Health Investment and Long run Macroeconomic Performance: a quantile regression approach

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Abstract

This paper analyses the relationship between health human capital and economic growth for a maximum sample of 92 countries over the period 1980-2010 applying the methodology proposed by Canay (2011) for regression by quantiles (Koenker 1978; 2004; 2012a,b) in a panel framework. This approach allows for the identification of different impacts of the explanatory variables across the growth rate distribution. According to Mello & Perelli (2003), quantile regression allows to capture countries' heterogeneity and assess how policy variables affect different countries according to their position on the conditional growth distribution. Quantile regression analysis allows us to identify those growth determinants that do not have the expected relationship with growth and hence determine the policy implications specifically for under-performing versus over achieving countries in terms of output growth. Our findings indicate that better health is positively and robustly related to growth at all quantiles, but the quantitative importance of the respective coefficients differs across quantiles in some cases, with the sign of the relationship greater for countries that recorded lower growth rates. These results apply to both positive (life expectancy, consumption of calories per person per day) and negative (infant mortality rate, prevalence of undernourishment in populations) health status indicators. Given the predominantly public nature of health funding, cuts in health expenditures should thus be carefully balanced even in times of public finances sustainability problems, particularly in times of growth slowdowns, since a decrease in the stock of health human capital can be particularly harmful for growth for under achievers.

Keywords: health; human capital; economic growth; quantile regression

JEL Classification: C31, C33, I15, O15, O47

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1. Introduction

Human capital is acknowledge as one of the prime sources of economic growth. As countries move towards knowledge-based economies, the existence of highly skilled human capital becomes increasingly important. It is thus not surprising that previous empirical research has focused on identifying the mechanisms of transmission from human capital accumulation to growth and assessing the respective magnitudes (see *e.g.* Benhabib & Spiegel 1994, 2005; Bloom *et al*. 2004; Howitt 2005; Hanushek & Woessmann 2011; Bleakley 2010). However, most previous studies focus on formal education as the main source of human capital, while the impact on growth of health human capital has not attracted as much interest. Health influences labour productivity, the capacity to learn at school and to grow intellectually and physically (Lewis & Jack, 2009). Simultaneously, the decrease in mortality and morbidity allows for an increase in the proportion of the working age population, therefore contributing to raise per capita income. Higher longevity also creates a greater need for people to save for their retirement (Bloom & Canning 2012). It is thus not surprising that "several of the great 'take-offs' in economic history […] were supported by important breakthroughs in public health, disease control, and improved nutritional intake […]" (Sachs 2001; p.22).

At the empirical level, Lewis and Jack (2009), p.2 "(…) caution the reader against expecting to find consensus in the empirical literature on the links from health to growth or even from health policies to health." In terms of econometric methodologies for the study of the relationship between health human capital and economic growth, applied studies usually assume homogeneity among countries by restricting the significance and magnitude of the relationships for the average economy. In fact, most previous studies use methodologies that estimate the average effect of health on output growth thus assuming that the parameters (slope coefficients) of the empirical model are country invariant, i.e. they assume parameter homogeneity. Allowing for parameter heterogeneity in the study of the health human capital-economic growth nexus in broad samples of countries can thus bring new insights. This is particularly true at a time when many countries are still under the effects of the 2007-08 financial crisis, with impressive growth slowdowns that demand a rigorous identification of the most effective sources of growth in periods of deceleration. The identification of different growth impacts of health human capital across the output growth rate distribution can be especially important for countries facing fiscal sustainability problems, such as Greece, Portugal and Ireland. Since investments in health are mainly publicly funded in many countries, a cut in public health expenditures, with the associated negative impact on health human capital, can be especially harmful for output growth in slow growing countries.

The main aim of this paper is to assess the importance of health human capital for economic growth in a broad sample of countries taking into account parameter heterogeneity. For this purpose, we allow for differentiated effects of health human capital on the output growth rate, conditioned by the location of the dependent variable at different parts of its distribution. Additionally, we will analyse the sensitivity of our results to the use of different proxies for health human capital, trying in this way to overcome, to some extent, measurement error problems. We apply a quantile regression approach to estimate output growth equations for a maximum sample of 92 countries over the period 1980-2010. According to Mello & Perelli (2003), quantile regression is a suitable estimation methodology in a growth context as it is possible to capture countries' heterogeneity and assess how policy variables affect countries according to their position on the conditional growth distribution. In terms of policy implications, as suggested by Barreto & Hughes (2004), it may be the case that, due to the presence of other (un-modelled) determinants countries grow slower (or faster) relative to the conditions suggested by the variables that are included in the model. Quantile regression analysis allows us to identify the growth determinants that do not have the expected effect on growth and hence determine the policy implications specifically for under-performing versus over achieving countries in terms of output growth.

The remainder of this paper is organized as follows: in section 2 we briefly review the theoretical predictions and empirical evidence on the nexus between health human capital and economic growth. Section 3 contains a data overview. In section 4 we present the empirical model and describe the methodological approach. In section 5 we present and discuss the results. Finally, section 6 contains the main findings and some suggestions for future research.

2. Is health correlated with economic growth? Literature overview

Human capital is widely recognized as an important source of economic growth. The link between human capital and growth has been explored and measured mainly considering formal education (Benhabib & Spiegel 1994, 2005; Miles 2004). During the 20th century, health improvements were impressive resulting in the extension of the concept of human capital to include, besides education, “the general state of health of the working population” (Savvides & Stengos 2009, p.4), notwithstanding the divergences at the empirical level on how to measure this concept.

The benchmark for modelling the relationship between health human capital and economic growth is the neoclassical growth model, which has its genesis in the work developed by Solow (1956) and Swan (1956). Mankiw Romer and Weil (1992) emphasized the role of human capital in explaining income and growth differences across countries in what became known as the Augmented Solow Model. Health, just like education, differs across individuals and consists of a stock that can depreciate or increase over time (Grossman 1972). Healthier workers are able to think better, are more focused and allocate more energy and higher effort to task performance. Health thus influences some of the workers’ characteristics that influence their productivity. Additionally, healthier workers are less likely to miss work due to sickness (Bloom & Canning 2000). The better is the health status for the same number of workers the higher is their productivity and the resulting total amount of output.

Health is thus considered in neoclassical growth models as just another input into the production of final goods alongside physical and education human capital. In light of the neoclassical growth theory, higher rates of accumulation of both human (health and education) and physical capital lead to permanently higher levels of income. In any case, poorer countries are predicted to grow at a faster pace in the neighbourhood of the steady state growth equilibrium, after differences in structural characteristics across countries are controlled for (Barro & Sala-i-Martin, 2004), known as the convergence hypothesis. Besides its role as an input into final goods production, health human capital can also play a role as an input into innovation and imitation activities. Endogenous growth theories that developed from the mid-1980s onward aimed at explaining how technological progress takes place. AK-type growth models assume that human capital contributes to economic growth because workers with higher human capital levels increase not only their own productivity but also that of other individuals with whom they perform different tasks, thus overcoming the growth effects of the diminishing marginal returns hypothesis (Lucas 1988). Human capital is also viewed by endogenous growth theory as being of major importance for innovation and technology diffusion activities (Romer 1990; Nelson & Phelps 1966; Barro & Sala-i-Martin 2004). If health human capital increases, the knowledge inducing the production of new ideas/technologies will also rise, there will be more ideas available and thus more innovation will take place in the technological leader countries. In the follower countries, a better health status will increase their absorption capacity in terms of adapting and implementing the technologies developed by the leaders.

Additionally, health human capital can produce an indirect growth impact through its influence over other growth determinants such as demography, education, physical capital, and income inequality and poverty (Bloom & Canning 2000; Howitt 2005; López-Casasnovas *et al*. 2005). If the health status of the population increases, school absence due to sickness is expected to decrease. Health allows enhancing learning capacity, since individuals will be better prepared, both physically and intellectually, to learn. In particular, better nourished children will have better cognitive skills (Alderman *et al*. 2006). Moreover, if health increases occur in the form of decreasing mortality or increasing longevity, the higher will be the incentive to invest in education and acquire additional school qualifications. Since education is a source of human capital that is predicted to impact growth positively, healthier populations will also present higher educational attainment levels and perform better at school, which in turn leads to higher growth and income levels. Is it thus not surprising that several studies have considered the health-education nexus when studying the impact of the former on economic growth (Miguel & Kremer, 2004). Moreover, increasing longevity influences savings decisions. If people expect to live longer, they will save more for their retirement. Higher savings rates will in principle lead to higher investment rates and thus more physical capital accumulation, which in turn fosters growth. On the contrary, if people's health is poorer and they have "a short time horizon because they expect to die young, they have less reason to save and the economy fails to grow.” (Lorentzen *et al*. 2008, p.82).

Finally, promoting health can not only spur economic growth and development but also reduce poverty (Sachs 2001). In fact, health improvements have larger impacts on the standards of living of the poorer with weaker health (Deaton 2003). Poorer people which are better nourished see their education capabilities improve (Lorentzen *et al*. 2008) with positive consequences on their performance and economic growth. This is often the reason why improving the health status of the poorer is seen as a way to escape from poverty traps (Sala-i-Martin, 2005).

At the empirical level, researchers have yet to reach a consensus on the impact of health status and accumulation on growth. Early empirical studies find a positive relationship between health and economic growth in line with the pioneer work of Preston (1975). There is evidence pointing to health as an important growth determinant regardless of the period under analysis, type and number of countries included in the sample, health proxies used and model specification. However, negative and statistically significant impacts of health on output growth have also been found (Lewis & Jack 2009). This has led researchers to search for patterns across specific regions and among countries within the same income level group (Eggoh *et al*. 2015; Poças & Soukiazis 2012; Aghion *et al*. 2011; Bhargava *et al*. 2001). Overall, results appear sensitive to the health proxies used.

As far as panel data studies with wide samples of countries are concerned, Bloom *et al*. (2004) review some previous studies that use life expectancy to proxy for health status and conclude that the majority find a positive effect running from the initial level of health to output growth. They also estimate growth regressions with life expectancy (initial level) as the main explanatory variable, over the period 1960-1990 for a sample of 104 countries. The results found point to a statistically significant and positive correlation, suggesting that health affects economic growth through its direct impact on labour productivity. Also using life expectancy to measure health human capital accumulation, Acemoglu & Johnson (2007) arrive at a negative correlation for a sample of 47 countries over the period(s) 1940-1980/1940-2000 implying that faster health accumulation is not beneficial for growth. According to the authors this is due to a Malthusian effect (the idea that population growth is expected to exceed resources growth) since for the period under analysis life expectancy grew at the same rate as population. In line with this work, Aghion *et al*. (2011) main aim is to study the impact on the results of using different health proxies and growth theories, translated in the influence of the levels vs. the accumulation of health on output growth rate. They estimate a cross-country regression for a sample 96 countries where they find a positive impact going from life expectancy (level) to growth although health accumulation reveals to be less robust (becomes statistically insignificant after a certain threshold). However, in OECD countries the only health proxy with a positive correlation with growth is the reduction in the mortality rate below age forty. For the same time span, Lorentzen *et al*. (2008) explore other channels through which health might influence growth and they conclude that health can affect growth in a quantitatively more important way when countries simultaneously invest in physical capital and by influencing fertility rates, rather than by the human capital channel.

A problem that hinders the robustness of the results from the previous studies concerns their ability to statistically summarize all the information of a particular relation between variables using standard estimation techniques such as OLS or IV. When assessing the relationship between health and economic growth, linear regression techniques estimate the average effect of health on output growth thus assuming that the parameters (slope coefficients) of the empirical model are country invariant, i.e. they assume parameter homogeneity.

Soukiazis & Cravo (2007), Bhargava *et al*. (2001) and Cooray (2013) try to go beyond assessing the average effect by dividing their samples into different income groups (low, middle and high-income countries). They also proxy health with life expectancy but Cooray (2013) uses a sample of 210 countries while Soukiazis & Cravo (2007) consider 77 countries (for the periods 1980-2000 and 1990-2008, respectively). Despite using the same health proxy, Cooray (2013) finds a correlation between health and other variables such as health expenditures and education while Soukiazis & Cravo (2007) do not. Increasing health, according to the results in Soukiazis & Cravo (2007), is growth enhancing for low income countries whereas it has no statistically significant impact in high income countries. When Cooray (2013) uses adult survival rates as a proxy for health, the results point to a positive growth influence in upper middle and high income countries while the influence is negative in low and low middle income countries. The study by Bhargava *et al*. (2001) proxies the health status with adult survival rates considering a sample of 92 countries and obtains results similar to those of Soukiazis & Cravo (2007). Their results, notwithstanding, indicate that the impact of health on growth is significant until it reaches a certain threshold, above which it becomes insignificant, providing a possible and reasonable explanation for the differences in the results from other studies. Similarly to some of the previous studies, Cooray (2013) also explores the interrelations (with interaction terms) between health and other variables that might influence economic growth. The author finds statistically significant and positive effects of health on education human capital and health expenditures. Other studies that tried in some way to deal with the issue of parameter heterogeneity are those that restricted the sample to specific countries within a geographical region or an institutional group thus focusing on more homogeneous groups of countries, as in Eggoh *et al*. (2015) for African countries and Poças & Soukiazis (2012) for OECD countries. Poças & Soukiazis (2012) find evidence that health boosts growth in OECD countries, especially when considering the proxy health care quality and the mortality rates associated with specific diseases. On the other hand, Eggoh *et al*. (2015) conclude that increasing health expenditures may have a negative growth influence, even when the level of health expenditures for the countries is low, if education expenditures are below a certain threshold.

However, the previous studies cannot provide information on whether the health-growth nexus differs across under-performers and over-performers in terms of growth, i.e. they fail to account for the entire conditional distribution of the output growth rate. As stated by Canarella and Pollard (2004), p. 3, "(…) finding the magnitude of the effects of the explanatory variables at the tails of the conditional growth distribution is likely to be more interesting and useful than finding the magnitude of such effects at the conditional mean." Wang (2011) and Miles (2004) are examples of studies that investigate heterogeneous effects of different growth determinants. Miles (2004) focus on educational human capital. This author considers a sample of 77 countries for the period 1970-1998 and applies a pooled quantile regression approach. He finds different marginal effects of human capital between slow growers and fast growers. In line with this reasoning and focusing on the relationship between health and growth, Wang (2011) investigates the impact of health expenditures on growth for a sample of 31 countries over the period 1986-2007 applying a quantile regression approach to identify different impacts according to the output growth rate distribution. The results obtained indicate that there is a positive influence among middle and high performers, while for low performers the influence is negative.

Despite the theoretical arguments in favour of a positive and important influence of health on economic growth, in the empirical literature there are still some gaps to fill in order to get a better understanding of the role of health on economic growth. The main aim of this work is to contribute to shed additional light on the health-growth nexus by applying quantile regressions and identifying potential differences between under and over achievers/performers. We also consider different health proxies in order to identify new insights and reach some consensus as well as to stimulate future research on the topic.

3. Data overview

Our broadest sample includes a balanced panel data set for 92 countries (see table A.1 in the Appendix [1]) from 1980 to 2010. The data needed for the estimation of our growth regressions were computed with information obtained mainly from the *Penn World Table* (PWT) (Feenstra *et al*. 2015), version 8.0, and the *World Development Indicators* (WDI). Using data originally from the PWT 8.0 we computed data for real GDP per capita at constant PPP by dividing output at constant international PPP at 2005 prices by total population. From the WDI we extracted several health proxies based on the following criteria: first, the availability of data for long periods of time and relative to a high number of countries; and second, our interest in capturing different growth effects through several perspectives on health status and accumulation.

[1] We started by considering all the countries for which there was information in the two main databases, the PWT and the WDI. We next excluded some observations based on the following criteria: first, we excluded the current members of the Organization of the Petroleum Exporting Countries (OPEC) and small countries (population less than one million according to WDI 2014 data.). In order to have a balanced panel data set we applied some data manipulation procedures for the variables population growth, prevalence of undernourishment and consumption of calories per person per day that were lacking a few observations for the period 1980-2010. Details on these procedures are available from the authors

Although the health status of a population and its accumulation are difficult concepts to measure, the classical procedure for their evaluation is based on 5 D's: death, disease, disability, discomfort, and dissatisfaction (Lohr 1988). These provide negative outcome indicators and therefore the doubt remains whether it is more accurate and conceptually correct to measure the lack of health (negative indicators) rather than its existence (positive indicators). The latter refers to wellness and quality of life, which involves a lot of subjectivity in its measurement. Thus, besides the criteria for selecting health variables previously described, we also considered both positive and negative health indicators. The positive health indicators used are life expectancy, female and male survival rates to the age of 65, and consumption of kilocalories per day per person. The negative health indicators are female and male adult mortality rates, infant mortality rate and the prevalence of undernourishment. Finally, we also proxy for health investments using public health expenditures per capita. For a summary of the variables used see Table A.2. in the Appendix. Table 1 presents some descriptive statistics for the main variables.

According to figure A.1 in the Appendix that contains a scatter plot relating countries' average growth rates for two sub-periods, 1980-1995 and 1995-2010, most of the observations are located in the first quadrant, although there are also some observations in the other three quadrants. This implies that the countries that were slow (fast) growers in the first sub-period remained slow (fast) growers in the second sub-period. This supports the importance of further investigating whether the explanatory variables we consider in our growth regressions have different growth impacts across different parts of the distribution of the output growth rate, our dependent variable. Countries can reap additional growth benefits from the identification of the growth determinants that have higher growth impacts according to the respective growth performance.

Table 1. Descriptive statistics for the main variables

Variable	Obs.	Mean	Stand. Deviation	Median	1st quantile (0.25)	3rd quantile (0.75)
Δly	552	0.0166	0.0392	0.0175	-0.0043	0.0369
le	552	64.77	11.1228	67.94	56.08	74.11
$asr.m$	552	0.6095	0.1618	0.6333	0.4864	0.7448
$asr.f$	552	0.6969	0.1785	0.7478	0.5577	0.8520
imr	534	0.0494	0.0419	0.0371	0.0114	0.0798
$amr.m$	540	0.2595	0.1240	0.2376	0.1629	0.3237
$amr.f$	540	0.1926	0.1302	0.1491	0.0886	0.2689
gh	270	820.93	1062.645	343.13	90.32	1248.04
$under$	252	0.2111	0.1331	0.1945	0.1003	0.3050
$kcal$	252	154.400	105.1652	142.344	70.125	229.000

Notes: $\Delta\mathbf{ly}$ - average annual growth rate of real GDP per capital; $\mathbf{le}$ – initial level of life expectancy; $\mathbf{asr.m}$ - initial level of adult male survival rate; $\mathbf{asr.f}$ - initial level of adult female survival rate; $\mathbf{imr}$ - initial level of infant mortality rate; $\mathbf{amr.f}$ - initial level of adult female mortality rate; $\mathbf{amr.m}$ - initial level of adult male mortality rate; $\mathbf{gh}$ - initial level of public health expenditures per capita; $\mathbf{under}$ – initial level of prevalence of undernourishment; $\mathbf{kcal}$ – initial level of consumption of calories per day per person. $\Delta\mathbf{ly}$, $\mathbf{le}$, $\mathbf{asr.m}$, $\mathbf{asr.f}$, $\mathbf{imr}$, $\mathbf{amr.m}$, $\mathbf{amr.f}$ relate to 1980-2010. $\mathbf{gh}$ relates to 1995-2010 and $\mathbf{under}$ and $\mathbf{kcal}$ relate to 1990-2010.
Source: Authors' calculations with R.

Table A.3 in the Appendix contains the correlation matrix between health indicators. The negative indicators (such as mortality rates and population undernourished) are negatively correlated to the positive ones (life expectancy, survival rates), as expected. In spite of being a positive health indicator, the variable measuring the consumption of calories presents a negative correlation with the other positive indicators, suggesting that in some countries of the sample the daily calories consumption is beyond that which is beneficial for health. The correlation between health expenditures and the other health indicators presents a positive sign relative to the positive health status indicators and a negative sign with the ones, as expected.

4. Empirical growth models and quantile regressions

In order to assess the importance of health and its different proxies for growth we estimate what is known in the literature as an *ad hoc* growth regression (Barro & Sala-i-Martin 2004) since it is not directly derived from a particular growth model but incorporates growth determinants highlighted by both the exogenous and the endogenous growth literature. We consider each health proxy alternatively (to avoid collinearity) together with a set of control variables identified as important growth determinants in the empirical and theoretical economic growth literature (Sala-I-Martin, Doppelhofer & Miller, 2004; Moral-Benito, 2012).

Our baseline growth regression is given by equation (1):

$$\frac{\Delta \mathrm{l}\, y_{it}}{T} = \beta_0 + \beta_1 h_{it-1} + \beta'_{[2\ldots p]} X_{it} + \epsilon_{it} \quad (1)$$

where $\frac{\Delta \mathrm{l}\, y_{it}}{T}$, the dependent variable, is the real GDP per capita annual average growth rate for each 5-year period; h_{it-1}, the main explanatory variable, is the proxy for health given by the initial level of the variable for each 5-year period; the vector X contains (p-1) control variables identified according to previous theoretical and empirical literature, corresponding to: $educ_{it}$, educational human capital proxied by Barro and Lee (2013) average years of total schooling; ly_{it-1}, the log of initial real GDP per capita (for each 5-year period) that controls for the existence of convergence among the countries in our sample; $gfcf_{it}$, the share of fixed capital formation in GDP; n_{it}, the average population growth rate for each 5-year interval; g_{it}, average government consumption share in output for 5-year period and $lopen_{it}$, the logarithm of trade share in output (see table A.2 in the Appendix). β_0 is a constant term and ϵ_{it} the error term with the usual properties, i.e. independent and identically distributed (iid). We divide the overall time period into 5-year intervals to overcome business cycle effects and we consider initial values of the health indicators to try to overcome to some extent the endogeneity between output growth and health. Using panel data also permits to control to some extent for measurement errors.

As far as the sign of the estimated coefficients is concerned, we assume that a better health status plays a key role in fostering workers' productivity. Thereby, real GDP per capita growth rates are believed to move in line with life expectancy, survival to age of 65, kilocalories per day and health expenditure per capita; and to vary inversely with adult and infant mortality rates and the prevalence of undernourishment. Increasing production capacity by investing in physical capital or in education represents the possibility of increasing the amount of output, and therefore these investments also play an important role in explaining differences in growth rates across countries. The initial level of output of a country will affect its performance as well, known as the convergence hypothesis, through diminishing returns or technological catch up.. Lower growth rates are associated with levels of output close to the steady state equilibrium, whilst poorer countries will present higher growth rates. In the neoclassical framework, the population growth rate has a negative growth impact. Additionally, a country's GDP per capita can growth faster as countries open their market to foreign countries and allow more goods to be traded with the rest of the world, due to scale effects, increased competitiveness and/or technological diffusion. Finally, Barro (1990) considers the share of government expenditures as a powerful determinant of growth rates. He argues that increasing the share of non-productive government expenditures can lower growth.

We have estimated equation (1) using quantile regression with the main aim of identifying health growth effects beyond those allowed by conventional estimation procedures. This method, first proposed by Koenker & Bassett (1978), estimates models for conditional quantile functions, $Q_\tau(\mathrm{Y}/\mathrm{X})$: the influence of a set of variables X on Y is estimated for univariate quantiles $\tau \in (0,1)$ of the distribution of Y rather than focusing on the expected value of the response variable as do least squares estimation, *E(Y/X)*. The mean effects reflect only a specific part of the distribution (the central part). Similarly, univariate quantiles of the empirical distribution also correspond to a particular location of the distribution with value y such that $P(Y \leq y) = \tau$. Thinking of quantiles as a central part of a particular location of the distribution (like the median or the mean) makes it possible to solve the minimization problem in the same way as that for the conditional mean[2].

In summary, quantile regression minimizes a weighted sum of absolute deviations given by:

$$\hat{\beta}_\tau = \arg\min\left[(1-\tau)\ \textstyle\sum_{i \in \{i:\, y_{it} < X'_{it}\beta\}}(y_{it} - X'_{it}\beta_\tau) + \ \tau\ \textstyle\sum_{i \in \{i:\, y_{it} \geq X'_{it}\beta\}}(y_{it} - X'_{it}\beta_\tau)\right] \quad (2)$$

By applying the quantile regression procedure it is possible to generate estimates of the influence of the covariates on the dependent variable for each quantile τ of the distribution of the response variable. The estimations were carried out using the linear programming procedure available for R studio (Koenker 2012b).

The quantile regression approach presents several advantages when compared to conventional estimation methods such as ordinary least squares (OLS).

[2] For the median ($\tau = 0.5$) the problem is solved by minimizing the absolute sum of deviations.

The most obvious one refers to the fact that it provides summary statistics on both the central part and the tails of the distribution of the response variable allowing for a more complete investigation of the influence of specific covariates[3]. Quantile regression is also a more robust estimation procedure when the errors are not iid since it is more robust to non-normal errors and outliers (as it minimizes asymmetrically absolute deviations) while ordinary least squares can be inefficient if the errors are highly non-normal. Furthermore, we can easily compare regression coefficients of specific quantiles to least squares estimates. The interpretation is very similar: a one-unit increase in the predictor variable associated to the estimated coefficient produces a change in the dependent variable expressed by the coefficient obtained for the specific quantile of the response variable.

Additionally, panel data enables us to control for unobserved fixed effects. To address the over parametrization resulting from parameter heterogeneity (Koenker 2004) we eliminate the fixed effects applying the method proposed by Canay (2011). This corresponds to a two-step estimator that is consistent and asymptotically normal as both the number of units and periods grow. Assuming that fixed effects affect all quantiles in the same way, the effect on the conditional mean will also be the same. Therefore, in a first step, we estimate the conditional mean within the model and then purge this model from the individual effects. In a second step, it is thus possible to run a simple quantile regression after subtracting the individual effects from the dependent variable. In the next section, we first present the estimation results of a panel fixed effects model for a better discussion and comparison of the results with those obtained when applying the fixed effects quantile regression proposed by Canay (2011) (for the 0.05, 0.25, 0.5, 0.75 and 0.95 quantiles).

[3] The quantile regression produces similar results to conditional mean estimation when the model fits the classical linear hypothesis.

5. Results

In this section, we present the results of estimating our baseline growth regression (see equation (1)) with the different health proxies for our sample of a maximum of 92 countries over the period 1980-2010. First, however, we applied unit root tests[4] to the variables and residuals of the regressions that proved to be stationary. We thus eliminated the possibility of obtaining spurious relationships. To estimate the panel least squares model we thought relevant to apply the Hausman (1978) test[5] in order to confirm fixed effects consistency that would otherwise jeopardize the panel methodology suggested by Canay (2011). The results from these preliminary tests allowed us to proceed to the estimation of our growth regressions with quantile regression techniques.

As far as the results from the quantile regression estimations are concerned, we present them in two different ways in order to facilitate the interpretation of our findings. On the one hand, we plot the evolution of the marginal effects of the different health proxies across quantiles, at 90% confidence intervals, together with the marginal effect of the least squares estimation, also at a 90% confidence interval. Additionally, for each variable we present the results of the test of coefficient homogeneity[6] across quantiles along the output growth rate conditional distribution. The null hypothesis corresponds to slope equality across quantiles so if the test rejects the null hypothesis we are in the presence of statistically significant differences in slope coefficients for the explanatory variables. Furthermore, to allow for a clearer interpretation of the graphical analysis, table 2 provides an overview of the health proxies' estimated coefficients for positive indicators and health expenditures. For the estimation, we considered five quantiles, τ's ($\tau = 0.05, 0.25, 0.5, 0.75, 0.95$) in order to get a better understanding of the potential changes in coefficients across the conditional distribution.

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[4] For this purpose we apply the Levin-Lin-Chu (2002) test using the econometric package. The results are available from the authors.

[5] This test evaluates the consistency between the fixed effects estimator and the random effects estimator. The results obtained enabled us to reject the null hypothesis of fixed effects inefficiency. The results are available from the authors.

[6] The test is the Wald test for marginal effects equality (Koenker & Bassett 1982).

Figure 1 plots the estimated coefficients for the different health proxies across output growth quantiles. As we can see in figure 1, part (a), the inverse of the life expectancy logarithm[7] (*ille*) shows a negative coefficient, as expected, that decreases from low (slow growers) to high (fast growers) deciles. These findings suggest that an increase in life expectancy (that corresponds to a decrease in *ille)* has a positive impact on growth (*ille* and growth rates vary inversely so life expectancy varies positively with growth rates). The estimation coefficients (table 2) are statistically significant at 0.001% for most quantiles with the exception of the coefficient for the 0.95 quantile that presents no statistical significance and the coefficient for the 0.75 quantile that is only significant at the 0.01% level. Besides these results being statistically significance and corresponding to different slopes for the estimated quantiles, also the p-value of the slope equality test indicates that in this case we can reject the null hypothesis of equal slopes for life expectancy in the growth regression.

Kilocalories consumption per day per person (*ilkcal*) is also a positive indicator and since it is also introduced in the regression as its inverse we expect that the estimated coefficient has a negative sign (just like life expectancy). According to the results presented in figure 1(b) and table 2, the estimated coefficients for this variable confirm the expected negative sign across all quantiles. Figure 1, part (b), suggests that the influence of calorie consumption across the quantiles of the growth rate distribution is quite similar to the results obtained when the regression is estimated by least squares until around the 0.8 quantile, when the magnitude becomes lower. However, the estimated coefficients for the lowest (0.05) and highest (0.95) quantiles are not statistically significant and the coefficients for the other quantiles are very similar which is indeed confirmed by the results of the slope equality test that do not allow us to reject the null hypothesis.

[7] Differences in life expectancy across some countries in our data are quite important and the same applies to public health expenditures per capita and calories consumption per day per person. For example, life expectancy at birth in Cambodia in 1980 was around 28 years whereas it was near 76 years in Sweden. We expect the gains in terms of output growth associated with further increases are lower in Sweden implying that this investment has decreasing marginal returns and the same reasoning applies to health expenditures and calories consumed per day per person. We thus consider these three variables as their inverse in the estimations.

Table 2. Estimates of the quantile panel model and fixed effects model for <u>positive</u> health indicators and health expenditure

		$ille$	$ilkcal$	$asr.m$	$asr.f$	$ilgh$
Fixed Effects		-1.3308*** (0.3532)	-0.0333 (0.0981)	-0.8320*** (0.1370)	0.1359 (0.0878)	-0.0566 (0.0915)
Quantile	τ = 0.05	-1.7878*** (0.3737)	-0.0432 (0.0315)	0.0087 (0.0700)	0.1458* (0.0633)	-0.8442*** (0.1139)
	τ = 0.25	-1.9006*** (0.3693)	-0.0628* (0.0277)	-0.0176 (0.0385)	0.1675*** (0.0362)	-0.7918*** (0.0775)
	τ = 0.50	-1.2211*** (0.3199)	-0.05219. (0.0281)	-0.0410 (0.0417)	0.1373** (0.0457)	-0.7583*** (0.0568)
	τ = 0.75	-0.9630** (0.3047)	-0.0688* (0.0343)	-0.0924* (0.0392)	0.1717*** (0.0411)	-0.8599*** (0.0662)
	τ = 0.95	-0.8711 (0.7011)	-0.0383 (0.0417)	0.0158 (0.0817)	0.0646 (0.0926)	-0.8858*** (0.1465)
Slope equality test		2.9263 (0.0198)*	1.5782 (0.1773)	0.9327 (0.4440)	1.6671 (0.1548)	1.2765 (0.2772)
No. countries		92	63	92	92	90
Time period		1980-2010	1990-2010	1980-2010	1980-2010	1995-2010

<u>Notes:</u> $ille$ – inverse of life expectancy; $asr.m$ – adult male survival rate; $asr.f$ – adult female survival rate; $ilgh$ – inverse of public health expenditures per capita; $ilkcal$ – inverse of consumption of calories per day per person. Standard errors in parenthesis. The slope equality test refers to the test's statistic ant with the p-value in parenthesis. ***, **, * and '.' denote the statistical significance at the 0.1%, 1%, 5% and 10% levels, respectively.
<u>Source:</u> Authors' calculations using R.

The adult survival rates as well as the adult mortality rates (for the latter results can be found in table 3) were disaggregated by gender (*amr.m*, *amr.f* and *asr.m*, *asr.f*, m for males and f for females). The results with both types of health indicators differ from the previous ones when considering the data for males. Overall, for this indicators the results of the slope equality test do not allow us to reject the null hypothesis of parameter homogeneity. Additionally, the estimated coefficients for males are only statistically significant for males after quantile 0.75. By contrast, the estimators for female variables present higher statistical significance and at more locations of the growth rate distribution. In this case, the estimated coefficient for quantile 0.95 presents the lowest value but is not significant, similar to the estimators for the previous health proxies. Furthermore, there appears to be no pattern of change for health coefficients across quantiles, again as previously found for the positive indicators, which we can confirm by looking at figure 1 (d) and (f). For instance, as far as the female survival rate is concerned, the correlation is positive for all quantiles but the magnitude of the impact does not show a monotonic behaviour: it increases from the 0.05 to the 0.5 quantiles, it then decreases when we move to the 0.5 quantile and increases again for quantile 0.75, when it reaches its highest value (table 2). This pattern also applies to the estimated coefficients for the female mortality rate (table 3), and the estimated coefficients are always negative, as expected. The main difference pertains to the significance for quantile 0.05 where female adult mortality rates are not statistically significant.

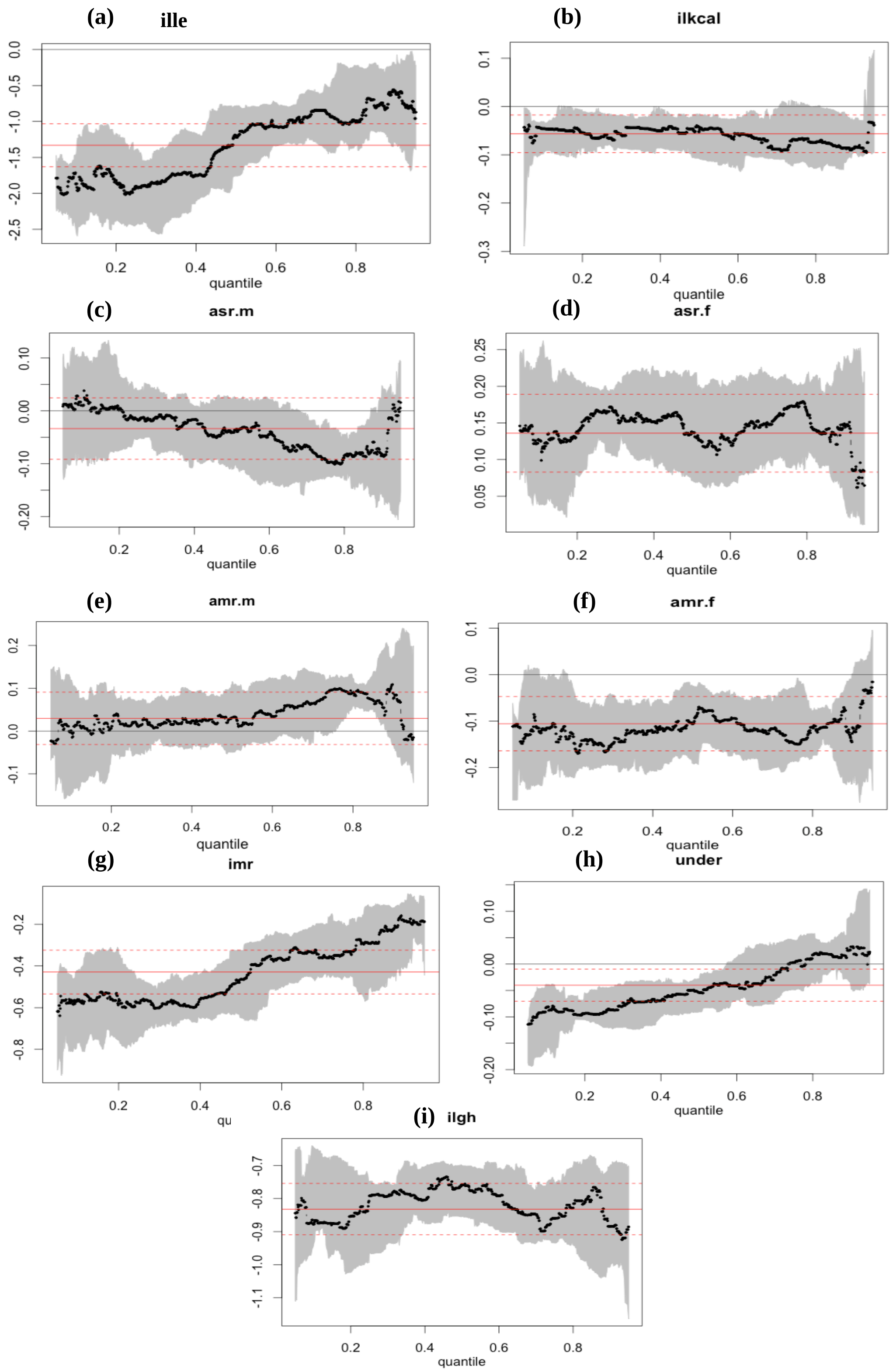
Table 3. Estimates of the quantile panel model and fixed effects model for <u>negative</u> health indicators

		imr	$amr.m$	$amr.f$	$under$
Fixed Effects		-0.4293** (0.1305)	0.0297 (0.0901)	-0.1055 (0.0901)	-0.0400 (0.0589)
Quantile	τ = 0.05	-0.6179*** (0.1761)	-0.0230 (0.0771)	-0.1114 (0.0721)	-0.1143** (0.0427)
	τ = 0.25	-0.5761*** (0.0973)	0.0144 (0.0428)	-0.1427** (0.0485)	-0.0909*** (0.0232)
	τ = 0.50	-0.4637*** (0.1001)	0.0312 (0.0465)	-0.1058* (0.0503)	-0.0538* (0.0246)
	τ = 0.75	-0.3436*** (0.0999)	0.0964* (0.0422)	-0.1457** (0.0503)	0.0029 (0.0304)
	τ = 0.95	-0.1878 (1.1664)	-0.0150 (0.0867)	-0.0150 (0.1093)	0.0227 (0.0597)
Slope equality test		2.1549 (0.0716) .	1.9437 (0.1005)	0.9001 (0.4629)	3.7563 (0.0048)**
No. countries		89	90	90	63
Time period		1980-2010	1980-2010	1980-2010	1990-2010

<u>Notes:</u> imr - initial level of infant mortality rate; $amr.f$ - initial level of adult female mortality rate; $amr.m$ - initial level of adult male mortality rate; $under$ - initial level of prevalence of undernourishment. Standard errors in parenthesis. The slope equality test refers to the test's statistic ant with the p-value in parenthesis. ***, **, * and '.' denote the statistical significance at the 0.1%, 1%, 5% and 10% levels, respectively.
<u>Source:</u> Authors' calculations with R software.

The pattern of behaviour across quantiles of the estimated coefficient for the infant mortality rate (imr) is similar to that obtained for life expectancy (see figure 1 (a) and (g)). The statistical significance is identical too: no significance is found for the 0.95 quantile and for the 0.75 quantile the estimated coefficient increases the statistical significance (from 0.01% to 0.001%). The results from the slope equality test indicate that it is possible to reject the null hypothesis of parameter homogeneity at the 10% significance level.

Figure 1. Evolution of health coefficients estimates from quantile regressions



Source: Authors' calculations with R.

As for the share of undernourishment in total population (*under*), the estimated coefficients are negative as expected and in some cases they are also statistically significant. The analysis of the results presented in figure 1(h) indicate that moving from low to higher quantiles of the output growth rate distribution the magnitude of the estimated coefficients increases. Additionally, the results of the slope equality test indicate that it is possible to reject the null hypothesis of parameter homogeneity at the 0.01% significance level. However, for the 0.05 and 0.95 quantiles the estimated coefficient for undernourishment is not statistically significant.

Also confirming theoretical predictions, the estimated coefficients when using the proxy corresponding to the inverse of the initial level of public health expenditures per capita (*ilgh*) are negative and statistically significant across all quantiles (see table 2), indicating a positive correlation between higher spending in health and growth. Regarding the magnitude of the estimated coefficients, the results for the slope equality test do not reject the null hypothesis of parameter homogeneity, although the estimated coefficients are slightly higher for the median and around the 0.8 quantile of the growth rate distribution. From the inspection figure 1(i) that contains the estimated coefficients for the variable *ilgh* it is possible to see that the black line that represents the coefficients across quantiles does not cross the red dashed line that represents the least squares confidence intervals. This also supports the finding that the estimated coefficients are not very different from the one obtained with least squares estimation. These results suggest that when countries face public finances sustainability crisis they should cut public expenditure carefully in order not to jeopardize long term output growth, especially for countries where health expenditures are mainly publicly funded. This result is in line with the findings of Wang (2011) for the period 1986-2007 who found a positive effect of health expenditures on growth but only for fast growers.

Finally, regarding the control variables considered, the results are very similar for the regressions with the different health proxies. Table A.4 in the Appendix contains the estimated coefficients with quantile regression as well the within least squares model considering life expectancy as the proxy for health human capital. The estimated coefficient for education (*educ*)is statistically significant and positive as expected and the slope equality test reveals parameter heterogeneity, a result in line with previous studies (Miles 2004). The variable controlling for convergence (*ly*) also presents the expected sign (negative) and is statistically significant across quantiles. Also statistically significant and with the expected sign (positive) across all quantiles is the variable which measures countries' openness to trade. Population growth (*n*) is statistically significant at the 0.01% significance level with fixed effects but it is only significant with quantile regression for the 0.05 and 0.25 quantiles (at the 10% significance level). Government consumption (*g*) presents an estimated negative coefficient but it is not statistically significant for any quantile. As for gross fixed capital formation (*gfcf*), the sign is negative, contrary to theoretical predictions. A possible explanation for this result is related to non-productive investments over period under analysis that could have resulted in a crowding-out effect relative to productive investments and thus hampering growth.

Overall, for the period under analysis the results indicate that increasing health human capital is growth enhancing. However, for the higher growth quantiles, in particular the 0.95 quantile, the estimated coefficients are not statistically significant (except for public expenditures on health). Furthermore, the results for the different health proxies present some interesting differences. For instance, when we consider health proxies according to gender, female health proxies are positively related with growth and the contrary applies to male proxies. This result could be related to the increasing share of females in the labour market over the last decade that enhanced the contribution of women's health human capital for growth. It could also be the case that the economic growth gains from female's health are higher than those from males' since there are potential externalities from better females' health associated with their children[8]. Nevertheless, the magnitude of this impact does not seem to vary across quantiles.

The most robust results in terms of differentiated growth impacts across quantiles are obtained when using the proxies life expectancy, infant mortality rates and undernourishment. The results from the slope equality test and the estimated coefficients across quantiles reveal differences in the magnitude of the positive

[8] The gender differences in human capital are examined in Knowles et al. (2002) for the case of education human capital based on the idea that the fact that females are mothers and usually have an important influence bringing up their children allows for externalities associated with increasing females human capital. The authors conclude that indeed there is a higher growth influence of female education human capital.

influence of these health proxies. Improvements in the health status have a greater impact on slow growers (located in the 0.05 and the 0.25 quantiles) compared to those that performed above the median growth rate (located in the 0.75 quantile). Therefore, slow growers benefit more from an increase in health relative to fast growers, highlighting the adverse growth effects of not investing in health during periods of growth slowdowns.

6. Conclusion

In recent decades, we have witnessed huge improvements in vaccination, infectious diseases treatments and access to medical care throughout the world. Nowadays, people are expected to live longer than ever before and with better quality of life. In this study, we revisit the role of health human capital on economic growth by applying a quantile regression approach in order to identify different signs and magnitudes for the influence of various health proxies across the distribution of the output growth rate. This can lead to more specific policy implications regarding health determinants of economic growth according growth performance. For this purpose, we considered a (maximum) sample of 92 countries over the period 1980-2010 and applied the quantile approach proposed by Canay (2011) that allows us to extend quantile regression to a panel data framework.

The results obtained endorse investing in health as a means of improving growth performance in our sample. Additionally, our findings suggest that the location on the output growth rate distribution matters in terms of the magnitude of the relationship between health and macroeconomic performance in the long run. Countries will benefit more from investments that improve the health status of the respective populations when they are experiencing growth slowdowns (higher estimated coefficients the lower quantiles of the growth rate distribution). This is true for the health proxies' life expectancy, infant mortality rate and the prevalence of undernourishment, for which we obtained statistically significant, with the expected sign that changed across quantiles. Additionally, the results indicate that both the health status of infants as well as that of adults have an important role in explaining per capita income growth. Furthermore, we found evidence supporting different growth contributions from mothers' (females) health relative to that of males, higher in the first case.

The former results lead to different policy implications for over-achieving versus under-performing countries in terms of actions that can foster output growth. For under achievers (those located at the lower growth quantiles) it is especially important not to overlook health improvements because this can have important negative repercussions on long run growth rates as well as further depressing growth in the medium-run.

While we have shown that there is evidence of parameter heterogeneity in the health-growth relationship in our sample over the period under analysis, further research is needed to understand why such parameter heterogeneity exists. Additionally, future research should explore other mechanisms of transmission from health to economic growth in order to provide a more complete picture in terms of direct and indirect effects and policy implications across the distribution of the growth rate of output.

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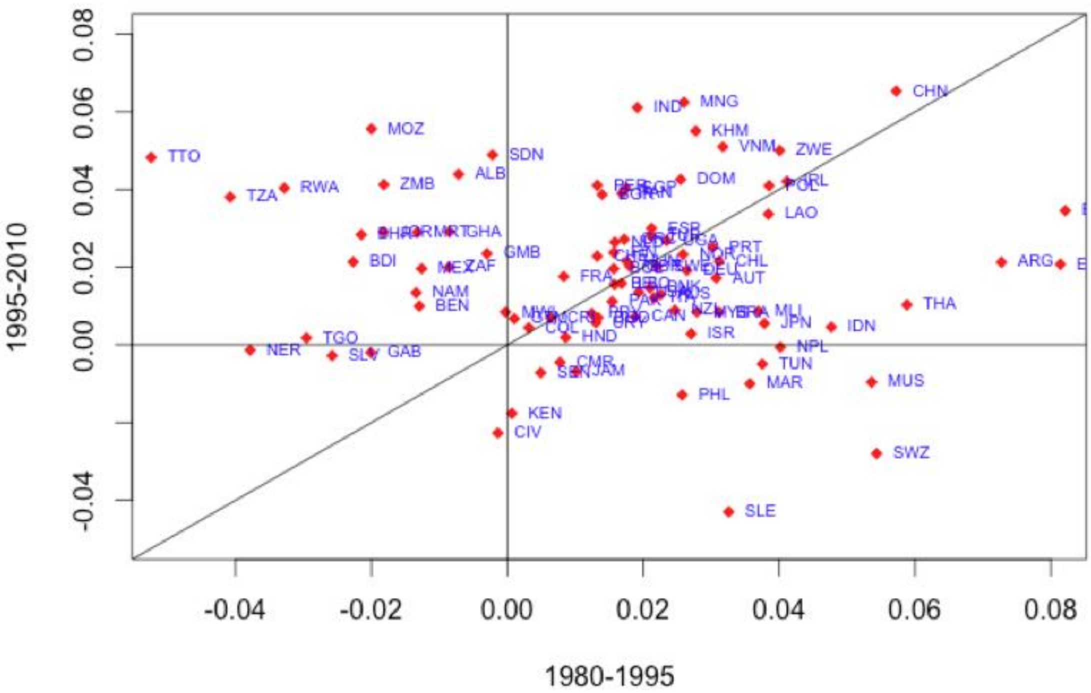
Appendix

Figure A. 1. Scatterplot of average GDP per capita growth rates for period 1980-1995 and 1995-2010 (92 countries)



<u>Source:</u> Authors’ calculations with R software.

Table A. 1. List of countries

Albania	Costa Rica	Ireland	Namibia	Sudan
Argentina	Cote d'Ivoire	Israel	Nepal	Swaziland
Australia	Denmark	Italy	Netherlands	Sweden
Austria	Dominican	Jamaica	New Zealand	Switzerland
Bahrain	Republic	Japan	Niger	Tanzania
Bangladesh	Egypt	Jordan	Norway	Thailand
Belgium	El Salvador	Kenya	Pakistan	Togo
Benin	Finland	Laos	Panama	Trinidad and
Bolivia	France	Lesotho	Paraguay	Tobago
Botswana	Gabon	Liberia	Peru	Tunisia
Brazil	Gambia	Malawi	Philippines	Turkey
Bulgaria	Germany	Malaysia	Poland	Uganda
Burundi	Ghana	Mali	Portugal	United Kingdom
Cambodia	Greece	Mauritania	Rwanda	United States
Cameroon	Guatemala	Mauritius	Senegal	Uruguay
Canada	Honduras	Mexico	Sierra Leone	Vietnam
Chile	Hungary	Mongolia	Singapore	Zambia
China	India	Morocco	South Africa	Zimbabwe
Colombia	Indonesia	Mozambique	Spain	

Source: Authors' own compilation.

Table A. 2. List of variables

Notation	Description	Source	Source's notation
Δly	Real GDP per capita annual average growth rate (calculated as the annual average growth rate of real GDP at chained PPPs divided by total population)	PWT 8.0	rgdpo; pop
ly	Logarithm of the initial level of real GDP per capita in PPP's (calculated dividing real GDP in 2005 international USD by total population)	PWT 8.0	rgdpo; pop
$gfcf$	Average investment share	PWT 8.0	csh_i
n	Population growth rate	World Bank	SP.POP.GROW
$lopen$	Trade (exports plus imports) as a percentage of GDP	PWT 7.1	openk
g	Share of government consumption in GDP at current PPP	PWT 8.0	csh_g
$educ$	Barro & Lee (2013) average years of total schooling of people aged 15 and over.	Barro and Lee (2013)	yr_sch
$ilgh$	Inverse of public health expenditures per capita (calculated multiplying total health expenditure per capita by public health expenditures as a share of total health).	WDI	SH.XPD.PCAP.PP.KD SH.XPD.PUBL
$ille$	Inverse of the logarithm of the initial level of life expectancy at birth in total years'	WDI	SP.DYN.LE00.IN
imr	Initial level of the share of infants dying before reaching one year of age	WDI	SP.DYN.IMRT.IN
$asr.m$	Initial level of the share of male new-born infants that would survive to age 65	WDI	SP.DYN.TO65.MA.ZS
$asr.f$	Initial level of the share of female new-born that would survive to age 65	WDI	SP.DYN.TO65.FE.ZS
$amr.m$	Probability of a 15-year old male dying before reaching age 60 at the beginning of the period	WDI	SP.DYN.AMRT.MA
$amr.f$	Probability of a 15-year old female dying before reaching age 60 at the beginning of the period	WDI	SP.DYN.AMRT.FE
$ilkcal$	Inverse of the logarithm of number of calories consumed per day per person	WDI	SN.ITK.DFCT
$under$	Prevalence of undernourishment in the population.	WDI	SN.ITK.DEFC.ZS

Source: Authors' own compilation.

Table A. 3. Health variables' correlation matrix (58 countries 1995-2010)

	le	$kcal$	$asr.m$	$asr.f$	$amr.m$	$amr.f$	imr	$under$	gh
le	1.00	-0.58	0.97	0.99	-0.91	-0.97	-0.93	-0.61	0.68
$kcal$	-0.58	1.00	-0.58	-0.59	0.56	0.58	0.60	0.99	-0.62
$asr.m$	0.97	-0.58	1.00	0.96	-0.97	-0.96	-0.86	-0.61	0.59
$asr.f$	0.99	-0.59	0.96	1.00	-0.91	-0.99	-0.90	-0.61	0.65
$amr.m$	-0.91	0.56	-0.97	-0.91	1.00	0.93	0.75	0.58	-0.49
$amr.f$	-0.97	0.58	-0.96	-0.99	0.93	1.00	0.86	0.61	-0.60
imr	-0.93	0.60	-0.86	-0.90	0.75	0.86	1.00	0.64	-0.80
$under$	-0.61	0.99	-0.61	-0.61	0.58	0.61	0.64	1.00	-0.63
gh	0.68	-0.62	0.59	0.65	-0.49	-0.60	-0.80	-0.63	1.00

Notes: Δly - average annual growth rate of real GDP per capital; le – initial level of life expectancy; $asr.m$ - initial level of adult male survival rate; $asr.f$ - initial level of adult female survival rate; imr - initial level of infant mortality rate; $amr.f$ - initial level of adult female mortality rate; $amr.m$ - initial level of adult male mortality rate; gh - initial level of public health expenditures per capita; $under$ – initial level of prevalence of undernourishment; $kcal$ – initial level of consumption of calories per day per person.
Source: Authors' calculations with R.

Table A.4. Quantile regression estimation results with Life expectancy as the main health related explanatory variable (1980-2010 for 92 countries)

	Fixed Effects	Quantile					Equality test
		τ = 0.05	τ = 0.25	τ = 0.5	τ = 0.75	τ = 0.95	
Int.		1.0694*** (0.1203)	1.1161*** (0.1116)	0.9658*** (0.0893)	0.8796*** (0.0876)	0.9196*** (0.1967)	
$ille$	0.1179*** (0.0312)	-1.7878*** (0.3737)	-1.9006*** (0.3693)	-1.2211*** (0.3199)	-0.9630** (0.3047)	-0.8711 (0.7011)	2.9263 (0.0198)*
ly	-0.0947*** (0.0067)	-0.0975*** (0.0362)	-0.0947*** (0.0030)	-0.0953*** (0.0017)	-0.0921*** (0.0027)	-0.0997*** (0.0061)	1.0509 (0.3793)
$educ$	0.035*** (0.0019)	0.0157*** (0.0018)	0.0123*** (0.0010)	0.0135*** (0.0008)	0.0118*** (0.0009)	0.0132*** (0.0021)	3.6312 (0.0058)**
n	0.4719** (0.1791)	0.5397 . (0.2770)	0.2919 . (0.1507)	0.2255 (0.1561)	0.1770 (0.1971)	0.0774 (0.5229)	0.3536 (0.8416)
$gfcf$	-0.0090*** (0.0020)	-0.0065 (0.0049)	-0.0093*** (0.0015)	-0.0108*** (0.0015)	-0.0096*** (0.0017)	-0.0085* (0.0034)	0.7577 (0.5537)
$lopen$	0.0225*** (0.0057)	0.0196*** (0.0048)	0.0207*** (0.0026)	0.0218*** (0.0017)	0.0258*** (0.0027)	0.0281*** (0.0048)	1.6778 (0.1522)
g	0.0110 (0.0110)	-0.0283 (0.0362)	-0.0121 (0.0150)	-0.0195 (0.0213)	0.0111 (0.0251)	0.0603 (0.0611)	1.0396 (0.3851)

Notes: $ille$ - inverse of life expectancy; ly - initial level of adult male survival rate; yr_sch - initial level of adult female survival rate; n - initial level of public health expenditures per capita; $gfcf$ – gross fixed capital formation relative to GDP; $open$ - share of trade in output; g - share of government consumption in output. Standard errors in parenthesis. The slope equality test refers to the test's statistic ant with the p-value in parenthesis. ***, **, * and '.' denote the statistical significance at the 0.1%, 1%, 5% and 10% levels, respectively.
Source: Authors' calculations with R.

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