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A NOTE ON THE CAUSALITY BETWEEN HEALTH AND EDUCATION[1]

ABSTRACT. Using a panel data approach we investigate whether schooling causes health or health causes schooling. We found evidence that supports the influence of the level of health in increases in education and the influence of education growth in health improvements. This means that a healthier population enhances education growth and growth in education facilitates further growth in health. We have also concluded that the channel from health to education is stronger than the channel from education to health.

***JEL Classification**:* I00, J24, O15, O50

Keywords: economic growth, education, health.

Introduction

There are three main reasons to be concerned with causality between education and health. First, both health and education may simply be outcomes of a separate cause such as time preference which causes a correlation but not causality. Second, education may affect health by improving the productivity of health services or by improving healthy habits. Third, poor health early in life limits educational attainment while poor health on the job may limit training and wage growth (for a survey on these reasons and on theories linking education to health, see Hunt-McCool and Bishop, 1998). However, the relative importance of each direction of causality is not yet clear.

Macroeconomic theory has focused on human capital accumulation as dependent on health and demographic features. Zhang *et al.* (2001, 2003) and Kalemli-Ozcan *et al.* (2000) assumed that a decrease in the mortality rate and the simultaneous decrease in fertility tend to increase parental investment in each child. Bloom, Canning and Sevilla (2001) and Cropper (2000) argue that the mortality rate is correlated with the health status of the population and thus a decrease in mortality triggers increases in the human capital quality and thus accumulation of human capital becomes more productive. Meltzer (1992) and Preston (1980) estimate that a high mortality rate reduces expected value of future returns from education. Most recently, Acemoglu and Johnson (2006) found a significant impact of life expectancy on fertility but no impact of life expectancy on schooling. This may be explained by the argument that increasing life expectancy increases both the returns to quality (human capital)

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and the returns to quantity (number of children), which Hazan and Zoabi (2006) call the "neutrality result". These studies analyzed the causality from health to education. As can be seen, however the magnitude of the empirical relationship is still controversial.

Moreover one can also think that education improves the health status of the population. Lleras-Muney and Cutler (2006) suggest that education influences both health "gradient" and health status because higher levels of education lead to different thinking and decision-making patterns. Both evidence and theories on the inverse causality are more recent and rare. For instance, Arendt (2005) uses a panel data analyses using school reforms in Denmark for identification but the analysis on the effect of education on health "remain inconclusive". Tamura (2006) found positive effects of education on adult survival and also positive influence of health on education, between 1850 and 1990 for a sample of 92 countries. Tamura estimates a non-linear relationship between mortality and education that comes from his own theoretical model and confirms the model prediction that education decreases mortality. He also estimates a fixed-effects regression that explains years of young adult schooling with different measures of mortality. He concludes that infant mortality, young adult and adult mortality decreases education, which is consistent with his theoretical model, except for the result on infant mortality.

Most of the empirical studies dealing with the relationship between health and education are micro- or country-level studies (with the remarkable exceptions of Acemoglu and Johnson, 2006 and Tamura, 2006). We can expect somewhat different results from those that have been obtained by micro studies. To mention some examples, at the macro level, the effects could be a result of aggregation bias, or that there are social-group wise-peer explanations at work at the macro level, beyond the individual level.[2] We contribute to the discussion with a cross-country study at the macro level, thus emphasizing the second aspect. We add to the literature the evaluation of causality between health and education, controlling for income in a broad cross-section of nearly one hundred countries, addressing the differences between poor and rich countries and using dynamic panel data methods that control for different types of endogeneity, namely simultaneity bias, omitted variables and measurement errors. Most studies use educational output variables without considering the quality of that output. We also innovate in considering a education variable that is weighted by a quality measure. Our results tend to confirm the causality from health to education growth and the causality from education growth to health growth.

The paper follows with a description of the empirical model in Section 2. In Section 3, we address the question of causality from health to education and in Section 4 we address the question of causality from education to health. We divide each of Sections 3 and 4 in two: one that describes the specification search and another that presented selected specifications. Finally we conclude in Section 5.

1. Empirical model

1.1. Data on education and health

We distinguish two different indicators of Education (which we name as H^u): the first indicator measures the quantity of schooling (years) in total population above 15 years old (*tyr*) and the second weights this quantity with a quality measure from Hanushek and Kimko (2001) (*tyrq*).[3] As a proxy for health (which we name as H^e), we use life expectancy, because

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2 We thank this note to an anonymous referee.

3 We use the first quality measure (QL_1) presented in Hanushek (2001). A measure of years of secondary school was also tested (in particular in rich countries), but as results did not differ significantly, we do not report them.

it is widely used and is the mostly available proxy for health. To control for family or society background when explaining schooling, we introduced income, measured by real *per capita* GDP using the chain index and adult education, measured by total years of primary education in total population above 25 years old. These variables were also used by Barro and Lee (2001) for the same purpose. Years of Education comes from the Barro-Lee (2000) database, Life Expectancy comes from World Development Indicators and GDP comes from the Penn World Tables 6.1. Our departure database is thus the Barro-Lee database with 138 countries and variables measured in five-year intervals from 1960 to 2000 (9 periods). A complete list of measures and sources is in *Table 1*. A list of countries used in regressions presented below is found in the Appendix B. In the next sub-section we briefly describe the data.

Table 1. Definition of variables

	Measure	**Source**
	Education Variables (H^u)	
tyr	total years of education in pop. above 15 [1]	Barro-Lee (2000)
$tyrq = tyr \times (QL_1)$	The last weighted by a measure of quality	Barro-Lee (2000) and HK (2001)
	Health Variable (H^e)	
Life Expectancy	Life Expectancy at birth [2]	WDI
	Society Background	
Log(*GDP*)	Real Chain Index GDP per capita	PWT
Adult Education	Primary Years of Education in pop. above 25 [3]	Barro-Lee (2000)

Abreviations: WDI – World Development Indicators Database, World Bank (2004); PWT – Penn World Table, Summers and Heston (2002); HK – Hanushek and Kim (2001).

Detailed Definitions of Variables:
1. *tyr*: Average total years of schooling in the total population above 15 years old.
2. Life expectancy at birth indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life.
3. *pyr*: Average years of primary schooling in the total population above 25 years old.

1.2. Descriptive statistics and correlations

Table 2 shows descriptive statistics on the variables used.

Table 2. Descriptive statistics

	N	**Average**	**S.D.**	**Min.**	**Max.**
		Education Variables (H^u)			
tyr	937	4.803	2.846	0.086	12.049
tyrq	734	0.254	0.155	0.006	0.615
		Health Variable (H^e)			
Life Expectancy	1066	59.2895	12.3193	31.8146	80.2466
		Society Background			
Log(*GDP*)	1000	8.146	1.054	5.717983	10.537120
Adult Education	930	3.134	1.817	0.023	7.667

The next table shows correlations between the dependent variables and the covariates used in the panel database. From these figures, we conclude that there is a strong positive association between income, adult education, life expectancy and schooling growth. However we cannot infer anything about causality.

Table 3. Correlations

$H^u_{j,i,t}$:	*tyr*	*tyrq*
	$H^e_{i,t}$: Health Variable	
Life Expectancy	0.87***	0.78***
	Society Background	
$Log(GDP)$	0.85***	0.81***
Adult Education	0.94***	0.88***
*** stands for a 1% significance level.		

1.3. Specification

We use the Dynamic Panel Data system estimator developed by Arellano and Bover (1995) and Blundell and Bond (1998). Compared with the single cross-section analysis, the panel data analysis increases the regressions' degrees of freedom due to the increased number of observations and, as a GMM method, it is robust to the presence of country-specific effects and other possible sources of endogeneity, such as omitted variables, measurement errors and causality. It is worth noting that as an instrumental variables estimator it is robust to time-varying sources of endogeneity, and as a first-differenced estimator it is also robust to fixed-effects. This is quite important in this context, as Hanushek *et al.* (1996) argued that aggregation implies a significant upward omitted variables bias, linked namely with different institutions and policies throughout countries. Given the properties of this estimator, we believe we are correcting for the problem. The use of this estimator is also extremely important due to our emphasis on causality, as it is also robust to the simultaneity bias.[4]

We estimated the following benchmark equations:

$$H^u_{i,t} = \alpha_0 + \alpha_1 H^u_{i,t-1} + \alpha_2 \log(GDP)_{i,t} + \alpha_3 H^e_{i,t-j} + v_i + \varepsilon_{i,t} \quad (1)$$

$$H^e_{i,t} = \beta_0 + \beta_1 H^e_{i,t-1} + \beta_2 \log(GDP)_{i,t} + \beta_3 H^u_{i,t-j} + u_i + \xi_{i,t} \quad (2)$$

with $i = 1,...,N$ being the number of countries, t = 65..,2000 the time periods, j = 1,2 the lag structure for health in (1) and education in (2), v_i and u_i are the country-specific effects. We use two variables for schooling (H^u): *tyr* and *tyrq*, and one for health (H^e): life expectancy (*LE*). For each *t*, GDP per capita and life expectancy are measured in the preceding five-year period (e.g. for 1965, $GDP_{i,t}$ and $H^e_{i,t}$ are the average between 1960 to 1964). Due to limited data for life expectancy prior to 1960 we use only eight periods from 1965 (corresponds to 1960 to 1964 in GDP and life expectancy) to 2000 (corresponds to 1995 to 1999 in GDP and life expectancy). For schooling variables (H^u), we use years of schooling on population above 15 years old (*tyr*) and a quality-weighted measure of total years of schooling (*tyrq*). Both equations use GDP in logs as a control and a complete set of time dummies.

This benchmark specification for equation (1) is based in previous literature on the determinants of Education. As most previous micro-studies mention family background as the

4 Because of its properties it has been suggested by Temple et al. (2001) for use in empirical economic growth studies, where causality is also a very important issue, as explained by those authors. It is appropriate for panels with a small time-series (*T*) and a relatively higher cross-section (*N*) dimension (*N*>*T*), which is the case of this one. Alternative approaches, such as panel cointegration techniques were only appropriate for a higher availability of the time-series dimension of the database (*T*).

main determinant of school performance (Hanushek, 1986, 2003) and Barro and Lee (2001) refer to family background and proxied it by GDP and Adult Education, equation (1) also includes Adult Education (*AE*) as a control in some specification exercises. The specification in equation (2) uses education and income as determinants of health, also inspired by previous literature. While in Tamura (2006) the only determinant of health is education and most theoretical models see health or mortality transition as exogenous (e.g. Lagërlof, 2003 sees it as a result of epidemic shocks), some recent articles explain mortality and demographic transition as a result of economic transition and economic integration (e.g. Strulik, 2000 and MacDermont, 2002). We therefore add GDP as a possible determinant of life expectancy evolution.

As the aim of the paper is to find robust specifications that link education to health, we present below some specification searches in order to obtain the most robust specifications. First, we perform specification searches between linear and logarithmic relationship. The overall relationship between health and education (see *Figure 1*) suggest a logarithmic specification, thus among non-linear relationships, we prefer the log specification. We note that given the definition of the right-hand side (rhs) variables given above, all of them are measured before the dependent variable. However, we do not know if further lags of the rhs variables are related to the dependent variable. Thus we also perform specification search among different lag structures in the equations. For the specification searches, we only use *tyr* as the variable for education. We then introduce *tyrq* in the selected specifications and we also present regressions with it.

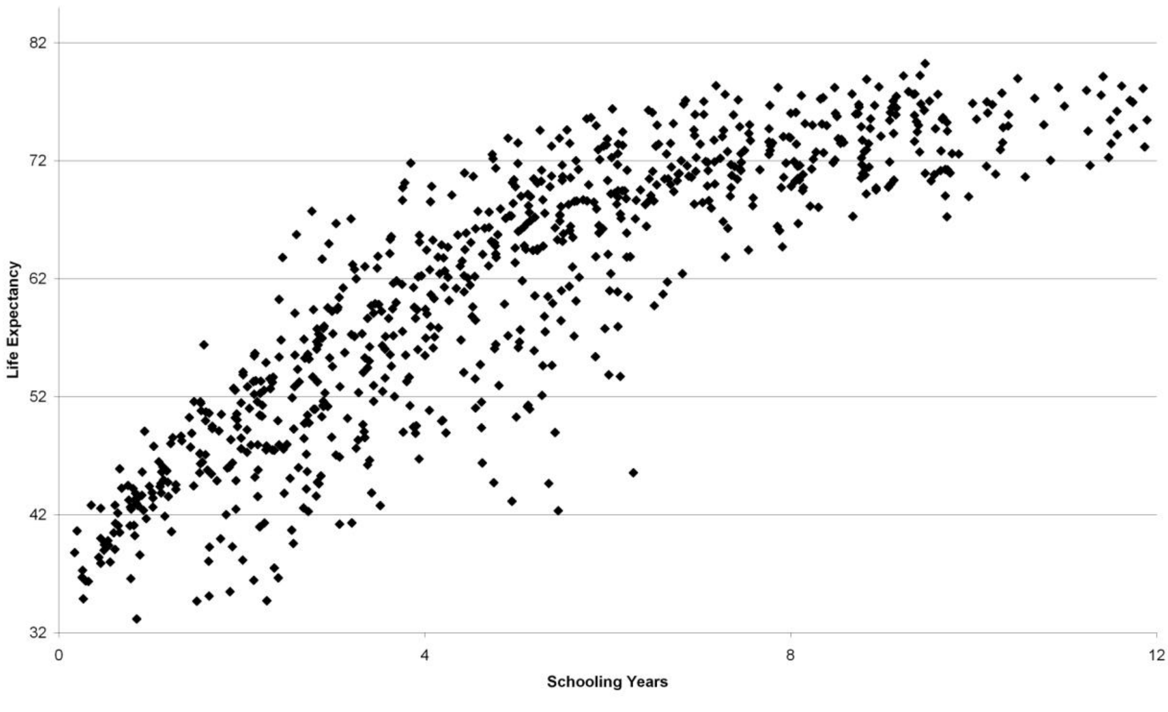

Figure 1. Relationship between schooling years and life expectancy

1.4. GMM estimators for dynamic panel models

Under the assumptions that (a) the error terms ($\varepsilon_{i,t}$ and $\xi_{i,t}$) are not serially correlated and (b) the explanatory variables are weakly exogenous (i.e., the explanatory variables are assumed to be uncorrelated with future realizations of the error term), the GMM dynamic panel uses the following moment conditions: $E[H^{u}_{i,t-1-s}\Delta\varepsilon_{i,t}]=0$, $E[X^{1}_{i,t-s}\Delta\varepsilon_{i,t}]=0$ and $E[H^{e}_{i,t-s}\Delta\xi_{i,t}]=0$, $E[X^{2}_{i,t-s}\Delta\xi_{i,t}]=0$, for $s\geq 2; t=3,...,T$; $i=1,...,N$, where X^{1} is the complete matrix of covariates in equation 1, which includes $Adult\ Ed_i$, H^{e}_{i} and GDP_i (in logs) and X^{2} is the complete matrix of covariates in equation 2, which includes H^{u}_{i} and GDP_i (in logs). Because we use the system GMM estimator, there are the following additional moment restrictions for the levels equation: $E[\Delta H^{u}_{i,t-1}(v_i+\varepsilon_{i,t})]=0$, $E[\Delta X^{1}_{i,t-1}(v_i+\varepsilon_{i,t})]=0$ and $E[\Delta H^{e}_{i,t-1}(u_i+\xi_{i,t})]=0$, $E[\Delta X^{2}_{i,t-1}(u_i+\xi_{i,t})]=0$, for $t=3,...,T$. It is worth noting that these conditions allow for the *levels* of explanatory variables to be correlated with the unobserved country-specific effects. With this, we are arguing that past education and past health are not correlated with current differences in omitted variables (but can be correlated with its levels) and also that past variations on education, health and explanatory variables cannot be correlated with fixed-effects and other omitted variables in levels.

We use these moment conditions and employ a GMM procedure to generate consistent and efficient parameter estimates. This system estimator is preferable to the difference estimator if the dependent variable is highly persistent, as is the case for education and life expectancy and if the number of time-series observations is relatively small, as is also the case.

Consistency of the GMM estimator depends on the validity of the instruments (i.e. the validity of the described moment conditions). To address this issue, we consider two specification tests: the first is the Hansen test of over-identifying restrictions, which tests the overall validity of the instruments; the second is the second-order autocorrelation test for the error term. Overall, both specification tests indicate that the instruments used are valid, if we would not reject the null of validity of instruments (Hansen Test) and if we would not reject the null of no second-order autocorrelation. However, first-order autocorrelation is expected in first-differences. In order to reject the null of the AR(1) test in differences, we introduced the lagged difference in the dependent variable in (2). This variable proved to be highly significant in regressions, as we will see.

When the comparison between the number of observations and the number of instruments indicates an overfitting bias in the empirical model (this is, an excess of instruments), we decrease the number of instruments so that this number approximates the number of countries. We do this successively reducing the number of lags and lag differences used as instruments.

2. Does health influence education?

In this section, we investigate the causality from health to education and present results for the estimation of specification (1). This is the direction of causality that has been widely covered by past literature. Nevertheless, past contributions are mostly theoretical in nature and a consensus on the empirical magnitude of the effect has not been achieved.

2.1. Specification search

In this section, we briefly describe the specification searches we present in *Tables A.1* and *A.2* in the *appendix*. First we test linear specification against log-log specification and log-linear specification (in which the dependent variable is at levels and life expectancy is at logs). We present results in *Table A.1*. This log-linear specification is tested because we can see that the life expectancy variable is much more volatile than the education variable (see *Table 2*). GDP is always introduced in logs as it is the most volatile variable and most previous analysis also introduce this variable in logs. When the *AE* control enters in regressions, it enters in logs when the dependent variable enters in logs and in levels when the dependent variable enters in levels. The overall conclusion is that life expectancy is almost always a significant determinant of education, but only in the log-log specification it subsists to the introduction of the Adult Education (*AE*) control (which is never significant), so we have selected this specification for further work.

This log-log specification is now tested using different lag structures (*Table A.2*). We present regressions in which health is introduced with one and two lags. When testing for further lags, we concluded that these are systematically non-significant thus we are not presenting them. We also present regressions in which health is introduced in first differences and lagged first differences. As both education and health are in logs, we are explaining education growth conditional on past education, income and health. It is possible to conjecture that health growth may have some effect in education growth, which could be interpreted as a short-run or transitional effect.

The overall conclusion is that health measured in the preceding five-year period (from education) and with one and two lags have a robust and positive influence on years of schooling, meaning that health in levels taken in the previous years explain the evolution of education (*Table A.2*, columns 1 to 6). This is compared with non-significant signs of coefficients of the first difference and lagged first difference in health (*Table A.2*, columns 7 and 8). Thus we conclude that a steady-state or long-run causality exists from health to education.

2.2. Selected regressions

In this section, we present the selected regressions that estimate the causality link from health to education. We present results for two equations, one of which use the number of schooling years as the dependent variable ($\log(tyr)$) and the other uses the number of schooling years weighted by a measure of quality ($\log(tyr)\times QL_1$), which we named as $tyrq$. We abstain from the presentation of equations with AE as we saw that this variable was almost always non-significant. Nevertheless, its inclusion would not change results. In these regressions we include current health (measured in the previous five-year period) and health lagged one and two periods. This is done to see how strong is the effect of past health, given the effects of health measured in other periods. To ease of interpretation, we write the equations and present p-values below the coefficients. We also indicate the level of significance using *** for 1%, ** for 5% and * for 10% significant levels, respectively. The first equation includes 100 countries (567 observations) and 90 instruments and the second includes 80 countries (455 observations) and 76 instruments.

$$\log(tyr)_{i,t} = \underset{0.002}{-1.8^{***}} + \underset{0.000}{0.74^{***}}\log(tyr)_{i,t-1} + \underset{0.584}{0.01}\log(GDP)_{i,t} + \\ + \underset{0.033}{0.56^{**}}\log(H^e)_{i,t} - \underset{0.158}{0.58}\log(H^e)_{i,t-1} + \underset{0.038}{0.54^{**}}\log(H^e)_{i,t-2} \quad (3)$$

$$Hansen = \underset{0.187}{90};\ AR(1) = \underset{0.000}{-4.28};\ AR(2) = \underset{0.468}{0.74}$$

$$tyrq_{i,t} = -\underset{0.960}{0.1} + \underset{0.000}{0.95}^{***} tyrq_{i,t-1} + \underset{0.473}{0.01}\log(GDP)_{i,t} +$$
$$+\underset{0.019}{0.22}^{**}\log(H^e)_{i,t} - \underset{0.158}{0.32}\log(H^e)_{i,t-1} + \underset{0.454}{0.11}\log(H^e)_{i,t-2} \quad (4)$$

$$Hansen = \underset{0.348}{69}; AR(1) = -\underset{0.000}{4.07}; AR(2) = \underset{0.430}{0.79}$$

Some important observations can be drawn by the analysis of equations. First, all specification tests indicate the accurateness of the analysis, as the Hansen test and the AR(2) tests do not reject and the AR(1) test rejects. Second we concluded for a positive impact of health measured in the preceding five years period (and indicated as current health in regressions). A rise in life expectancy in 2 years would increase 1.47 years of schooling, which reveals a very important effect. Also, a rise in 2 years in life expectancy would increase 0.15 our measure of schooling years weighted by quality. We can also distinguish from short-run impacts, where education is affected by health, taking past education as constant, and also steady-state effects, where education would be constant. In this last case, the effect of a 2 years rise in life expectancy would imply an increase of 4.45 years of schooling. This variation in life expectancy would also increase *tyrq* in 3.05. We can clearly say that, when compared with GDP, health is more significant in determining education.

Next, we divide the sample into poor and rich samples. We consider rich countries as those that are above the median for the majority of periods considered (considering all the period, the median is 3347 USD). Otherwise, we consider the country as poor.

For the rich sample, we obtained the following equations. The first equation includes 56 countries (320 observations) and 56 instruments. The second equation includes 25 countries (141 observations) and 24 instruments.

$$\log(tyr)_{i,t} = -\underset{0.797}{0.2} + \underset{0.000}{0.82}^{***}\log(tyr)_{i,t-1} + \underset{0.024}{0.04}^{**}\log(GDP)_{i,t} +$$
$$+\underset{0.288}{0.32}\log(H^e)_{i,t} - \underset{0.589}{0.27}\log(H^e)_{i,t-1} - \underset{0.968}{0.13}\log(H^e)_{i,t-2} \quad (5)$$

$$Hansen = \underset{0.482}{45}; AR(1) = -\underset{0.000}{3.49}; AR(2) = \underset{0.313}{1.01}$$

$$tyrq_{i,t} = \underset{0.771}{0.1} + \underset{0.000}{0.98}^{***} tyrq_{i,t-1} + \underset{0.668}{0.00}\log(GDP)_{i,t} +$$
$$+\underset{0.047}{0.38}^{**}\log(H^e)_{i,t} - \underset{0.275}{0.28}\log(H^e)_{i,t-1} - \underset{0.353}{0.12}\log(H^e)_{i,t-2} \quad (6)$$

$$Hansen = \underset{0.655}{36}; AR(1) = -\underset{0.000}{3.52}; AR(2) = \underset{0.230}{1.20}$$

In rich countries we note that GDP becomes more important than health in explaining quantity of schooling (years). However, we also reach the interesting result that health in period t influences the quality-weighted measure of schooling. We should note however that if each variable of health would be introduced separately (as we did in the specification search for the whole sample) non-significant results would be obtained in all of them.

Results for the poor sample are presented in the following equations. The first equation includes 44 countries (247 observations) and 34 instruments. The second equation includes 25 countries (141 observations) and 24 instruments.

$$\log(tyr)_{i,t} = -\underset{0.000}{3.1}^{***} + \underset{0.000}{0.69}^{***}\log(tyr)_{i,t-1} + \underset{0.559}{0.03}\log(GDP)_{i,t} + $$
$$+\underset{0.989}{0.01}\log(H^e)_{i,t} - \underset{0.847}{0.15}\log(H^e)_{i,t-1} + \underset{0.005}{0.98}^{***}\log(H^e)_{i,t-2} \quad (7)$$

$$Hansen = \underset{0.289}{26}; AR(1) = -\underset{0.004}{2.90}; AR(2) = \underset{0.915}{0.04}$$

$$tyrq_{i,t} = -\underset{0.067}{1.0}^{*} + \underset{0.000}{0.84}^{***} tyrq_{i,t-1} + \underset{0.352}{0.02}\log(GDP)_{i,t} -$$
$$-\underset{0.103}{0.22}\log(H^e)_{i,t} + \underset{0.158}{1.51}^{*}\log(H^e)_{i,t-1} - \underset{0.145}{0.57}\log(H^e)_{i,t-2} \quad (8)$$

$$Hansen = \underset{0.717}{9.7}; AR(1) = -\underset{0.008}{2.65}; AR(2) = -\underset{0.359}{0.92}$$

For poor countries, the effect of health in education is lengthier than for the whole sample, as only health with two lags (equation 7) and one lag (equation 8) have significant effects on education. We should note however that if each variable of health would be introduced separately (as we did in the specification search for the whole sample) significant results would be obtained in all of them. Quantitatively, we can say that the effect is strong in this sub-sample as two more years in life expectancy would have an effect of 1.97 additional years of education after two periods. In the steady-state, this effect would rise to 8.94 years, nearly twice the effect in the whole sample. Thus, quantitatively, we obtained a much stronger effect of health in education in poor countries than that we found in rich countries. This fact should have policy consequences as it reveals a potential positive influence of health in improving schooling outcomes.

3. Does education cause health?

In this section, we investigate the causality from health to education and present results for the estimation of specification (2).

3.1. Specification search

As in the above section, in this section we implemented a specification search for the causality from education to health. First we tested linear, log-linear and log-log specifications. Results are presented in *Table A.3* in the *Appendix A*. In this case, the level of education (in years) significantly reduces increments in health in the three specifications. As we cannot select a preferred specification as we did in the last section, we further test all specifications about the lag structure. With the specification search for the lag structure (*Tables A.4* and *A.5*), we discovered that the lagged levels continue to be negatively related to education. However, we have also discovered that first and lagged first differences in life expectancy positively influences education. From all the tested specifications the one that shows a higher significance is the log-log specification (*Table A.5*). Thus we present results for this specification in the following section. In order to obtain the full verification of the moment conditions, which imply a rejection of the AR(1) test (which was not obtained in *Tables A.3* to *A.5*), we also introduce as a regressor the first difference of the dependent variable.

3.2. Selected regressions

In this section, we present the selected regressions that estimate the causality link from education to health. This regression employs 100 countries (560 observations) and uses 93 instruments.

$$\log(H^e_{i,t}) = \underset{0.928}{0.07} + \underset{0.000}{0.98}^{***}\log(H^e_{i,t-1}) + \underset{0.000}{0.60}^{***}\Delta\log(H^e_{i,t-1}) + \underset{0.044}{0.08}^{**}\log(GDP)_{i,t} + \\ + \underset{0.007}{0.06}^{***}\Delta\log tyr_{i,t} + \underset{0.142}{0.13}\Delta\log tyr_{i,t-1} \quad (9)$$

$$Hansen = \underset{0.183}{93.43}; AR(1) = \underset{0.091}{-1.69}; AR(2) = \underset{0.632}{-0.48}$$

Next, we present the regression with the alternative quality-adjusted measure of education. This regression employs 80 countries (452 observations) and uses 77 instruments.

$$\log(H^e_{i,t}) = \underset{0.170}{-0.21} + \underset{0.000}{1.04}^{***}\log(H^e_{i,t-1}) + \underset{0.000}{0.94}^{***}\Delta\log(H^e_{i,t-1}) + \underset{0.547}{0.00}\log(GDP)_{i,t} + \\ + \underset{0.009}{0.11}^{***}\Delta tyrq_{i,t} + \underset{0.145}{0.04}\Delta tyrq_{i,t-1} \quad (10)$$

$$Hansen = \underset{0.212}{74.88}; AR(1) = \underset{0.020}{-2.32}; AR(2) = \underset{0.951}{0.06}$$

From the analysis of the above equations, we can note that the first difference on education (both measured as years of schooling and measured as quality-adjusted years of school) positively influences the level of life expectancy (given the past level and lagged differences in past life expectancy). As life expectancy and education are in logs we can say that education growth influences life expectancy growth. This means that we can interpret this effect as a short-run or transitional effect. Quantitatively, this effect means that an increase of 1% in the education growth rate would imply an increase of 0.06% in life expectancy. When comparing this effect with the effect of education in health, we can say that the effect from schooling to health is quantitatively smaller.

In the following analysis, we will present and discuss regressions for the poor and for the rich sample. We begin by the rich sample. The following regression used 56 countries (320 observations) and 53 instruments.

$$\log(H^e_{i,t}) = \underset{0.433}{0.16} + \underset{0.000}{0.97}^{***}\log(H^e_{i,t-1}) + \underset{0.035}{0.29}^{**}\Delta\log(H^e_{i,t-1}) - \underset{0.604}{0.02}\log(GDP)_{i,t} + \\ + \underset{0.184}{0.05}\Delta\log tyr_{i,t} + \underset{0.073}{0.03}^{*}\Delta\log tyr_{i,t-1} \quad (11)$$

$$Hansen = \underset{0.461}{42.22}; AR(1) = \underset{0.004}{-2.90}; AR(2) = \underset{0.162}{-1.40}$$

The second regression for the rich sample used 55 countries (314 observations) and 53 instruments.

$$\log(H^e_{i,t}) = \underset{0.293}{0.19} + \underset{0.000}{0.97}^{***}\log(H^e_{i,t-1}) + \underset{0.051}{0.28}^{*}\Delta\log(H^e_{i,t-1}) - \underset{0.129}{0.00}\log(GDP)_{i,t} + \\ + \underset{0.129}{0.10}\Delta tyrq_{i,t} + \underset{0.072}{0.06}^{*}\Delta tyrq_{i,t-1} \quad (12)$$

$$Hansen = \underset{0.405}{53.57}; AR(1) = -\underset{0.003}{2.96}; AR(2) = -\underset{0.177}{1.35}$$

Thus, we note that in rich countries the lagged differences in log schooling have a slight significant influence in life expectancy in both regressions. We should note that if we drop non-significant first differences in education, the coefficients of the lagged differences would remain significant.

We finally present regressions for the poor sample. In these regressions the introduction of the first difference in health as a regressor does not help in rejecting first order autocorrelation, so we dropped this variable. The first regression used 44 countries (276 observations) and 43 instruments.

$$\log(H^e_{i,t}) = -\underset{0.069}{0.21^*} + \underset{0.000}{1.01^{***}}\log(H^e_{i,t-1}) + \underset{0.184}{0.02}\log(GDP)_{i,t} + \\ + \underset{0.013}{0.06^{**}}\,\Delta\log tyr_{i,t} + \underset{0.190}{0.02}\,\Delta\log tyr_{i,t-1} \quad (13)$$

$$Hansen = \underset{0.358}{34.29}; AR(1) = -\underset{0.293}{1.05}; AR(2) = \underset{0.211}{1.25}$$

The second regression for the poor sample used 25 countries (160 observations) and 25 instruments.

$$\log(H^e_{i,t}) = \underset{0.626}{0.22} + \underset{0.000}{0.88^{***}}\log(H^e_{i,t-1}) + \underset{0.340}{0.03}\log(GDP)_{i,t} + \\ + \underset{0.401}{0.20}\,\Delta tyrq_{i,t} + \underset{0.129}{0.16}\,\Delta tyrq_{i,t-1} \quad (14)$$

$$Hansen = \underset{0.134}{19.87}; AR(1) = \underset{0.240}{1.17}; AR(2) = \underset{0.119}{1.56}$$

In the sample of poor countries, we confirm a positive influence of first differences of the log of schooling years. We recognize however that in these regressions first order autocorrelation is not rejected as expected.

Conclusions

This article adds evidence based on a panel data approach to the discussion of causality between education and health. We employed system GMM dynamic panel data method to sort out the issue of causality and introduced a new measure of quality-weighted education. We found evidence that supports the influence of the level of health in increases in education and the influence of education growth on health improvements. Thus, using the typical interpretation of levels and difference effects on variables, we can say that health has both a short-run effect and a long-run effect on education but education has only a short-run effect on health. Life expectancy (our measure for health) in the past affects both poor and rich countries. However, only quality-weighted education is affected in the rich sample. One interesting interpretation for this result is that health increases both years and quality of schooling in poor countries but only increases quality of schooling in rich countries. The effect of education growth in health growth is stronger in the poor countries than in the rich but again quality-weighted schooling is a significant determinant of health in the rich sample.

Comparing these results and those in Tamura (2006) we also came to the conclusion that there is a positive effect of health in education. Contrary to the results in that reference, however, we reach the conclusion that it is the growth rate of education (and not its levels) that positively influences health. In both cases a non-linear logarithm specification was considered the appropriate to relate both variables. Nevertheless in Tamura (2006), only the causality from education to health is non-linear.

Quantitatively, our research concluded that an increase in 2 years of life expectancy would increase years of schooling in one year and a half in the short run and in four years and a half in the long-run, which is an important effect. This effect is even stronger in the poor countries, which implies that health policy has an important external effect on education.

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Appendix

A. Specification searches

A.1. Does health cause education?

Table A.1. Does health influence education?

Dependent variable	Specification search: log non-linearity					
	(1)	(2)	(3)	(4)	(5)	(6)
$H^u_{j,i,t}$	tyr	$\log(tyr)$	tyr	tyr	$\log(tyr)$	tyr
$H^u_{j,i,t-1}$	0.887***	0.793***	0.896***	0.795***	0.728***	0.925***
(p-value)	0.000	0.000	0.000	0.000	0.000	0.000
$\log(GDP_t)$	0.096	0.004	0.129	0.250**	0.016	0.011
(p-value)	0.281	0.796	0.153	0.014	0.290	0.713
$H^e_{i,t}$	0.018***	–	–	0.008	–	–
(p-value)	0.004			0.276		
$\log(H^e_{i,t})$	–	0.435***	0.815**	–	0.369***	0.268
(p-value)		0.000	0.013		0.002	0.481
AE	–	–	–	0.109	0.070	0.121
(p-value)				0.233	0.309	0.179
N. Instruments	97	97	97	86	86	86
Hansen J (p-value)	0.366	0.443	0.356	0.321	0.303	0.318
AR(1) (p-value)	0.000	0.000	0.000	0.000	0.000	0.000
AR(2) (p-value)	0.563	0.959	0.564	0.567	0.946	0.523
N. Countries	100	100	100	98	98	98
N. of Observations	738	738	738	726	726	726

Notes: (1) p-values based on robust variance-covariance matrix in parentheses;
(2) *** stands for a 1% significance level; ** for 5% and * for 10%.

Table A.2. Does health influence education?

Dependent variable	Specification search: lags and differences							
$H^u_{j,i,t} : ln(tyr)$	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$ln(tyr_{t-1})$	0.793***	0.755***	0.671***	0.727***	0.643***	0.676***	0.725***	0.748***
(p-value)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
$\log(GDP_t)$	0.004	0.001	0.008	0.016	0.009	0.011	0.050***	0.050***
(p-value)	0.796	0.953	0.779	0.290	0.702	0.686	0.001	0.002
$\log(H^e_{i,t})$	0.435***	–	–	0.369***	–	–	–	–
(p-value)	0.000			0.002				
$\log(H^e_{i,t-1})$	–	0.570**	–	–	0.579***	–	–	–
(p-value)		0.014			0.006			
$\log(H^e_{i,t-2})$	–	–	0.792**	–	–	0.632**	–	–
(p-value)			0.028			0.026		
$\Delta\log(H^e_{i,t})$	–	–	–	–	–	–	0.322	–
(p-value)							0.105	

$\Delta\log(H^{e}_{i,t-1})$	–	–	–	–	–	–	–	0.074
(p-value)								0.248
AE	–	–	–	0.070	0.105	0.036	0.118*	0.074
(p-value)				0.309	0.171	0.675	0.078	0.248
N. Instruments	97	88	77	86	93	81	93	81
Hansen J (p-value)	0.443	0.226	0.338	0.306	0.327	0.223	0.456	0.352
AR(1) (p-value)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AR(2) (p-value)	0.956	0.966	0.557	0.940	0.997	0.615	0.934	0.614
N. Countries	100	100	100	98	98	98	98	98
N. of Observations	738	653	567	726	642	557	642	557

Notes: (1) p-values based on robust variance-covariance matrix in parentheses;
(2) *** stands for a 1% significance level; ** for 5% and * for 10%.

A.2. Does education cause health?

Table A.3. Does education influence health?

Dependent variable	Specification Search: log non-linearity		
	(1)	(2)	(3)
$H^{e}_{j,i,t}$	LE	$\log(LE)$	$\log(LE)$
$H^{e}_{j,i,t-1}$	1.037***	1.053***	0.964***
(p-value)	0.000	0.000	0.000
$\log(GDP_t)$	1.341***	0.004	0.028***
(p-value)	0.002	0.419	0.000
$H^{u}_{i,t-1}$	- 0.738***	–	-0.012***
(p-value)	0.000		0.000
$\log(H^{u}_{i,t-1})$	–	- 0.031***	–
(p-value)		0.000	
N. Instruments	88	88	88
Hansen J (p-value)	0.267	0.164	0.356
AR(1) (p-value)	0.237	0.308	0.229
AR(2) (p-value)	0.431	0.698	0.742
N. Countries	103	103	103
N. of Observations	656	656	656

Notes: (1) p-values based on robust variance-covariance matrix in parentheses;
(2) *** stands for a 1%, ** for 5% and * for 10% significance levels, respectively;
(3) LE stands for Life Expectancy

Table A.4. Does education influence health?

Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)
	Specification Search: lag structure					
$H^{e}_{j,i,t}$	LE	$\log(LE)$	LE	$\log(LE)$	LE	$\log(LE)$
$H^{e}_{j,i,t-1}$	0.954***	0.879***	0.968***	0.935***	0.910***	0.855***
(p-value)	0.000	0.000	0.000	0.000	0.000	0.000
$\log(GDP_t)$	2.106***	0.044***	0.209	0.005	0.722*	0.018**
(p-value)	0.000	0.000	0.379	0.219	0.082	0.022
$H^{u}_{i,t-2}$	- 0.746***	-0.012***	–	–	–	–
(p-value)	0.000	0.000				
$\Delta H^{u}_{i,t}$	–	–	0.996**	0.014**	–	–
(p-value)			0.018	0.032		
$\Delta H^{u}_{i,t-1}$	–	–	–	–	0.745**	0.009
(p-value)					0.030	0.104
N. Instruments	81	81	88	88	81	81
Hansen J (p-value)	0.245	0.100	0.188	0.152	0.096	0.083
AR(1) (p-value)	0.282	0.325	0.146	0.254	0.202	0.316
AR(2) (p-value)	0.940	0.706	0.823	0.865	0.973	0.737
N. Countries	103	103	100	100	101	101
N. of Observations	650	650	653	653	647	647

Notes: (1) p-values based on robust variance-covariance matrix in parentheses;
(2) *** stands for a 1%, ** for 5% and * for 10% significance levels, respectively;
(3) LE stands for Life Expectancy.

Table A.5. Does education influence health?

Dependent variable	Specification Search: lag structure		
	log-log specification		
	(1)	(2)	(3)
$H^{e}_{j,i,t}$	$\log(LE)$	$\log(LE)$	$\log(LE)$
$H^{e}_{j,i,t-1}$	1.002***	0.950***	0.875***
(p-value)	0.000	0.000	0.000
$\log(GDP_t)$	0.013*	0.006	0.018**
(p-value)	0.063	0.214	0.029
$\log(H^{u}_{i,t-2})$	-0.030***	–	–
(p-value)	0.000		
$\Delta\log(H^{u}_{i,t})$	–	0.067***	–
(p-value)		0.001	
$\Delta\log(H^{u}_{i,t-1})$	–	–	0.070***
(p-value)			0.002
N. Instruments	81	88	81

Hansen J (p-value)	0.054	0.112	0.077
AR(1) (p-value)	0.321	0.213	0.199
AR(2) (p-value)	0.998	0.839	0.519
N. Countries	103	100	101
N. of Observations	650	653	647

Notes: (1) p-values based on robust variance-covariance matrix in parentheses; (2) *** stands for a 1%, ** for 5% and * for 10% significance levels, respectively; (3) LE stands for Life Expectancy.

B. List of Countries

List of countries used in Tables A.1 and A.2 (100): Algeria, Argentina, Australia, Austria, Bahrain, *Bangladesh*, Barbados, Belgium, *Benin*, *Bolivia*, *Botswana*, Brazil, *Cameroon*, Canada, *Central Afr. R.*, Chile, *China*, Colombia, *Congo*, *Costa Rica*, Cyprus, Denmark, *Dominican Rep.*, Ecuador, *Egypt*, El Salvador, Fiji, Finland, France, *Gambia*, Germany, *Ghana*, Greece, Guatemala, *Guinea-Bissau*, *Guyana*, *Haiti*, *Honduras*, Hong Kong, Hungary, Iceland, *India*, *Indonesia*, Iran, Ireland, Israel, Italy, Jamaica, Japan, *Jordan*, *Kenya*, Korea, Kuwait, *Lesotho*, *Malawi*, Malaysia, *Mali*, Mauritius, Mexico, *Mozambique*, *Nepal*, Netherlands, New Zealand, *Nicaragua*, *Niger*, Norway, *Pakistan*, Panama, *Papua New Guinea*, Paraguay, Peru, *Philippines*, Poland, Portugal, *Rwanda*, *Senegal*, *Sierra Leone*, Singapore, South Africa, Spain, *Sri Lanka*, *Sudan*, Swaziland, Sweden, Switzerland, *Syria*, *Tanzania*, *Thailand*, *Togo*, Trinidad & Tobago, Tunisia, Turkey, *Uganda*, United Kingdom, United States, Uruguay, Venezuela, *Zaire*, *Zambia*, *Zimbabwe*.

Notes: 1. When Adult Education is considered in regressions Guinea-Bissau and Tanzania exit the sample and thus we rest with 98 countries as is explicit from Tables A.1 and A.2. 2. The sub-sample of poor countries used in the equation (7) are in *italic* (44). The remaining countries (56) constitute the sub-sample of rich countries used in equation (5).