Health and Education:

Another Look with the Proper Data*

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Abstract

During the XXth century, life expectancy levels have converged across the world. Yet, macroeconomic studies, as Acemoglu and Johnson (2007), estimate that improvements in health have no impact on growth or any factors of growth; in particular, they find no impact of life expectancy increases on education. We argue that their pessimistic results with respect to schooling investment is due to the use of an imprecise proxy. Indeed, when life expectancy increases at time t, *only the cohort born at t* should increase its human capital investment. On the contrary, Acemoglu and Johnson (2006) look at the impact of life expectancy improvements on the average education of *the whole population aged above 15*, which evolves much slower. We have reproduced their estimations with a cohort-based measure of education and find a positive and significant impact of life expectancies on education, of a magnitude between 20% and 47%. Finally, we use both the Cohen-Soto (2007) and the Barro-Lee (2010-2013) databases on education, and explain in the text why the former delivers better results than the latter.

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1 Introduction

During the second half of the twentieth century, the gap in life expectancies between rich and poor countries has reduced. Convergence in health development should give hope for future convergence in economic development. Indeed, given that health is a cornerstone of human capital, health improvement triggers higher productivity, and therefore has a direct impact on growth.[1] Moreover, it has also indirect effects. Theoretically, an increase in life expectancy makes investments more profitable, in particular in education. And better educated populations should be more productive.

The seminal paper showing theoretically that longer life expectancy implies higher education has been written by Ben-Porath in 1967. Ben-Porath states that individuals with a longer time horizon invest more in schooling, since the period during which they can benefit from their returns on that investment is longer.[2] The recent research on the relation between economic takeoff and demographic transition - mostly overlapping-generation models (OLG) endogenizing demographic variables - is based on that Ben-Porath mechanism.[3]

Yet, the stylized facts and the empirical research on the causal impact of life expectancy on education are disappointing, at the macroeconomic level.[4] Descriptive statistics show that, while the gap in life expectancies reduced, the average level of education in the populations of poor countries did not catch up the one of rich countries, as pointed out by Cohen and Soto (2004). Moreover, there exists few empirical studies on this subject at the macroeconomic level, and they mostly draw pessimistic conclusions.[5]

Acemoglu and Johnson (2007) use the epidemiological transition of the 1940s, a period when penicillin and DDT pesticide have spread throughout the world, to build an instrument for life expectancy at birth.[6] They conclude that the causal link between expected longevity and growth is small and insignificant. In their NBER working paper version of 2006, they also test the causal impact of the expected longevity on education, and find that the impact is small and insignificant. Lorentzen, McMillan, and Wacziarg (2008) instrument several proxies for health by climatic factors, geographic

[1]See the commission report for the World Health Organization on macroeconomics and health, chaired by Jeffrey Sachs in 2001, quoting Fogel (1999, 1994), Barro and Sala-i-Martin (1995), Gwatkin (2000).

[2]The same time horizon effect can be at work in the savings decision, i.e. for the accumulation of physical capital. See for instance Chakraborty (2004).

[3]See for instance Boucekkine, De la Croix and Licandro (2002) or Soares (2005) for models with exogenous mortality, or Cervellati and Sunde (2005) and De la Croix and Licandro (2007) for endogenized mortality.

[4]At the microeconomic level, Jayachandran et Lleras-Muney (2009), Miguel and Kremer (2004) or Bleakley (2007) find a positive causal relation of life expectancy on education.

[5]Indeed, the concern of reverse causality implies to find an exogenous source of variation for life expectancy, which is particularly difficult at the macroeconomic level.

[6]Note that their aim is not to test a time horizon effect but the effect of health on economic growth. Yet, they quote the Ben-Porath effect as one of the mechanisms that would justify a causal impact of health on economic growth. Besides, it is obviously very difficult to distinguish the effects of time horizon from the effects of heath.

features and the malaria ecology indicator constructed by Sachs et al. (2004). Their estimations of the causal impact of mortality on economic growth are encouraging, but they still find no significant effect on education.

These results are critical for the theoretical research on economic growth that partly relies on the Ben-Porath effect. Besides, the absence of any Ben-Porath effect prevents from hoping for a takeoff in education in developing countries, that would be triggered by better health.

Several research works have disputed the conclusions of Acemoglu and Johnson (2007). Aghion, Howitt and Murtin (2011) have put forward that in a Nelson and Phelps (1966) framework, the initial level of life expectancy matters as much as its evolution for growth. Cohen and Soto (2004) underline that mincerian returns to education imply a convex relation between education and longevity.[7] Finally, Cervellati and Sunde (2011) show that countries at different stages of the demographic transition do not all experience the Ben-Porath effect at the same strength. All these studies put forward different elaborate theoretical explanations to suggest that we expect a lower Ben-Porath effect in countries with low levels of expected longevity than in countries with already high levels of expected longevity.

The aim of this paper is to dispute the pessimistic conclusions of previous empirical studies on the Ben-Porath effect at the macroeconomic level by putting forward a simple, countable explanation. Indeed, Acemoglu and Johnson (2006) use, as a proxy for education, the average years of schooling in the total population (above age 15).[8] This proxy measures a *stock* of schooling attainments which results from the aggregation of the *flows* of average years of schooling per cohort. In a period of transition, flows and stocks do not evolve at the same pace. The first young cohorts to experience a rise in education constitute at the beginning of the transition only a small part of the total population. Therefore the takeoff of the average years of schooling in the whole population is evidently lessened compared to the average years of schooling per cohort. This may explain why the takeoff of the *stock* of education in least advanced countries is not yet visible.

A measure of the stock of education is not the right proxy to test the Ben-Porath effect. Indeed, when life expectancy increases at time t, most people aged above 15 at time t have already completed their education, and therefore there is no reason for a *current* increase in life expectancy to have any major effect on the *current* population schooling attainments. On the contrary, the Ben Porath mechanism predicts that, when period life expectancy at birth increases at time t, *only* the cohort born at t will invest more in schooling[9]. Because of the differences in the evolution paces of the *stock* and the *flows*

[7] Mincer (1974).

[8] There exist mainly four databases for this measure: Barro and Lee (2001) and (2010), de la Fuente and Domenech (2000), Lutz, Goujon and Sanderson (2007) and finally Cohen and Soto (2007).

[9] Acemoglu and Johnson (2006) estimate the impact of an increase in life expectancy at time t on the average years of

of schooling attainments, taking the former as a proxy for education to test the Ben-Porath effect, while theoretically the latter is more suitable, may trigger misleading conclusions.

Therefore we have used the information on average years of education per age-groups from Cohen-Soto (2007) database to infer the average years of schooling per cohorts born from 1940 to 1980 in 95 countries. Using this cohort-based measure, we have then estimated the causal impact of life expectancy on education, reproducing the methodology of Acemoglu and Johnson (2007), that is to say instrumenting life expectancy as they did, thanks to the epidemiological transition of the 1940s. While their estimations, based on a stock measure, give no significant results, we find that an increase by one year of period life expectancy at birth translates into an increase of time spent at school by 0.23 year, and an increase by one year of life expectancy at 20 translates into an increase of time spent at school by up to 0.47 years.

We finally come back on the debate over the quality of the education databases. We compare our results with those obtained when the cohort-measure of education is extracted from the Barro and Lee (2010-2013) database. We argue that the quality of their measurement of education per cohort is not as satisfactory as those presented in Cohen and Soto (2007), explaining why the results obtained with their data are less significant.

Section 2 derives a theoretical model on the causal relation between life expectancy and schooling. Section 3 presents the source of the average years of education per cohorts and shows descriptive statistics on flows and stocks of education. Section 4 shows our econometric results with the methodology of Acemoglu and Johnson (2007) on a cohort measure of education. Section 5 enventually comes back to the debate over the quality of the data on schooling: it compares our results with those obtained when the cohort measure of education is extracted from Barro and Lee (2010-2013) database, or from a single census decomposed over the age structure. Section 6 concludes.

2 Motivating theory

The individual's problem is to choose her human capital investment in order to maximize the present value of her disposable earnings. She lives from 0 to$T$, her date of death with certainty, and spends the first x years studying. Assuming that schooling costs nothing, her maximisation problem boils down to:

$$max_x \int_x^T w(x)e^{-rt}dt$$

education in the working-age population at $t+10$, $t+20$ and $t+30$. Yet, the Ben-Porath effect will be underestimated even considering this leads. Indeed, the cohort born at t will enter the working-age population only at $t+20$, and even then, will be averaged in the stock measure with older cohorts whose education has been chosen before the increase in life expectancy at t.

where $w(.)$ is the wage.

The returns to schooling is a (perceived) linear function:

$$w(x) = w_0 e^{\delta(\bar{x})x}$$

in which $\delta(\bar{x})$is a decreasing function of aggregated schooling, not internalized in the decision of the individual.

The first-order condition is:

$$\delta e^{\delta x} \int_x^T e^{-rt} dt = e^{(\delta - r)x}$$

It can be written at equilibrium as:

$$e^{r(x-T)} = 1 - \frac{r}{\delta} = \mu(x)$$

The left-hand side is an increasing function of x, while the right-hand side is a decreasing function (as is δ). The equation can be rewritten as :

$$x = T + \frac{1}{r} \log \mu(x)$$

As $\mu < 1$, $\log \mu < 0$.

The relevant solution must be positive obsiously, so that education only starts for a minimum level of life expectancy:

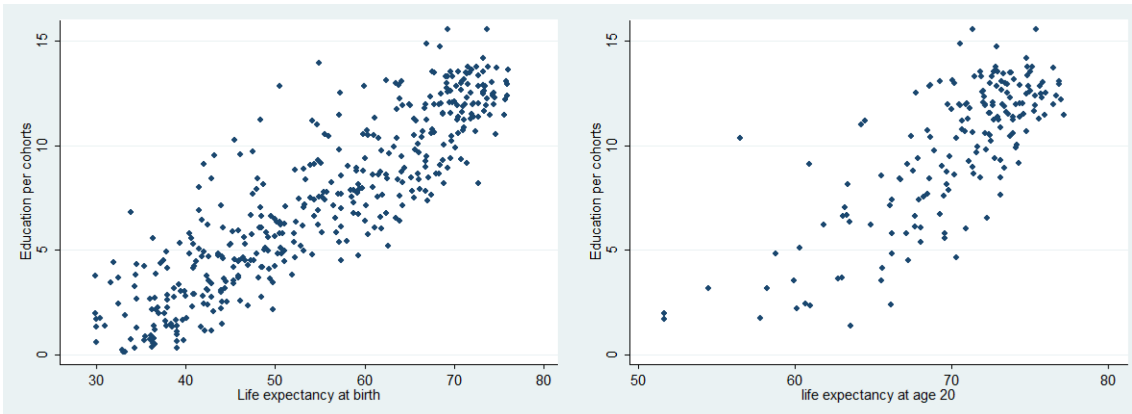
$$T > T^* = -\frac{1}{r} \log \mu(0)$$

When life expectancy is under the threshold T^*, the elasticity of schooling attainments with respect to life expectancy is simply 0. Cohen-Soto (2004) had already pointed out the existence of such a threshold, revealing a highly non-linear relationship between education attainments and life expectancy. Simply looking at the scatter plots of education per cohort and life expectancies at birth and at 20 (Figure 3), we see that the relationship between these two variables seems positive only above a certain threshold, around 30 and 50 respectively.

When $T > T^*$, we can differenciate with respect to T each side of the equation, and obtain:

$$\frac{\partial x}{\partial T} = \frac{u}{u + \varepsilon} < 1$$

Figure 1: Education per cohort and life expectancies



*Life expectancy at 20 corresponds to the expected life time horizon at 20 + 20.

in which $u = \delta - r$, and $\varepsilon = -\frac{\delta'}{\delta}$, so that in general the derivative will always be smaller than one.

We simulate the model with the following values: $r = 4\%$, $\delta = 7.5\%$, $\varepsilon = 0.05$, which is obtained by postulating that a 10 years increase in schooling reduces the returns to education by 5%, from say 12.5% to 7.5%, which corresponds to the gap between African and Scandinavian yields. This fits $X = T - x = 40$ years and delivers $\frac{\partial x}{\partial T} = 0.4$.

Clearly, the results are highly sensitive to our assumptions. They serve to give back of the envelope ideas that will appear to fit the econometric results below.

3 The question of measurement and descriptive statistics

3.1 Data

Average years of schooling per cohort

As developed in the previous section, the Ben-Porath effect states that each individual takes into account her own expected lifetime horizon to decide on the level of schooling she is willing to invest in. Hence, to test the Ben-Porath effect, we need to compare the education demands of people facing different lifetime horizons, *ceteris paribus.*[10] The average years of schooling in the population above 15 or above 25, two measures widely used, merges the schooling attainments of people who faced different life expectancies at the time when they took their schooling decisions. We therefore claim that it is not a good proxy for education to test the Ben-Porath effect. Indeed, we need a measure that

[10] We do not take into account the fact that individuals may anticipate that an education investment may increase their life expectancy.

dinstinguishes people facing different life expectancies. As life expectancy is computed at the cohort level, we have decided to use a cohort-based measure of education.

To infer this information, we use the decomposition in age groups of Cohen-Soto database (2007). Following their methodology, we make the plausible assumption that people may enroll at school until the age of 25. Hence, before a cohort turns 25, its average level of schooling attainment rises as a share of the cohort continues to go to school. But once a cohort has reached that age, its average level of schooling attainment will evolve only due to changes in its composition. Indeed, two factors may affect the composition of a cohort with respect to education attainments: mortality and migrations. Mortality is not evenly distributed over a cohort, but strikes more strongly low educated people. Therefore, as a cohort ages, its average level of schooling attainment rises, even after the cohort has turned 25. Migration rates neither are evenly distributed, but have ambiguous effects. To reduce as much as possible these two bias, we have decided to use the average years of education of people aged 25-29 or 30-34 at time t as a proxy for the schooling attainments of the cohorts born between $t-29$ and $t-25$ or $t-34$ and $t-30$[11].

As a robustness check, section 5 shows our results with alternative databases (Barro-Lee 2010-2013, and information from the most recent census) and discusses their relative quality.

Average years of education in the population aged 15 and above

To make the link between flows and stocks, and to reproduce the results of previous studies that failed to bring to light a causal link between life expectancy and education, we use the measure of the average years of education in the population aged over 15 from Cohen and Soto (2007).

Life expectancy

Life expectancy at birth is obtained from the Demographic Yearbooks published by the United Nations. From 1940, we unfortunately have information on life expectancy for a subset of only 62 countries (labelled subset 1). The appendix lists the countries comprised in each subset. Life expectancy at birth may not be the best proxy for expected longevity at the time when the education decision is taken. Indeed, it comprises child mortality, which should not be taken into account, as primary education begins after the age of 5. The Demographic Yearbooks give also life expectancy at 20 which eliminates child mortality. From 1940, we have life expectancy at 20 for a subset of 31 countries, for which we also have both measures of education, labelled subset 1B in the appendix.

[11] Because the Cohen-Soto database collects informations every 10 years, we need those two age-groups to have information for cohorts born every 5 years.

3.2 Convergence in health vs. non-convergence in education? The interest of a decomposition at the cohort level.

As already pointed out by Cohen and Soto (2004), while the discrepancies in life expectancy levels between rich and poor nations reduced since the 1940s, education levels, measured as average years of schooling in the population above 15, did not converge. Table 1 presents raw data on these two variables since 1940[12]. The difference in absolute levels of education (in the population above 15) between rich and poor countries remains between 4.03 and 4.63 years, while the difference in absolute levels of life expectancy reduced continuously from 20 years in 1940 to 9.1 years in 2000.

Table 1: Life expectancy and schooling in the working age population.

	1940	1950	1960	1970	1980	1990	2000
Education in the population above 15							
Rich countries[1]	6.56	6.92	7.79	8.65	9.55	10.28	10.93
Developing countries[2]	2.17*	2.54*	3.25	4.02	4.96	6.02	6.90
Difference rich/developing	*4.39*	*4.38*	*4.54*	*4.63*	*4.59*	*4.26*	*4.03*
Life expectancy at birth							
Rich countries[1]	61.10	67.75	70.14	71.77	74.15	76.18	77.71
Developing countries[2]	41.40*	49.34*	53.05	58.20	62.50	66.50	68.61
Difference rich/developing	*20.0*	*18.41*	*17.09*	*13.57*	*11.65*	*9.68*	*9.1*

[1]Rich countries are 21, listed in subset 1 (see appendix)

[2]Developing countries are 32 in 1940 and 1950, and 41 from 1960, listed in subset 1 (see appendix).

Yet, improvements in health should have an impact on the demands of education of people in age of going to school. These people enter the stock measure we use with a delay of 15 years, and are then averaged with older and less educated cohorts. That is why, as advocated before, we rather look at a cohort-based measure of education.

In a period of transition, cohorts and stocks are not likely to evolve at the same pace. At the beginning of the take-off, the schooling attainments of young cohorts evolve quickly. But in the stock measure of education, these young cohorts are averaged with older ones for which education is close to zero. Hence the stock measure evolves at a slower pace. At the end of the transition, on the contrary, the level of education of younger cohorts improves at a much slower pace. The stock measure catches up with the cohort measure, as older and less educated cohorts die. Figure 2 illustrates this idea presenting the stock and cohort measures of a developing country, Algeria, and a rich country, Sweden. Figure 2 shows that the trends of the relation between education and life expectancy are very different in these

[12]Education data for 1940 and 1950 are taken from Morrisson and Murtin (2009), who augmented Cohen and Soto (2007) database with the same methodology. It reduces our subset of 62 countries to 53 countries.

two countries, according to the proxy used for education.

Figure 2: Stock and cohort measures of education.

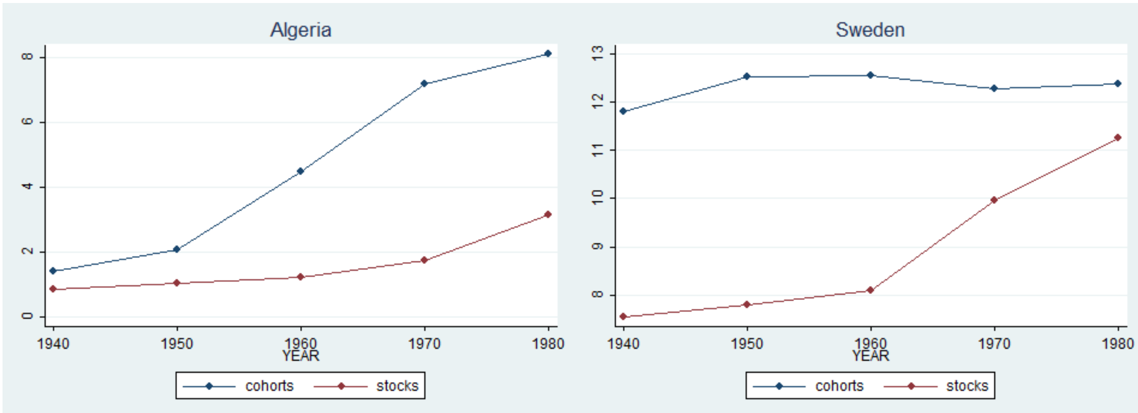
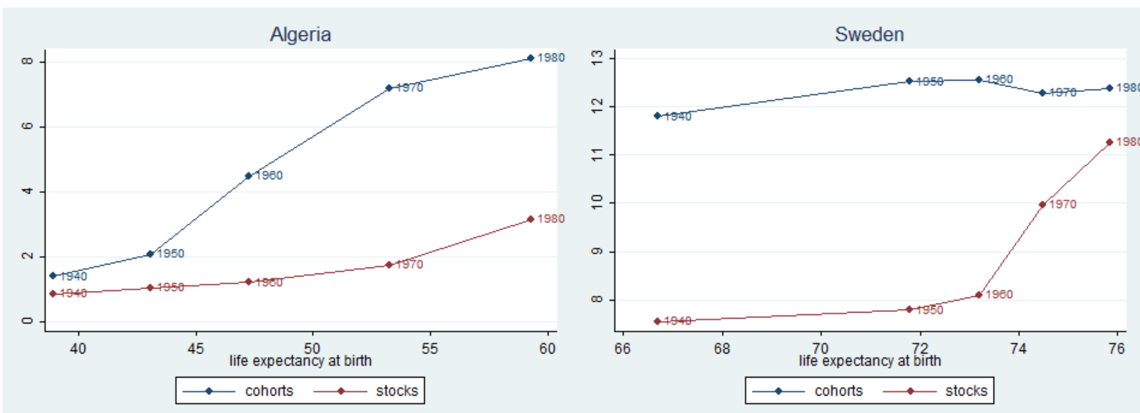


Figure 3: Education and life expectancy at birth. Stock vs. cohort measures.



Not surprisingly, Table 2 shows that at the cohort level, the discrepancy in schooling attainments between rich and developing countries reduced in absolute levels, from 6.03 years, for the cohort born in 1940, to 3.37 years for the cohort born in 1980.

Table 2: Life expectancy and schooling per cohort.

	1940	1950	1960	1970	1980
Education per cohort born in					
Rich countries	10.30	11.22	11.68	12.21	12.60
Developing countries	4.27	5.41	6.94	8.09	9.23
Difference rich/developing	*6.03*	*5.81*	*4.74*	*4.12*	*3.37*
Life expectancy at birth					
Rich countries	61.10	67.75	70.14	71.77	74.15
Developing countries	40.85	48.61	53.05	58.20	62.50
Difference rich/developing	*20.25*	*19.14*	*17.09*	*13.57*	*11.65*

Rich and developing countries are respectively 21 and 41, listed in subset 1 (see appendix).

The difference in the evolutions of the stock and the cohort measures have important implications with respect to the impact of life expectancy on education. As shown in Table 3, for the stock measure, the ratio of variation of education over variation of life expectancy is twice bigger in rich countries than in developing countries. But for the cohort measures, the trends are close, and around 0.2.

Table 3: Variation of education / variation of life expectancy. 1940-1980.

	Stock measure	Cohort measure	Number of countries
Rich countries	0.28	0.20	21
Developping countries	0.13	0.23	32

Hence estimating this ratio with the stock measure may bury the Ben-Porath effect since it is likely to be low in developing countries.

4 Econometrics

Now that we have shown descriptive statistics on the difference of the evolution between the stock measure and the cohort measure of education, we reproduce the empirical tests of the Ben-Porath effect conducted by Acemoglu and Johnson (2006), with the latter measure.

4.1 OLS estimates

Table 4 reports OLS regressions of average years of schooling per cohort (denoted "cohorts") and average years of schooling in the population above 15 with a 20-year lead (denoted "stocks")[13] on life

[13] Acemoglu and Johnson (2006) regress education with a 10 to 30-year lead on life expectancy, arguing that life expectancy should trigger an education increase with a delay. We reproduce here only regressions on the measure with a 20-year lead, but taking a 10-year lead, 30-year lead, or no lead does not change our results, as in Acemoglu and Johnson (2006).

expectancy at birth or at 20. Country and year fixed effects are included in all regressions, so that all estimates exploit only the within-country variation. Standard errors are clustered by countries. We use, from subsets 1 and 1B, panels of 62 and 31 countries respectively, with observations at 10 year intervals between 1940 and 1980[14].

We notice that the estimated coefficients on life expectancy at birth and at 20 are positive and significant for the cohort measure, while they are small for the stock measure, and insignificant for life expectancy at 20. Moreover, the estimated effect of life expectancy at 20 is much higher than the estimated effect of life expectancy at birth on schooling per cohort (0.323 for the latter against 0.134 for the former). Life expectancy at 20 does not comprise infant mortality, which should not be taken into account for schooling decision.

These simple OLS estimates support the interest of using a cohort measure of education. Indeed, they show that no correlation between education and life expectancy appears when using the stock measure, while it does when using the cohort measure. Yet, as the relation between life expectancy and education attainments presents obvious endogeneity issues[15], we follow in the next subsection Acemoglu and Johnson (2006) who propose an instrumentation of life expectancy.

Table 4: OLS estimates for cohorts and stocks. Panel 1940-1980.

	(1)	(2)	(3)	(4)
	Cohorts	Cohorts	Stocks[1]	Stocks[1]
Life expectancy at birth	0.134***		0.0360***	
	(0.0302)		(0.0111)	
Life expectancy at 20		0.323***		0.0151
		(0.0698)		(0.0298)
Observations	310	143	310	143
Countries	62	30	62	30
R-squared	0.955	0.961	0.985	0.987

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1
Countries are listed in subsets 1 and 1B (see appendix)
[1]Stocks with a 20 years lead

4.2 Instrumentation

We apply the Acemoglu and Johnson (2006) methodology to instrument life expectancy at birth and at 20. Their empirical strategy is to use the exogenous variation in mortality triggered by the international

[14]Beside their panel regressions, Acemoglu and Johnson (2006) also regress all their variables of interest on life expectancy using only the years 1940 and 1980. They argue that this second approach is "less vulnerable to problems caused by serial correlation in the error term" and may give better results if changes in life expectancy affect education only in the long-run. We have not shown our results when using only 1940 and 1980, since they do not change our conclusions (as in Acemoglu and Johnson, 2006), but they are available on demand.

[15]Reverse causality is at work. Kitagawa and Hauser (1973), Strauss and Thomas (1995), Schultz (2007), or Cutler et al. (2008), for instance, look at the causal impact of education on life expectancy. We may also think of omitted variable biases: richer countries may invest more both in health and education.

epidemiological transition around 1940 due to global drug innovations (and more particularly the discovery of penicillin), the discovery of DDT, and the establishment of the World Health Organization. More precisely, they construct an instrument for life expectancy, the predicted mortality instrument in the following way:

$$M_{it}^{I} = \sum_{d \in D} ((1 - \Delta_{dt}) M_{di40} + \Delta_{dt} M_{dFt}$$

where M_{dit} denotes mortality in country i from disease d at time t, Δ_{dt} is a dummy for intervention for disease d at time t (equal to 1 for all dates after the intervention), D includes 15 diseases. M_{di40} refers to the pre-intervention mortality from disease d in country i and M_{dFt} refers to mortality from disease d at the health frontier of the world at time t. The only source of variation of the instrument comes therefore from the interaction of the baseline distribution of diseases with global intervention, and is unrelated to any actions or economic events in the country. Acemoglu and Johnson (2006) find a positive effect of life expectancy on population, but no effect on GDP, GDP per capita and human capital, measured by average years of schooling in the whole population (using the Barro and Lee dataset).

Table 5 shows the first-stage regressions for our panels from subsets 1 and 1B of 62 countries for life expectancy at birth and 31 countries for life expectancy at age 20 respectively. Country and year dummies are again included. The coefficients are respectively between -8.998 and -6.194 and significant at the 1% level. Hence the predicted mortality variable, built by Acemoglu and Johnson (2006), is still a good instrument for our panels.

Table 6 reports the reduced form regressions for average years of schooling per cohorts ("cohorts") and average years of schooling of the population above 15 with a 20-year lead ("stocks"). As in the OLS regressions, time and countries fixed effects are included, and standard errors are clustered by countries. For the cohort measure, the coefficients on life expectancy at birth and at 20 are significant at the 1% level, and higher than in the OLS regressions: 0.230 and 0.407 respectively. The coefficients estimated with the stock measure of education are small and insignificant.

Table 5: First stage. Panel 1940-1980.

	(1)	(2)
	Life expectancy at birth	Life expectancy at 20
Predicted mortality	-8.998***	-6.194***
	(2.768)	(1.505)
Observations	310	179
Countries	62	30
R-squared	0.945	0.922

Table 6: 2SLS estimates for cohorts and stocks. Panel 1940-1980.

	(1)	(2)	(3)	(4)
	Cohorts	Cohorts	Stocks[1]	Stocks[1]
Life expectancy at birth	0.230***		0.0370	
	(0.0767)		(0.0348)	
Life expectancy at 20		0.407***		-0.0194
		(0.147)		(0.0600)
Observations	310	143	310	143
Countries	62	30	62	30
R-squared	0.949	0.959	0.985	0.986

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1
Countries are listed in subsets 1 and 1B (see appendix)
[1]Stocks with 20 years lead

This reveals that, while we do not see any significant effect from life expectancy on education if we consider the stock measure, the effect is both significant and high for the cohort measure. Indeed, we estimate that a share of 20% to 23% of each year of life expectancy at birth gained is spent at school, and a share of 40% of each year of life expectancy at 20 gained (which excludes gains due to the decrease of infant mortality, that has no effect on education).

4.3 Aghion et al. (2011) specification

Finally, we come back to the argument presented by Aghion et al. (2011) against Acemoglu and Johnson (2006). Aghion et al. (2011) have made the point that in a growth model *à la* Nelson-Phelps (1966), the initial level of life expectancy should matter as much as the first difference for economic growth[16]. Therefore they introduce the initial level of life expectancy in the regressions run by Acemoglu and Johnson (2006). To that aim, they have used as additionnal instruments the 16 climatic and geographical variables used by Lorentzen, McMillan and Wacziarg (2008).[17]

[16]Indeed, in that model, the *evolution* of the productivity parameter in the per capita GDP equation depends on the level of human capital, whether in the Lucas (1988) framework, it is the *level* of the productivity parameter that depends on the level oh human capital.

[17]These variables are: the malaria ecology index by Sachs et al. (2004), eleven climate variables borrowed from the Koeppen-Geiger climate zones classification (tropical rainforest climate, its monsoon variety, tropical savannah climate, steppe climate, desert climate, mild humid climate with no dry season, mild humid climate with a dry summer, mild

Given that they were interested only in growth, Aghion et al. (2011) did not test their results on education. We apply here their framework to estimate the impact of both the *change* of life expectancy and of the *initial level* of life expectancy on the evolution of schooling attainments. Table 7 shows the 2SLS estimates with their specification both for the stock and the cohort measures of education[18].

Table 7: Aghion et al. (2011) specification. Panel 1940-1980.

	(1)	(2)	(3)	(4)
	Cohorts	Cohorts	Stocks[1]	Stocks[1]
Life expectancy at birth	0.207***		0.156***	
	(0.0140)		(0.0110)	
Initial life exp. at birth	0.0612***		0.0665***	
	(0.0114)		(0.00894)	
Life expectancy at 20		0.384***		0.321***
		(0.0382)		(0.0360)
Initial life exp. at 20		0.0864***		0.0801***
		(0.0279)		(0.0263)
Observations	300	143	300	143
Countries	60	30	60	30
R-squared	0.948	0.967	0.960	0.957

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1
Countries are listed in subsets 1 and 1B (see appendix), but Myanmar and Mauritius are excluded because we do not have the additionnal instruments for these two countries.
[1]Stocks with 20 years lead

Regarding the stock of education, adding the initial level of life expectancy does change dramatically the significance of the results. The coefficients on the *change* of life expectancy are now significant at the 1% level, as well as the *initial level* of life expectancy on the 20-lead stock of education. Regarding the cohorts, the coefficients on the *change* of life expectancy at birth remains essentially identical to those found previously both for life expectancy at birth and at 20 (respectively 20.7% and 38.4%). Yet, the *intial levels* are also significant at the 1% level. What is remarkable is that the order of magnitude regarding stocks and cohorts are now noticeably similar. One explanation is that controlling for the level as well as the change of life expectancy allows to track for the non linearities exhibited in the previous sections. As a test (not reported here), we tried a log-log formulation for stocks, and the significance of initial levels falls down dramatically. The fact that the introduction of the initial level of life expectancy, at birth or at 20, does not affect our results (nor the significance, nor the magnitude of the coefficients) when the dependent variable is the education per cohort gives us confidence that

humid climate with a dry winter, snowy-forest climate with a dry winter, snowy-forest climate with a moist winter and highland climate), a variable measuring the proportion of land with more than five days of frost per month in winter, and finally the distance of a country's centroid from the equator, the mean distance to the nearest coastline, the average elevation, and the logarithm of land area.

[18]Introducing the initial level of life expectancy prevents from controlling for both country and year fixed effects. For a better comparison with our previous results, we have chosen to test a within-country variation and introduced country-fixed effects in the regressions. To alleviate the presentation, we have not displayed the results of OLS regressions, but they are close to those of the 2SLS regressions and available upon request.

they are indeed robust to change of specification.

5 Quality of the data

Let us now return to the debate over the quality of education databases. To extract a cohort measure of education, the alternative database to Cohen and Soto (2007) is Barro and Lee (2010-2013), since they have augmented their previous database (Barro and Lee, 2001) with 5-year age groups, following the methodology of Cohen and Soto (2007). To check the robustness of our results and the quality of our measurement, we have therefore reproduced our regressions on the cohort measure derived from Barro and Lee (2010-2013), labelled "BL" in Tables 8 and 9[19]. The results of the 2SLS regressions - both if we take the intersection of countries for which we have all measures, which restricts the sample to 50 countries, or if we take the whole subset for which we have the Barro and Lee measure [20] - are disappointing[21][22]. Why is there such a difference in the results when using the Barro-Lee database?

At first sight, Barro-Lee (2010-2013) rely on the methodology of Cohen-Soto (2007)[23]. They use censuses with a decomposition by five-year age groups, and, for years for which they have no census, they extrapolate or retropolate the informations of these censuses the following way: making the assumption that a cohort stops to go to school after it has reached the age of 25, and ignoring the mortality bias and the migration bias, it is possible to infer the education of all age-groups above 35 at time $t+10$ from a census conducted at t. Moreover, it is possible to infer from a census conducted at t education of most age-groups at time $t+5n$ or $t-5n$ (n is an integer). Only younger groups, who have not finished their schooling at t, are missing when extrapolating, and older groups, who are already dead at t, when retropolating. The average years of schooling attainments of these young and

[19]We have not reproduced the regressions on the stock measure from the Barro and Lee (2010-2013) database. The coefficients are also small and insignificant, as with the Cohen-Soto (2007) database.

[20]We have not reported the first stage regressions for the subsets of countries of Tables 8 and 9, but the instrument is still of good quality for these subsets. Similarly, we have not reported OLS regression results, but they are similar to the 2SLS regressions.

[21]Here we have included all countries in the Barro-Lee (2010-2013) database for which we have the "predicted mortality" instrument. The sample contains 71 and 32 countries respectively for life expectancy at birth and life expectancy at 20 which are listed in the appendix as "subset 2 and 2B". We have also reproduced the OLS and 2SLS regressions on the Barro-Lee measure, but for the countries of sample 1 and 1B, for better comparison with the Cohen-Soto measure. The results are not presented here, but are not very different from those of samples 2 and 2B.

[22]Hansen (2012), who has also estimated the causal impact of life expectancy on education per cohort, using Acemoglu and Johnson methodology, reports similar results to ours when using the Cohen-Soto database, while he specifies that he extracted his cohort measure from the Barro-Lee database. Yet, he used the 15-19 age group, who have not finished their education. These results are not robust to changing the reference age group: extracting the cohort measure from the 20-24, 25-29, 30-34 age groups leads to low and insignificant estimates of the causal impact of life expectancies on education per cohort.

[23]Indeed, Barro-Lee (2010-2013) augments Barro-Lee (2001) incorporating the critics of Cohen and Soto (2007), who were the first to propose a database differenciated over the age structure. The decomposition in 5-year age groups enables to make much more precise extrapolations and retropolations of the censuses informations. Extrapolations and retropolations in Barro-Lee (2001) did not take into account the fact that mortality is not evenly distributed on the different age groups.

old groups are estimated with enrollments in primary, secondary and terciary education, duration of these levels in each country, repetition rates and dropout rates, according to the methodology of Cohen and Soto (2007).

But Barro and Lee (2010-2013) and Cohen and Soto (2007) diverge in the application of this shared methodology. Indeed, Barro and Lee (2010-2013) rely on as many censuses as they can to build their database of 10 points between 1950 and 2010: 3.5 censuses in average for each country - and as much as 8 to 10 censuses for some countries. On the contrary, Cohen and Soto (2007) use only a few censuses for each country and derive much of their informations from enrollments[24]. We state that estimations from the enrollment rates are likely to be more precise with respect to the construction of a cohort measure, and that informations should not be taken from many different censuses to construct a good quality measure at the cohort level. Indeed, while there must be noise between censuses conducted at two different points in time, data within one census are homogenous. Suppose that the reported schooling attainments $s_{i,t}$ for age-group i in a census conducted at time t takes the following form:

$$s_{i,t} = s_{i,t}^R + e_{i,t} + e_t$$

where $s_{i,t}^R$ is the real value of schooling attainment of age-group i, $e_{i,t}$ the measurement error specific to age-group i in this census, and e_t the general measurement error linked with the time at which the census has been conducted, and which is equal for all age-groups. In this case, the measurement error of the difference between schooling attainments of two cohorts taken from one age-group i in two different censuses at t and t' is $e_{i,t} - e_{i,t'} + e_t - e_{t'}$, while the measurement error of the difference between schooling attainments of the same two cohorts taken grom two age-groups in a single census at t is lower: $e_{i,t} - e_{i,t'}$.

Because of a wider use of informations from enrollments, and the choice of fewer censuses per country, we state that the measure derived from Cohen and Soto (2007) is of better quality. To test this hypothesis, we have also constructed a cohort measure from a *single* census: the most recent one. Because of the mortality bias, the measure should overestimate the education of older age-groups, that is to say of cohorts born at the beginning of the period considered. Therefore, the trend of the evolution of education with respect to life expectancy is underestimated. Yet, Tables 8 and 9 shows that this alternative measure (labelled "CL") gives positive and significant results, even if they are not as high as those obtained with the measure derived from Cohen and Soto (2007).

[24]The Barro-Lee update of April 2013 incorporates more information from enrollments, but only for young groups aged 15-19 and 20-24 who have not completed their education.

Table 8: 2SLS regressions on altervative databases. Intersection.

	(1)	(2)	(3)	(4)	(5)	(6)
	CS	CS	BL	BL	CL	CL
Life expectancy at birth	0.195**		0.115		0.150**	
	(0.0736)		(0.0797)		(0.0615)	
Life expectancy at 20		0.583**		0.333		0.355*
		(0.247)		(0.234)		(0.199)
Observations	100	58	100	58	100	58
Countries	50	29	50	29	50	29
R-squared	0.959	0.933	0.937	0.922	0.959	0.957

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

The quality of a cohort measure database is higher when using fewer censuses and informations from enrollments.

Table 9: 2SLS regressions on altervative databases. All observations

	(1)	(2)	(3)	(4)
	BL	*BL*	*CL*	*CL*
Life expectancy at birth	0.0266		0.137**	
	(0.0525)		(0.0544)	
Life expectancy at 20		0.135		0.290*
		(0.116)		(0.145)
Observations	355	153	280	148
Countries	71	32	56	31
R-squared	0.935	0.935	0.959	0.967

Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1
Countries of the BL dataset are listed in subsets 2 and 2B (see appendix)

Countries of the CL dataset are listed in subsets 3 and 3B (see appendix)

6 Conclusion

This article contributes to the debate over why previous macroeconomic studies testing the impact of life expectancy on education, such as Acemoglu and Johnson (2006) and Lorentzen, Mc Millan and Wacziarg (2008), did not find any significant effect. Other papers have answered this question arguing over the specification of the functional relation between those two variables, or between life expectancy and growth, or other factors of growth.

We do agree that the debate over the specification of the relation is eventually important, but we clarify why it is so with a simple accounting explanation. Indeed, previous studies use as a proxy for education the average years of schooling attainments of the population aged above 15. Therefore, they measure a stock of education, which aggregates people facing different life time horizons, and who have completed for most of them their education. This measure is likely to react only indirectly to changes in longevity.

On the contrary, Ben-Porath (1967) - the seminal paper modelling the education investment decision as a function of life time horizon - predicts that when life expectancy increases, only the cohort facing that new life horizon should increase its human capital investment. To test the Ben-Porath effect, we therefore need to compare education decisions of people facing different life expectancies, *ceteris paribus.* That is why we have derived a cohort based measure of education from Cohen and Soto (2007) database on education. Such a measure enables to compare education between cohorts, that is to say of people who have faced different expected life time horizons when they took their schooling decisions.

We have indeed reproduced the estimations of Acemoglu and Johnson (2006) with our cohort-based measure: we have used their instrument for life expectancy, based on the changes due to the epidemiological transition of the 1940s. When taking the average years of schooling per cohort as a proxy for education, we find a positive and significant impact of life expectancies at birth and at 20, of respectively 23% and 40.7%.

The causal impact of life expectancy on schooling per cohorts will eventually pass through to the stock of education in the economy. But during the transition period from a low-educated to a high-educated economy, the stock of education in the population above 15 evolves non-linearly. This is due to the existence of a threshold of life expectancy under which the Ben-Porath mechanism is not at work, and to changes in the age structure of the population. That is the reason why linear estimations fail to bring out the causal impact of life expectancy on the stock of education. On the contrary the specification proposed by Aghion et al. (2011), that is to say the introduction of the initial level of life expectancies as a control, reveals a positive and significant effect of life expectancies also on the *stock* measure of education, of a magnitude comparable to the magnitude of the effect on the cohort measure of education.

In a nutshell, our results suggest that a takeoff of education investments is at work in developing countries. Life expectancy causes a linear increase of education per cohort, above a certain threshold, that eventually translates into an increase of the stock of education in the working-age population, which is a determinant of economic development.

Finally, we contribute to the debate over the quality of the data on education: we argue that, for a good quality *cohort-based measure* of education, the use of too many censuses is prejudicial (as in Barro and Lee 2010-2013). On the contrary, we advocate for a parsimonious use of censuses, and a wider use of enrollment rates.

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7 Appendix

7.1 Subset 1 and 1B (respectively 62 and 30 countries from Cohen-Soto database)

Subset 1 comprises 62 countries, out of which 21 are "rich" and 41 are "developping".

Rich: Australia, Austria, Belgium, Canada, Switzerland, Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Ireland, Italy, Japan, Netherlands, Norway, New Zealand, Portugal, Sweden and the United States.

Developing: Algeria, Argentina, Bangladesh, Bulgaria, Bolivia, Brazil, Chile, China, Colombia, Costa Rica, Dominican Republic, Ecuador, Egypt, El Salvadore, Guatemala, Guyana, Haiti, Honduras, Hungary, India, Indonesia, Iran, Iraq, Jamaica, Korea, Malaysia, Mauritius, Mexico, Morocco, Myanmar, Nicaragua, Panama, Peru, Philippines, Paraguay, Romania, Thailand, Tunisia, Uruguay, Venezuela, and South Africa.

Subset 1B comprises 30 countries, out of which are 20 "rich" and 6 are "developping".

Rich: the same as in subset 1, except for Japan.

Developing: Argentina, Bangladesh, Chile, Guatemala, Hungary, India, Korea, Mexico, Panama, Thailand.

7.2 Subset 2 and 2B (respectively 71 and 32 countries from Barro-Lee database)

Subset 2 comprises 71 countries out of which 22 are "rich" and 49 are "developing".

Rich: As in subset 1, plus Iceland.

Developing: As in subset 1, except Dominican Republic, plus Belize, Barbados, Czech Republic, Sri Lanka, Pakistan, Poland, Russian Federation, Trinidad and Tobago, Vietnam.

Subset 2B comprises 32 countries out of which 20 are "rich" and are 12 "developing".

Rich: As in subset 1B.

Developing: Argentina, Bangladesh, Chile, Czech Republic, Guatemala, Hungary, India, Korea, Mexico, Panama, Poland, Thailand.

7.3 Subset 3 and 3B (respectively 56 and 31 countries from Cohen-Leker database)

Subset 3 comprises 56 countries out of which 22 are "rich" and 34 are "developing".

Rich: As in subset 2.

Developing: Argentina, Bangladesh, Bulgaria, Bolivia, Brazil, Barbados, Chile, China, Colombia, Costa Rica, Czech Republic, Algeria, Ecuador, Guatemala, Hungary, Indonesia, Iran, Jamaica, Korea, Mexico, Mauritius, Malaysia, Pakistan, Panama, Peru, Philippines, Poland, Paraguay, Russian Federation, El Salvador, Thailand, Tunisia, Uruguay, South Africa.

Subset 3B comprises 31 countries out of which 20 are "rich" and 11 are "developing".

Rich: As in subset 1B.

Developing: Argentina, Bangladesh, Chile, Czech Republic, Guatemala, Hungary, Korea, Mexico, Panama, Poland, Thailand.