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The Role of Education in Health System Performance: A Propos World Health Report 2000

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Abstract

I investigate the role of education on health, using country level data and the production frontier framework suggested by the World Health Organization to assess performances of health care systems.

I find that the role of human capital is much smaller than what appears in the WHO frontier model, and the relationship exhibits diminishing return in the observed range. Taking into account the heterogeneity in this relationship generates a different ranking of countries according to the efficiency of their health care system. This suggests that the method currently used by the WHO indeed favors health care systems operating in countries which underinvested in education in the past.

The relationship between education and health changes around an average value of 8 years of education per individual: above that level, the return of years of education in health is zero.

Keywords: Human capital, Rate of return, Economic impact, Efficiency

JEL Classification: I18

1. Introduction

This study investigates the role of education in the production of health, and in particular, heterogeneity in the impact of education on health depending on the baseline level of education. The work has been motivated by two concerns. The first is the surprising logical consequences of the education-health relationship as estimated by the WHO in its World Health Report 2000 (WHO, 2000), which posited a single education–health relationship for both highly developed and under-developed countries. The increasing marginal return of education on health found by the WHO implies that all countries would improve population health substantially if they redistributed monies from their health care system to the education system. The second is the relative neglect of the shape of the education-health relationship in the empirical literature, which to date has emphasized proving or disproving the causal effect of education on health (Grossman and Kaestner, 1997).

I hypothesize that the marginal impact of education on health differs below and above a threshold level of education. I use the framework of a population health production function at the aggregate (country) level to test this hypothesis. I estimate the impact of education on health separately in low- and high-education countries, where the threshold education level that divides the sample is set so as to minimize the sum of squared errors across the two equations. The results strongly support differing health returns to education in the low-and high-education samples. I then illustrate the importance of this heterogeneity for assessing health system performance in the same spirit at WHO2000. More generally, however, a better understanding of the shape of the relationship between education and health can inform policies guiding public spending in education and health.

The present analysis of aggregated data can provide a first hint on this issue: the impact of education on health is strong among countries with low levels of education but small and rapidly decreasing among countries with an average number of years of education greater than six. As a consequence, analyzes of the efficiency of health care systems failing to account for this heterogeneity overestimate the possibility frontier among countries with high educational achievements (therefore underestimate the performance of their health care system).

2. The shape of the relationship between human capital and health: what do we know?

2.1 Individual Level Analyses of the Human Capital-Health Relationship

A first strand of empirical literature concerning the return of education on health stems from Grossman's seminal paper on health capital (Grossman, 1972). The focus of this empirical literature has been to disentangle the causal impact of education on health from a mere correlation between the two variables. The literature has not paid much attention to the shape of the education-health relationship (e.g., linear, convex or concave). Although Grossman (1975) suggested that, unlike income, education continues to influence health even at high level of inputs, this proposition is absent from more recent reviews by Grossman and Kaestner (1997) and Grossman (2000). There appears to be little systematic investigation of the form of the relationship based on individual level studies. Some studies (e.g., Curtin and Nelson 1999; Ross and Mirowski 1999 and Duleep (1986) offer suggestive evidence from disparate contexts, but Gilleskie and Harrison (1998) constitutes perhaps the strongest individual-level study that estimated the relationship between education and health at various levels of education while controlling for other factors (age, race, income, and body mass index). They found that the gain in self-assessed health (percentage in good or excellent health) from an additional year of education decreases with the base level: every additional year of schooling between 8 and 11 increases the proportion by 2.3 percentage points for men and 3.7 for women, the 12th year increases it by 2.4 and 3.5, every year between 12 and 16 by 2.1 and 2.5, and between 16 and 18 by 1.8 and 2.1.

These individual-level studies suggest that the relationship between education and health is non linear, somewhat concave, and may differ in rich countries with a high average level of education than in poor countries with low educational attainment.

2.2 Aggregate Analyses of the Human Capital-Health Relationship

The literature on aggregate analyses of the link between human capital and health stems from a different tradition, started by Adelman (1963), that focuses on the impact of health care services on health outcomes, and for which education is treated as an 'environmental' factor to be controlled for, as are income, life-style indicators, or geographical location. The underlying model is of a health production function, where an indicator of population health in the area (mortality, sometimes the prevalence of a given condition) is the dependent variable, the density of physicians or hospital beds the factor of interest, and education is measured as the average number of years of schooling of the population in each geographical area. The specifications often deal inadequately with issues such as the time lags between the determinants and health outcomes (SPRG, 2002, Grignon, 2001), potential non-linearities (all these studies assume that the link between years of schooling and population health is linear), and the potential endogeneity of education (though Auster et al. 1969 addressed potential endogeneity of health care expenditures.) As summarized by Newhouse and Friedlander (1980), the effect of education often appears significant in this literature, mostly based on comparisons across regions of the United States. By contrast, the impact of medical care appears small and insignificant. Among developing countries, the health transition literature demonstrates that women's literacy is strongly associated with reduced infant mortality (Caldwell, 1993).

The more recent literature estimate production frontiers that allow for non-linearities in the relationship between education and health. In its World Health Report 2000, the WHO estimated a Translog two factors (health expenditure and number of years of schooling) production function (Evans et al. 2000) in which a quadratic relationship was estimated for each factor, as well as an interaction term. This more flexible functional form yields a better estimate of the rates of return of education on health at various levels of education.

Since the focus of this literature is “performance” (what economists call technical efficiency, Kumbhakar and Lovell, 2000), Evans et al (2000) estimate a stochastic production frontier: instead of the average relationship between human capital and health, they calculate the maximum amount of health a country could be expected to produce given the average number of years of education of its population.

The estimates of Evans et al. (2000) imply increasing returns of education on health (the coefficient of squared education is positive and significant) That is, the impact on health of increasing schooling by one year is larger in a country with an average of 12 years of schooling than in a country with an average 5 years of schooling. This finding, however, has been heavily criticized and does not appear to be robust.

Evans et al (2000) used repeated observations (yearly, from 1993 to 1997, on a set of 191 countries) to estimate a fixed-effect (or within estimator) production frontier. In this framework, the error term is decomposed into a time invariant term, measuring the country-specific deviation from the average linear relation between inputs and outputs and a pure random error term, varying over time for the same country. Gravelle et al (2002), re-estimate the production frontier using the same data as Evans et al. (2000) but using a “between” estimator (data for all years for a same country are pooled together) rather than the “within” estimator. The coefficient on the squared value of years of schooling is significantly negative, yielding a diminishing rate of return of education on health. Moreover, the between strategy seems to better fit the data, due mainly to a lack of variance over repeated observations for a same country.

In addition, Hollingsworth and Wildman (2003) show that, even when they use a within estimator, the production frontier among OECD countries exhibits diminishing returns of education on health. The impact on health of increasing population schooling from 4 to 5 years is more than double the impact of one more year of schooling from 8 to 9 years. Their estimates also suggest the kind of heterogeneity that is the focus of this analysis. In their analysis based on the within estimator, the coefficient for squared number of years of education is negative among OECD countries and positive among non OECD countries. Since OECD countries also are characterized by a much higher level of education (8.93 years on average versus 5.30) there are good reasons to suspect this heterogeneity simply reflects a decreasing return of education on health beyond a threshold.

As noted, my main focus in this paper is heterogeneity. I address it directly, by testing for two distinct regimes in the relationship between human capital and health, separated by a cut-off level of human capital rather than an external characteristic (such as being an OECD country or income per capita).

3. Methods

The primary objective of this analysis is to investigate the shape of the relationship between education and health, and the extent of distinct regimes. I test whether the relationship between education and health differs across low and high-education countries, and determine the cut-off point in the distribution of education separating the two sets of countries. Within each set, the relationship between education and health is homogeneous, but the relationship differs across the two sets.

As is described in more detail below, the study uses aggregate data on health, educational attainment and other health determinants from a cross-section of 111 countries. This section presents key aspects of the methods employed to assess heterogeneity in the education-health relationship.

I follow the standard approach of using current education achievement at the country level as an independent variable in the production function of health.

Following Hollingsworth and Wildman (2003), I estimate two sets of equations; however, instead of separating two sets of countries using an external threshold (being an OECD member) I separate countries based on their average levels of education. Because my main concern in this study is with the heterogeneity of the relationship between education and health, I keep the baseline simple: I use the translog specification with health outcome (H) on the left hand side of the equation, a measure of health care (M), education (E) and its squared value (E2) on the right hand side (other factors are included in the sensitivity analysis). The equation to be estimated using OLS is as follows:

$$H_i = B_0 + B_1 M_i + B_2 E_i + B_3 E2_i + \varepsilon_i$$

I test for heterogeneity using a standard mis-specification test known as parameter inconstancy (Kennedy, 2003). The procedure is as follows: first, I split the population of 111 countries into two subsets, one comprised of countries with values for E below a threshold and one comprised of countries with values of E above the threshold. I estimate the model under varying levels of the threshold and identify the threshold value of E that minimizes the sum of SSR (sum of squared residuals) in both equations. The cut-off value is therefore the value that separates the data into two regimes in order to better fit a piece-wise quadratic relationship between health and the inputs (health care expenditures, education and its squared value). I then use a Chow test to test whether the two regimes thus identified are significantly different, in other words, that the coefficients estimated below and above the cut-off points really are different.

There exist more sophisticated procedures to identify such different regimes in the relationship between two variables, e.g. non-parametric estimates. I rely on simpler approaches for two reasons: first, with only 111 observations in the sample, non-parametric approaches wouldn't work; second, because I subsequently use the specified relationship to estimate a production frontier, I must keep it reasonably simple.

To illustrate the impact of the mis-specification that arises from assuming homogeneity in the relationship across low and high-education countries, I estimate two production frontiers, one for countries with educational attainment below the cut-off point and one for countries above, and compare the resulting efficiency rankings of national health care systems with those derived from the mis-specified relationship when all countries are restricted to have the same relationship.

Because I do not have repeated cross-sections, I must use methods appropriate for a single cross-section. Among stochastic frontier estimates, the composed error model is the natural choice with such data. In order to decompose the error term, I use a "normal half-normal" hypothesis (the purely random term is normal, and the efficiency term follows a half-normal non positive distribution) following Kumbhakar and Lovell, (2000). They show that in most of cases imposing a more flexible constraint on the distribution of the error term (such as truncated distributions) adds computation difficulties but does not yield substantially different estimates. However, since there is no compelling underlying model to choose a distribution for the error term, as a sensitivity analysis (see section 5-3), I re-estimate the frontier using several distributional assumptions.

In the composed error model, the following equation is estimated:

$$H_i = A_0 + A_1.M_i + A_2E_i + A_3E2_i + u_i + v_i$$

where u_i is the efficiency component in the error term of the regression, constrained to be nonnegative, and v_i is the random component in the error term. The sum $e_i=(u_i+v_i)$ is skewed, indicating potential inefficiency.

The frontier provides the maximum achievable level of H for a given country, and the efficiency of the country's health care system is the ratio of the observed level of H for this country to the maximum achievable. For each unit, technical inefficiency is given by $TE_i = E(\exp(-u_i)|e_i)$ (Kumbhakar and Lovell, 2000).

I also applied to the frontier estimation the testing procedure suggested by Kennedy (splitting the population using a cut-off point, estimating on each separate population, then calculating the Log-likelihood) to identify two regimes. The results are less clear-cut (for some cut-off points, convergence is not achieved, and there are local maximums). However, the cut-off corresponding to the overall maximum is close to the one selected by the OLS procedure outlined above. In section 5-3, I therefore use the same cut-off point to re-estimate the frontier on two sets of countries.

4. Data and Variable Specification

<u>Dependent variable: health measures</u>

The output H is measured as disability adjusted life expectancy (DALE), the life expectancy at birth, minus the portions of years of life "lost" due to impairment or disability when lived in a less than perfect health state (Murray and Lopez 1996). Although this measure has been criticized (Williams, 1999, Nord, 2002), it is the best of all measures of the health of populations currently available: it encompasses more than life expectancy and is available for a large set of countries. The data on DALE's are taken from those published in the World Health Report 2000 for each country in 1997.

<u>Independent variables: education, other controls</u>

Education:

I use the average number of years of schooling in the population aged 15 and over in 1995 as published by Barro and Lee (2000, table #3). This is the same indicator as was used in the World Health Report 2000 (see HSPA, page 687). Note that this indicator is better suited to developing countries than to developed countries where a large fraction of individuals age 15 to 25 are still out of the labor force.

Barro and Lee provide data for 112 countries only in 1995, 111 of which are in the WHR00 panel (Taiwan is not a member state of the WHO). They use data from censuses and UNESCO data to estimate the average number of years of schooling in the population. Their measure captures quantity of education rather than quality, and, on the subset of countries for which the average number of years of education and students' scores are known, correlation between these two measures is weak (at 0.38); I use this indicator of human capital, although it is far from perfect, to preserve comparability with the world health report 2000 and because it is available for many more countries than other indicators.

Other control variables:

Health care: I use yearly health care expenditures in 1997, measured in international (PPP) dollars, in 1997 and published in the World Health Report 2000 (WHO, 2000). Although it might be preferable to use indicators of physical resources such as the density of physicians and/or hospital beds, such data are not available or reliable for most developing countries. Consequently, no insight can be provided on allocative efficiency of a country's health care system (choosing the wrong mix of inputs given their relative prices).

In order to run sensitivity analyzes, I use other controlling factors potentially correlated with education and health outcome. These other variables include income per capita, income inequality, quality of governance, and environmental and sanitation measures (Greene 2004, Hildebrand and Van Kerm, 2005). I also test the use of female education, measured as the sex ratio in schools, as an alternative measure of education (Jamison, Sandbu and Wang, 2001)

Income per capita is measured in international $; I use the value for 1997 as estimated by the World Bank (www.devdata.worldbank.org/query/default.htm). There are 106 countries with data.

For income inequality, I use the database created by Klaus W. Deininger and Lyn Squire, which can be found at:

http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/0,,contentMDK:20699070~pagePK:64214825~piPK:64214943~theSitePK:469382,00.html

This database provides the Gini coefficient for 130 countries, among which three (Taiwan, Hong Kong, and Puerto Rico) are not part of my set of countries. I have also excluded Argentina from the database, for lack of recent data of good quality. 13 countries have data of less than high quality. For 80 countries, income inequality was last measured between 1989 and 1993, but for 26 countries, the most recent year if older than 1985. 70 countries also have data for several years in the database; for a given country the Gini coefficient averaged over the most recent 10 years available, or averaged over all available years don't differ much from the most recent value, therefore I made the decision to use the most recent value.

Access to sanitation, pure water, and gender inequality in access to education are available in the World Development Indicator (World Bank, 2004); among rich countries (therefore within the set of countries with more than 5.8 years of education on average), there is not much variance in these variables.

Governance is measured through six indicators by Kaufmann, Kraay and Mastruzzi (2003). These are measured for the years 1996, 1998, and 2000, but since Kaufman, Kraay and Mastruzzi show that "the changes (…) over time are small relative to the margin of errors associated with [the] estimates of governance", I make use of the values for 1998. The indicators are based on surveys and summarize perceptions of participation of citizens in the choice of their government as well as freedom of the press ('voice'), perceptions of political stability and peaceful political processes (‘stability’), perceptions of quality of public service provision and independence of the administration (‘effectiveness’), perceptions of excessive regulation (‘regulatory quality’), confidence in and compliance to the law (‘rule of law’), and perceptions on the control of corruption (‘corruption’). These measures range between -4 and +2, higher values signalling better levels of governance.

All independent variables are entered as natural logarithms, except for the six governance ones, which take values between -4 and +4.

Descriptive statistics for all variables are provided in table 1 below.

Table 1: descriptive statistics, main variables used in the estimation

Variables	Average: all countries (N=191)	Average: countries with non missing values on years of education only (N=111)	Average: countries with high level of education (N=57)	Average: countries with low level of education (N=54)
Disability adjusted life expectancy (in years)[1] 1997	56.8	57.3	66.1	48.1
Health care expenditures per capita, (in US$PPP)[1] 1997	442.4	553.6	945.1	140.3
Average number of years of education 1995[2]	6.0	6.0	8.3	3.6
GDP per capita (in US$PPP) 1997[3]	7385.4	8783.6	13898.8	3054.6
Gini: last available year[2]	40.07	40.74	37.26	44.75
Improved sanitation facilities (%of population with access) 2000[4]	73.63	74.40	88.39	64.12
Improved water source (%of population with access) 2000[4]	79.07	80.78	91.60	72.12
Ratio of girls to boys in primary and secondary education (%) 1998[4]	94.45	96.21	101.39	89.56
Governance: voice*[(3)]*	-0.01	+0.10	+0.68	-0.51
Governance: political stability*[(3)]*	-0.02	+0.03	+0.62	-0.59
Governance: government effectiveness*[(3)]*	-0.03	+0.19	+0.84	-0.49
Governance: regulatory quality*[(3)]*	-0.02	+0.28	+0.77	-0.24
Governance: rule of law*[(3)]*	-0.03	+0.19	+0.83	-0.48
Governance: control of corruption*[(3)]*	-0.03	+0.20	+0.87	-0.52

Sources:
1. World Health Organization, World Health Report 2000
2. Barro and Lee (2000).
3. World Bank
4. Deininger and Squire
6. Kaufmann, Kraay and Mastruzzi (2003)
7. World Development Indicators (World Bank, 2004)

5. Results and sensitivity analysis

5.1 Baseline analysis – Heterogeneity and the shape of the education-health relationship

I searched for such an education threshold in the range 4.09 to 7.25 years of education, which would split the data set into two subsets of reasonable size (neither below 30). Table 2 provides the SSRs obtained for various thresholds used to split to population of 111 countries into two subsets, one with values for education below the threshold, and the other subset above the threshold. Table 2 provides SSRs for threshold values between 5.0 and 6.8 only as SSR values outside this range were much higher.

Table 2: Values of sum of squares of residuals, each subset of countries being determined according to a threshold value for EDU

Threshold value (in years of education)	Numbers of countries below	SSR subset below threshold	SSR subset above threshold	Sum of SSRs
5.0	42	0.871	1.324	2.195
5.1	43	0.879	1.216	2.095
5.2	46	1.153	1.020	2.173
5.3	46	1.153	1.020	2.173
5.4	47	1.154	1.014	2.168
5.5	51	1.364	0.735	2.099
5.6	51	1.364	0.735	2.099
5.7	52	1.425	0.635	2.060
5.8	**54**	**1.428**	**0.604**	**2.032**
5.9	55	1.701	0.513	2.214
6.0	57	1.767	0.276	2.043
6.1	61	1.993	0.056	2.049
6.2	63	2.143	0.054	2.197
6.3	63	2.143	0.054	2.197
6.4	63	2.143	0.054	2.197
6.5	66	2.250	0.048	2.298
6.6	66	2.250	0.048	2.298
6.7	67	2.255	0.048	2.303
6.8	68	2.256	0.048	2.304

The results indicate that 5.8 years of education is a reasonable cut-off point between two regimes of the relationship between education and health. The best cut-off from a linear model-fitting perspective is 5.8, though any value between 5.5 and 6.0 would be reasonable. The results suggest that after six years of education (the beginning of a secondary level in many countries, around the age of 12), there is a change in the relationship between education and health. The Chow test confirms that coefficients differ below and above the threshold of 5.8, with a Fisher statistic $F(4,103)$ equal to 6.45 which is significant at a level below 0.1%.

Table 3: OLS coefficients, regression of DALE on expenditure and education, translog specification – using the cut-off value at 5.8 years of education

1) Low education countries (below 5.8)

	Model 1	Model 2 (incl. income per capita)	Model 3 (stepwise, without income per capita)	Model 4 (stepwise, incl. income per capita)
Intercept	+ 2.68	+1.81	+4.07	+0.90
	(0.16)	(0.26)	(0.98)	(0.41)
Ln(Health Expenditure)	+ 0.24	+0.04	+0.26	ns
	(0.04)	(0.06)	(0.05)	
Ln(education)	+ 0.24	+0.17	+0.34	+0.10
	(0.14)	(0.12)	(0.12)	(0.06)
$[Ln(education)]^2$	- 0.12	-0.10	-0.16	ns
	(0.08)	(0.07)	(0.07)	
Ln(income per capita)	--	+0.24	--	+0.16
		(0.06)		(0.04)
Ln(Gini coefficient)	--	--	-0.20	ns
			(0.11)	
Ln(% Girls in schools)	--	--	-0.52	ns
			(0.21)	
Ln(% Population with access to sanitation facilities)	--	--	+0.06	+0.06
			(0.05)	(0.05)
Ln(% Population with access to purified water)	--	--	+0.31	+0.38
			(0.13)	(0.11)
Governance indicator: government effectiveness	--	--	-0.06	ns
			(0.04)	
N (countries with non missing data)	54	50	27	26
R2 (adjusted)	0.60	0.69	0.85	0.84

2) High education countries (over 5.8)

	Model 1	Model 2 (incl. income per capita)	Model 3 (stepwise, without income per capita)	Model 4 (stepwise, incl. income per capita)
Intercept	-0.59	-0.29	-0.44	-0.50
	(1.58)	(1.67)	(2.92)	(3.02)
Ln(Health Expenditure)	+ 0.05	+0.07	ns	ns
	(0.02)	(0.05)		
Ln(education)	+ 4.10	+3.87	+4.60	+4.66
	(1.52)	(1.54)	(2.56)	(2.65)
[Ln(education)]^2	- 0.94	-0.88	-1.00	-1.02
	(0.36)	(0.37)	(0.61)	(0.64)
Ln(income per capita)	--	-0.02	--	ns
		(0.07)		
Ln(% Population with access to sanitation facilities)	--	--	+0.70	+0.70
			(0.20)	(0.21)
Ln(% Population with access to purified water)	--	--	-0.75	-0.76
			(0.29)	(0.29)
Ln(% Population living in rural areas)	--	--	-0.10	-0.10
			(0.05)	(0.05)
N (countries with non missing data)	57	56	27	26
R2 (adjusted)	0.38	0.38	0.60	0.60

3) All countries

	Model 1	Model 2 (incl. income per capita)	Model 3 (stepwise, without income per capita)	Model 4 (stepwise, incl. income per capita)
Intercept	+ 3.12	+2.27	+3.22	+3.21
	(0.09)	(0.21)	(0.62)	(0.64)
Ln(Health Expenditure)	+ 0.11	+0.03	+0.99	+0.10
	(0.02)	(0.04)	(0.04)	(0.05)
Ln(education)	+ 0.25	+0.17	+0.12	+0.12
	(0.08)	(0.08)	(0.05)	(0.05)
$[Ln(education)]^2$	- 0.04	-0.04	ns	ns
	(0.03)	(0.03)		
Ln(income per capita)	--	+0.20	--	ns
		(0.05)		
Ln(Gini coefficient)	--	--	-0.25	-0.25
			(0.07)	(0.08)
Ln(% Population with access to purified water)	--	--	ns	+0.33
				(0.12)
Ln(% Population in rural areas)	--	--	-0.11	-0.11
			(0.05)	(0.05)
Governance indicator: control of corruption	--	--	-0.11	-0.11
			(0.03)	(0.03)
N (countries with non missing data)	111	106	54	52
R2 (adjusted)	0.68	0.72	0.75	0.74

Figure 1:

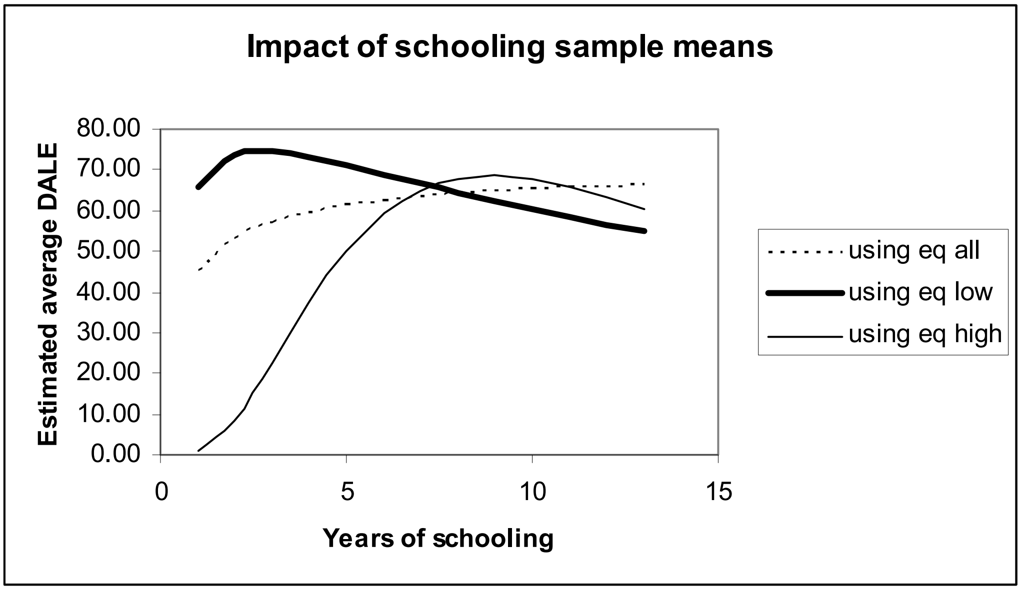

Table 3 shows the coefficients estimated in each subset of countries defined by the threshold of 5.8 years of education. Based on the estimated relationships, Figure 1 illustrates the heterogeneity in the impact of education on health for a country spending US554 per capita and per year (the average health care expenditure on all countries). When the relationship is estimated over the full sample of 111 countries, the rate of return diminishes then stabilizes at a positive value, so the impact on health of adding one year of schooling is approximately the same at 10 years of education as it is at 4 years of education. However, when separate estimates are obtained for low- and high-education countries, the rate of return for low-education countries begins diminishing at around three years of education while the rate of return in high-education countries begins decreasing at around six years of education and is 0 at the base level of 9. These OLS estimates suggest that raising schooling above 3 years would not yield benefit in health among low education countries, and raising it above 9 years would not yield benefit in health among high education countries. As shown below (section 5-3), frontier analysis brings the same conclusion among high education countries, but the rate of return on maximum (rather than average) health is never null among low education countries.

The relationship between health and its determinants reasonably fits in the present study even among the subset of high education countries (R^2 = 38%). This contrasts with the findings of Hollingsworth and Wildman (2003) for OECD countries. The set of high education countries includes most of OECD countries, but also some non-OECD countries, indicating that heterogeneity and inconstancy in parameters might derive from the level of education input rather than from differences in income per capita[1].

The analysis therefore provides evidence on heterogeneity in terms of education levels in the production of health at the population level and identifies potential heterogeneity by identifying a cut-off point and two regimes in the relationship between education, expenditure and health.

Two robust regressions (one on each subset of countries) with health care expenditure, education and its squared value yields coefficients that are close to those in table 3, except that education and the squared number of years of education are not significant anymore at the 10% level in the subset of countries with 5.8 years of education and over.

5.2 Sensitivity analyses: Determinants of health other than health care expenditure and education

Although this study does not aim to fix other specification issues raised in the literature on the WHO 2000 report, most importantly the absence of income per capita or of the inequality in the distribution of income (Greene, 2004), I ran several linear regressions (ordinary least squares)

[1] Almost all OECD are in the high education regime, except for Turkey, Portugal and Luxembourg, the latter having no information available for 1995. 32 non OECD countries also are in this high education regime.

of DALE including other plausibly important determinants of the health of the population. I first checked that introducing income per capita leaves the main conclusions of the study unchanged. Secondly, I introduce other plausible determinants following a stepwise procedure to keep only those estimated to have a significant impact on health.

The main findings are as follows:

Introducing income per capita:

As indicated in column 3 of table 3 (labelled “Model 2”), the coefficient on expenditure turns out to be non significant anymore and the coefficient on the log of income is strongly and significantly positive (+0.20); more important for this study, however, the coefficients on education and squared education are not much affected by the introduction of income per capita.

Performing the Chow test on the coefficients for income (GDP per capita), education and its squared value also confirms that there are two regimes in the relationship between education and health at the aggregate level: the Fisher statistic for the test of any difference in the value of the coefficients for education and its squared value between the two groups of countries (those with less than 5.8 years of education and those with more) is 7.89 ($p < 0.1\%$) and for any difference in the value of the coefficients for income, education, and its squared value the statistic is 6.03 ($p < 0.1\%$). Moreover, qualitative effects (returns of education on health) are the same when income is substituted for health care expenditure in the equation. Therefore, this study confirms previous conclusions by Hollingsworth and Wildman (2003), and Greene (2004) regarding the respective roles of income and health care expenditure in the production frontier of health, but also points that the relationship between education and health is not affected by the choice of the variable for the ‘wealth’ (income or expenditure) of countries’ health care systems.

Other controls are entered using a stepwise method (“forward” method at the 20% threshold). A first regression enters all variables except income per capita (“Model 3”) and a second one enters all variables including income per capita (“Model 4”).

Column 4 (“Model 3”) of table 3 shows that the most significant factors of health among countries with a number of years of education smaller than 5.8 are health care expenditure, education and its squared value, income inequality (log(Gini)), gender inequality in access to primary and secondary education (log ratio of girls to boys), the indicator of governance for government effectiveness, access to pure water (log percentage of population with access to purified water), and to sanitation facilities. As expected, income inequality has a negative impact on health (significant at the 10% level), and access to purified water of sanitation facilities have a positive impact on health in poor countries. Less intuitive is the negative impact of government effectiveness and of access of girls to education on health. Health care expenditures and education are significant at the 0.1% level and squared education at the 5% level. Coefficients are close to those of Model 1. The estimation is based on 27 countries with non missing values on all variables. When income per capita is introduced in the regression (“Model 4”, in column 5) the squared value of education is not significant anymore, and the two counter-intuitive effects disappear.

In the subset of countries with a greater number of years of education, Model 3 predicts that health care expenditure has no significant impact on health, but that education and its squared value have approximately the same impact as in model 1: therefore, model 3 confirms the strong diminishing returns of education on health among rich countries. Among other determinants, access to sanitation facilities has a positive impact on health. The percentage of rural population and access to purified water both affect health negatively, the latter finding being counter-intuitive. Introducing income per capita leaves the coefficient unchanged.

5.3 Implications of Heterogeneity for Assessing Health System Efficiency

As emphasized in the literature section above, many of the studies linking education to health at the aggregate level do so in the context of evaluating heath system performance. Such studies are more interested in the frontier (maximum health outcome attainable) than in the average relationship. To illustrate the importance of heterogeneity across countries in the relationship between education and health, I estimate two production frontiers, one on the set of countries with a low level of human capital and one on the set of countries with a level of human capital above the cut-off determined using the previous (OLS) analysis. I then compare the efficiency values and rankings derived from these two frontiers, accounting for heterogeneity, with those derived from a single frontier estimated on all countries simultaneously.

Table 4: values of coefficients estimated on both subsets of countries for the production frontiers:

Coefficient	Low education countries (below 5.8) N=54	High education countries (above 5.8) N=57
Intercept	+ 3.35	+ 1.09
Expenditure	+ 0.10	+ 0.04
Education	+ 0.29	+ 2.78
Education, squared	- 0.05	- 0.65
Sigma v (random term)	0.028	0.000
Sigma u (efficiency term)	0.276	0.138

Figure 2:

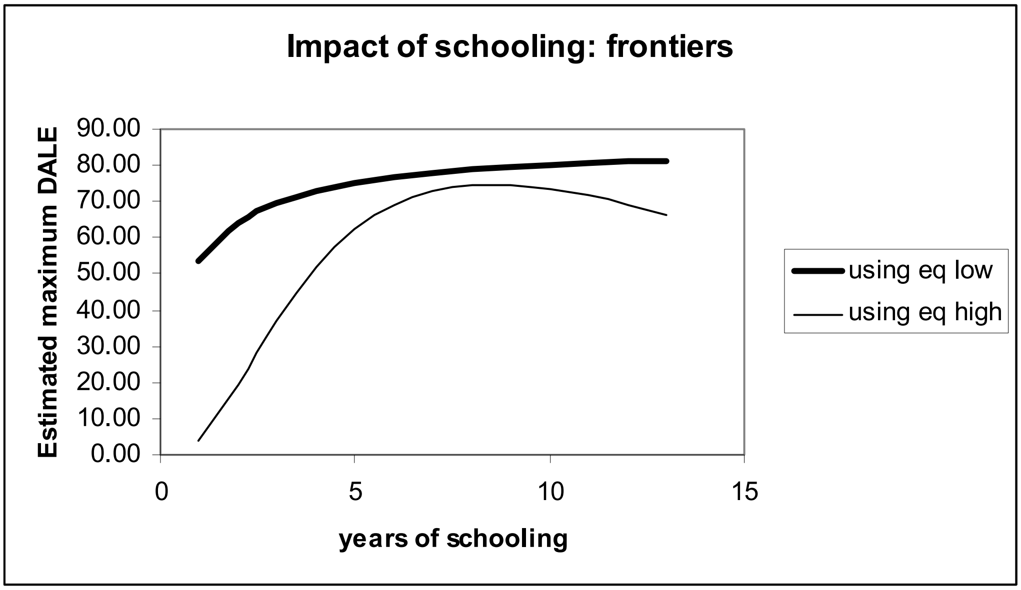

Table 4 presents the results of the estimation of the production frontiers. In both cases the coefficient for the squared value of education is negative, indicating diminishing returns of education on health. The impact of education on the maximum attainable level of health differs across the subsets. In low education countries, adding one year of education on a base of 5.8 adds 1.02 years of disability adjusted life expectancy, and the marginal impact of education on health becomes negative above approximately 20 years of education. In high education countries, increasing the education level one year from 5.8 to 6.8, adds 1.06 years to DALE, (instead of 1.02), but the rate of returns decreases steadily toward 0 at 8.48 years (exp(2.78/1.30)). If this production frontier is correct, there is no gain in population health in investing in education above 9 years but there are still gains to be made in investing in countries with a low level of human capital. Among low education countries, findings from the frontier analysis differ from those of the OLS.

These results based on aggregated data are consistent with the limited individual-level studies showing stabilization or even a decrease in health between those having completed high school and those with more education.

Table 4 also indicates that, among high education countries, the frontier is almost deterministic, with a very small variance for the pure random part of the error term (and consequently, a very high value for the ratio of the inefficiency variance to the random variance).

Distributional assumptions on the error term:

In the baseline estimation I use the normal - half-normal distribution, and I re-estimate the frontier based first on the normal – exponential, then on the normal – truncated distribution.

Table 5: alternative distributional assumptions on the error term:

Coefficient	Low education countries			High education countries		
	Normal-Half normal	Normal-Expo-nential	Normal-Trunca-ted	Normal-Half normal	Normal-Expo-nential	Normal-Trunca-Ted
Intercept	+ 3.35	+ 3.45	+ 3.45	+ 1.09	+ 2.85	+ 2.85
Expenditure	+ 0.10	+ 0.07	+ 0.07	+ 0.04	+ 0.05	+ 0.05
Education	+ 0.29	+ 0.28	+ 0.28	+ 2.78	+ 1.03	+ 1.03
Education, squared	- 0.05	- 0.03	- 0.03	- 0.65	- 0.24	- 0.24
Sigma v (random term)	0.028	0.027	0.000	0.000	0.022	0.000
Sigma u (efficiency term)	0.276	0.193	1.040	0.138	0.003	0.561

As shown on table 5, the frontier is robust to these alternative distributional assumptions of the error term. The impact of education on health is even smaller within the set of countries with more than 5.8 years of education in these two alternative specifications than with the normal – half-normal one, reinforcing the argument pursued in this study.

Impact on technical efficiency and countries rankings:

First, I use the two frontiers, one on each subset of countries (low and high education) to calculate technical efficiencies for all 111 countries and then rank the countries according to these technical efficiencies; therefore, I produce a league table in which countries are ranked https://webmail.mountaincable.net/src/signout.phpaccording to their relative efficiency, even though these efficiencies are derived from two different frontiers.

I compare these rankings to those obtained using a frontier estimated on all countries lumped together, without distinguishing high and low education countries (called one set in table 6).

Table 6: comparison of efficiency when estimation is based on one frontier (no correction for heterogeneity) and when it is based on two frontiers (correction for heterogeneity) – only countries with a higher efficiency and ranking in the corrected estimation than in the un-corrected one are listed below; countries are sorted according to the difference in ranking across the two methods of estimation.

Country	Technical Efficiency Frontier using 2 subsets	Technical Efficiency Frontier using 1 set	Ranking, frontier using 2 subsets	Ranking, frontier using 1 set	Difference in ranking
Norway	1.000	0.894	3	68	65
United States of America	0.957	0.841	23	87	64
New Zealand	0.965	0.873	19	77	58
Canada	0.992	0.897	7	62	55
Sweden	0.999	0.909	5	55	50
Switzerland	0.957	0.896	22	66	44
Australia	0.992	0.923	6	41	35
Germany	0.928	0.877	45	75	30
Kuwait	0.938	0.897	38	64	26
Finland	0.936	0.900	40	61	21
Israel	0.935	0.904	42	59	17
Belgium	0.941	0.914	33	48	15
Netherlands	0.943	0.915	32	47	15
Republic of Korea	0.898	0.846	69	84	15
Croatia	1.000	0.963	1	14	13
Denmark	0.911	0.878	60	73	13
Poland	0.923	0.903	48	60	12
Ireland	0.927	0.905	47	58	11
Japan	0.980	0.949	12	23	11
Paraguay	0.961	0.938	21	32	11
Czech Republic	0.928	0.909	44	54	10

The correlation between the two arrays of efficiency scores is .95 and the Spearman's rank correlation is .79. Overall, therefore, most efficiency scores are left unaffected by the treatment of heterogeneity.

However, as shown in table 6, using the "one set" estimation (one frontier for all countries, whatever their education level) dramatically affects the score and ranking of a subset of 21 countries. In table 6, countries are sorted according to the difference in their relative ranking in the two approaches (when the frontier is estimated using all countries, compared to when two frontiers are estimated, one on each subset of countries).

Countries such as Norway, the USA, New Zealand, Canada, and Sweden tend to do much better in the league corrected for heterogeneity (two frontiers), where human capital plays a smaller role at high levels. Therefore, they appear in the first rows of table 6. A distinguishing feature of this subset of countries is their high level of education, with an average of 9.6 years (compared to an overall average of 6.0); with the exception of Kuwait, Paraguay, and Croatia, all the countries in this subset are above 9 years of schooling in the population, a level above which the rate of return of education on health is null or negative (see figure 2).

This alternative league table, where human capital plays a much smaller role among high-education countries, seems therefore more realistic (it gives a fairer account of the true endeavour of health care systems) than the frontier estimated on an heterogeneous set of countries. However, it is not exempt from the criticisms addressed to the production frontier in health as developed by the WHO and calls for further inquiry into health-education relationship at the aggregate level.

6. Conclusions

Using data at the country level and a production frontier framework built upon that suggested by the WHO in its World Health Report 2000, I show that the impact of education on health (disability adjusted life expectancy) follows two different regimes. One regime includes countries with a low level of education (below 5.8 years on average), for which the elasticity of health to education declines from 0.15 when the average years of education is 4 years to 0.11 when the average is 6 years of education. The second regime includes countries with a high level of education, for which it doesn't pay (in health) to increase education above 8 years per individual on average in the population. This finding should be tested with other data, focusing on the functional relationship between schooling and health rather than on the mere significance of the effect, but it suggests that the marginal impact of schooling on health is smaller when the individual has received 8 years of schooling.

The second finding from this study is that the evaluation of efficiency of health care at the national level using country level data and modeling health care systems as producers of population health requires thorough investigation of the specification of the production frontier, and of the role of human capital on health.

To conclude with a word of caution, it is worth noting that, while the present study focuses on the extent of two different regimes in the relationship between education and health at the country-level, no attempt has been made to correct for reciprocal causality of health on human capital. In this I have followed a course well established in the field of health system performance assessment; however, correcting for endogeneity biases in the measurement of the production function of health by health care systems would add to the robustness of the analysis and allow for more policy-oriented recommendations based on its findings. This opens a new avenue for research, starting with a systematic review and assessment of databases and variables that may be used as instruments for education and other factors of production of health at the country level.

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