to economic outcomes. We find that countries which reduce the degree of inequality in the distribution of education for young age groups tend to have, ceteris paribus, higher growth rates of income per capita. This implies that intergenerational mobility of education has positive effects on income growth on average. Our results confirm the theoretical insights of Galor and Tsiddon (1997) and expand some of the results found in the literature. Our estimates indicate that the returns of policy actions aimed at providing broad-based access to schooling and improving intergenerational education mobility in terms of income growth go beyond the direct effect that higher average educational attainment has on economic growth.

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# A Appendix

## A.1 Adjusting the duration of formal education cycles

We adjust country-specific information on the duration it takes to complete education level $i$ ($dur_i$) such that it coincides with the four broad categories of the IIASA/VID dataset. In doing so we follow the method proposed by KC, Barakat, Goujon, Skirbekk, Sanderson, and Lutz (2010) to account for uncompleted attainment levels and compute the cumulative mean duration of each educational attainment level by age and sex ($y_{a,s,i}$) as follows.

$$
\begin{aligned}
y_{a,s,1} &= 0, \\
y_{a,s,2} &= 0.25dur_2 + 0.5dur_2 \left[1 - \frac{p_{a,s,1}}{p_{a,s,1} + p_{a,s,3} + p_{a,s,4}}\right], \\
y_{a,s,3} &= dur_2 + 0.25dur_3 + 0.5dur_3 \left[1 - \frac{p_{a,s,2}}{p_{a,s,2} + p_{a,s,4}}\right], \\
y_{a,s,4} &= dur_2 + dur_3 + dur_4.
\end{aligned}
$$

We assume zero years of schooling for people reporting that they did not attain any formal education. We further assume the mean duration of primary and secondary education to be contained between the 0.25 and the 0.75 quantile of the respective formal duration. Within these extremes, the adjusted years depend on weights given by surrounding education levels. For example, in India the formal duration of primary education was 8 years in 2000. The mean duration is hence at least 2 years. In the 25-54 age group, 41.5% of the population did not attend formal education, while 35.9% have attained at least secondary education. This results in a mean duration of 3.85 years. On the other hand, the duration of primary schooling was 9 years in South Korea in 2000, whereas only 0.2% did not attend formal schooling. As the share of individuals with at least some secondary education is 98.3%, the mean duration of primary education (6.74) almost equals the presumed maximum of 6.75 years. We adopt a similar rule for computing the mean duration of secondary education. In general, this algorithm follows the intuition that the share of people completing primary or secondary education is increasing with the share in subsequent education categories. Finally, as category four comprises only people who have *completed* higher education, mean duration equals the cumulative years it takes to complete the first cycle of tertiary education.

## A.2 Countries included in the panel regression

Algeria
Azerbaijan
Argentina
Australia
Austria
Bahamas
Bangladesh
Armenia
Belgium
Bolivia
Brazil
Bulgaria
Belarus
Cameroon
Canada
Cape Verde
Chile
China
Costa Rica
Cuba
Cyprus
Czech Republic
Denmark
Dominican Republic
Ecuador
El Salvador
Ethiopia
Estonia
Finland
France
Gabon
Greece
Guatemala
Guinea
Honduras
Hungary
Iceland
India
Indonesia
Iran
Ireland
Italy
Japan
Kazakhstan
Jordan
Kenya
Korea
Kyrgyzstan
Lesotho
Latvia
Luxembourg
Madagascar
Malaysia
Mali
Malta
Mauritius
Mexico
Moldova
Morocco
Mozambique
Namibia
Netherlands
New Zealand
Nicaragua
Norway
Pakistan
Panama
Paraguay
Peru
Philippines
Poland
Portugal
Russian Federation
Senegal
Singapore
Slovenia
Spain
Sudan
Swaziland
Sweden
Switzerland
Syria
Tajikistan
Thailand
Tunisia
Turkey
Uganda
Ukraine
Macedonia
Egypt
United Kingdom
Tanzania
United States of America
Uruguay
Venezuela
Zambia

## A.3 Changes in Education Mobility: 2010-2050

| Country | Educ. Mob. 2010 | Educ. Mob. 2050 | Change 2050 − 2010 | Change 2030 − 2010 | Change 2050 − 2030 |
|---|---|---|---|---|---|
| Norway | 1.62 | 1.10 | -0.52 | -0.35 | -0.18 |
| Germany | 1.11 | 0.70 | -0.41 | -0.25 | -0.16 |
| Iceland | 0.87 | 0.64 | -0.24 | -0.09 | -0.15 |
| Denmark | 1.22 | 1.07 | -0.15 | -0.13 | -0.02 |
| Luxembourg | 0.59 | 0.46 | -0.13 | -0.17 | 0.04 |
| France | 0.49 | 0.39 | -0.11 | -0.13 | 0.02 |
| Austria | 0.94 | 0.85 | -0.09 | -0.06 | -0.03 |
| Finland | 1.06 | 0.97 | -0.09 | -0.05 | -0.04 |
| Greece | 0.49 | 0.40 | -0.08 | -0.12 | 0.04 |
| Netherlands | 0.57 | 0.56 | -0.01 | -0.01 | 0.00 |
| Spain | 0.53 | 0.52 | -0.01 | -0.06 | 0.05 |
| Switzerland | 0.88 | 0.90 | 0.02 | -0.04 | 0.07 |
| United Kingdom | 0.57 | 0.62 | 0.05 | -0.02 | 0.08 |
| Portugal | 0.39 | 0.47 | 0.09 | -0.03 | 0.12 |
| Turkey | 0.51 | 0.63 | 0.11 | 0.10 | 0.02 |
| Bulgaria | 0.50 | 0.63 | 0.13 | 0.18 | -0.05 |
| TFYR Macedonia | 0.34 | 0.49 | 0.15 | 0.08 | 0.08 |
| Belgium | 0.36 | 0.53 | 0.17 | -0.01 | 0.18 |
| Czech Republic | 1.19 | 1.39 | 0.20 | -0.01 | 0.21 |
| Bosnia & Herzegovina | 0.23 | 0.43 | 0.20 | 0.07 | 0.13 |
| Cyprus | 0.34 | 0.54 | 0.20 | -0.03 | 0.23 |
| Malta | 0.42 | 0.63 | 0.21 | -0.15 | 0.36 |
| Slovakia | 1.04 | 1.26 | 0.22 | 0.02 | 0.20 |
| Ireland | 0.40 | 0.68 | 0.28 | 0.08 | 0.21 |
| Italy | 0.31 | 0.66 | 0.35 | 0.04 | 0.31 |
| Romania | 0.28 | 0.68 | 0.41 | 0.23 | 0.17 |
| Sweden | 0.32 | 0.76 | 0.44 | 0.24 | 0.20 |
| Poland | 0.59 | 1.10 | 0.51 | 0.50 | 0.01 |
| Republic of Moldova | 0.22 | 0.76 | 0.54 | 0.33 | 0.21 |
| Montenegro | 0.21 | 0.76 | 0.54 | 0.20 | 0.34 |
| Latvia | 0.37 | 0.94 | 0.56 | 0.43 | 0.13 |
| Slovenia | 0.49 | 1.06 | 0.57 | 0.35 | 0.22 |
| Serbia | 0.22 | 0.80 | 0.58 | 0.25 | 0.33 |
| Hungary | 0.36 | 0.95 | 0.59 | 0.35 | 0.23 |
| Estonia | 0.34 | 0.94 | 0.60 | 0.44 | 0.16 |
| Lithuania | 0.24 | 0.86 | 0.62 | 0.44 | 0.18 |
| Albania | 0.19 | 0.85 | 0.65 | 0.33 | 0.32 |
| Croatia | 0.22 | 0.91 | 0.69 | 0.22 | 0.47 |
| Russian Federation | 0.30 | 1.07 | 0.77 | 0.51 | 0.26 |
| Ukraine | 0.20 | 1.17 | 0.97 | 0.64 | 0.33 |
| Belarus | 0.22 | 1.36 | 1.14 | 0.63 | 0.51 |

Projections based on the Global Education Trend scenario by KC, Barakat, Goujon, Skirbekk, Sanderson, and Lutz (2010). Countries ordered by change in the intergenerational education mobility indicator, 2010-2050.

Table 2: Intergenerational education mobility index projections for Europe