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JEL Codes: D31, E27, F02, N00, O40

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Education Inequalities and the Kuznets Curves: A Global Perspective Since 1870*

Christian Morrisson - Fabrice Murtin[†]

Abstract

This paper presents a new dataset on educational attainment (primary, secondary and tertiary schooling) at the world level since 1870. Inequality in years of schooling is found to be rapidly decreasing, but we show that this result is completely driven by the decline in illiteracy. Then, we turn to inequality in human capital and focus on a Mincerian production function that accounts for diminishing returns to schooling. It explains the negative cross-country correlation between Mincerian returns to schooling and average schooling contrary to other functional forms. As a result, we show that world human capital inequality has increased since 1870, but does not exceed 10% of world income inequality. Next, we analyse the relationships between the national distributions of income and schooling. We show that human capital within countries exhibits an inverted U-shaped curve with respect to average schooling, namely a “Kuznets curve of education”. We find that the usual Kuznets curve of income inequality is significant both in pooled and fixed-effects regressions over the period 1870-2000, and is robust to the inclusion of other variables in the regression such as schooling and human capital inequality. However, the “Kuznets effect” associated to GDP per capita is 4 times smaller in magnitude than the externality of average schooling favouring the decrease of income inequality within countries since 1870.

JEL classification: D31, E27, F02, N00, O40.

Keywords: Inequality, human capital, economic history, Kuznets curve.

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1 Introduction

Education is recognized to be a key factor of economic development, not only giving access to technological progress as emphasized by the Schumpeterian growth theory, but also entailing numerous social externalities on long-term outcomes such as health improvement or political participation, that shape in turn the extent of redistributive policies. If the evolution of world distributions of income and longevity over the last two centuries have been described by François Bourguignon and Christian Morrisson (2002), changes in the world education distribution have remained unexplored until now, despite their major importance.

What has been education inequality at the world level over the twentieth century? How does it compare with income inequality? What are the links between income and human capital inequality? Up to now, the various studies on education inequality have had limited spatial coverage and time period. For example, Amparo Castello and Rafael Domenech (2002), Vinod Thomas et al. (2001) provide a descriptive analysis of years of schooling inequality for a broad panel of countries but only since 1960. Also, they remain at the country level and do not consider the world distribution of years of schooling, which takes into account educational differences both within and between countries.

In contrast, this paper depicts the world distribution of education over 130 years, on the basis of an original world dataset for years of schooling since 1870. It was not possible to elaborate longer series because we need enrolment series since 1820-1830 in order to estimate the average years of schooling in 1870. Even in Western European countries and the US there is no data before that date. This dataset allows us to infer the distribution of years of schooling sum up by four quantiles¹ in each country, and to describe the average stocks of primary, secondary and tertiary schooling by region over more than a century. Then we estimate the world inequality in years of schooling,

¹individuals with no schooling, with only primary schooling, with primary and secondary schooling, and those having received higher education.

which has been dramatically reduced since 1870.

This paper also raises an important methodological issue on the measurement of education inequality. We show that a very large part of inequality in years of schooling has been mechanically explained between 1870 and 2000 by a single component of the education distribution, which is the population that has not attended school, subsequently called the illiterate population. Thus, the observed decrease of inequality in years of schooling over the century mostly captures the decline of illiteracy. We believe that this result, derived both theoretically and empirically, could be helpful to reconsider an empirical fact discussed in the literature on education inequality, which is the cross-countries negative correlation between average schooling and education inequality. This correlation is shown here to be mainly driven by the mechanical correlation between average schooling and illiteracy.

Following the recent macroeconomic literature, we then turn to human capital as defined by Mincer because it is more pertinent than years of schooling for comparing education and income inequalities. We propose estimates of the world inequality in human capital, following a definition of human capital that accounts for the existence of diminishing returns to schooling. The functional form we retain is able to explain the cross-countries negative correlation between Mincer returns to schooling and average educational attainment contrary to any other functional form, making our definition of human capital the most appropriate. As a result, we find that world human capital inequality has increased since 1870, and represents about 10% of income inequality as measured by the Theil index in 2000.

Last, we examine the relationships between national distributions of income and schooling. We find that human capital inequality within countries follows a clear inverted-U curve with respect to average schooling attainment, what we call the “Kuznets curve of education”. We also find that the usual unconditional Kuznets hypothesis for income inequality is valid over the period 1870-2000, even after controlling for coun-

tries' unobserved heterogeneity. This finding is robust to the inclusion of human capital inequality and a quadratic in schooling within the regressions. The quadratic in schooling turns out to be significant, suggesting that there are positive but marginally decreasing externalities of average schooling favouring the reduction of income inequality within countries over that period. Importantly, the magnitude of this externality in terms of variations in inequality is about four times higher than the effect associated to GDP per capita, the "Kuznets effect".

In section 2 we present the methodology and the data. Section 3 concerns the overall distribution of world education since 1870. Section 4 focuses on inequality in education. Section 5 presents the functional forms tested for human capital, while the subsequent section exhibits the "Kuznets curve of education" and its relationship with income inequality. Last section concludes.

2 Methodology and data

We applied the same methodology as François Bourguignon and Christian Morrisson (2002), using 33 macro-regions or large countries for the sake of simplicity, as well as for comparability purposes with income inequality results. Before estimating average years of schooling, we updated the figures on GDP per capita and population, adding 2000 and using the last estimates of Angus Maddison (2003). For education, estimates of the mean number of years of schooling were assembled for 91 countries from 1870 to 2000, then averaged to build an educational attainment dataset for the 33 macro-countries². Each country or country group represents at least 1 per cent of world population or world GDP in 1950. All countries which are important are considered individually. To allow a simpler analysis, these countries or country groups

²our sample of countries represents more than 95% of the world population all over the period. We have assumed that missing countries have the same educational level as the macro-country they belong to. Excepted for the three macro-countries "46 African countries", "45 Asian countries", and "37 Latin American countries", population of missing countries represents on average 3.6% of the macro-country's population. This figure reaches respectively 15%, 39% and 18% for the three latter macro-countries.

were aggregated into 8 blocks, defined geographically, historically or economically: Africa, China, South Asia (composed of Bangladesh, Burma, India and Pakistan), other Asian countries excluding Japan, Korea and Taiwan, these 3 countries, Latin America excluding Argentine and Chile, Eastern Europe (which include all the countries of the ex-USSR), Western Europe (including Austria, Hungary and Czechoslovakia) and its offshoots in America (Canada, US, Argentine, Chile) and in the Pacific.

More precisely we associated two datasets, the first for 1870-1960 being a new one whereas the second (1960-2000) is given by Daniel Cohen and Marcelo Soto (2001)³. It is impossible to estimate the years of schooling before 1870 because one needs enrolment data 50 years before in order to obtain the school attainment of the population aged between 15 and 65 years.

In Western European countries statistics of school enrolment are available since 1820-40 in Brian R. Mitchell (2003 a-b-c), but in other countries we cannot find any statistics before the end of the 19th century. For the less developed countries, the series concerning enrolment begin often in 1920 or later. In these countries we have assumed a steady growth of the enrolment rate starting from a minimum which is very low in 1820 (1 or 0.1%). We argue that this assumption is nevertheless innocuous with respect to the stock of average schooling, because the first observed enrolment rates are most of the time very low (typically under 1%). The absolute error on stocks of years of schooling will therefore be very low, without any significant incidence on the world educational distribution. For more developed countries observations begin much earlier in time: as a whole, we can consider that in 1900 measurement errors due to initial condition assumptions are negligible. This is supported by some simulations for India and France given in a companion appendix.

We compute the average number of primary, secondary and tertiary years of schooling by inferring the enrolment rates for each cohort of age at each date. This is made possible because the series from Brian R. Mitchell (2003 a-b-c) provide the number

³eight countries not available in this dataset were taken from Robert J. Barro and Jong-Wha Lee (2001).

of children in primary, secondary and tertiary schools as well as population by age. Usually age pyramids were available each ten years and missing data has been interpolated. To achieve the computation we also needed some information on schooling's duration, dropout and repetition rates. While we used Unesco (2006) data for the two latter variables, completed primary and secondary were both assumed to last a maximum of six years⁴, while tertiary was assumed to last a maximum of four years. This insures comparability across time and countries of education distributions, in spite of the many worldwide reforms of schooling systems over the period.

In a companion appendix we describe in details the procedure used to infer average years of schooling in primary, secondary and higher education. We also provide a robustness analysis with respect to the underlying assumptions on repetition and dropout rates, maximal schooling durations, and initial enrolment rate, showing that they have quite a limited effect on the stocks of years of schooling.

These stocks are equal to the number of pupils having attended each grade multiplied by the amount of time they have done so. To infer the distribution of schooling, we need some additional information on either the number of pupils, or the mean durations. We observe the mean durations in primary, secondary and higher education in 2000 from Unesco (2006), and we have calibrated the corresponding values in 1870 with the help of a second database on illiteracy rates based on Unesco (1957) and specific historical studies⁵. Given the calculated stocks $H^{P,S,H}$ of primary, secondary and tertiary schooling and their respective mean durations $h^{P,S,H}$, we can infer the per-

⁴This assumption is a rough estimate that we can use because there is no detailed information on the lengths of primary and secondary schooling in each country from 1870 to 2000. The length varies according to the country and the period. For example in present day France the respective lengths are 5 (primary) and 7 (secondary) ; but until 1950, the two lengths were equal (the pupils engaged in secondary schooling left primary school after 5 years, but the others who represented a large majority remained in primary school 7 years).

⁵we have retained seven groups of durations ranging from three years in primary and secondary for low-developed countries up to more than 5 years for Western Europe countries. The first level corresponds to a 20% annual dropout rate, the last to a rate of 2.5%. Importantly, these figures provide us with a correlation of more than 97% between our historical illiteracy rates and those deriving from subsequent formulas (1). Between 1870 and 2000 durations have been interpolated linearly, while an analysis provided in appendix suggests that other scenari of duration's growth entail very minor changes.

centage p^P of the population displaying only primary schooling, the percentage p^S of the population displaying primary and secondary schooling, the percentage p^H of the population displaying primary, secondary and tertiary schooling, and the complementary part, the percentage p^I of the population that has not attended school. In what follows we will denote the latter group as the "Illiterates", even if this definition could be ambiguous (literacy could require more than a few years of primary schooling and some individuals who have not attended schools could be literate). These percentages⁶ are given by

$$\left\{ \begin{array}{l} H^P = h^P p^P + 6 (p^S + p^H) \\ H^S = h^S p^S + 6 p^H \\ H^H = h^H p^H \\ p^P + p^S + p^H + p^I = 1 \end{array} \right. \quad (1)$$

Inequality indices are computed on the distribution of these 4 groups x 33 countries = 132 groups. All the groups are pooled and ranked according to the number of years of education and then the cumulative function and Lorenz curve of the world distribution of education is computed. We assumed no heterogeneity in years of schooling inside each group⁷.

3 Trends in World Educational Achievement since 1870

Table 1 presents the distribution of years of schooling at the world level since 1870. In the mid twentieth century, the world is divided into two classes: those who have attended school, and those who have not. Over the whole period Figure 1 clearly shows a huge reversal: illiterates and educated individuals are in reverse proportions

⁶As an example, a comparison with the first educational survey by US Census (1940) shows that our US figures differ only slightly from the actual ones. This paper: 61.2%, 27.5% and 11.3% for Primary, Secondary and Higher education; Census (1993, Table 4 p.18): 62.9%, 26.7%, 10.4%

⁷As the number of grades used to describe the schooling distribution could influence the resulting inequality levels, we show in annex some results based on a smoothed schooling distribution. The main conclusions of the paper remain the same.

in 1870 and in 2000, around three to one. What explains this result is clearly the development of primary schooling, which attendance was 20% of the world population in 1870 and 75% in 2000. Moreover, 35% of the world population attended secondary education in 2000, but this development is quite recent since this proportion was only 15% in 1960. In a sense, higher education is today the exact equivalent of secondary schooling in 1960: 8% of the world population attained higher education in 2000, which means a third of that displaying only secondary education, while in 1960 the latter group represented 12% of the world population and a third of the population with only primary schooling. Last, the overall level of schooling has been multiplied by 6.7, this increase being inequally spread over the period: plus 3 average years of schooling between 1870 and 1960, and the same amount over the last forty years. Schooling attainment in fact accelerated after 1950, with a constant increase of 0.7 years every ten years.

How this global increase has been distributed across countries? Table 2 provides a geographical overview of education attainment, with the average schooling by region: its total, its distribution in primary and secondary schooling, the difference being equal to the stock of higher education, as well as illiteracy rates. We observe three distinct groups in 1870: the highest with Western Europe and offshoots, which exceeds 3 years; an intermediary one with Latin America, Eastern Europe, Japan, Korea, Taiwan and China; the lowest, with less than 0.25 years, in Africa, South Asia and other Asian countries. The illiteracy rate is around 37% in the first group, 80% in the second one, and 95% in the third one. So there is a huge gap between Western Europe and the third group. An important point is the advance of China and Japan with respect to other Asian countries, including the India empire, and Africa. In those two countries average schooling was about one year (education was higher in Japan than in Korea and Taiwan); in fact this means that around 35% of men and 5% of women could read and write 1500 graphic signs, which demands about 3 or 4 years of schooling. A small

minority knew several thousand signs after 6 or 8 years of schooling. As the average schooling in China and Japan was approximately the same at the beginning of the eighteenth century, these countries were the only ones in the world which had the same average schooling than Western Europe three centuries ago.

In 2000, the third group is only composed of Africa and South Asia, because the average schooling in other Asian countries has increased much more than in India. The schooling is 4 years in this group instead of 11 years in Western Europe and the ratio has been reduced from 1:30 to 1:3, although absolute differences in average schooling have increased from 3 years up to 7 years. Moreover, Japan, Korea and Taiwan have caught up with Western Europe, as well as Eastern Europe to a lesser extent. In the intermediate group, we find Latin America, China, and other Asian countries who have caught up as well, with an average schooling around 6.6 years. The differences between Western Europe and this group are about four average years of schooling, consisting of one year of primary schooling, two and a half years of secondary schooling, and a half year of higher education. Figure 2 illustrates clearly the process at work: it is striking that mean absolute differences between groups have remained the same in the postwar period.

Illiteracy, which was the rule in 1870 with rates exceeding 80% everywhere except in Western Europe, is now a regional problem. It remains important only in Africa, more precisely in Sub-Saharan Africa, and South Asia (including India, Bangladesh, Burma and Pakistan) with rates around 45%.

In 2000, there is about a two years gap of secondary schooling between the leading group and the rest of the world. This fact is unexpected because we observe today the expansion of secondary schooling everywhere. But the average secondary schooling in 2000 depends on enrolment rates since 1950, so that one should not forget the low rates in the 1950s and the 1960s. Until 1980, secondary schooling was lower than 1 year everywhere except in the first group. From the early nineteenth century up to

1980, the differences in primary schooling have induced the main regional inequalities in schooling. But in the next years, the expansion of secondary schooling will become the key factor.

The decomposition of world population into 8 blocks is helpful to understand the changes in the world distribution of education since 1870. Table 3 shows the composition of 3 quantiles: the bottom 80%, the 9th and 10th deciles between the 8 blocks, the first line giving the population distribution. The main factors which explain the variations from one year to the other are the different rates of growth of average education and of population (the shares in world population of Latin America and Africa respectively, have been multiplied by 3 and 2 between 1870 and 2000, whereas the shares of Western Europe and Eastern Europe have decreased).

The two opposite blocks are Western Europe and Africa. In 1870, Western Europe and its offshoots had an edge on the rest of the world, which remained about the same until 1910. At that time the share of Western Europe in the top decile reached almost 60%. It was equivalent to the share of the same region in the top income decile, 64%. If we consider that secondary schooling is the condition of access to technology, in 1910, Western Europe had in some respect the quasi-monopoly of advance in knowledge and technology. Today this monopoly has disappeared. The share of Western Europe in the top decile is only 30%, less than the share of Asia, excluding Japan, Korea and Taiwan. If we include these 3 countries, the share of Asia reaches 42%. Extrapolating these trends, we can foresee that in a few years Asia will attain 50% and Western Europe less than 25%, which will entail important consequences in the world distribution of scientific and technological supremacy⁸.

The African case is a counter-example. First, it is today the poorest region in the world, but this handicap is not new. In 1870, the share of Africa in the top decile was

⁸Moreover there is a significant contrast between the share of Western Europe in income top decile and education top decile. The income share is around 65%, the same than in 1910, whereas the education share is around 30% after a large decrease since 1910. So Western Europe has kept an important advantage in world income distribution in spite of losing its supremacy in education.

about 1%. Here is the legacy of the past: at the beginning of the 19th century nearly all African populations were illiterate, except the Arab population in the north of Africa, while in Asia nearly 40% of Chinese and Japanese men could read and write. Even if the situation remains unfavourable, Africa is slowly catching up with the rest of the world. We must remember the situation in the 19th century in order to understand better its current lag.

Of course the success story of world education is Japan, Korea and Taiwan. If we take into account the population effect, the share of these countries in the top decile was more or less similar to the share of Eastern Europe in 1870. In 2000, they are the same as Western Europe's share. It is the only group of countries which has caught up completely with Western Europe. The situation of Latin America and Eastern Europe, given the population effect, has improved, particularly in Eastern Europe, but the gap with Western Europe has not disappeared.

4 Inequality in years of schooling

This section provides a first-step analysis of inequality in education around the world, where education is measured by the number of years of schooling. How much is inequality in years of schooling ?

Table 4 reports the evolution of inequality in years of schooling for the coefficient of variation, the Gini and the Theil indices⁹, and also recalls the inequality in income. We did not report the standard errors for the sake of clarity, but we did compute them by introducing a measurement error on stocks of schooling. The variance of these noises was calibrated so that the width of any stocks' confidence interval amounts to 10% of stock's value. The resulting standard errors on inequality levels were found to be small, never exceeding 7% of their value over the period. As a result, Table 4 shows an exceptional inequality in 1870 with a Gini coefficient reaching 0.82 and a Theil index

⁹the mean logarithmic deviation was not reported since it is only defined over strictly positive outcomes.

of 1.61. The world in 1870 was characterized by a huge gap between the literate and illiterate populations which is unimaginable today. However throughout the period, years of schooling inequality has decreased steadily so that the Gini coefficient has decreased by 50%, and the Theil index is less than a quarter of what it was.

It is meaningful to draw a comparison between illiteracy rate and extreme poverty (less than 1 dollar a day). The illiteracy rate has decreased since 1870 from 79% to 24% and extreme poverty from 66% to 16%. Therefore, the evolutions of these two essential indicators, namely the percentages of people who don't have any access to an education or to a minimum income are parallel and they show an improvement, which has never happened before in mankind history.

The decomposition of education inequality into two components is instructive: the within component of schooling inequality has decreased much more than the within component of income inequality: less 72% instead of less 12% for the Theil index. Moreover the between component has fallen rapidly: the Theil index in 2000 was only 0.08 instead of 0.56 in 1870. For the period 1960-2000 estimates are given by World Bank (2005) but it does not take into account the weighting by population. Despite this difference, we observe a comparable decrease of the Theil Index: -60% (World Bank 2005), -78% (Table 4). In total inequality, the contribution of the between component plays only a marginal part: 21% in 2000 for the Theil index, a figure in agreement with the World Bank estimate (less than 20%). It is the exact opposite for income inequality between countries, which represents two thirds of total income inequality in 2000, while the gap between the poorest region, Africa, and Western Europe for average schooling is only 1 to 3, instead of 1 to 12 for average income. This fall of inequality between countries is the result of the extension of primary schooling in a large majority of countries (except in Pakistan, the north of rural India and several sub-saharian African countries where enrolment rates of girls are often much lower than those of boys).

However, computing inequality in years of schooling raises a couple of comments and critics, that we enumerate now. First, we observe opposite trends in income and years of schooling inequalities, as mentioned before. How to reconcile those trends, if not by reconsidering the relevance of years of schooling as the appropriate educational productive factor ?

Second, inequality indices might be "excessively" sensitive with respect to individuals endowed with zero years of schooling¹⁰. As reported in Table 4, if we rule out the illiteracy group and compute a Gini index on educated individuals only, we will find a Gini equal to 0.16 in 1870, 0.22 in 1960, and 0.23 in 2000. This is the exact opposite trend of inequality variations computed on the whole population, with inequality levels ranging from 20% to 50% of their original values when we include illiterates. It is somewhat disturbing that the bulk of inequality in years of schooling captures illiteracy, and variations of inequality reflect mainly illiteracy's decrease. Some authors such as Amparo Castello and Rafael Domenech (2002) or Jean-Claude Berthélemy (2005) have already pointed out the negative correlation between years of schooling inequality and average years of schooling, offering various explanations. The following proposition exhibits the mechanical link between illiteracy and years of schooling inequality. We present this proposition under its most general form since it will have applications in next sections as well.

Proposition 1. *Let us call f the distribution of a random variable X taking values over a domain $[m, M]$ with $0 \leq m < +\infty$ and $M \leq +\infty$. Assume that this distribution can be decomposed as the mixture*

$$f(x) = p\delta_{x=m} + (1 - p)g(x) \quad (2)$$

where $\delta_{x=m}$ is a mass point in the minimum value and g the distribution of the popula-

¹⁰For instance, if we remember that the Gini index is twice the area situated below the Lorenz curve, then illiteracy will have a huge impact on this index by shifting away the origin of the curve from zero to the percentage of illiterates in the population.

tion for which $X > m$. We call $\mu(f)$ the mean outcome for a distribution f , $G(f)$ the corresponding Gini index, and $I_{GE}^\alpha(f)$ the Generalized-Entropy index. Then the Gini index decomposes into

$$G(f) = p \frac{\mu(f) - m}{\mu(f)} + (1 - p) \frac{\mu(f) - pm}{\mu(f)} G(g) \quad (3)$$

and the Generalized-entropy indices $I_{GE}^\alpha(f)$, for $\alpha \neq 0$ ¹¹

$$I_{GE}^\alpha(f) = (1-p)^{1-\alpha} \left(\frac{\mu(f) - pm}{\mu(f)} \right)^\alpha I_{GE}^\alpha(g) + \frac{1}{\alpha^2 - \alpha} \left((1-p)^{1-\alpha} \left(\frac{\mu(f) - pm}{\mu(f)} \right)^\alpha + pm^\alpha \mu(f)^{-\alpha} - 1 \right) \quad (4)$$

Proof. see in annex □

Regarding years of schooling we have $m = 0$, and the Gini index computed on the whole population is a linear combination of the illiteracy rate and the Gini index computed on the educated population. Formally $G(f) = p + (1 - p)G(g)$, and as a particular case, the Theil index decomposition is obtained when $\alpha \rightarrow 1$, so that $\text{Theil}(f) = \text{Theil}(g) - \ln(1 - p)$.

This shows that illiteracy variations explains *almost all* of years of schooling inequality variations over the period. Indeed, imagine that inequality in the educated population remains equal to 0.20, its grand mean all along the educational development process. According to the latter formula an illiteracy level of 79% should bring the Gini index for the whole population at a value of 0.83, while an illiteracy level of 24% would bring it at 0.39. These figures are extremely close to the current values of the Gini index calculated on the whole population (0.82 in 1870 and 0.41 in 2000), which means that *all* of the decrease of the latter index between 1870 and 2000 is encompassed in illiteracy's decline¹². This is important with respect to the litterature on

¹¹the proposition is still valid for the Mean Logarithmic Index, i.e. when $\alpha = 0$, if $m > 0$.

¹²Similarly for the Theil index, inequality computed on the educated population is small in comparison to the illiteracy component (less than 4% in 1870 up to one third in 2000). In any case, its variations over the period are negligible with respect to those of illiteracy: they represent 2.5% of it.

education inequality, that has often described and failed to interpret simply the cross-countries negative correlation between average schooling and education inequality: in fact, the latter only reflects the negative correlation between average schooling and illiteracy, which is mechanical.

Two other comments can be raised against the computation of inequality in years of schooling, and both have to do with the invariance properties of inequality indices. First, the between component of the Theil index, which is not subject to the illiteracy bias, might partly decrease because the Theil index is not invariant by translation contrary to the Gini index. Indeed, recall that the world evolution of schooling has been characterized, above all after 1940, by a translation of all average educational levels. Second, applying traditional inequality indices on years of schooling might be after all in contradiction with any invariance property (scale or translation), since the marginal cost of schooling increases as one comes closer to the highest grade, this comment being equally relevant for any upper bounded outcome, such as life expectancy¹³. Therefore, the crucial issue in the measurement of inequality in education is certainly the search for an equivalence scale of years of schooling. This is what we propose now by focusing on human capital.

5 Inequality in Human Capital

5.1 Defining human capital

The macroeconomic literature has gradually moved away from considering average years of schooling as a factor of production, as in N. Gregory Mankiw et al. (1992), to focus on the Mincerian definition of human capital as proposed by Robert E. Hall and

¹³Derivation of an economic equivalent of years of schooling, such as educational public spending, might be an answer to this criticism. Unfortunately, there is a huge variance across countries and across time in the relative weight of primary, secondary and higher education in total educational spending, as well as in the latter volume measured as a percentage of GDP. Thus, computation of inequality indices in educational public transfers might not be an easy thing to do

Charles I. Jones (1999). For an educational quantile j in a country i at date t we have:

$$h_{i,j,t} = e^{r_{i,j,t} S_{i,j,t}}$$

where $S_{i,j,t}$ is average years of schooling of quantile j , $r_{i,j,t}$ the return to schooling, $h_{i,j,t}$ human capital.

As a first step, we believe that it is useful to rule out any heterogeneity in the return to schooling across time, countries and quantiles for the sake of simplicity¹⁴. This will tell us how the exponential functional form modifies the results on years of schooling inequality. Thus, we first set $\forall i, j, t, r_{i,t} = r$, while considering an usual value for the return to schooling r : an average world return to schooling of 10% is selected following George Psacharopoulos and Harry A. Patrinos (2004), and inequality in human capital is computed.

As a second step, we argue that returns to schooling decline with the rise of average educational attainment because schooling has diminishing returns. As described extensively by George Psacharopoulos and Harry A. Patrinos (2004)¹⁵, the returns to schooling are higher for Primary schooling than for Secondary or Higher education, whatever the level of development and the geographical zone of the country. As a consequence, we follow Jacob Mincer (1974) and David Card (2001) among others and specify a quadratic function of schooling for each country i at time t

$$\log y_{i,j,t} = a + \rho_{i,t} S_{i,j,t} - \frac{1}{2} k_{i,t} S_{i,j,t}^2 + u_{i,t}$$

where y is income. Then, we need to derive some plausible values for coefficients $\rho_{i,t}$ and $k_{i,t}$. So in a first step we use IUPMS Census data that depict 1% of the US popula-

¹⁴We also rule out any externality of education and assume that the Mincer framework is still valid with income replacing wages.

¹⁵see their Table 1 and 2 on returns to investments in education. As the latter include tuitions and taxes, they are slightly different from Mincer returns as emphasized by James J. Heckman et al. (2005), who point at the higher returns of some *specific* years of schooling such as graduation years. We could not include these refinements in our historical framework.

tion, and estimate Mincer equation including a quadratic in experience and a quadratic in years of schooling. Table 5 shows that from 1940 to 1980, the quadratic function for schooling is found to be concave as expected. For 1990 and 2000, it turns out to be convex, but the schooling variable upon which this result relies is unaccurate¹⁶.

What about the rest of the world? For a schooling level $S_{i,j,t}$ the equation above entails a Mincer return to schooling equal to

$$r_{i,j,t} = \rho_{i,t} - k_{i,t}S_{i,j,t}$$

If the model is correct at the micro level - in particular if $k_{i,t}$ does not depend on j -, then in country i at date t the Mincer return to schooling is equal to $\rho_{i,t} - k_{i,t}S_{i,..,t}$, with $S_{i,..,t}$ being average schooling. Average estimates for the US over the period 1940-1980 are $\rho_{i,t} = 11.1\%$ and $k_{i,t} = 2 * 0.00155 = 0.0031$. Having matched the returns to schooling of 59 countries taken from George Psacharopoulos and Harry A. Patrinos (2004) with our data on average schooling attainment at corresponding dates, we estimated the following OLS regression:

$$r_i = \underset{(0.009)}{0.125} - \underset{(0.0017)}{0.0040}S_{i,..,t} + u_i$$

Those estimates are very close to average US estimates, which suggests that most countries share the same characteristic of diminishing returns to schooling with coefficients of the same magnitude. Figure 3 illustrates the negative correlation between returns to schooling and average educational attainment. It explains the decrease of returns to education as a *composition bias* linked to the growth of more educated cohorts that display a lower return to schooling. In practice, this means that national returns to schooling should not be specified as decreasing functions of average schooling as it is done in some macro-economic studies, which assume implicitly that the demand for

¹⁶IUPMS data display a detailed version of grades achieved until 1980, then years of schooling have to be reconstructed from a categorical variable.

education augments less quickly than its supply. Instead, there should be a distribution of returns to schooling as there is a distribution of years of schooling.

So our central definition of human capital is the following: given a schooling distribution $S_{i,j,t}$ in country i at date t , human capital of educational quantile j is equal to

$$h_{i,j,t} = e^{0.1254S_{i,j,t} - 0.002S_{i,j,t}^2}$$

from which average human capital in country i can be deduced by averaging over quantiles. This definition has the drawback of necessitating the knowledge of the schooling distribution, and the advantage of being micro-funded and stable across countries.

We have to make the additional assumption that this relationship is constant over time. In the US, it is well known¹⁷ that there have been periods in which the return to schooling has decreased or increased, following skill-replacing or skill-biased technological shocks. So we introduce some country-specific¹⁸ technological shocks and run a bootstrap experiment in order to derive a confidence interval for human capital inequality. We assume that countries face technological shocks that are autocorrelated with a sizeable degree of autocorrelation equal to 0.5. This value sets the half-life of a shock on the return to schooling to a standard 10 years. So our second assumption on human capital of educational quantile $S_{i,j,t}$ states that

$$\begin{aligned} h_{i,j,t} &= e^{0.1254S_{i,j,t} - 0.002S_{i,j,t}^2 + u_{i,t}} \\ u_{i,t} &= 0.5u_{i,t-1} + 0.025e_{i,t}, \quad e_{i,t} \rightarrow \mathcal{N}(0, 1) \end{aligned}$$

where the standard error of $e_{i,t}$ is calibrated to match the variance of residuals from above regression.

The choice of a particular functional form is important because the rest of the paper

¹⁷see Claudia Goldin and Lawrence Katz (1999) for instance.

¹⁸as noticed by Daron Acemoglu (2002), skill-biased technological change does not affect all countries similarly, particularly in Europe.

will rely on it. The one we use is common in the empirical literature, and has the important property of exhibiting diminishing returns to education. But there is another functional form, mostly used in some theoretical studies¹⁹, with such a property. This alternative form is the power function which states that for a quantile $S_{i,j,t}$ human capital is equal to

$$h_{i,j,t} = (\theta + S_{i,j,t})^{\alpha_{i,j,t}}$$

For comparability purposes with the Mincer function it is convenient to set $\theta = 1$ so that uneducated workers have one unit of human capital. The power function has diminishing returns to schooling equal to $\alpha_{i,j,t}/(1 + S_{i,j,t})$. So for each country in 1990, we have computed the average return to schooling implied by the national distributions of education. We found that this functional form entails a world distribution of returns to schooling that is not supported by the data. Indeed, common values of α provide either much too high returns on the right tail of the world distribution, or much too low on the left tail²⁰. Hence, we argue that our choice for the human capital function is the only one that exhibits diminishing returns at the micro-economic level and fits on the same time the observed negative correlation between returns and average schooling.

5.2 Results

Table 6 provides estimates of human capital inequality for these two specifications ($r = 10\%$ and diminishing returns). Let us mention the four main points we are going to focus on. First, the contrast between schooling inequality and human capital inequality is striking, since their trends appear to be opposite: human capital inequality increases, whereas inequality of schooling decreases in a large proportion. Second, the level of inequality is much lower: for instance in the first simulation the human capital Theil varies between 0.04 and 0.12 instead of 0.42 and 1.61 for schooling inequality.

¹⁹e.g. Matthias Doepke and David de la Croix (2003)

²⁰with $\alpha = 0.8$ the smallest equivalent Mincer return is the US with 5.5% and the highest is Bangladesh-Pakistan with 25.7%; with $\alpha = 1$ those values are respectively 6.8% and 31.5%. Most of the Mincer returns are smaller than 12% in Psacharopoulos and Patrinos (2004).

Third, there are few differences between the two definitions of human capital. Last, illiteracy does not influence human capital inequality as much as years of schooling inequality.

As measured by the Theil index, human capital inequality has been multiplied by respectively 3.5 and 3.0. At first sight it could be counter-intuitive that inequality in human capital is increasing over time, while inequality in years of schooling is decreasing, and the return to schooling is kept constant in the first simulation, or is decreasing in the process of development in the second simulation. The interpretation is nevertheless straightforward: let us assume for illustrative purposes that schooling has a normal distribution with mean m and coefficient of variation s . Laplace transformation of a normal variable simply provides the coefficient of variation of human capital h and a first-order approximation gives

$$s(h) = \sqrt{e^{r^2 m^2 s^2} - 1} \simeq r m s \quad (5)$$

where r stands for the return to schooling. Now it is clear that this coefficient of variation depends positively on inequality in years of schooling (s), positively on the return to education (r), and also positively on the average level of schooling (m). Due to the convexity of the exponential function, inequality in human capital increases across the century simply because countries become more educated in average. Moreover, this convexity effect overcomes the reduction in inequality entailed by decreasing returns to education and more equal distribution of years of education. Empirically, the average years of schooling has been multiplied by 6.7 in 130 years, while the coefficient of variation of years of schooling has been divided by 2.6. The above formula entails that inequality in human capital should have been multiplied by 2.6 with constant returns, which is not far from what we find in the first simulation given distributional patterns differences.

Although the Gini index of human capital inequality represents around 25% of

income inequality over the period, there remains a question about the low levels of the Theil and MLD indices, which are about 6% of income inequality in 1870 and 12% in 2000. This stems from the fact that at any date, 95% of the world population has, relative to the world average, a human capital comprised between 0.5 (for the illiterates) and 2. Over this short segment, the dispersion is too small to generate high levels of inequality²¹. On the contrary, the income distribution is characterized by a wider domain over which the latter convexity approximations are no longer valid, since relative to the world average, income is comprised between 0.04 and 26.2.

What are the differences between the two simulations? In the second simulation, returns to education are higher in countries with lower educational attainment. Thus, they partly compensate the gap in average schooling, and as a result human capital inequality is smaller than in the first simulation. On Figure 4, we reported the world human capital inequality according to the two simulations, as well as the confidence interval that stems from the bootstrap experience. The evolutions diverge gradually in time, but remain highly comparable and do not differ by more than a standard error.

Last, we address the impact of illiteracy on human capital inequality. Intuitively, it might be much smaller since, if we consider the Gini index, the Lorenz curve should not be shifted away from the origin. We can use the former proposition in the particular case where $m = 1$. Regarding human capital, the Gini index computed for the whole population is a linear combination of the illiteracy rate and the Gini index computed over the educated population. With former notations we have $G(f) = G(g) + p[\mu(f) - 1 - G(g)(\mu(f) + 1 - p)] / \mu(f)$. This shows that the two Gini indices differ by a term which is equal in the first simulation to 0.009 in 1870 and 0.063 in 2000. Therefore the “excess sensitivity” of the Gini index with respect to illiteracy has disappeared, and the inequality indices now capture modifications from all parts of the human capital distribution. Considering the Theil index in the simulations, it is

²¹in fact, on this segment the mean of the log is almost equal to the log of the mean, so that $MLD = \sum_i p_i \log \frac{h_i}{h} \simeq \log \left(\frac{\sum_i p_i h_i}{h} \right) = 0$. The same idea applies for the Theil index.

clear from Table 6 that inequality computed for the educated population represents at least 60% of total inequality, rather than 5% when considering years of schooling.

Until that point, the main results of the paper were to show, first, that inequality in years of schooling has declined dramatically because of illiteracy's decline; that we can adopt a Mincer definition of human capital that explains the negative correlation between returns to schooling and average schooling across countries on the basis of diminishing returns; that the convexity effect associated to this definition dramatically modifies the results based on years of schooling, so that inequality in human capital has increased, but remains a low proportion of income inequality. For the rest of the paper, we would like to turn to the following question: what does our knowledge of the national distributions of education bring to the comprehension of the national distributions of income?

6 The Kuznets Curves of Income and Human Capital Inequality since 1870

6.1 Description

What explains the global increase and decrease of income inequality within countries since 1870? If we refer to François Bourguignon and Christian Morrisson (2002), the surge of inequality within countries until 1910 is mostly concentrated in Western Europe and offshoots as well as in Eastern Europe. Then, a huge reduction in inequality took place in those geographical areas, as well as in China *before* the communist era and in India in a lesser extent. Factors explaining the decrease in inequality are the rise of redistribution and convergence of wealth across states in the most advanced areas²², and half a century of economic stagnation in China and India. Two other trends deserve

²²some macro-countries are the aggregation of several smaller countries, hence convergence of mean income translates into a diminution of within inequality in our framework.

to be mentioned: as it becomes evident on Figure 5, within inequality has gradually increased in Africa from 1930 and risen quickly in Latin America in the 60s. Over the last thirty years, inequality has increased within the most advanced countries, Eastern Europe, China and Africa.

Turning to human capital in Figure 6 - second definition of human capital averaged on the various drawings of technological shocks - we find an overall increase of human capital inequality within countries since 1870, that has been followed by a decrease in Western Europe from the 50s and in China from the 60s. In the remaining regions, inequality has stabilized from the 80s, which perhaps announces a global decrease in the forthcoming decades.

If Simon Kuznets' (1955) hypothesis of an inverted U-shaped curve for income within inequality has been much discussed, what remained unknown until now was the existence of an inverted-U curve for human capital within inequality. Figure 7 plots both of them for the period 1870-2000. It is striking that the "Kuznets curve of human capital inequality" is so well defined and so clear-cut relatively to the Kuznets curve of income inequality. This is perhaps not surprising because many factors contribute to the differences across countries of the income distribution: human capital of course, but also the extent of redistribution, macro-economic shocks, and historical path dependency in general. For instance Daron Acemoglu et al. (2006) have emphasized the importance of the legacy of the past in the building of institutions, that affect and are simultaneously the long-term product of the income distribution. In contrast, differences in human capital inequality only take into account differences in the distribution of schooling. As it follows from before, the existence of an educational Kuznets curve relies on the diminution of inequality in years of schooling within countries and on diminishing returns to schooling.

Let us turn now to the key issue of the paper: what is the impact of education on the Kuznets curve? What is the link between income and human capital inequalities within

countries? As shown by Figure 7, it is striking that the turning points of both curves are quite close, though that of the income inequality curve might come first. Indeed, the turning point of the income Kuznets curve is about $\exp(7.5) = 2000$ dollars, and that of the human capital Kuznets curve around 5.5 years. A look at Figure 8, which plots the correlations between inequality and level variables, shows that those turning points almost match since countries with a GDP per capita of 2000 dollars have about 4 years of average schooling.

As human capital affects income, a possible explanation for the observed Kuznets curve of income inequality would be that it reflects the clear-cut Kuznets curve of human capital inequality. Indeed, the relationship between human capital inequality and schooling could translate into the income dimension because as shown on Figure 8, income and schooling variables appear to be well correlated. For the same reason, another possibility is that the Kuznets curve of income inequality would be driven by an externality of average schooling, and not by the level of GDP per capita. In the following, we test the conditional Kuznets hypothesis, namely we test whether the Kuznets hypothesis still holds given that we control for human capital inequality and potential externalities of education.

6.2 A test of the conditional Kuznets hypothesis

Testing for the existence of an inverted-U curve for income inequality has been a much discussed issue in the literature. It has raised many problems linked to the data, to the functional form retained to conduct the test, and to the statistical model. To sum up, the most two prominent studies have been conducted by Klaus Deininger and Lynn Squire (1998) and Robert J. Barro (2000). Both find a Kuznets curve in pooled regressions, but in the first study its significance disappears when the authors control for fixed-effects. In contrast, the Kuznets curve is always significant in the second study, even with fixed-effects. This difference stems from the fact that the data slightly differ between both

studies, and that the functional forms are not the same (GDP per capita Y and $1/Y$ in the first study, $\log(Y)$ and $\log(Y)^2$ in the second).

As emphasized by Garth Frazer (2006), there has been important heterogeneity in income inequality trajectories across countries since 1960. A simple look at Figure 7 shows clearly that country-period cells are quite dispersed around the quadratic trend. Christian Morrisson (2000) has showed that the Kuznets hypothesis was valid for some countries over the last two centuries, but not for some others. As a sum, the Kuznets hypothesis is far from being the “iron law” of economic development.

Still, it has never been examined on such a long period and at a global level. A reason could be that the data on income distributions taken from François Bourguignon and Christian Morrisson (2002) are necessarily affected by measurement errors in the distant past. Even for the post-war period, Anthony Atkinson and Andrea Brandolini (2001) have shown that the use of secondary data on inequality could be problematic. These are limitations inherent to the exploration of economic mechanisms on the long-term. Also, many countries are aggregated into larger macro-countries, which makes the comparison with other studies quite delicate.

Nevertheless, we do find similar results as former authors for the period 1960-2000 with our dataset. Table 7 reproduces the analysis of the above two studies, both for pooled regressions and fixed-effects panel models. As reported by Columns 1 to 4, we do find that the Kuznets curve is significant in OLS and fixed-effects regressions with a log specification, but disappears with fixed-effects and the other specification, which seems clearly to have a smaller explanatory power. Interestingly, the Kuznets curve disappears when we control for a quadratic in schooling as well as human capital inequality²³ as shown in Column 5. As no variable is significant anymore, it could be due to the small sample size.

What happens over more than a century? First, the Kuznets curve is always significant, with both specifications and both statistical models, as shown by Columns 1

²³we obtain the same result by adding only a quadratic in schooling.

to 4 for 1870-2000. So what occurred to the Kuznets curve in Klaus Deininger and Lynn Squire (1998)'s study is plausibly linked to data's too short time span and to the retained functional form. Second, Column 10 shows that controlling for the a quadratic in schooling and the Theil of human capital *does not* eliminate the significance of the quadratic in log-income. Hence, the "Kuznets curve of income" is not the by-product of the "Kuznets curve of human capital". This was expected because variations in human capital inequality have a too small magnitude to explain those in income inequality. But what was less obvious is the fact that the Kuznets curve is jointly driven by the variations of income and education. Third, we find a coefficient of 0.96 in front of the human capital Theil, when a coefficient of 1 is expected once all education externalities have been taken into account. Indeed, we have the following proposition demonstrated in annex:

Proposition 2. *Let $\mu(f)$ be the mean outcome for a distribution f and $I_{GE}^\alpha(f)$ the Generalized-Entropy index. For two independant random variables X and Y one has*

$$I_{GE}^\alpha(f_{XY}) = I_{GE}^\alpha(f_X) + I_{GE}^\alpha(f_Y) + (\alpha^2 - \alpha)I_{GE}^\alpha(f_X)I_{GE}^\alpha(f_Y) \quad (6)$$

Taking $\alpha = 1$ and $\alpha = 0$ for respectively the Theil Index and the Mean Logarithmic Deviation index, one has

$$Theil(f_{XY}) = Theil(f_X) + Theil(f_Y)$$

$$MLD(f_{XY}) = MLD(f_X) + MLD(f_Y)$$

Hence, when income inequality has been purged from education externalities and the residual is the product of human capital and another independant component, then human capital inequality should affect the residual income inequality in a one-for-one basis. In reverse, the proposition suggests that a quadratic in schooling in the above

regression is a good functional form that captures well education externalities.

As a sum, we can conclude that Kuznets hypothesis is valid over the period 1870-2000, both unconditionally and conditionally on the distribution of education; that education has two impacts on income inequality within countries: a direct one embodied in the human capital Theil, and an indirect one passing through education externalities. Given the magnitude and the sign of the coefficients of the quadratic in schooling, this externality is positive: the higher average schooling, the lower income inequality. The positive sign of the quadratic term shows that this externality has diminishing marginal returns.

Importantly, this externality is found to be very large: everything else equal, income inequality falls by 0.10 points of Theil (resp. 0.04) when average schooling goes from 0 to 2 (resp. 10 to 12). When schooling goes from 0 to 10, the total effect of this externality is a diminution of 0.4 points of Theil. In comparison, the “Kuznets effect” linked to the quadratic function in log-income is an increase of less than 0.10 points of Theil when a country moves from a GDP per capita around 1000 dollars - e.g. Haiti or Kenya in 2000 - to a GDP per capita around 5000 or 6000 dollars - Brazil or Russia in 2000 -, and an equal decrease until this country reaches 20 000 dollars - France in 2000.

Also we have run another fixed-effects regression explaining human capital inequality by a quadratic in schooling. The results are

$$\text{Theil}(h_{i,t}) = \mu + \delta_t + a_i + \underset{(0.0015)}{0.0057} S_{i,t} - \underset{(0.0001)}{0.0012} S_{i,t}^2 + u_{i,t}$$

Interestingly, a quadratic in log income is not significant when included in this regression and marginally affects the coefficients of schooling²⁴. From the estimates of this regression it turns out that the impact of education on human capital inequality is first a negligible increase when average schooling goes from 0 to 2 years, and then a de-

²⁴This is not a by-product of the way human capital was constructed in each country. Indeed, it depends on the whole educational distribution and not only on its first moment.

crease of 0.07 points of Theil until the country reaches 10 years of schooling. This effect passes to the income inequality dimension, bringing the total impact of education on income inequality to a reduction of $0.4 + 0.96 \times 0.07 \simeq 0.47$ points of Theil when average schooling goes from 0 to 10. So the “Kuznets effect” does exist and entails a rise and fall of 0.10 points of Theil, but this magnitude represents at most 20% of education’s total impact.

Education’s externality remains to be explained: if the Kuznets hypothesis is an ‘iron law’, the “golden rule” is still to be discovered. Still, we believe that this educational externality can be interpreted in a simple way. As suggested by Roland Benabou (1996), it could be that political participation of poor people increases with their educational level, and that consequently redistributive policies arise with educational development. This mechanism is emphasized by François Bourguignon and Thierry Verdier (2000), who focus on the economic incentives of political actors to invest into education, possibly leading to a reduction of their political power some years after. However, the reverse causality from redistribution to schooling attainment cannot be excluded. Redistributive policies might alleviate the credit constraint faced by households, who can start investing in children education. The overall interaction between education and institutions has been discussed by Daron Acemoglu and James A. Robinson (2006) and Edward L. Glaeser et al. (2004). As fixed-effects models do not control for reversal causality, we believe that a more structural approach would be useful to analyse the long-term relationships between inequality and growth of income and schooling as well as the key role of institutions.

7 Conclusion

This article presents the first estimates of the world distribution of years of schooling and of human capital over a long period, 130 years. We have shown that the educational comparative advantage of Western Europe has decreased rapidly since the beginning of

the twentieth century. As a consequence the context of the two globalization processes, the first in 1860-1914, the second starting in the late 70s, are very different. In world economic competition, education is a crucial advantage at least because it enables access to technological progress. The situation has completely changed in a century. In 1910, 70% of individuals who achieved secondary schooling lived in Western Europe and offshoots. In 2000, among people who have received higher education, only 36% come from Western Europe, and an equal proportion come from Asia. So there is a discrepancy between the advantage of Western Europe in the world income distribution and the weight of Asia in world education.

Furthermore, we have shown that computing inequality in years of schooling raises some important problems. From a practical and empirical perspective, we advise disentangling in a systematic way the impact of illiteracy from that of education inequality among educated individuals; otherwise, the former will cancel the latter if both are aggregated into a single index of education inequality. In the context of growth regressions for instance, it will lead clearly to misinterpretation of the results.

In response to that criticism, we have studied human capital inequality. Evidences on diminishing returns to schooling at the micro-level led us to choose a convenient functional form for human capital. This property of diminishing returns with respect to educational level explains the negative cross-countries correlation between Mincer returns to schooling and average schooling. As a result, we find that human capital inequality has increased, but does not exceed 15% of income inequality.

Turning to the link between income and human capital inequality within countries, we find an inverted-U pattern of human capital inequality along educational development - "the Kuznets curve of human capital". We show that the Kuznets hypothesis for income within inequality could be validated over the period 1870-2000, even after controlling for the direct and indirect impacts of education. Education has a positive though marginally decreasing externality on income inequality, which explains the

bulk of the observed decrease in income inequality within countries. This suggests that political economy models of long-run growth should focus on this new empirical fact.

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A Tables

Table 1 - The World Distribution of Years of Schooling

	1870	1890	1910	1930	1950	1960	1970	1980	1990	2000
Illiteracy Rate	78.9	73.6	67.0	59.7	51.2	44.9	39.1	33.3	27.7	23.6
Proportion Having only Primary	19.9	24.2	29.1	33.8	38.4	40.1	39.9	41.3	41.0	40.8
Proportion Having only Secondary	0.7	1.7	3.2	5.5	8.6	12.2	16.6	20.1	25.1	27.6
Proportion Having Higher Education	0.4	0.4	0.6	0.9	1.8	2.8	4.3	5.2	6.1	8.0
Average Years of Schooling	1.0	1.4	1.8	2.4	3.2	3.9	4.7	5.3	6.1	6.7
Average Years of Schooling in Primary	4.5	4.7	4.8	5.0	5.1	5.2	5.3	5.3	5.4	5.4
Average Years of Schooling in Secondary	10.5	10.8	11.1	11.2	11.3	11.3	11.4	11.5	11.6	11.7
Average Years of Schooling in Higher Education	14.8	15.0	15.2	15.4	15.5	15.6	15.6	15.6	15.7	15.7

Table 2 - Average Years of Schooling and Illiteracy Rates, 1870-2000

	Africa	Japan Korea Taiwan	Latin America	Eastern Europe	Europe and offshoots	China	South Asia	Other Asian countries
1870								
Total	0.13	0.63	0.59	0.83	3.02	1.00	0.03	0.25
Primary	0.12	0.61	0.52	0.77	2.89	0.90	0.02	0.22
Secondary	0.01	0.02	0.05	0.05	0.09	0.09	0.00	0.02
Illiteracy	96.5	82.9	86.0	79.1	37.2	82.3	99.3	94.6
1910								
Total	0.27	2.41	1.28	1.61	5.00	1.26	0.27	0.50
Primary	0.25	2.32	1.16	1.44	4.31	1.15	0.23	0.47
Secondary	0.02	0.08	0.09	0.16	0.63	0.10	0.03	0.04
Illiteracy	93.8	46.2	71.8	67.8	16.1	78.6	94.6	89.6
1950								
Total	0.79	6.31	2.81	5.05	7.22	1.65	0.88	1.43
Primary	0.67	4.65	2.53	4.44	5.35	1.47	0.76	1.29
Secondary	0.11	1.57	0.24	0.54	1.67	0.16	0.11	0.13
Illiteracy	85.2	13.2	44.7	12.1	4.5	73.8	83.9	73.4
1970								
Total	1.71	8.78	4.13	7.65	9.06	3.33	2.25	3.35
Primary	1.41	5.57	3.34	5.21	5.78	2.83	1.67	2.76
Secondary	0.27	2.97	0.67	2.25	2.85	0.43	0.49	0.45
Illiteracy	70.5	4.1	32.7	7.0	1.7	50.9	66.9	46.4
1980								
Total	2.37	9.58	4.89	8.02	9.83	4.55	2.91	4.35
Primary	1.93	5.74	3.76	5.32	5.81	3.68	2.09	3.47
Secondary	0.41	3.44	0.95	2.47	3.44	0.82	0.74	0.69
Illiteracy	60.4	2.0	26.6	6.6	1.6	37.1	60.1	34.5
1990								
Total	3.18	10.29	6.22	9.47	10.50	5.66	3.31	5.57
Primary	2.49	5.85	4.36	5.45	5.84	4.37	2.40	4.28
Secondary	0.64	3.89	1.59	3.66	3.92	1.24	0.80	1.15
Illiteracy	50.2	1.2	18.4	6.9	1.7	26.0	54.3	21.1
2000								
Total	4.02	10.98	6.94	9.86	10.99	6.64	4.02	6.52
Primary	3.07	5.90	4.67	5.58	5.87	4.79	2.77	4.72
Secondary	0.86	4.24	1.91	3.75	4.29	1.77	1.07	1.55
Illiteracy	39.5	1.3	14.5	5.5	1.8	19.7	48.3	15.3

Table 3 - Regional Composition of World Years of Schooling Quantiles

	Africa	Japan Korea Taiwan	Latin America	Eastern Europe	Europe and offshoots	China	South Asia	Other Asian countries
1870								
Total	6.6	3.5	2.7	10.6	19.2	28.3	20.6	8.6
Bottom 80	8.1	3.6	2.9	10.6	9.1	29.5	25.9	10.3
Decile 9	1.4	3.6	2.1	12.8	57.6	19.7	0.6	2.3
Decile 10	0.9	2.3	1.6	9.1	57.1	26.2	0.7	2.1
1910								
Total	6.3	3.6	3.8	13.0	21.7	24.6	18.2	8.8
Bottom 80	8.4	2.4	4.0	12.8	7.6	28.1	25.1	11.4
Decile 9	1.5	7.5	4.1	14.6	49.8	15.6	3.5	3.3
Decile 10	1.0	5.3	2.9	12.4	55.0	17.8	2.8	2.6
1960								
Total	9.1	4.3	6.1	10.7	19.3	22.1	18.4	10.0
Bottom 80	10.6	4.0	5.4	10.8	14.9	22.9	21.1	10.2
Decile 9	4.7	6.1	9.3	15.8	24.1	18.2	11.4	10.4
Decile 10	4.2	5.3	8.2	10.0	33.7	19.5	9.9	9.2
1980								
Total	10.6	3.9	7.2	9.3	15.7	22.2	19.9	11.1
Bottom 80	14.0	4.0	7.0	5.7	10.7	22.3	24.8	11.7
Decile 9	6.6	4.2	8.2	13.7	19.0	24.2	12.5	11.6
Decile 10	3.5	2.9	6.2	17.0	32.6	17.8	12.3	7.7
2000								
Total	13.2	3.2	7.8	7.6	13.2	20.8	21.8	12.5
Bottom 80	18.6	1.0	7.3	3.5	4.1	19.6	31.0	14.9
Decile 9	10.3	3.9	8.5	9.4	15.7	25.1	14.3	12.9
Decile 10	5.3	7.5	7.6	14.3	30.5	16.7	11.9	6.2

Table 4 - The World Marginal Distributions of Income and Education

	1870	1890	1910	1929	1950	1960	1970	1980	1990	2000
Income¹										
Coefficient of Variation	1.786	1.919	2.021	1.915	1.771	1.725	1.676	1.739	1.815	1.838
Coefficient of Gini	0.553	0.586	0.614	0.635	0.648	0.644	0.652	0.665	0.664	0.646
Theil Index	0.669	0.762	0.833	0.813	0.775	0.788	0.780	0.854	0.853	0.876
between country group	0.188	0.251	0.324	0.403	0.482	0.485	0.492	0.529	0.528	0.494
within country group	0.481	0.511	0.509	0.410	0.293	0.303	0.288	0.325	0.325	0.382
Mean Logarithmic Deviation	0.527	0.605	0.678	0.749	0.800	0.798	0.825	0.883	0.852	0.793
between country group	0.162	0.217	0.299	0.381	0.471	0.508	0.518	0.577	0.517	0.472
within country group	0.365	0.388	0.379	0.368	0.329	0.290	0.307	0.306	0.335	0.321
Mean Income (PPP \$ 1990)	890	1113	1453	1768	2145	2759	3774	4483	4922	6035
Years of Schooling										
Coefficient of Variation	2.118	1.842	1.601	1.396	1.213	1.094	0.992	0.896	0.803	0.744
Coefficient of Gini	0.822	0.779	0.727	0.673	0.613	0.571	0.533	0.489	0.445	0.414
Coefficient of Gini, educated population	0.159	0.164	0.174	0.188	0.207	0.222	0.233	0.234	0.233	0.234
Theil Index	1.615	1.392	1.178	0.986	0.805	0.688	0.591	0.500	0.416	0.361
between country groups	0.559	0.519	0.450	0.381	0.331	0.260	0.179	0.128	0.101	0.076
Theil Index, educated population	0.059	0.062	0.069	0.076	0.087	0.092	0.095	0.094	0.092	0.092
Average Years of Schooling	1.03	1.38	1.85	2.44	3.21	3.95	4.71	5.35	6.07	6.71
Illiteracy Rate	78.9	73.6	67.0	59.7	51.2	44.9	39.1	33.3	27.7	23.6
Population (millions)	1267	1451	1722	2044	2507	3021	3663	4419	5314	6071

¹source: Bourguignon-Morrisson (2002)

Table 5 - Estimated Coefficients from Mincer Regressions for Men with a Quadratic in Schooling

	Coefficient of Schooling	Coefficient of Squared Schooling
1940 ¹	10.1** (0.1)	-
	11.3** (0.2)	-0.070** (0.009)
1950 ¹	6.4** (0.1)	-
	11.9** (0.3)	-0.298** (0.016)
1960 ¹	8.4** (0.0)	-
	13.6** (0.1)	-0.256** (0.007)
1970 ¹	7.6** (0.0)	-
	8.1** (0.1)	-0.023** (0.006)
1980 ¹	7.2** (0.0)	-
	10.4** (0.2)	-0.130** (0.006)
1990 ²	8.8** (0.0)	-
	4.8** (0.2)	0.169** (0.006)
2000 ²	9.5** (0.0)	-
	0.8** (0.1)	0.366** (0.005)

Controls for a quadratic in experience were included. ¹ years of schooling variable: highest grade achieved (detailed version).

² years of schooling variable constructed with educational attainment variable (degrees): 14 years for some years of college but no degree or an associate degree, 16 years for a bachelor's degree, 17 years for a professional degree, 18 years for a master degree and 21 for a Doctorate.

source: IUPMS Census Data 1% samples.

Table 6 - The World Marginal Distributions of Income and Human Capital

	1870	1890	1910	1929	1950	1960	1970	1980	1990	2000
With r = 10%										
Coefficient of Gini	0.104	0.130	0.160	0.191	0.224	0.247	0.267	0.272	0.272	0.273
educated population	0.094	0.104	0.119	0.137	0.161	0.181	0.198	0.203	0.205	0.211
Theil Index	0.035	0.047	0.062	0.079	0.100	0.113	0.125	0.126	0.123	0.123
between country	0.010	0.016	0.024	0.032	0.044	0.047	0.045	0.041	0.040	0.034
educated population	0.030	0.034	0.040	0.048	0.060	0.067	0.073	0.074	0.073	0.076
Mean Logarithmic Deviation	0.029	0.039	0.052	0.068	0.087	0.103	0.117	0.121	0.122	0.125
between country	0.009	0.015	0.022	0.030	0.042	0.045	0.043	0.039	0.038	0.033
educated population	0.024	0.028	0.034	0.041	0.052	0.060	0.068	0.070	0.071	0.075
Average Human Capital	1.14	1.19	1.27	1.36	1.50	1.63	1.79	1.92	2.07	2.21
With Diminishing Returns										
Coefficient of Gini	0.106	0.131	0.157	0.182	0.205	0.219	0.233	0.238	0.240	0.241
standard error	0.013	0.015	0.018	0.020	0.022	0.022	0.024	0.025	0.025	0.026
educated population	0.098	0.107	0.119	0.130	0.145	0.159	0.170	0.176	0.182	0.187
Theil Index	0.034	0.044	0.056	0.068	0.080	0.087	0.096	0.098	0.098	0.099
standard error	0.009	0.011	0.014	0.017	0.021	0.020	0.022	0.024	0.022	0.023
between country	0.012	0.018	0.026	0.033	0.044	0.045	0.045	0.045	0.046	0.046
educated population	0.022	0.026	0.031	0.036	0.044	0.050	0.055	0.058	0.061	0.064
Mean Logarithmic Deviation	0.029	0.038	0.049	0.060	0.072	0.080	0.089	0.092	0.094	0.095
standard error	0.007	0.008	0.011	0.013	0.016	0.016	0.018	0.020	0.019	0.021
between country	0.011	0.017	0.023	0.030	0.040	0.042	0.041	0.041	0.042	0.043
educated population	0.008	0.009	0.012	0.012	0.016	0.016	0.016	0.016	0.017	0.017
Average Human Capital	1.14	1.20	1.27	1.35	1.45	1.55	1.65	1.75	1.86	1.94
standard error	0.02	0.03	0.03	0.04	0.06	0.07	0.09	0.10	0.12	0.14

B Figures

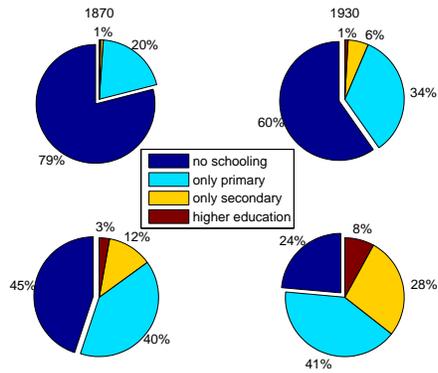


Figure 1: The World Distribution of Years of Schooling 1870-2000

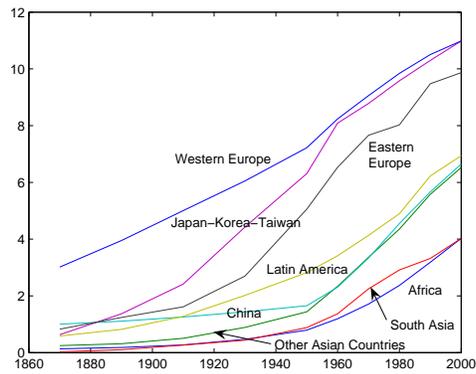


Figure 2: Average Years of Schooling by Region 1870-2000

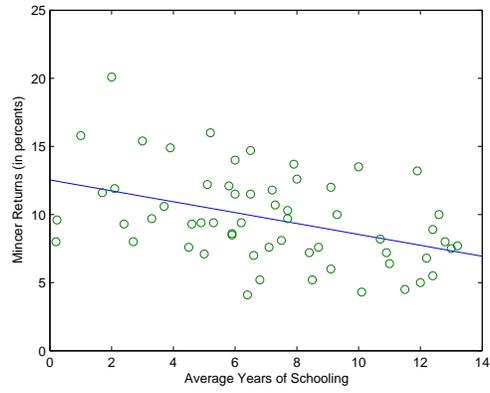


Figure 3: The Return to Schooling and Average Schooling in 59 Countries around 1990

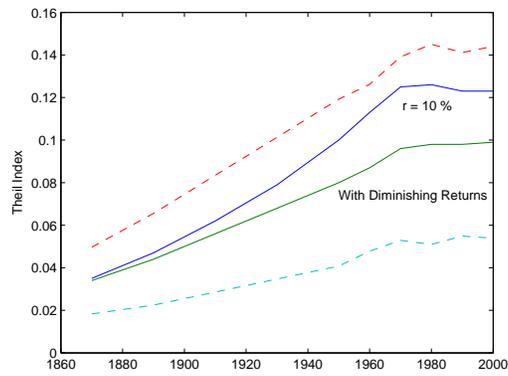


Figure 4: World Human Capital Inequality 1870-2000 - Theil Index

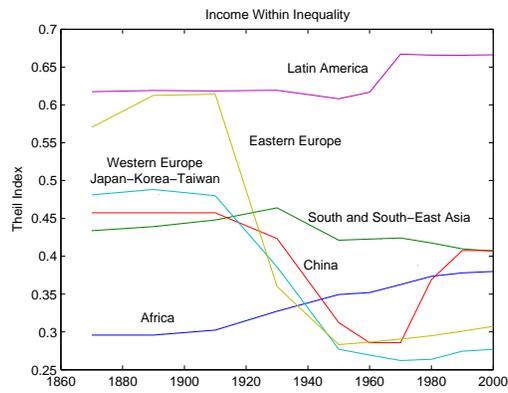


Figure 5: Inequality in Income Within Countries by Geographical Zone 1870-2000 - Theil Index

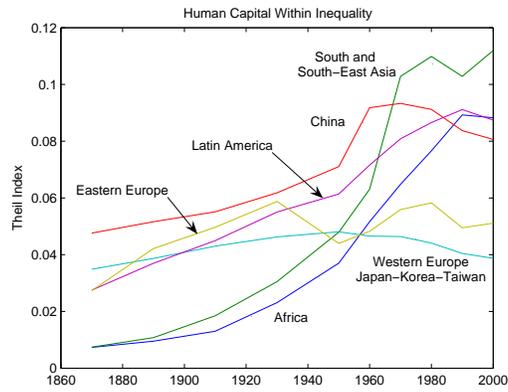


Figure 6: Inequality in Human Capital Within Countries by Geographical Zone 1870-2000 - Theil Index

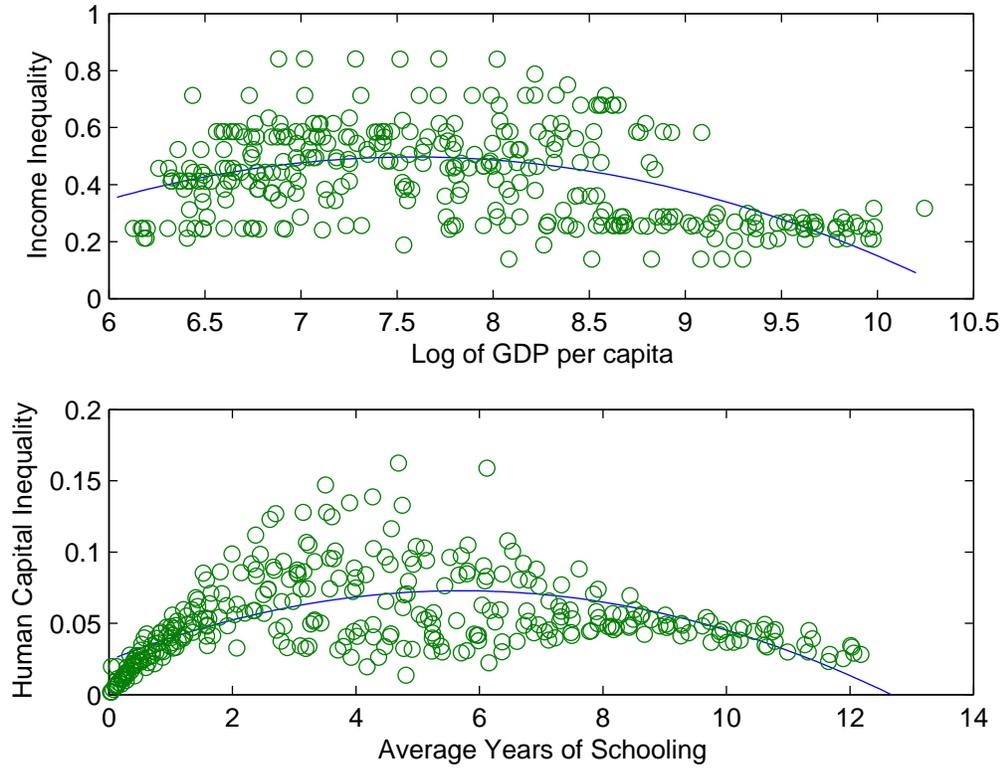


Figure 7: The Kuznets Curves of Income and Human Capital Inequality 1870-2000 - Theil Index

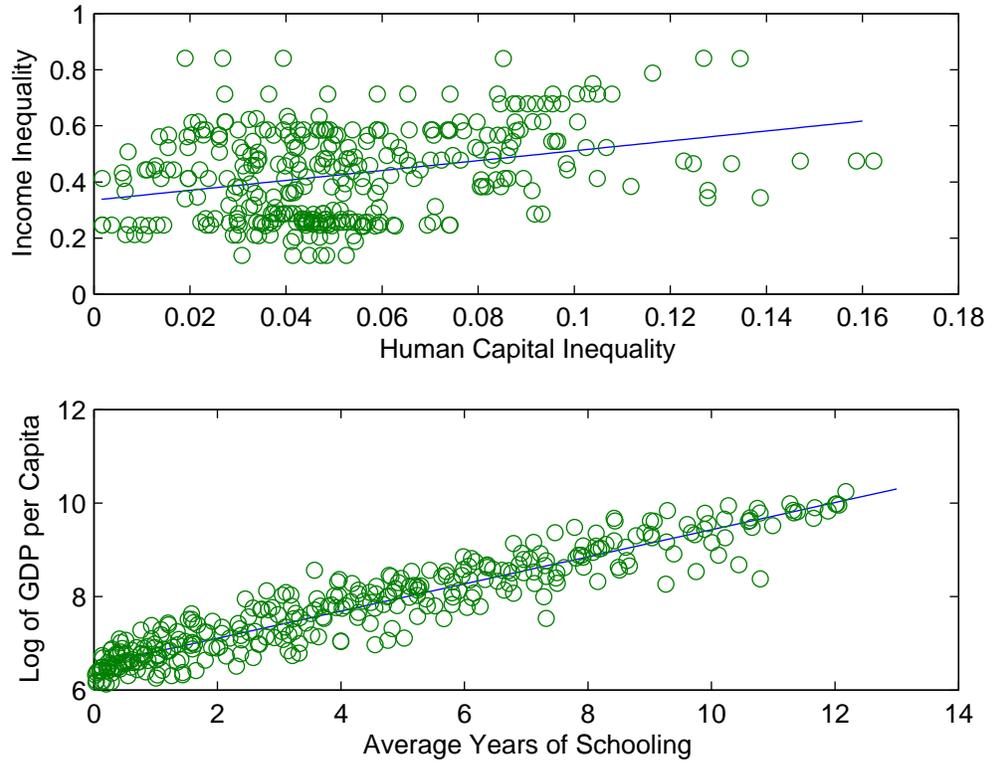


Figure 8: Income vs Human Capital Inequality and Log-GDP per capita vs Schooling

C The impact of illiteracy on education inequalities

We consider here a continuous outcome x that can take values greater or equal to m . For a fraction p of total population we have $x = m$. Then the distribution f of the outcome can be viewed as the mixture

$$f(x) = p\delta_{x=m} + (1-p)g(x)$$

where $\delta_{x=m}$ is a mass point in m and g the distribution of the outcome in the population with an outcome strictly greater than m . For the Gini index we use its mean-differences definition. Writting $\mu(f)$ as the mean outcome for a distribution f and $G(f)$ the corresponding Gini index we have

$$\begin{aligned} G(f) &= \frac{1}{2\mu(f)} \int \int |x - x'| f(x)f(x') dx dx' \\ &= \frac{p^2}{2\mu(f)} \int \int |x - x'| \delta_{x=m} \delta_{x'=m} dx dx' + \frac{p(1-p)}{\mu(f)} \int \int |x - x'| \delta_{x=m} g(x') dx dx' \\ &\quad + \frac{(1-p)^2}{2\mu(f)} \int \int |x - x'| g(x)g(x') dx dx' \end{aligned}$$

by symetry. The first term cancels out. Since m is the minimum value of the outcome the above expression simplifies into

$$\begin{aligned} G(f) &= \frac{p(1-p)}{\mu(f)} \left(\int \int x' \delta_{x=m} g(x') dx dx' - \int \int x \delta_{x=m} g(x') dx dx' \right) \\ &\quad + \frac{(1-p)^2}{2\mu(f)} \int \int |x - x'| g(x)g(x') dx dx' \\ &= \frac{p(1-p)}{\mu(f)} (\mu(g) - m) + \frac{(1-p)^2}{\mu(f)} \mu(g)G(g) \end{aligned}$$

The means $\mu(f)$ and $\mu(g)$ are simply related by $\mu(f) = pm + (1-p)\mu(g)$, which provides

$$G(f) = p \frac{\mu(f) - m}{\mu(f)} + (1-p) \frac{\mu(f) - pm}{\mu(f)} G(g)$$

or alternatively

$$G(f) = G(g) + \frac{pm}{\mu(f)} \left[\frac{\mu(f)}{m} - 1 - G(g) \left(\frac{\mu(f)}{m} + 1 - p \right) \right]$$

Similarly, the GE-index is given by

$$\begin{aligned} I_{GE}^\alpha(f) &= \frac{1}{\alpha^2 - \alpha} \int \left[\left(\frac{x}{\mu(f)} \right)^\alpha - 1 \right] f(x) dx \\ &= \frac{1}{\alpha^2 - \alpha} \int \left(\frac{x}{\mu(f)} \right)^\alpha f(x) dx - \frac{1}{\alpha^2 - \alpha} \\ &= \frac{p}{\alpha^2 - \alpha} \int \left(\frac{x}{\mu(f)} \right)^\alpha \delta_{x=m} dx + \frac{1-p}{\alpha^2 - \alpha} \int \left(\frac{x}{\mu(f)} \right)^\alpha g(x) dx - \frac{1}{\alpha^2 - \alpha} \\ &= \frac{1-p}{\alpha^2 - \alpha} \left(\frac{\mu(g)}{\mu(f)} \right)^\alpha \int \left(\frac{x}{\mu(g)} \right)^\alpha g(x) dx + \frac{pm^\alpha}{\alpha^2 - \alpha} \mu(f)^{-\alpha} - \frac{1}{\alpha^2 - \alpha} \\ &= \frac{(1-p)^{1-\alpha}}{\alpha^2 - \alpha} \left(\frac{\mu(f) - pm}{\mu(f)} \right)^\alpha \left[I_{GE}^\alpha(g) + \frac{1}{\alpha^2 - \alpha} \right] (\alpha^2 - \alpha) + \frac{pm^\alpha}{\alpha^2 - \alpha} \mu(f)^{-\alpha} - \frac{1}{\alpha^2 - \alpha} \\ &= (1-p)^{1-\alpha} \left(\frac{\mu(f) - pm}{\mu(f)} \right)^\alpha \underbrace{I_{GE}^\alpha(g) + \frac{1}{\alpha^2 - \alpha} \left((1-p)^{1-\alpha} \left(\frac{\mu(f) - pm}{\mu(f)} \right)^\alpha + pm^\alpha \mu(f)^{-\alpha} - 1 \right)}_A \end{aligned}$$

which achieves the decomposition. Let us examine now the case when $\alpha = 1$ (for the Theil index). We use Taylor expansions

$$\begin{aligned} A &= \frac{1}{\alpha^2 - \alpha} \left[(1-p)^{1-\alpha} \left(1 - \frac{pm}{\mu(f)} \right)^\alpha - \left(1 - \frac{pm^\alpha}{\mu(f)^\alpha} \right) \right] \\ &\simeq \frac{1}{\alpha^2 - \alpha} \left[\left(1 - \frac{pm}{\mu(f)} \right)^\alpha + \left(1 - \frac{pm}{\mu(f)} \right)^\alpha (1-\alpha) \log(1-p) - \left(1 - \frac{pm^\alpha}{\mu(f)^\alpha} \right) \right] \\ &= -\frac{1}{\alpha} \log(1-p) \left(1 - \frac{pm}{\mu(f)} \right)^\alpha + \frac{1}{\alpha^2 - \alpha} \left[\left(1 - \frac{pm}{\mu(f)} \right)^\alpha - \left(1 - \frac{pm^\alpha}{\mu(f)^\alpha} \right) \right] \end{aligned}$$

$$\begin{aligned} A &\simeq -\frac{1}{\alpha} \log(1-p) \left(1 - \frac{pm}{\mu(f)} \right)^\alpha \\ &\quad + \frac{1}{\alpha^2 - \alpha} \left[\left(1 - \frac{pm}{\mu(f)} \right) + \left(1 - \frac{pm}{\mu(f)} \right) (\alpha-1) \log \left(1 - \frac{pm}{\mu(f)} \right) - \left(1 - \frac{pm^\alpha}{\mu(f)^\alpha} \right) \right] \\ &= -\frac{1}{\alpha} \log(1-p) \left(1 - \frac{pm}{\mu(f)} \right)^\alpha + \frac{1}{\alpha} \left(1 - \frac{pm}{\mu(f)} \right) \log \left(1 - \frac{pm}{\mu(f)} \right) - \frac{1}{\alpha^2 - \alpha} \frac{pm}{\mu(f)} \left(1 - \left(\frac{m}{\mu(f)} \right)^{\alpha-1} \right) \\ &\simeq -\frac{1}{\alpha} \log(1-p) \left(1 - \frac{pm}{\mu(f)} \right)^\alpha + \frac{1}{\alpha} \left(1 - \frac{pm}{\mu(f)} \right) \log \left(1 - \frac{pm}{\mu(f)} \right) + \frac{1}{\alpha} \frac{pm}{\mu(f)} \log \left(\frac{m}{\mu(f)} \right) \end{aligned}$$

Then taking the limit $\alpha \rightarrow 1$ we have

$$\text{Theil}(f) = \text{Theil}(g) + A - \frac{pm}{\mu(f)} \text{Theil}(g)$$

$$\text{where } A = -\log(1-p) \left(1 - \frac{pm}{\mu(f)} \right) + \left(1 - \frac{pm}{\mu(f)} \right) \log \left(1 - \frac{pm}{\mu(f)} \right) + \frac{pm}{\mu(f)} \log \left(\frac{m}{\mu(f)} \right)$$

D The decomposition of inequality in the product of two independant variables

Let X and Y be two random variables, f_X and f_Y their respective probability density function, f_{XY} that of their product, and μ_X, μ_Y, μ_{XY} the corresponding means. If X and Y are independant then $f_{XY} = f_X f_Y, \mu_{XY} = \mu_X \mu_Y$, and we have

$$\begin{aligned} I_{GE}^\alpha(f_{XY}) &= \frac{1}{\alpha^2 - \alpha} \int \int \left[\left(\frac{xy}{\mu_{XY}} \right)^\alpha - 1 \right] f_{XY}(xy) dx dy \\ I_{GE}^\alpha(f_{XY}) &= \frac{1}{\alpha^2 - \alpha} \left[\int \left(\frac{x}{\mu_X} \right)^\alpha f_X(x) dx \int \left(\frac{y}{\mu_Y} \right)^\alpha f_Y(y) dy - 1 \right] \\ I_{GE}^\alpha(f_{XY}) &= \frac{1}{\alpha^2 - \alpha} [(1 + (\alpha^2 - \alpha) I_{GE}^\alpha(f_X)) (1 + (\alpha^2 - \alpha) I_{GE}^\alpha(f_Y)) - 1] \\ I_{GE}^\alpha(f_{XY}) &= I_{GE}^\alpha(f_X) + I_{GE}^\alpha(f_Y) + (\alpha^2 - \alpha) I_{GE}^\alpha(f_X) I_{GE}^\alpha(f_Y) \end{aligned}$$

Complementary information on the building of average years of schooling (Not to be included in the final version)

This dataset on human capital for 1870-2000 is based on two datasets. The first for 1870-1960 is a new one, the second for 1960-2000 has been published by D. Cohen and F. Soto (2001), quoted hereafter as Cohen-Soto. Several countries such as Poland or USSR/Russia were missing on the list and have been taken from Barro and Lee (2001). The Cohen-Soto database has been chosen because it provides very reliable estimates as proved by a comparison of these data with the datasets published by R. Barro and J-W Lee (2001), V. Nehru et al. (1995), A. De La Fuente and R. Domenech (2000). Cohen-Soto has systematically used as sources the national censuses which give the school attainments of population (usually aged 15 to 64). The long series of B. Mitchell (2003 a-b-c) on primary, secondary and high school enrolments were used only to fill missing cells.

Estimating the average years of schooling in 1870 or before is difficult because information on school enrolments before 1870 are needed. Mitchell provides series for European countries, US, Canada, Australia before 1870, but in Latin America, in Eastern Europe, in some Asian countries, the series begin only around 1870 or 1880. Moreover for African countries, other Asian countries, Mitchell gives no data before 1930 or 1950-60. So we estimated the average years of schooling in all countries where series are not available by interpolation. We assumed an enrolment rate in primary school of 1% in 1820 (Europe, North America, Oceania) or 0.1% (Asia, South America, Africa) and a constant rate of increase between 1820 and the first year of Mitchell's series.

We believe this assumption to be innocuous, because most of the time the first observed enrolment rate is very low, and close to the latter values. Robustness analysis illustrates below the weight of the latter assumption, as well as those underlying the construction of Mitchell's series that we describe below.

At a given period, the educational situation of a country can be assessed directly by census data, provided that it exists, or can be derived from demographic and educational information over the past generations. The latter procedure estimates the mean educational attainment of cohorts of i years-old individuals at date t by computing the enrollment rate in the primary school at date $t - i + 6$, and by relying on an estimate of duration at school. Such a procedure introduces much uncertainty than census data, but enables us to recover educational data over very long periods for which census data does not exist.

Some problems have been recognized to arise from this enrollment-based procedure. First, the population's structure in year t is not necessarily the outcome of year $t - T$ given a mortality rule between those two periods, because migrations can affect a substantial proportion of population. Between the 19th and the 20th century, countries from the Commonwealth, Latin America, North-America, and some of Europe have had intense periods of migrations. Depending on the human capital of the migrants relatively to their compatriots, the net impact of migration can be positive or negative. A second problem is that the intake rate, i.e. the ratio of new entrants in primary school to the six-years population, is subject to measurement errors due to the presence of repeaters and dropouts. We derive human capital measurement by ignoring the migration problem.

Let $P_{i,t}$ be the population of age i at time t , E_t and N_t be respectively the total number of pupils at school and the number of intakes - those attending their first year of school in year t . Given a cohort of age i at time t , the probability to have been an intake at the age of 6 is simply

$$\frac{N_{t-i+6}}{P_{6,t-i+6}}$$

As in Cohen and Soto (2001) we consider the impact of repeaters and dropouts by assuming that a pupil can repeat a maximum of three years during her scolarity, which lasts P years. Let d and r be the dropout and repeating rates, and g the growth rate of intakes. The expression linking total enrollment E_t to first-year enrollment N_t is

$$\begin{aligned} E_t &= N_t \sum_{j=0}^{P-1} (1-d-r)^j \left[\frac{1}{(1+g)^j} + \frac{r \binom{j+1}{1}}{(1+g)^{j+1}} + \frac{r^2 \binom{j+1}{2}}{(1+g)^{j+2}} + \frac{r^3 \binom{j+1}{3}}{(1+g)^{j+3}} \right] \\ &= N_t \mu(d, r, g, P) \end{aligned}$$

This formula simply decomposes each grade at school between students who have repeated 0, 1, 2 or 3 times before. Our data provides total enrollment E_t , from which is deduced the number of intakes N_t from 1870 to 1960. Then a cohort i at time t displays a mean number of schooling equal to

$$\frac{N_{t-i+6}}{P_{6, t-i+6}} \cdot \left(\sum_{j=0}^{P-1} j (1-d)^j \cdot d + P (1-d)^P \right) = \frac{N_{t-i+6}}{P_{6, t-i+6}} \lambda(d, P)$$

In this equation the $\lambda(d, P)$ term is the mean duration of primary school which is held constant over time and does not take into account repeated years. From (2) and (3), human capital $H_{i, t}$ of cohort i at time t is given by

$$H_{i, t} = \frac{E_{t-i+6}}{P_{6, t-i+6}} \frac{\lambda(d, P)}{\mu(d, r, g, P)}$$

In the case where $d = r = g = 0$, one simply has $H_{i, t} = E_{t-i+6}/P_{6, t-i+6}$ since $\lambda(d, P) = \mu(d, r, g, P) = P$. Furthermore human capital does not depend on any assumption on the duration P of schooling, since there is a perfect trade-off between the mean number of years at school (λ) and the mean number of pupils at each grade (E/μ).

The data consists in demographic and enrolment files beginning in various years. The demographic files present the structure of the population by age group. The number of countries for which age pyramids are available in 1820 is scarce. For the others, we postulate that the distribution of mortality F is Weibull (a, b) , which parameters are calibrated on the life expectancy of the population and the survival rate after 60 years (taken equal to 10% in 1820). Life expectancy is corrected from children mortality, equal to $m_0 = 20\%$ at birth and to $m_1 = 7\%$ the following 4 years. Formally life expectancy LE is given by

$$\begin{aligned} LE &= m_0 + m_1(2 + 3 + 4 + 5) + (1 - m_0)(1 - m_1)^4 \sum_{k \geq 6} p_k k, \quad p_k \rightsquigarrow \text{Weibull}(a, b) \\ &= \nu(m_0, m_1, a, b) \end{aligned}$$

Once calibrated, the survival function $1 - F$ gives the relative weight of each cohort of age inside each age group

$$\frac{p(\text{Age} = i)}{p(\text{Age} = j)} = \frac{1 - F(\text{Death} \leq i)}{1 - F(\text{Death} \leq j)}$$

Age pyramids for the subsequent years are then interpolated with the first observation for the country, or if not available, with a rescaled age pyramid derived from a neighbour country.

The initial enrolment assumptions might bias human capital estimates in early years. We provide hereafter two figures that indicate that in 1900 differences might be very low with respect to the retained value in 1820; in the first one, we assumed that the enrolment rate in France was equal to 0, while in the second it is equal to its first observed value in 1852, 50%. We did the same for India, with a value of 0% or 1% (that of 1851) in 1820. Both examples show minor differences in 1900.

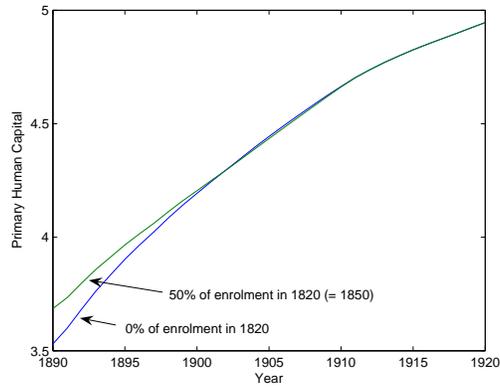


Figure 9: The weight of initial enrolment rate in France

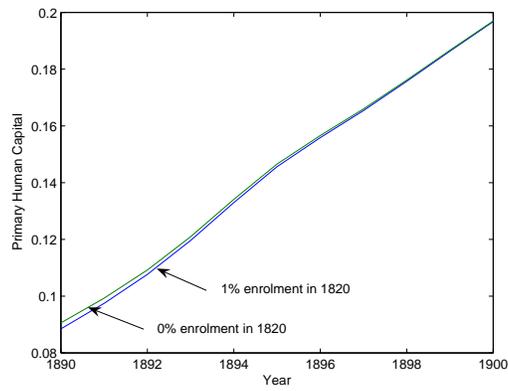


Figure 10: The weight of initial enrolment rate in India

Importantly, some countries exhibited enrolment rates in primary that were higher than 100% given our benchmark assumption $P = 6$. Those were most of the time western countries. We adopted the rule to select the maximal duration P for which the enrolment rate was the closest to 100% in 1950, but still being below this level. The average years of schooling over 6 years were then reported as secondary schooling rather than primary schooling. Next figure illustrates the procedure with France. Notice that years of primary schooling in 1950 on the bottom right are still below 6 years because repeated years are not taken into account and the dropout rate is non-null. Anyway, this procedure should only marginally modify *total* years of schooling in a given country.

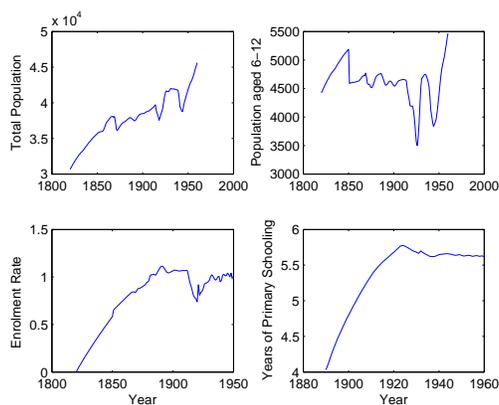


Figure 11: The building of the schooling stocks series: primary schooling in France 1820-1950

Robustness analysis with respect to dropout and repeating rates

Dropout and repetition rates are derived from Unesco data (1957, 1965, 1970,1999) and are used to adjust the illiteracy rate stemming from Mitchell's series with that of Unesco when available. In average, the repeating rate was taken equal to 0.05% per year in Europe and North America in 1870, and 10% elsewhere. The dropout rate was comprised between 1 and 8% in the former two continents, was about 15 % in South America and Asia, and 20% in Africa. This latter figure is below the lowest survival rates at the world level in 2000, which were about 15% for Rwanda and Madagascar.

Sensibility with respect to those two parameters was found to be reasonable, if not very low for repeaters. Next figure describes, from left to right and top to bottom, average number of primary schooling with respect to maximum duration P , repeating rate r , and dropout rate for Brazil in 1910 and 1929. All of them seem to display a variation less than 15% for reasonable values of the parameters. Importantly, the kink in the two upper graphs are explained by the report of years of primary schooling over six years to secondary schooling.

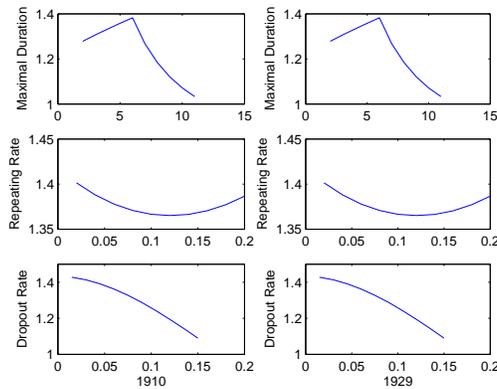


Figure 12: Sensibility of stock of primary schooling years with respect to maximal duration, repeating rate and dropout rate in Brazil, 1910 and 1929

Robustness of inequality indices with respect to duration and classes

We test the sensitivity of major results (inequality in schooling, inequality in human capital) with respect to our main duration assumption, ie that durations have raised continuously until 2000, and with respect to the number of classes used to describe the schooling distribution.

For the latter point we estimate years of schooling inequality with a continuous education distribution, which is obtained by smoothing the stepwise cdf of years of schooling. In practice we use the trapeze method to conserve equal stocks of schooling in primary, secondary and higher education after numerical integration. Notice that as schooling is not likely to be scattered continuously, the real inequality is probably closer to estimates of Table 4, which constitutes nevertheless a lower bound.

For durations we consider the alternative scenario where durations have raised continuously until the levels of 2000 but attained them in 1960. That scenario provides an upper bound of fast convergence, since it is not likely that emerging countries have displayed the same duration at school for 40 years.

The first simulation provides mixed results since inequality levels are quite different from their benchmark counterparts, especially for years of schooling; the decrease of inequality between 1870 and 2000 is similar, even if the trend might be somewhat different (the inequality differences between the smoothed and the benchmark distributions are not constant over time). The same comments apply for human capital.

The last simulation presents negligible differences with the benchmark case: the timing of the convergence towards current values does not seem to matter a lot, providing that it is the same for all countries.

	1870	1910	1950	1970	1980	1990	2000
Benchmark							
Years of Schooling							
Gini	0.822	0.727	0.613	0.533	0.489	0.445	0.414
Theil	1.615	1.173	0.805	0.591	0.500	0.416	0.361
Human Capital ¹							
Gini	0.127	0.173	0.210	0.249	0.255	0.244	0.242
Theil	0.053	0.072	0.086	0.113	0.113	0.100	0.098
Smoothed Distribution							
Years of Schooling							
Gini	0.856	0.793	0.697	0.650	0.589	0.508	0.479
Theil	1.715	1.341	0.963	0.828	0.672	0.502	0.449
Human Capital ¹							
Gini	0.164	0.205	0.248	0.283	0.300	0.292	0.288
Theil	0.090	0.102	0.121	0.150	0.156	0.141	0.137
Faster Duration Growth							
Years of Schooling							
Gini	0.822	0.734	0.628	0.542	0.496	0.448	0.415
Theil	1.615	1.210	0.858	0.620	0.519	0.425	0.361
Human Capital ¹							
Gini	0.127	0.176	0.217	0.254	0.259	0.246	0.242
Theil	0.053	0.074	0.092	0.118	0.117	0.102	0.098

¹using a piecewise return to schooling

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