Longevity and Education Externalities: Evidence from Macroeconomic Data*

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Abstract

We argue that education exerts positive external effects on health, beyond the standard internal effects documented in the literature. We implement an innovative approach to control for endogeneity and omitted variables problems and present evidence for the significant role played by higher education in explaining longevity across countries. Our findings provide empirical evidence in support of our hypothesis of educational externalities on health.

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1 Introduction

The main idea of the paper is to test whether there is an externality effect of education on health. In practice, we are looking for an effect of higher education that is external to the household in which the educated person lives. We test for this possibility by considering cross-sectional cross-country regressions of the unpredicted component of life expectancy (given by deviations of actual life expectancy averaged over 1995-2004 relative to its forecast) on lags of the exogenous component of tertiary education averaged over 1961-1980, along with various controls designed to deal with endogeneity of education and omitted variables, while utilizing a number of alternative measures of education including the corrected Cohen and Soto (2007) educational attainment data.

Our purpose in writing this paper is to contribute to the understanding of the determinants of international health outcomes. A recent strand of the macroeconomic literature proposes various explanations for the observed evolution of life expectancy across countries. Some of these papers underscore the important role played by economic growth, while others emphasize non-income factors as in Becker, Philipson and Soares (2005) and Soares (2007a, 2007b), consistent with the view that health is a separate component of welfare.[1] A related large body of research in development and health economics has long established the importance of maternal education for the health status of family members.[2] Instead, perhaps as an artifact of the focus of this literature on micro-data for specific geographic regions, there has not been as much emphasis on externalities arising due to the aggregate level of education in a country.[3]

We hypothesize a role of education that goes beyond the widely accepted role of parental education at the individual family level. We ask whether education has positive externalities on health. Does a person's educational choice exert beneficial effects on the health of people outside the household? Equivalently, does the education level in a country have a positive influence on average life expectancy beyond what could be attributed to improved longevity within educated households? Despite the interest that such a possibility arises and although the issue of externalities from education on income growth has been debated for over two decades, at least since Lucas (1988), these are novel questions in economics.[4]

Several authors have noted the role of education in health, but they have always focused on benefits accruing directly to the educated person or to members of his/her household. Soares (2007a) states that "[*t*]echnologies related to individual-level inputs used in the production of health seem to be subject to the effectiveness with which individuals can use these inputs" so that "more educated individuals have higher survival advantage in

[1] To the extent that income is not the sole determinant of health outcomes one can view health as a separate component of welfare, and factors driving welfare growth might well be different from those relevant for economic growth with important policy implications.

[2] See Wolfe and Behrman (1982), Haines and Avery (1982), Merrick (1985), Barrera (1990), Hobcraft (1993), and Glewwe (1999).

[3] Indeed, Krueger and Lindahl (2001, p.1108) point out that "estimating relationships with aggregate data can capture external returns to human capital that are missed in the microeconometric literature."

[4] The related "...significant open question ... whether the social returns to human capital investment substancially exceed the private return" (Topel, 1999, p. 2973) has been raised as early as Becker (1975).

diseases for which medical progress has been important." Similarly, Cutler, Deaton and Lleras-Muney (2006, p. 115) write that "the differential use of health knowledge and technology [*is*] almost certainly [*an*] important part of the explanation" as to why "[*t*]here is most likely a direct positive effect of education on health." They review evidence from studies that compare experiences across countries and studies that use data within particular countries. For the first group of reviewed papers, no study points to a positive impact of education on health external to the household, focusing instead on basic education whose role is summarized by their statement that "*t*o the extent that education improves an individual's ability to undertake these changes, more educated mothers will have healthier babies" (p. 110). For the second group, using within-country data, the positive effect of higher education is mentioned but the focus is solely on the channel internal to the household, whereby "educational differences [...] maintain a gradient in health whenever there exists a mechanism or technology that more knowledgeable and educated people can use to improve their health" (p. 115). As compared to the papers reviewed in this survey, our paper puts forward an original hypothesis (the externality) and tests its plausibility using cross-country data.

To the best of our knowledge only Parashar (2005) explicitly considers educational externalities on health.[5] That study is based on a combination of individual-level and census data from India, and tests whether the educational level of women in the community surrounding the household positively affects health related behavior of mothers. It finds that "a positive and significant relationship exists between the proportion of literate females in a district and a child's complete immunization status within that district, above and beyond the child's own mother's education as well as district-level socioeconomic development and healthcare amenities" (p.989). Our approach is considerably different, though possibly complementary, while our scope is international and our focus on aggregate health outcomes rather than individual ones.

Let us now more precisely define the two direct roles that education plays in enhancing longevity.[6] We refer to one effect as internal to the household (internal channel) and the other effect as external. For the individual, education -whether own, parental, or spousal- is crucial in facilitating access to and the understanding of health-related information. The level of education within the household will thus enhance the longevity of its members by affecting crucial factors such as understanding medical treatments, assessing the risks that hazardous behavior entails, or providing children with healthy food. For example, Kenkel (1991) emphasized better information on health and Grossman (1972) better decision-making by more educated individuals. This individual household internal channel is discussed in detail in the next section, where a number of potential mechanisms for this are outlined.

[5] Moreover, Lleras-Muney (2005) estimates the effect of education on mortality rates within one and the same cohort. Since she relies on US census data the estimated effect includes the beneficial effect of education on the mortality of the educated person, but it may also capture some of the additional external effects acting at the level of a cohort. However, that paper does not explicitly consider nor discuss possible external effects of education on mortality.

[6] There is also an *indirect* role of education on health outcomes as it increases the quantity and quality of purchased health inputs by raising individual income.

The availability of health-related knowledge and quality of health treatment individuals could hope to be able to access to begin with, depends (among other factors) on the overall level of education in the country. Education can therefore play a second direct role in the determination of health outcomes, acting through the *external* channel. That is, the aggregate level of education in the economy could improve both health-related behaviors and the quality of health services in a country. One reason for this is that the average level of education improves a country's absorptive capacity for health-related ideas and technologies in line with much of the literature on technology absorption (see e.g. Coe and Helpman, 1995). The latter literature emphasizes that the degree of technology diffusion and spillover of ideas depend on the 'absorptive capacity' of each country, and that one of the main determinants of 'absorptive capacity' is the level of a country's human capital, as emphasized by the seminal paper of Nelson and Phelps (1966).

A second reason is that we would expect physicians to be more likely to adopt and implement new treatments to the general population in countries or regions where the average patient is more educated. This arises as a result of health specialists being more willing to learn about, explain, and implement new treatments when they expect their patients to be more receptive to new medical knowledge. As shown by Cutler and Lleras-Muney (2006, p.16) more educated patients trust science more than less educated ones, are typically the first ones to use new health related information, and it is thus likely that physicians would expect them to be more receptive to new medical knowledge. Rogers (1962) also suggests that early adopters of innovations typically have a higher social status, and advanced education at levels higher than late adopters. Third, health-related information might flow from individuals with higher education to the remaining individuals enabling the latter to make better informed health decisions and maintaining a healthier lifestyle as the seeds of a new health culture take root. Social status, often related to educational status of an individual, might make it much more likely that the rest of society imitates the behavior of a more highly educated individual.[7] Mankiw (1997, p.107) notes a similar externality where "educated people generate good ideas that enter society's pool of knowledge." Related to but distinct from the above rationals for an education externality, it can be argued that individuals with higher education have a larger and often international reference group, that enables them to learn of and induces them to adopt new ideas much faster.[8] Last, there is the standard health externality where in the presence of a disease arrival rate which is lower for more highly educated individuals, the entire community would benefit from a lower probability of disease transmission.

We test the empirical plausibility of the direct role played by education external to the household in determining longevity. To this end, it is necessary to address a number of issues. First, what is the most appropriate empirical approach? Second, to what extent can we hope that our analysis uncovers causation from more education to better health rather than the other way around? Third, how can one identify external effects,

[7] We thank Oded Stark for pointing out this reqularity from the Development Economics literature on technology diffusion at a micro-level, say village adoption of a particular new procedure or use of new machinery.

[8] Again, we thank Oded Stark for bringing this regularity to our attention.

given that both internal and external effects are responsible for the causal direct effect of education on health? Fourth, how can we control for the other potential determinants of life expectancy so that we can identify the supposed role of education?

First, the objective of our analysis offers direct guidance in the choice of the empirical approach. Given that the externality from education can be expected to act on a geographical scale, it seems appropriate to compare data across countries. We also need a data set including sufficient variation in both life expectancy and the various measures of educational level of the population used. It is thus desirable to consider developing countries as well as industrialized economies. This comes at the cost of the time dimension of the sample since quite a few of the variables we consider are exceedingly sparse over time, especially so for developing countries. However, we note that focusing on long-run time averages in levels also seems more appropriate due to the inherent long-run nature of the relation under study. Moreover, averaging over long periods helps alleviate potential measurement error problems. This greatly improves the reliability of the education data used as shown in previous work by Topel (1999), Krueger and Lindahl (2001) and Cohen and Soto (2007) (CS). In light of all the above, we opt to explore the cross sectional dimension of a sample of 67 countries using education variables averaged over 1961-80 and other explanatory variables averaged (for the most part and where possible) over 1961-95 to explain life expectancy averaged over the period from 1995 to 2004. Moreover, we use a variety of sources for measuring higher education, that includes Barro and Lee (2001) (BL), CS, and Lutz et al. (2007) (LGSS).

Second, how can we estimate a causal effect of more education on better health? A major empirical concern arises as a result of the possibility that individuals incorporate forecasts of future longevity in making educational decisions. To address problems in capturing the direction of causality, we consider a procedure that utilizes demographic forecasts for life expectancy around 2000 as assessed by UN demographers in 1973. This is consistent with individuals making forecasts of future longevity which are as accurate as those carried out with the help of complicated demographic models. For example, individuals might simply adopt the UN longevity forecasts once these become publicly available. Given publication and diffusion lags, the latter mechanism would then imply that it might actually take a few years for individuals to adopt these forecasts. We use the component of education not explained by the UN forecasts[9], to explain deviations of actual life expectancy averaged over 1995-2004 relative to its forecast.[10] These deviations represent the unpredicted component of life expectancy that presumably does not affect educational decisions. If these deviations are explained by exogenous variation in 1961-80 education variables, we can interpret this as evidence of causality from education on life expectancy. We note that there is an IV interpretation of our procedure, where the instrument for education would be the residual from a first-stage regression of education on the forecast of longevity and all other exogenous variables.

[9] The residual from a regression of higher education averaged over 1961-80 on the 1973 forecast of longevity and all other exogenous variables.

[10] This gives identical point estimates for higher education as an OLS regression of life expectancy averaged over 1995-2004 on education averaged over 1961-80, and on the 1973 forecast of end-of-period longevity. There is also an IV analogy of this procedure, producing again identical point estimates for higher education.

Third, we turn to the issue of identifying the education externality. Our goal is to look for evidence for the existence of an externality rather than to measure its degree. Thus, we prefer to err on the safe side and tend to understate this externality as much as possible.[11] To ensure that we do not overstate the case for the presence of an education externality, we will include two different forms of education as determinants of longevity, but will interpret the estimated coefficient for basic education as not adding to the external effect. Since there is evidence that basic forms of education capture a good part of the internal channel[12], including basic in addition to higher education will remove part of the internal effect that would otherwise inflate the estimated coefficient for tertiary education. However, we still allow the tertiary education coefficient to be interpreted as capturing the internal in addition to the external channel[13]. Our identification of the externality will then stem from a counterfactual argument about unrealistic estimated gains in life years for highly educated individuals if the internal channel was the only one at work. In order to understand our argument, note that life expectancy is computed as an average across educational groups. The fact that the absence of an external effect of education suggests that only those who acquire tertiary education benefit from their actions, allows us to make a heuristic argument for the presence of an externality: If *only* those that choose to acquire tertiary education or only members of their household benefit (the *internal* channel), then the implied increase in expected years to be enjoyed by this group would be implausibly large based on our estimated effect of tertiary education on life expectancy. In contrast, if we hypothesize that others benefit as well, then the implied increase in expected years to be enjoyed by this larger group of individuals is plausibly small. This would then be evidence of an externality from higher education to the extent that for a given observed estimated elasticity of average life expectancy with respect to higher education to be consistent with a plausible increase in expected years for different segments of society, we would have to assume that individuals other than those that choose to acquire higher education benefit as well.

[11] This is why we introduce two forms of education at the same time, and choose not to interpret the impact of basic education as part of the education externality we identify. This is also why we interpret some of the estimated effect of tertiary education on longevity to be due to the internal channel rather than assuming that any effect of higher education is evidence of an externality.

[12] There is evidence that the internal channel is characterized by diminishing returns so that basic literacy might suffice to capture a good part of this channel. Diminishing returns at the individual household level is consistent with evidence in Haines and Avery (1982), Merrick (1985) and Thomas (1991) using individual-level data from Costa Rica and Brazil, who find female education to exhibit diminishing returns in enhancing family health output. Haines and Avery (1982, p. 43) find that "*t*he results indicate a much greater elasticity of response of child mortality to an additional year of education for women with less education than with more education (11 % against 2 %)". Merrick (1985, p.6) finds that although mortality ratios fall with education attainment, "*t*he most striking difference in mortality ratios, however, is the contrast between mothers with no formal education and other groups", and even suggests (p.10) that the role of education at the household level "may be limited to such basic steps as boiling contaminated water." Thomas et al. (1991, p.205) find that "being semi-literate [*mothers*] has a significant positive effect on child height", but "the marginal additional impact of being literate over semi-literate is small".

[13] On the other hand, allowing for the possibility that tertiary education captures an external in addition to an internal effect, is justified on the following grounds: The external effect of education depends in part on the ability and readiness of the health sector to take advantage of best practices. This is a high-tech sector experiencing fast technological progress, and efficient use of new medical technologies requires understanding of scientific findings. The sophisticated character of international knowledge diffusion and use in this sector suggests higher education constitutes its crucial determinant. Another rational, is that higher education impacts upon health behaviors via the within-country transfer of health knowledge and health habits across individuals. Health-related information might flow from individuals with higher education and associated social status to others. Mankiw (1997, p.107) notes that "it seems unlikely that [*externalities*] are the same at all levels of schooling ... educated people generate good ideas that enter society's pool of knowledge ... *t*his externality might well flow largely from the most educated members of society ... so, differences in ... higher education would be more important ...".

Finally, we want to account for the role played by a number of other factors in determining life expectancy so as to be able to identify the separate effect of education. These include private purchases of medical inputs and publicly provided health inputs affecting the environment in which households live and make decisions. Thus, we control for the effect of pharmaceutical spending, density of physicians, real initial income per capita, sanitation, and efficiency of the health system pertaining to health infrastructure. In addition, we account for the prevalence of disease and the roles of geography and political institutions. Moreover, we include a forecast of longevity in 1973 which proxies for a number of otherwise omitted demographic variables that might have been impacting on educational decisions in the mid 1970's. We also include initial life expectancy levels averaged over the same early period as the measures of higher education in order to capture any omitted variables that might have been acting on life expectancy over the same period as the higher education variables but would otherwise be left unaccounted for. We capture the role of basic education with female literacy, consistent with micro-based research on the importance of maternal education for the health status within a family.

Our main goal in writing this paper is to consider empirically the possible existence of an externality from education on aggregate health outcomes. We examine the determinants of aggregate health outcomes with emphasis on the mechanisms through which education impacts upon longevity, with due attention paid to the role played by a number of other factors. In the presence of the abovementioned controls, we find that higher education is a separate and significant determinant of average longevity. Its impact is higher than the health impact of own education found in studies utilizing micro-economic data for individuals, and is consistent with an aggregate externality role for education.

The next section sets the background for the empirical application. In section three we describe the data, in section four we outline our methodology, and in section five we report the results. After interpreting these results in section six, we put them in perspective in the concluding section.

2 The education-longevity nexus and the externality hypothesis

In this section, we review the mechanisms through which education might impact health outcomes as measured by longevity, while pointing out potential links that go in the opposite direction, i.e. from longevity to education. We also discuss the justification for including a number of possible covariates in explaining life expectancy. In what follows, we denote π_{ijt} to be the longevity of an adult individual of household i at date t in country j, and e_{ijt} to be the respective level of education.

The first link arises in considering the educational decision of individual i made in youth conditional on her expectation about own longevity. As put forward in human capital theory, the economic return to education is a decreasing function of the individual discount rate (Becker, 1975) which depends on the individual expectation about own longevity. An increase in the expected longevity raises the return on human capital and induces more education. We refer to this link as the *patience formation channel*[14]:

$$\Delta E_i\left(\pi_{ijt}\right) > 0 \Rightarrow \Delta \text{impatience}_{ijt} < 0 \Rightarrow \Delta e_{ijt} > 0$$

Moreover, it is well known that being in good health when young is favorable to learning, so that individuals who have been healthy in youth are expected to attain higher education levels. At the same time, good health in youth is highly correlated to individual longevity (Cutler, Deaton and Lleras-Muney, 2006, p.105-106). This is the *early morbidity channel*:

$$\Delta \text{youth morbidity}_{ijt} < 0 \begin{array}{l} \Rightarrow \Delta e_{ijt} > 0 \\ \Rightarrow \Delta \pi_{ijt} > 0 \end{array}$$

The third obvious link runs from education to health outcomes through the economic return on human capital. If the individual can intentionally invest in health to reduce her mortality risk and own health is a normal good, health investment (denoted m_{ijt}) by the individual should increase along with her permanent income. This is the case with nutrition as emphasized by Fogel (1994), but also with privately financed medical care and purchases of drugs. Hence, if education is privately productive so that a better educated person has a larger permanent income, then we should observe an indirect causal link to which we refer to as the *permanent income channel*:

$$\Delta e_{ijt} > 0 \Rightarrow \Delta \text{permanent income}_{ijt} > 0 \Rightarrow \Delta m_{ijt} > 0 \Rightarrow \Delta \pi_{ijt} > 0$$

Moreover, since education shifts the income profile over the life cycle toward adulthood, investing in own health in order to improve the probability of surviving to adulthood pays off relatively more for educated individuals than for less educated ones (see Ricci and Zachariadis, 2008). This argument unveils a causal link from more education to higher individual longevity, which we dub the *economic stake of longevity channel*:

$$\Delta e_{ijt} > 0 \Rightarrow \Delta \left(\frac{\text{adulthood income}}{\text{youth income}}\right)_{ijt} > 0 \Rightarrow \Delta m_{ijt} > 0 \Rightarrow \Delta \pi_{ijt} > 0$$

Fifth, it is well understood that education of household members, particularly of the mother, has a favorable effect on the health of all its members, resulting in lower mortality hence higher longevity. It has been empirically established that mothers' education improves children's health (see references in footnote 2). Even in developed economies an educated parent appears to invest more in her children's future health by bearing less risky behavior (e.g. Currie and Moretti, 2003), and, moreover, it is well documented that circumstances in early childhood have long standing consequences on health (evidence is reviewed in Smith, 1999 p.160-162). There is also evidence that more educated individuals take greater advantage of technological innovation in medicine

[14]Becker and Mulligan (1997) used this term for a model where education directly affects the rate of preference for the present by improving the ability to "imagine the future".

(Kenkel, 1991).[15] In particular, educated mothers are able to take advantage relatively efficiently of available information. For all these reasons, the level of education of adults in the household has a beneficial effect on the health of all household members.[16] This effect is however limited to the household and is presumably taken into account by individuals when matching to form a household. We can therefore expect there to exist a *direct internal channel* (internal to the household) through which education favorably affects longevity:

$$\Delta e_{ijt} > 0 \Rightarrow \Delta \pi_{ijt} > 0 \text{ and } \Delta \pi_{ijt+1} > 0$$

where the subscript $t+1$ refers to children's longevity. According to the empirical literature, this direct internal effect of e on π is stronger for an additional year of basic education as compared to higher levels of education.

The five channels outlined above concern links between education and health that may be considered as internal to households, so that they may be taken into consideration by decision-makers within the household. In contrast, several factors that may be relevant for health outcomes are considered as exogenously given by any household in isolation. Hence, *ceteris paribus*, an individual endowed with some education investing in her education and health and marrying an educated spouse, experiences lower mortality risk and expects a higher longevity if she lives in a country j where these public or environmental factors are relatively favorable. Most of these factors are not directly related to education. For instance, geography affects the rate of arrival of diseases faced by the individual. Similarly, the risk of outbreak of epidemics or of violent conflicts will negatively affect one's expected longevity for any given level of health and education investment. Other such factors are indirectly related to the population's education and the public effort in supplying health services and infrastructure. This effort is determined by the amount of inputs as well as by the efficiency with which they are used to promote good health conditions in the population. The macroeconomic externality from education on health put forward in this paper, hinges precisely on this last possibility: members of a given household will enjoy better health if they live in a country with more educated citizens, holding everything else equal. The theoretical arguments for this case are presented below after reviewing the role of public inputs and investment not directly related to education in the next paragraph.

Public inputs are investments affecting the general health conditions. Access to clean water, the availability of sanitation facilities, vaccination campaigns, and the preemptive maintenance of stocks of drugs, are some examples of such inputs. Even though for each of these examples private services are provided to individual beneficiaries, their implementation requires collective action. One expects public inputs to be relatively abundant in rich countries. Since wealth is highly correlated with education, one could find a spurious correlation

[15] This crucial role of education applies also to non-health-related knowledge and technology as in the case of the diffusion of high-yield variety seed across farmers in rural India over 1968-81 studied by Foster and Rosenzweig (1996). They conclude that "faced with new information, educated individuals are better able to take advantage of technical change." (p.951).

[16] This beneficial effect is not limited to the children in the household. For example, Cutler and Lleras-Muney (2006, p. 10) cite studies that find "those who are married to more educated spouses have lower mortality rates" and better health behaviors pertaining to smoking or alcohol consumption, even when one controls for own education.

between education and health if these public inputs were to be excluded from the estimated specification. To the extent that the aggregate level of education (or its average level $\bar{e}_{jt}$) affects national income (or per capita income) a *public health inputs channel* can be hypothesized, according to which:

$$\Delta\bar{e}_{jt} > 0 \Rightarrow \Delta\text{GDP per capita}_{jt} > 0 \Rightarrow \Delta\text{public health inputs}_{jt} > 0 \Rightarrow \Delta\pi_{jt} > 0$$

where π_{jt} denotes the life expectancy at any given age in country j at date t. Since the effect of education is indirect here, an improvement in health arising from this sixth channel would be captured empirically by larger public health investment or GDP per capita.

Once we start thinking of how private and public health inputs are transformed into good health conditions, we are concerned with the determinants of the productivity of the health system. Differences in productivity of health systems across countries may be due to different levels of medical technology and/or differences in their efficiency. The efficiency of the health sector positively depends on the average education of the labor force, but potentially also depends on other features of the health system such as the quality of its organization and management. In the empirical exercise, we therefore try to control for differences across countries in the latter features by considering an index of overall efficiency of health systems that will be presented in the next section.

Our main hypothesis is instead that the average education in the country positively affects both the technology level and the efficiency with which inputs and knowledge are mobilized in the health sector at large. This reflects in a causal link from education on longevity arising at the aggregate level, to which we refer to as the seventh *direct external channel*:

$$\Delta\bar{e}_{jt} \Rightarrow \Delta\pi_{jt} > 0 \text{ or/and } \Delta\pi_{jt+1}$$

where the external effect may be either contemporaneous or delayed. We hypothesize that a society with a better educated population is better at learning about, screening, and diffusing health-related information. This statement is qualitatively different from the Kenkel (1991) approach, because it points to an external effect of education generally not taken into account by households' decision-makers when planning their own or their childrens' investment in education. One rationale for this is that the average level of education improves a country's absorptive capacity for health-related ideas and technologies as in the technology absorption literature, consistent with Nelson and Phelps (1966) and Coe and Helpman (1995). A second reason, is that physicians are more willing to adopt new treatments where the average patient is more educated, related to the fact that health specialists are more willing to learn about, explain, and eventually implement new treatments to those patients they expect to be more receptive to new knowledge, consistent with Cutler and Lleras-Muney (2006)[17]. A complementary possible reason is based on social learning of health-related practices, given that

[17] They argue that "[*t*]he more educated ... appear to make use of new health related information first" and "are more likely to trust science." (p. 16)

the presence of educated individuals in a community facilitates the flow of health-related information from these individuals to the remaining ones, enabling the latter to make better informed health decisions and maintain a healthier lifestyle, consistent with Mankiw (1997). Consistent with this, since individuals with high social status are more likely to be imitated by the rest of society, the fact that social status is often closely related to educational status of an individual, suggests that we should expect society to imitate the behavior of more highly educated individuals to a greater extent than behavior of less educated ones. Related to but distinct from the above arguments, it should be noted that individuals with higher education have a larger and often international reference group enabling them to learn of and inducing them to adopt new ideas faster than the rest of society. Finally, as far as transmissible diseases are concerned, a higher education externality arises since if more educated individuals are less likely to contact a disease then other individuals benefit from a lower probability of contacting it.

We now summarize the arguments presented in this section to provide guidance for the empirical analysis. Our objective is to test the hypothesis of a direct external channel. We have noted that the patience formation channel warns for a possible problem of inverse causality. What one can do to control for this is to have a proxy for the expectations about own longevity upon the time of educational investment. To control for the early morbidity channel one could account for basic education and/or the contemporaneous effect of health (e.g. life expectancy). We have also noted that income can affect both educational investment and health investment in several ways. Considering income helps control for the permanent income channel, for the public input channel and for the intergenerational endowment effect. Moreover, one should consider purchases of direct private health inputs, such as private health expenditures or drugs consumption to control for the permanent income channel and the economic stake of longevity channel. Similarly, measures of the quantity or effectiveness of public inputs such as access to sanitation facilities or the incidence of the AIDS epidemic (proxying for the degree of effectiveness of public policies to counteract its spread) can help control for the public inputs channel. Controlling for all these, one is left with the two direct channels of education on longevity, the first internal to households, the second external. Moreover, in order to isolate the latter channel, one should also be careful to control for other possible measures of health system efficiency. Next, we explain in some detail the variables we have collected to accomplish this task. We then turn to the hard questions, namely tackling the issues of reverse causality and of identifying the externality.

3 Data description

In this section, we describe the empirical measures we have assembled to test our main hypotheses, and take a first look at the bivariate relationship of longevity with each of these.

The focus of our study, average longevity, is measured by life expectancy at birth. This measure indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life. This index is constructed from period life tables using age-specific population size and number of deaths. In practice, life expectancy at birth reflects at once the mortality rates of each age group and the demographic structure of the population. The measure we use is not gender, nor educational or income group specific. Changes in life expectancy at birth capture both changes in infant mortality, which are very important for some countries, and changes in adult mortality, which is relatively important in other countries. In this respect, it is preferable to alternative measures such as infant mortality rates, which would put more weight on a subsample of the countries (the least developed ones). The index of life expectancy at birth we use is taken from the *World Development Indicators* (WDI) 2005 database.

We use female literacy rate as our measure of basic education.[18] As explained in the introduction, this is a control meant to absorb part of the effect of the internal channel in order to avoid inflating the estimated coefficient of tertiary education. We use female literacy since this best reflects a mother's ability to understand information relevant to keeping oneself in good health, which is apparently most important for households' members health.

We use higher educational attainment rates and average years of higher education from BL for comparability to the vast body of previous work that has studied the relation between educational attainment and economic growth using these same data. These are available in 5-year steps from 1960 to 2000 for 107 countries. We focus on higher educational attainment in *levels averaged over a long time period* (1961-80). One issue that arises is the measurement error that has been shown to characterize the BL data when considering changes of education rather than levels, and when considering time horizons of ten or less years long. The use of long-run average levels in our application ensures that the measurement error to signal ratio is greatly reduced, as shown in previous work by Topel (1999), Krueger and Lindahl (2001) and CS. Krueger and Lindahl (2001) compute reliability ratios suggesting that the BL education data in levels "have considerable signal" which is greater than when using differences over time, and that considering longer horizons improves reliability ratios considerably. Similarly, CS show (page 59) that "if we were to use a longer time scale ... the bias would disappear." Moreover, comparing their data to BL, they state (page 61) that "over the whole 1960–1980 period, both series provide a similar estimate of the total change in schooling." Finally, they report (in their Table 5) a correlation between their data and the BL education data in levels that is about 90 % across 84 countries found in both datasets. Similarly, comparing the BL data in levels to the high quality De la Fuente and Domenech (2006) data available for 21 OECD countries, they report a "fairly high" correlation equal to 91 %. In light of all the above, we opt to focus on estimates utilizing higher education levels averaged over long periods.

We also utilize the CS higher educational attainment data. These are available every ten years from 1960 to

[18] The female illiteracy rate is the percentage of females ages 15-24 who cannot, with understanding, read and write a short simple statement on their everyday life. We convert these numbers to literacy rates by subtracting illiteracy percentages from 100. The source of data is again the WDI 2005 database.

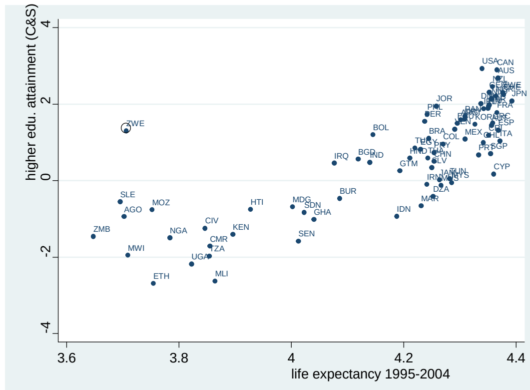

Figure 1: Longevity and education (C&S data)

2000 for 95 countries. This dataset is based on information from the OECD database on educational attainment, from UNESCO surveys and national censuses. The authors avoid using censuses based on different classification systems of education, making the series consistent for each country over time. They also account for differences in mortality rates across but not within age groups. A potential problem, shared with other cross-country education datasets, relates to the assumption that immigrants have the same educational level as the host country population. Once again, we consider time averages over the same long period (1961-80) as with the BL data. We include only countries that exist in the BL dataset, subject also to availability of the other explanatory variables. Zimbabwe (circled in Figure 1) appears to be an obvious outlier in the relation of CS (log) higher educational attainment rates averaged over 1961-80 with (log) life expectancy averaged over 1995-2004. Moreover, average higher educational attainment for Zimbabwe over the period differs greatly relative to the other two datasets we consider: CS report an average value of 3.678 %, BL 0.619 %, and LGSS a value of 0.797 %. For the period until 1995 the comparison is similar, with CS reporting an average value of 6.059 %, BL 1.475 %, and LGSS a value of 1.227 %. For these reasons, Zimbabwe is excluded in the analysis that follows when using the CS data, leaving us with a sample of 62 countries.

In addition to BL and CS education data, we use educational attainment rates put together by LGSS. These data are constructed applying demographic methods that allow for a backward projection starting with 2000 as the base year and going back to 1970 in 5-year steps. Educational attainment for the base year is constructed using national censuses obtained from UNESCO and Demographic and Health Surveys. The methodology utilized to construct these allows for differential mortality rates across educational groups. Moreover, this dataset is available with age detail at each level of educational attainment, allowing us to consider the impact of tertiary education decisions taken by people at a young age. We consider age groups 20-24 and 20-29 which we view as the most relevant for tertiary education decisions. This age-specific dataset is available for a somewhat different time period than the education data used so far, but has the advantage that we can consider educational

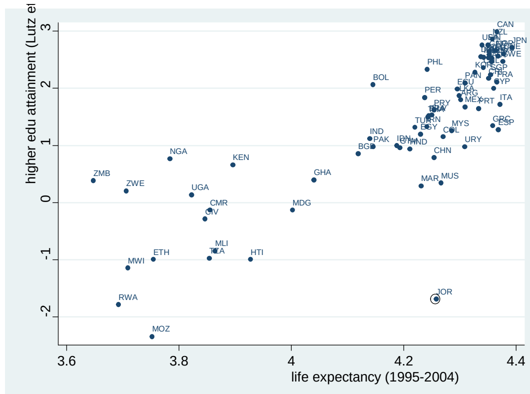

Figure 2: Longevity and education (Lutz et al. data)

decisions of individuals with the typical age profile for higher education. Higher educational attainment for ages 20-24 is averaged over 1970 to 2000 to capture cohorts making educational decisions during this period. Attainment rates for ages 20-29 are averaged over 1970-1990 for consistency with individuals assumed to be making educational decisions and longevity forecasts around the mid seventies, a point we elaborate on later. The correlation between these age-specific measures and the BL higher educational attainment rates averaged over 1961-1980, is 81 % for the age-group 20 to 24, and 89 % for the age group 20 to 29. Jordan (circled in Figure 2) appears to be an obvious outlier in the relation of the average LGSS (log) higher educational attainment rates with (log) life expectancy. Moreover, average higher educational attainment for Jordan over the period considered differs greatly relative to the other two datasets, with LGSS reporting an average[19] value of 0.185 % contrasted with average values of 6.35 % for BL and 16.6 % for CS. For these reasons, Jordan is excluded in the analysis that follows when using the LGSS data, so that we are left with a sample of 58 countries that are common with BL.

The effectiveness of the health system in providing services to citizens, leading to lower mortality and longer life expectancy, differs across countries for a host of possible reasons, other than education. One could conceptually distinguish three features: "environmental" factors, the inputs to the health system, and the "efficiency" of the health system, noting that the distinction among these is not always clear-cut in practice.

Concerning environmental factors, we control for fixed geographic factors and for variables capturing the risk of being exposed to viruses faced by individuals. For the latter purpose, we use sanitation from the WDI 2005.[20] Clearly this variable also captures the importance of the inputs devoted to the health system at large. We also use a measure of the incidence of AIDS, defined as number of cases per thousand persons, from Papageorgiou

[19] This is an average of all age groups in the population that is comparable to the average higher educational attainment rate used in the case of the BL and CS data over the period under study.

[20] Access to improved sanitation facilities refers to the percentage of the population with at least adequate access to excreta disposal facilities that can effectively prevent human, animal, and insect contact with excreta. Improved facilities range from simple but protected pit latrines to flush toilets with a sewerage connection.

and Stoytcheva (2007), in an effort to control for the adverse effects of the AIDS epidemic.[21] The geographic concentration of AIDS also means that this is a bio-geographic variable that captures certain (adverse) aspects of geography. We use geographic data on temperature and humidity levels as two indicators for weather conditions. For example, discomfort or diseases are usually associated with hot humid climates. On the other hand, warm climates might be conducive to living longer as compared to cold climates, which is evident for instance in the migration within the U.S. of retirees from northern states to Florida. For given income levels, warm climate countries might also coincide with the abundance and access to fresh healthy basic foods such us fruits and vegetables, and to a healthier food culture such us the "Mediterranean diet" for example. We thus include a measure of the "maximum monthly high temperature" and a measure of "afternoon maximum humidity" obtained from Parker (1997).[22]

Moreover, environmental factors affecting the health of individuals are also related to societal practices and outcomes. One of these possible variables has to do with the quality of institutions which may be impacting upon health directly, or indirectly by affecting the efficiency of institutions in charge of preventing the spread of diseases for example.[23] We therefore control for the quality of institutions as much as possible, using data on political stability and on violent conflicts.

We use the level of government stability to capture political institutions, consistent with Woodruff (2006) who argues for the use of variables measuring both formal and informal institutions. Government stability captures "government's ability to stay in office and carry out its declared programs depending upon such factors as the type of governance, cohesion of the government and governing parties, approach of an election, and command of the legislature." It is created from three subcomponents: government unity, legislative strength and popular support, and given on a scale between zero and 12 from least to most stable. This is taken from the International Country Risk Guide (2008) dataset made available by the Political Risk Service (PRS) group, and is reported for 1984 to 2003 for at least 140 countries.

We also measure the degree of conflict during the period as the fraction of years between 1961 and 2004 with some conflict (Gleditsch et al., 2002).[24] Since conflict might affect health outcomes contemporaneously as a result of hardship, injury, and death in battle, or via the disruption of supply-chains, in constructing our measure of conflict we include information from the period 1995-2004 over which our dependent variable is measured. Since conflict might also affect health outcomes indirectly by affecting the environment and general conditions faced by individuals growing up in the middle of such conflicts with possible impact on future health

[21] AIDS prevalence can also be interpreted as an output of the health system and the public policies that shape it, rather than as an environmental factor.

[22] Within our sample the correlation coefficient of life expectancy with respect to these two measures is -1,3% for temperature and +11,3% for humidity.

[23] This interpretation is very close to considering quality of institutions as an appropriate proxy for the efficiency of the health system at large.

[24] The Uppsala Conflict Data Program compiling these data, defines a country as experiencing a conflict in a given year if there are more than 25 violent deaths directly due to a conflict among two parties, one of which is a government.

outcomes, in constructing our conflict measure we also include information over the earlier period since 1961 prior to the contemporaneous period 1995-2004.

We now turn to inputs of the health system. As already argued, a country's average income is a first candidate (Pritchett and Summers, 1996) so we control for real GDP per capita in PPP dollars from the WDI 2005. We also consider more direct measures such as real health spending per capita from the WDI 2005[25] and imports of pharmaceuticals. In general, we prefer to account for significant theoretically-implied control variables posing the strictest possible robustness check for our main hypothesis pertaining to the education externality on health. We report results obtained using the micro-based measure of health spending instead of the aggregate measure of real health expenditure per person, which turned out to have a statistically indistinguishable from zero impact on longevity. Real pharmaceutical imports per capita are constructed utilizing product-level imports and likely proxy for private health spending better than the aggregate WDI measure described above.[26] Specifically, the construction of this micro-based measure utilizes pharmaceutical expenditures of each country in the sample for imports from ten "medical frontier" countries, based on data derived from the OECD *International Trade by Commodity Statistics* (ITCS) database, also used in Papageorgiou, Savvides, and Zachariadis (2007).

In addition, we consider the number of physicians per thousand inhabitants (available from the WDI 2005). Anand and Bärnighausen (2004) and Farahani et al. (2009) suggest that the availability of physicians is a good proxy for the health system resources, capturing a large fraction of cross-country variation in infant and under-5 mortality rates.[27] In our perspective, physicians represent at once a direct input to the health system and a vehicle for disseminating health related information and culture. As such, their availability constitutes one ingredient of a country's absorptive capacity for medical technology.

In an effort to capture determinants of the efficiency of the health system other than the average education of the general labor force, we consider a measure of the overall efficiency of the health system constructed by the WHO (2000). This work by researchers at the WHO is a rare, if not unique, attempt to build a comparable and comprehensive index of the efficiency of national health systems for a large number of countries. The overall performance index for the health system is a composite measure computed as a weighted average of five measures of performance.[28] The efficiency of a health system is estimated by comparing the observed level of

[25] Total health expenditure is the sum of public and private expenditures as a ratio of the population, and covers provision of preventive and curative health services, family planning, nutrition activities and health-designated emergency aid, excluding provision of water and sanitation. Private health expenditure includes direct household out-of-pocket spending, private insurance, charitable donations and direct service payments by private corporations. Public health expenditure consists of recurrent and capital spending from central and local government budgets, external borrowing and grants (including donations from international agencies and nongovernmental organizations), and social or compulsory health insurance funds.

[26] Pharmaceutical imports in part capture the embodied channel of technology diffusion to importing countries. However, to the extent that the price set by the exporter for these imports reflects the utility enjoyed by the importer, there should not be additional gains in terms of technological spillovers to the importing country as a result of these imports, over and above what individuals have paid for these. As such, spending on pharmaceutical imports can be treated as a private health input into the production function of health in importing countries.

[27] Admittedly, the number of physicians per thousand inhabitants is an imperfect measure of inputs devoted to the health system, since phenomena such as absenteeism may be widespread in some countries (see Chaudhury et al., 2006). However, it reflects well the relative size of the health sector in each country.

[28] The index is presented in the detail in Tandon et al. (2000), where at page 4 one reads the weights for the five components

the performance index to the maximum and minimum estimated potential level, conditional on the amount of real expenditure in health and on the aggregate education level.[29]

Finally, we use the initial level of life expectancy averaged over the same period as our higher education variables in order to control for the early morbidity channel, and also utilize a measure proxying for expectations of future longevity at the time of investment in education to control for the patience formation channel. This helps address the potential problem of reverse causality highlightened by these two channels reviewed in the previous section. Smith et al. (2001, p.1126) find that "an individual's longevity expectation is a fairly accurate index of survival probability, both in its responsiveness to events that experts would suggest increase the odds of death and as a prediction of future mortality". Hamermesh (1985) shows that individuals incorporate changes in life expectancy in their expectations about own longevity. We use the 1973 UN forecasts of life expectancy for the period 1995 to 2000 to capture longevity expectations of individuals making decisions around that period. These were obtained from Table 41 in Annex IV of United Nations (1977, pages 138-147.)[30] The forecasts were built using demographic models where mortality and fertility rates are supposed to converge across countries in the very long run, initially relatively fast in the case of mortality rates. These forecasts include information about a host of variables that would have otherwise been omitted from our regression specifications. Thus, this measure assists us in addressing the endogeneity and omitted variables problems that haunt any such exercise.

A first look at the data

Theory suggests that a country's life expectancy at birth is positively correlated with education, private and public health investment (measured by per capita income, pharmaceutical imports, health spending, physicians availability, health institutions, and sanitation), and to measures of political institutions and geography.

In the dataset (constrained to a common set of countries for all variables), end of period (1995-2004) average life expectancy has a correlation of 87 % with lagged higher education enrollment rates, 86 % with LGSS age-specific (20-29) higher education attainment rates, 85 % with lagged CS higher educational attainment rates (see Figure 1) and with LGSS age-specific (20-24) higher education attainment rates, 83 % with BL lagged (averaged over 1961-1980) higher education attainment rates (see Figure 3), and 79 % with BL lagged (1961-1980) average years of higher education. Its correlation with female literacy and with physicians (both averaged over the period 1961-1995) is also very strong at 66 % and 86 % respectively. Moreover, the correlation of end-of-period life expectancy with overall efficiency of the health system is stronger than with any other variable, at 91 %. Its

"25% for health (DALE [*disability adjusted life expectancy*]), 25% for health inequality, 12.5% for the level of responsiveness [*an index obtained from surveys on the degree of satisfaction of citizens with respect to the health system*], 12.5% for the distribution of responsiveness [*a measure of fairness of treatment across social and ethnic groups*], and 25% for fairness in financing."

[29] The approach is presented in Evans et al. (2001) and is similar in spirit to the estimation of efficiency in production. We note that the ranking of efficiency thus obtained is sensitive to assumptions and selection of control variables as shown by Jamison and Sandbu (2001).

[30] Table titled "Estimates and projections of life expectancies at birth for both sexes, males and females, by region and country, 1950-2000, medium variant." This is the earliest ever published document containing country-specific estimates of life expectancy for the period 1995-2000.

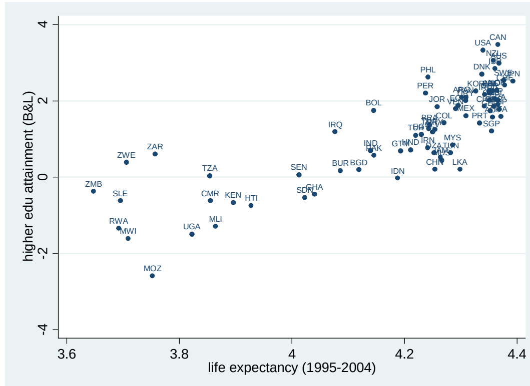

Figure 3: Longevity and education (B&L data)

correlation with sanitation is 67 %, with pharmaceutical imports 63 %, with government stability 53 %, with aids prevalence minus 27 %, and equal to minus 17.4 % with the degree of conflict. With the exception of the last two correlations, all other reported correlations are statistically significant at the one percent level.

Nearly all candidate health inputs are strongly related with real income per capita. This is especially true in the case of physicians availability (89 %), CS higher educational attainment rates (84 %), higher education enrollment (84 %), BL higher educational attainment rates (82 %), pharmaceutical imports (81 %), BL average years of higher education (79 %), LGSS 20-29 age-specific higher educational attainment rates (79 %), and LGSS 20-24 age-specific higher educational attainment rates (68 %). Moreover, several of these inputs are highly correlated with each other raising a warning flag regarding potential collinearity problems in the regressions that follow. Notably, the correlation of CS and BL higher educational attainment rates with physicians is 86 % in both cases, that for the 20-29 age-specific measure from LGSS is 81 %, and that for the 20-24 age-specific measure from LGSS is 73 %. We thus consider specifications both with and without the apparently highly collinear physicians-availability variable.

Finally, the 1973 UN forecast of longevity for 1995-2000 has a correlation of 85 % with end-of-period life expectancy, suggesting that it captures a whole spectrum of factors related to future longevity outcomes. The high correlation between forecasts and outcomes implies that the former are highly correlated with our included explanatory variables, in addition to a number of unknown omitted determinants of longevity. The forecast is highly correlated with the 1961-80 average of BL higher educational attainment rates at 79 %, CS higher educational attainment rates at 81 %, LGSS 20-24 age-specific tertiary educational attainment rates over 1970 to 2000 at 76 %, LGSS 20-29 age-specific tertiary educational attainment rates over 1970 to 1990 at 80 %, higher education enrollment rates at 82 %, and BL average years of higher education at 75 %. The physicians measure averaged over 1961-95 has a correlation with the forecast of 88 %, and overall efficiency of the health system has a correlation with the longevity forecast of 86 %. Finally, the correlation of the forecast with real income averaged over 1961-80 is 81 %, with initial longevity this is 94 %, and its correlations with female literacy, sanitation, pharmaceutical imports, and government stability are 78, 76, 70, and 53 percent respectively. The longevity forecast has a mere minus 24 % correlation with our measure of conflict whose degree is in part unpredictable, and close to zero correlation with AIDS prevalence which was an unpredictable shock standing back in 1973.

4 Methodology

We were able to put together the above series for 67 countries, shown in Table 1. The great majority of these are not available frequently over time and in some cases are exceedingly sparse in the time dimension. Since the cross-sectional dimension of the dataset is more complete and because of the inherent long-run nature of the relation under study, we opted for exploring the cross-sectional dimension of the data. Averaging over long periods helps reduce measurement error problems that haunt any exercise considering a sample of countries at different levels of development, as demonstrated in a number of studies, and more recently in Johnson et al. (2009). We average the data over the period 1995 to 2004 for life expectancy and over 1961 to 1995, subject to availability, for explanatory variables other than higher education and initial income. Below we first present our approach and then explain how the higher education variables are averaged over the time dimension in a manner consistent with our concerns about the possible presence of endogeneity as well as the goal of limiting measurement error.

One important concern is the extent to which life expectancy could be forecasted by individuals, and this forecast then endogenized in their educational choices according to the patience formation channel. We allow for individuals able to make forecasts of future longevity as accurate as those undertaken by UN demographers. We use forecasts of longevity regarding the period 1995-2000, as assessed by UN demographers in 1973. We consider the component of education that cannot be explained by these forecasts (the residual from a regression of higher education averaged over 1961-80 on the forecast of longevity as of 1973 and on all other exogenous variables), to explain deviations of actual life expectancy relative to the 1973 forecasts. These deviations represent the unpredicted component of life expectancy around 2000, presumed not to have an impact on educational decisions made in the period from 1961 to 1980. Therefore, if these deviations are explained by exogenous variation in lagged education variables, we can interpret this as evidence of causality from education on longevity.

Towards the goal of addressing potential endogeneity problems and establishing some evidence of temporal causation, we implement a simple procedure that provides identical point estimates for higher education to those obtained by using deviations of actual from forecasted longevity. Specifically, we apply OLS estimation of actual life expectancy at the end of the period on lagged higher education, including the forecast of life expectancy on the right-hand-side along with the other explanatory variables. In this case, the included forecast has an omitted variables interpretation where factors taken into account by UN demographers and individuals in 1973 are accounted for in the regression through the use of this proxy. There is also an IV interpretation of this procedure where the instrument for education is the residual from a first-stage regression of education on the forecast of longevity and all other exogenous variables. By construction, IV estimation produces the same point estimates for higher education as those reported in Table 2.

Let us now explain our choice for averaging higher education variables over time. We use lagged values averaged over the earlier period 1961-80, more closely corresponding to the period of availability of the 1973 UN longevity forecasts, to obtain the results shown in Tables 2, 3, 6, and 7 where we use four alternative measures of higher education: BL attainment rates, CS attainment rates, enrollment rates, and BL years of education. These education measures are averaged over the 1961-80 period to be consistent with the available 1973 UN forecasts of life expectancy for the period around 2000.[31]

In Tables 4 and 5, we use two other measures of higher education: LGSS age-specific educational attainment rates for ages 20-24 averaged over the whole period of availability of this measure from 1970 to 2000, and LGSS age-specific educational attainment rates for ages 20-29 averaged over the period 1970 to 1990. We view these age groups as the most relevant for tertiary education decisions. We note that these two higher education measures serve different purposes. Higher education attainment rates for ages 20-29 averaged over 1970-90 measures the stock of human capital most likely to have been influenced by 1973 forecasts of longevity, reflecting tertiary education decisions of cohorts aged 13-22 years old between 1963 and 1983, i.e., within a decade from the time of release of the UN forecasts.[32] Thus, for this measure, it is possible for us to use 1973 longevity forecasts to address the endogeneity issue. On the other hand, the contemporaneous stock of human capital is closer to the theoretical concept of the education externality. In this respect, the measure of higher education attainment rates for ages 20-24 averaged over 1970-2000 capturing cohorts making educational decisions during this period may be preferable, since it is similar to higher education attainment rates in 2000 averaged across ages 20-54. Its drawback is that it is more likely to suffer from endogeneity due to its contemporaneous nature in relation to longevity outcomes for 1995 to 2004, and that the 1973 forecasts seem relatively less adequate to solve the

[31] Assuming that education decisions are taken up to age 25, the aggregate measures of higher education attainament rates given by BL and CS averaged over the period 1961-80 concern mainly cohorts aged 25 in 1980 and older. Individuals in these cohorts are aged at least 40 in 1995 and 49 in 2004. Hence, expectations of life expectancy over 1995-2004 inform of expectations on mortality patterns at ages beyond 40 years old, which seem crucial as far as expectations of the private return on investment in higher education are concerned.

[32] We average attainment rates for ages 20-29 over 1970-90 to capture tertiary education decisions that were most likely to have been influenced by the 1973 forecast of longevity. We assume that the information in this forecast is relevant for individuals that are of the right age to make forward looking educational decisions within a decade prior to or after 1973. Individuals on the lower bound of the age cohort being considered, i.e., those aged 20-29 years old in 1990, were 13-22 years old in 1983. Individuals on the upper bound of the age cohort being considered, i.e., those aged 20-29 years of age in 1970, were 13-22 years of age in 1963. The remaining individuals we consider fall in the 20-29 age group in 1975, 1980, or 1985 and are even more likely to be making decisions that utilize the information in the 1973 forecast. We note that averaging these cohorts over time has the attribute of placing more weight on individuals likely to be making decisions around the middle of the period, and less weight on those making decisions at the beginning and end of the period being considered. This is desireable since the information in the 1973 longevity forecast is more relevant for the former group of individuals.

endogeneity problem as they become outdated over time and especially so by the end of the period.[33] For these reasons and to alleviate the omitted variables problem, when using this latter measure of education we will also include life expectancy averaged over the period from 1960 to 1995 as an explanatory variable for life expectancy during the period from 1995 to 2004.

In order to address the omitted variables problem, we account for a number of measures in addition to the longevity forecast variable described above. The forecast variable includes information about a host of otherwise omitted variables that would have been excluded from our regression specifications but might have been acting on life expectancy at the same period as higher education. Not accounting for these otherwise omitted variables that are captured by the forecast of life expectancy back in 1973, could plausibly inflate estimates of the health impact of higher education. Similarly, we include initial life expectancy in order to capture otherwise omitted variables that might have been acting on life expectancy over the same period as the higher education variables but would otherwise be left unaccounted for. Including the lag of our dependent variable as given by life expectancy averaged over the period 1961-1980 along with tertiary education averaged over the same period, helps capture any unobserved correlates acting contemporaneously on both education and life expectancy, so that their impact is removed from the estimated effect of education averaged over 1961-1980 on life expectancy averaged over 1995-2004.

We also take account of the fact that income can be a major determinant of health, by including initial period time-averages of real income per capita in the regression specifications presented in all Tables of results. Real income per capita largely determines individual purchasing power for inputs related to health. These would include medical expenditures but also spending on food.[34] Moreover, real income per capita is likely related to the provision of public health services, such as access to sewage systems for instance. Controlling for income helps isolate the part of the effect of each input that is unrelated to income. In addition, we include a number of other measures to account for private purchases of medical inputs and publicly provided health inputs affecting the environment in which households live and make decisions. These are: pharmaceutical spending, density of physicians, sanitation, efficiency of the health system and health institutions. Moreover, we account for the prevalence of disease, and the roles of geography and political institutions.

We isolate a lower bound for the external effect from education by interpreting the basic literacy coefficient as not adding to the external effect while allowing the tertiary education coefficient to be interpreted as capturing both internal and external effects. The evidence for an education externality being present is simply based on the fact that the separate estimated impact of tertiary education on longevity is too large to rest exclusively on the internal channel. That is, our identification of the education externality depends on the counterfactual

[33] On the other hand, using more recent forecasts of longevity for year 2000 made in the 1990's would not leave much of an unpredicted component to be explained.

[34] Thus, including income conforms with Fogel's (1994) emphasis on nutrition as a determinant of health. We note that including total calories along with income, total calories never had a positive significant impact on longevity.

discussed at some length in the introduction: Since life expectancy is computed as an average across educational groups, the relatively large estimated elasticity of life expectancy with respect to tertiary education that we estimate would imply unrealistically large gains in life years for those who choose to acquire tertiary education, if they were the only ones benefitting from their education or if only members of their household benefited. To make sense of the estimated elasticities, we need to allow for the possibility that others, outside the household, benefit as well as a result of the educational choices of these highly educated individuals. In section 6, we provide a numerical example to illustrate this argument, using the estimated elasticities and data from our sample.

Overall, the estimation procedure described in this section helps identify the impact of higher education on longevity, over and above that of basic education, as it addresses the endogeneity problem intrinsic to the relation between education and longevity and the associated omitted variables problem. Results from this specification are reported in Tables 2 and 3 for BL and CS educational attainment rates respectively, Tables 4 and 5 for LGSS age-specific educational attainment rates, Table 6 for higher education enrolment rates, and Table 7 for BL years of education data.

5 Results

In the first column of each table of results starting with Table 2, we report elasticity estimates[35] from OLS regressions of end-period (1995-2004) average life expectancy on real income per capita and higher education averaged over the initial period from 1961 to 1980, and on female literacy, sanitation, pharmaceutical spending per capita, and AIDS per hundred thousand population all averaged over 1961-95 subject to data availability.[36]

For all the results reported in columns (1) to (7) of Table 2, we handle the endogeneity problem utilizing the procedure outlined in the methodology section based on longevity forecasts as of 1973. That is, we consider the unpredicted component of life expectancy as the difference between actual life expectancy averaged over 1995-2004 and the 1973 forecast of life expectancy around 2000. Our test for a role of higher education as a determinant of longevity consists of an attempt to explain the unpredicted part of life expectancy at the end of the period, using the component of higher education over 1961-80 not explained by the 1973 forecast of life expectancy around 2000. We implement a procedure that provides the same point estimates for higher education as the one just described but which is more straightforward and provides us directly with the correct standard errors. Moreover, it provides a direct test of the relation between the initial forecast and actual life expectancy at the end of the period. Specifically, we include the 1973 forecast of longevity around 2000 as an explanatory variable along with higher education averaged over 1961-80 and the remaining explanatory

[35]All estimates are elasticities since both the dependent and independent variables are expressed in natural logarithms. The exceptions are the measures of overall efficiency of the health system which takes values between zero and one, and the degree of conflict which is measured as the fraction of years with conflict during the period.

[36]AIDS appears only since 1979. Moreover, LGSS data are available starting in 1970. Thus, higher education attainment rates of the age group 20-24 are averaged over the period 1970-2000, and for the age group 20-29 these are averaged over 1970-1990 for all reported specifications in Tables 4 and 5 respectively.

variables, in order to explain longevity averaged over the end of the period from 1995 to 2004. As alluded to above, a number of additional control variables, including initial life expectancy averaged over the same period as the higher education variable are also included in order to allow for otherwise omitted factors that might have been impacting positively on life expectancy over the same period as higher education. This exercise shows that higher education, as proxied by educational attainment rates from the BL database, likely has a causal impact on longevity. This impact is positive and statistically significant in all columns of Table 2.

The estimated elasticity of life expectancy with respect to BL higher educational attainment rates in column (1) of Table 2 equals three percent and ranges to a value as high as 4.3 % in column (6) once additional control variables including geography-related ones are accounted for. The estimate in column (1) suggests that doubling the attainment rate of higher education would increase life expectancy by as much as three percent. We note that not including the longevity forecast, the estimated impact (not shown in the Table) of higher education on longevity is 5 % using higher education averaged over 1961-95 and 4 % using higher education over 1961-80. These latter estimates would then appear to be inflated relative to those in columns (1) to (7) of Table 2 that were estimated in a manner that appropriately handles the issue of reverse causality from longevity to education. In column (2) of Table 2, initial life expectancy averaged over the same period as the lag of higher education is added to the regression analysis. Although life expectancy is a persistent variable (the correlation between beginning and end-of-period values is 82% in our sample), the estimate for the impact of higher education on end-of-period life expectancy is unchanged relative to that reported in column (1). This might be because the forecast of longevity as of 1973 introduced in the specification reported in column (1), already captures the omitted variables initial life expectancy could be proxying for here. This is consistent with the fact that the effect of the latter is statistically indistinguishable from zero in column (2).

In column (3), political institutions as measured by the stability of government during the period, are included in the regression analysis. The elasticity of life expectancy with respect to higher education is very close to what is reported in columns (1) and (2) at 3.3 %, and government stability is estimated to have no significant impact on life expectancy. In column (4), we allow for the degree of conflict during the period under study. This enters negatively as expected but marginally insignificant, leaving the estimate for higher education almost unchanged at 3.1 %. In column (5), we allow for the quality of the health system and health institutions as proxied by the overall efficiency of the health system. The impact of higher education is now 3.5 %, somewhat higher than the estimates reported in columns (1)-(4). Moreover, the estimated impact of the health system's overall efficiency on higher education is estimated to be 36 %. In column (6), we add two geography variables capturing temperature and humidity respectively. These are estimated to have a perhaps surprising positive impact on life expectancy. The estimated impact of higher education is now estimated to equal 4.3 %, bigger than the estimates reported in any of the other columns. Finally, in column (7) of Table 2, we include the density of physicians in the regression analysis. As a result, the estimated impact of higher education falls relative to the estimate reported in column (6), and now equals 3.7 % which is once again strongly significant beyond the one percent level and higher in value than any of the estimates for higher education reported in columns (1) to (5). The estimated impact of physicians is equal to 2.9 % and significant at the ten percent level. The main findings regarding our remaining control variables are as follows:

While the estimated life expectancy elasticity of female literacy is around ten percent and statistically significant in specifications (not shown in the Tables) excluding the forecast variable, it is small and insignificant in columns (1) to (4) of Table 2. It then increases to a value of 7.5 % and statistically significant in column (5) once we introduce a measure of the health system's efficiency, and to about 9 % and strongly significant in columns (6) and (7).

The forecast of life expectancy has a very strong and significant impact on end-of-period life expectancy, which takes values ranging from 87.8 % in column (1) up to 123 % in column (6), suggesting that it is a rather good predictor of future longevity capturing a number of otherwise omitted demographic variables that were known as of the mid seventies. The impact of real income per capita is about five percent and statistically significant (not shown in the Table) as long as we exclude the forecast variable, but disappears once the latter variable is included as shown in columns (1) to (7) of Table 2. Spending on pharmaceuticals has an estimated elasticity just below two percent which remains significant in columns (1) to (4), but becomes statistically insignificant for the specifications with additional variables reported in columns (5)-(7), once a measure of the health system's overall efficiency is included in the specification. The estimated impact of AIDS is around three percent in columns (1) to (4) and around two percent in columns (5) to (7) remaining negative and strongly significant throughout. Finally, sanitation has no significant impact on health in this sample of countries.[37]

The measure of overall efficiency of the health system is found to have an elasticity estimate of 36 % in column (5) and about 46 % in columns (6) and (7), with strong statistical significance in each case. Moreover, the measure of conflict has negative but marginally insignificant impact in columns (4) and (5), which increases in absolute terms to minus 7.5 % and minus 6.1 % and statistically significant in columns (6) and (7) once we include the geography variables. Initial life expectancy has a negative impact that is statistically indistinguishable from zero for the specifications reported in columns (2) to (4), takes a marginally insignificant value of minus 40.5 % in column (5), and becomes statistically significant with estimated elasticities around 70 % in columns (6) and (7) once we account for the two geography-related variables. This finding suggests that conditional on geography and the other included variables, there is convergence in life expectancy for countries starting with lower values of life expectancy at the earlier part of the period.

In Table 3, we replicate the above exercise using the CS educational attainment data. The estimated elasticity of life expectancy with respect to CS higher educational attainment rates ranges from a low value

[37] Interestingly, microeconomic evidence on the health impact of improved access to sanitation facilities is inconclusive (Lee, Rosenzweig and Pitt, 1997).

of 2.5 % in column (1) to a high of 3.3 % in column (6) once additional variables like the health system's overall efficiency and geography are accounted for. We note that excluding the longevity forecast variable, the estimated coefficient (not shown in the Tables) would be 6 % for higher education averaged over1961-95, and 4.7 % for higher education averaged over 1961-80. Again, these estimates appear to be inflated relative to those reported in columns (1) to (7) of the Table that were estimated in a manner that addresses the issue of reverse causality from longevity to education. In column (2) of Table 3, initial life expectancy averaged over the same period as the lag of higher education is added to the regression analysis, and the estimate for the impact of higher education on end-of-period life expectancy goes to 2.7 % relative to 2.5 in column (1). In column (3), political institutions are included in the regression analysis, with the estimated elasticity of life expectancy with respect to higher education reaching 2.9 %. In column (4), we allow for the degree of conflict during the period under study, which reduces somewhat the estimated impact of higher education to 2.6 %. In column (5), we allow for the overall efficiency of the health system, and the estimated impact of higher education becomes 3.1 %. Next, we add two geography variables, which leaves the estimated impact of higher education reported in column (6) relatively unchanged at 3.3 %. In the last column, we include the density of physicians in the regression analysis, and the estimated impact of higher education on life expectancy equals 2.7 %. As in the previous table of results, the longevity forecast, overall efficiency of the health system, physicians, AIDS, and female literacy (in columns 5 to 7) are all found to have a significant impact on life expectancy, with the impact of the latter measure of education reaching as high as 12.7 % and 12.5 % in columns (6) and (7) respectively. Initial life expectancy is again shown to be inversely related to life expectancy at the end of the period once we include a role for geography, implying conditional convergence.

In Table 4, we perform an estimation exercise resembling that in Tables 2 and 3 but utilizing age-specific LGSS educational attainment rates for ages 20-24 averaged over all cohorts from 1970 to 2000. In the first column of Table 4, we consider again estimates from OLS regressions of end-period (1995-2004) average life expectancy on higher education, the longevity forecast, real income per capita averaged over the initial period from 1961 to 1980, and female literacy, sanitation, pharmaceutical spending per capita, and AIDS per hundred thousand population all averaged over 1961-95. Turning to the results reported in column (1) of Table 4, the estimated elasticity of life expectancy with respect to LGSS age-specific higher educational attainment rates is 4.5 %. The longevity forecast has a strongly significant impact of 81 % as shown in column (1) of Table 4. Again, we note that excluding the longevity forecast, the estimated elasticity of life expectancy with respect to the LGSS educational attainment rate (not reported in the Table) is 6.7 %. In column (2) of Table 4, we include initial life expectancy averaged over 1961-1995 as an explanatory variable of life expectancy averaged over 1995 to 2004. This is consistent with the time sample over which we consider the LGSS age-specific measure of educational attainment, thus capturing the impact of a number of variables that might have been acting to affect end-of-period life expectancy at the same time as the higher education variable, but would otherwise be left unaccounted for. The estimate for the impact of higher education on end-of-period life expectancy is now 3.4 %. Moreover, life expectancy averaged over 1961-1995 is now shown to be a strong and significant predictor of end-of-period life expectancy with an elasticity of 84 % as shown in column (2), displacing in effect the longevity forecast in its role as a proxy for a number of otherwise omitted variables. We note, however, that the impact of the 1961-1995 longevity average becomes insignificant once we account for the overall efficiency of the health system. In columns (3) and (4), we add sequentially a measure of the stability of government and a measure of conflict during the period under study, with the estimated elasticity of life expectancy with respect to higher education remaining at 3.5 %. In column (5), we allow for the overall efficiency of the health system, decreasing the estimated impact of higher education to 3 %. In column (6), adding the two geography variables reduces further the estimated impact of higher education to a low of 2.6 % and marginally insignificant (p-value of 0.119.) Finally, accounting for physicians in column (7) increases somewhat the estimated impact of higher education to a statistically significant 2.8 %.

In Table 5, we repeat the estimations using the age-specific LGSS educational attainment rate for ages 20-29 averaged over the cohorts from 1970 to 1990. In the first column of Table 5, we consider again estimates from OLS regressions of end-period (1995-2004) average life expectancy on higher education, the longevity forecast, real income per capita averaged over the initial period from 1961 to 1980, and female literacy, sanitation, pharmaceutical spending per capita, and AIDS per hundred thousand population all averaged over 1961-95. The estimated elasticity of life expectancy with respect to the LGSS educational attainment rate for ages 20 to 29 is 4.2 % in column (1), and remains the same in columns (2) and (3) where we add sequentially a measure of initial life expectancy and a measure of government stability as explanatory variables. This compares to an estimated impact of higher education on longevity of 6 % (not shown in the Table) when the longevity forecast is excluded from a specification otherwise similar to the one in column (1). The impact goes down to 3.8 % in column (4) when we include a measure of conflict, and remains about the same in columns (5) and (6) when we allow for the overall efficiency of the health system and the two geography variables respectively. In column (7), the estimated elasticity of longevity with respect to higher education becomes 3.2 %, once we account for the density of physicians.

In Table 6, we consider the same specifications as in the earlier tables, utilizing data on higher education enrolment rates. In the first column of Table 6, we consider again estimates from OLS regressions of end-period (1995-2004) average life expectancy on higher education averaged over 1961-80, and a number of other covariates including the longevity forecast variable. The estimated elasticity of life expectancy with respect to higher education enrollment rates is 4.9 % in column (1)[38] and remains close to this in columns (2) to (6), ranging from a high of 5.4 % in column (3) to 4.5 % in column (6). The estimated impact of higher education

[38]Excluding the longevity forecast, the estimated coefficient for higher education averaged over 1961-95 is 6.2 %, and 6.4 % for higher education averaged over 1961-80.

takes its lowest value of 3.7 % in column (7), once we account for physicians.

Finally, in Table 7, we repeat our analysis using data on higher education years of attainment from BL. In the first two columns of Table 7, we consider again estimates from OLS regressions of end-period (1995-2004) average life expectancy on higher education averaged over 1961-80. The estimated elasticity of life expectancy with respect to BL years of higher education reported in columns (1) to (7) of Table 7 takes its lowest value of 2.6 % in column (1).[39] The estimates of higher education averaged over 1961-80, then range from a low of 2.7 % in column (2), up to 3.8 % in column (6) once the geography variables are included. In column (7), the estimated impact of higher education years of attainment on longevity equals 3.3 % and remains strongly significant. Finally, we note that the estimated impact of our measure of basic literacy is estimated to be strongly significant and equal to 9.8 % in column (7).

6 Appraisal

Overall, we find that higher education matters significantly for longevity and is more robust than female literacy, sanitation, spending on pharmaceuticals, political institutions, geography-related variables, initial life expectancy and per capita income. Higher education is a robust determinant of life expectancy even once we control for the density of physicians and the overall efficiency of the health system. Whatever the variable used to measure higher education, its estimated effect on longevity is always positive and statistically significant in all cases (except for one column of Table 4 where it is marginally insignificant). This by itself is an original and interesting result.

The relationship we unveil is causal since we take care of the endogeneity problem by including the longevity forecast measure. Comparing point estimates of the elasticity of life expectancy with respect to higher education in Tables 2 to 7, to estimates obtained while excluding the longevity forecast (reported in the previous section but not in Tables 2 to 7), they appear to be smaller suggesting that our approach alleviates the endogeneity and omitted variables problems that would otherwise inflate tertiary education parameter estimates. However, it could also be argued that our approach likely minimizes any effect of higher education on longevity. For example, in the likely scenario that the average individual cannot predict future longevity as accurately as complex UN demographic models do, then the problem of reverse causality from expected longevity to education facing our estimation exercise would be less severe than we assume it to be. In this case, the true elasticity of longevity with respect to higher education would be larger that those estimated implementing our procedure in Tables 2 to 7). More importantly, we argue that the causal relationship from higher education on life expectancy implies the presence of external effects of education on health.

The effect of higher education on longevity, controlling for female literacy, is estimated to be positive and

[39] Estimates (not shown in the Table) obtained excluding the longevity forecast, are 4.6 % and 3.4 % for higher education averaged over 1961-95 and 1961-80 respectively.

significant. We note, however, that in those cases in which the estimated elasticity of life expectancy with respect to female literacy is statistically significant,[40] this is two to four times larger than the estimated elasticity with respect to higher education. This finding is coherent with much of the empirical literature based on micro-economic data that points to diminishing returns on education for health outcomes within households, i.e. the direct internal channel.

A counterfactual argument for externalities

Could this internal channel by itself explain the size of the coefficient on the higher education variables? With most countries in our sample having small average values of higher educational attainment[41], these estimated effects suggest that if higher education operated only through the internal channel in improving life expectancy, the relatively small proportion of individuals acquiring higher education would have to experience unrealistically large improvements for the population average to be affected by as much as we find in the aggregate data. For example, based on the lowest estimated elasticity in Table 2 which equals three percent, this would amount to an implausible 70 years of extra life for those acquiring tertiary education, if they were the only ones benefitting from their actions. Since this gain appears unrealistic, we interpret our estimated results as evidence for a causal external effect of higher education on average life expectancy.

It is useful to illustrate in detail how the implausible gain of 70 years mentioned above is computed: Consider an increase in higher education attainment from 2.64% to 4.24%, i.e. from the cross-country median to the cross-country mean for 1961-80. This implies a hypothetical change of $\beta \ln(4.24/2.64)$ in log life expectancy, which equals 0.014 using the lowest estimated coefficient for β (i.e. 0.03) from Table 2. Applying this change in life-expectancy to the level (77.98 years) for the median country in the distribution of higher education, we obtain an increase of 1.119 years. This is due to access to higher education by only 1.6% $(4.24 - 2.64)$ of the population. Suppose then that only these latter individuals experience improved longevity (a strict interpretation of the internal channel.) It then turns out that each of these individuals should experience a gain of 69.73[42] years! Similar implausible gains are obtained for alternative values of the parameter estimates.[43] What is wrong? The assumption of the absence of an externality imposed in the above computation! In fact, if having 1.6% more of the population attaining higher education improves longevity for other individuals whose education is not increased, then the years of life gained by attending college could be made more plausible.[44]

[40] As described in the results section, female literacy has a significant impact on longevity in Tables 2, 3, and 7 which include the BL and CS higher educational attainment rates and BL higher education years of education respectively, but not in the specifications utilizing the Lutz et al. age-specific education measures nor when using higher education enrolment rates.

[41] Nearly 70 percent of countries in our sample had attainment rates less than 0.02 in 1960, and about half had rates less than 0.10 even by 1995. The median across countries was 0.0264 for 1961-80 and 0.0489 for 1961-95.

[42] $1.119=0.016\times\Delta+0.984\times0$, so that $\Delta=69.73$ extra life years

[43] Using $\beta=0.037$ (column (7) of Table 2) the implausible increase in life years for those acquiring higher education is 86 years.

[44] If, for instance, 24% of the population experiences a longer life, then the average gain across this share of the population would be of the order of 5 instead of 70 more years. (The implied gain would be smaller and more plausible if we allowed a greater fraction of the population to benefit.) However, this would still imply that the decision by 1.6 % to obtain higher education exerts a positive external effect on the rest of the population equal to 22.4% of the population in this example, implying a value beyond any reasonable standard household size for these 1.6 % of the population.

Comparison to micro-based estimates

How does our estimated effect of higher education on longevity compare to evidence from micro-studies using individual-level data to examine the relation between education and health outcomes? Evidence on the effect of the level of education of adults on their own or their children's health found in the literature, is based on a variety of measures of individual education and health outcomes. Among the different measures of education we came across in this literature, number of years of education and attainment rates are the ones that can be most straightforwardly compared to measures used in our study. Our estimates of the longevity impact of the latter measures of education can then be compared to studies that estimate the effect of education on adult mortality rates, once changes in age-specific mortality rates are converted into changes in life expectancy at birth by adjusting the life tables to compute life expectancy.

Elo and Preston (1996) estimate the average effect of an additional year of education on the odds of dying over the five years following 1979 for men and women aged 25-64, using U.S. individual-level data from the National Longitudinal Mortality Survey. Computing the elasticity of the mortality rate with respect to years of education, one obtains 0.26 for males and 0.32 for females.[45] The elasticity implied by our results for the U.S. based on our preferred specification in column (7) of Table 7, equals 0.41 for men and 0.68 for women.[46] Hence, our estimated effect of years of education on mortality is about 56% (for men) to more than double (for women) larger than the respective estimates in the Elo and Preston (1996) study.[47]

Cutler et al. (2009) use individual-level data from the 1990 National Health Interview Survey in the U.S. matched with data on deaths, to estimate the marginal effect of total years of education and other variables on the probability of dying during the following 10 years, on a sample of individuals aged 25 to 64 years old. Considering the estimated coefficient from column (2) of Table 1 in Cutler et al. (2009), obtained for a specification including income, occupation, ethnicity, demographic variables and other indicators of socioeconomic status, we obtain an estimated elasticity of the 10-years mortality rate with respect to years of education equal to .357.[48] Using

[45] We use the estimated effect for $\gamma \equiv \partial \ln(\text{odds})/\partial yrs$ from Table 4 of Elo and Preston (1996), where yrs stands for years of education. Denoting the mortality rate as q, then odds$\equiv q/(1-q)$, and $\gamma = \frac{\partial q}{\partial(yrs)}/[q(1-q)]$. As a result, the elasticity of the mortality rate with respect to years of education is computed from $(\partial q/\partial yrs)/(q/yrs) = \gamma(1-q)yrs$, using estimates for γ from their Table 4 (.025 for men and .0311 for women), data reported in Table 1 of the same paper for q (.00496 for men and .00245 for women), and data from LGSS for average years of education in the U.S. in 1980 (i.e. 10.5 for men and 10.3 for women, for the population aged 25 and older).

[46] The coefficient on higher education in Table 7 is an estimate of $\beta \equiv \partial \ln \pi/\partial \ln(yrs)$. Treating life expectancy π as a function of the average mortality rate, one can write $\beta \equiv [(\partial\pi/\partial q)/(\pi/q)][(\partial q/\partial yrs)/(q/yrs)]$. Hence the implied elasticity of mortality with respect to education is $(\partial q/\partial yrs)/(q/yrs) = \beta/[(\partial\pi/\partial q)/(\pi/q)]$, where the elasticity of life expectancy π with respect to adult mortality q, is computed by simulating the effect of a 1% decrease in the mortality rate for age groups 25-64 in the US life tables for 1980-84 (in 5x5 format obtained from the Human Mortality Database internet site). We obtain an elasticity of life expectancy with respect to mortality equal to .081 for men and .048 for women.

[47] Using instead the lowest point estimate we obtain (from column (1) of Table 7), we obtain an indirect estimate of the elasticity of q with respect to yrs equal to .32 for men and .54 for women, i.e. approximately 23% higher than the one obtained by Elo and Preston (1996) for men, and 69% for women.

[48] Cutler et al. (2009) report the marginal effects from logit estimations, evaluated at the means of the independent variables. This gives an estimate of the change in the probability of dying over the following 10 years implied by a marginal increase in years of education, yrs, conditional on other independent variables. This probability over the sample corresponds to the 10-years mortality rate, ${}_{10}q$. The coefficient gives an estimate of $\partial_{10}q/\partial yrs = \gamma$. The elasticity of ${}_{10}q$ with respect to yrs is computed as $(\partial_{10}q/\partial yrs)/({}_{10}q/yrs) = \gamma \cdot yrs/{}_{10}q$. The number given in the text is obtained using the coefficient in column (2) of Table 1 in

the relevant life tables, we calculate the elasticity of the 5-years mortality rate with respect to average years of higher education implied by the estimated coefficient in column (7) of Table 7, and obtain .546, i.e. 52% higher than the one implied by the Cutler et al. (2009) estimate.[49]

From the above quantitative comparisons to the literature, we conclude that our estimated impact of higher education on life expectancy goes beyond what one would expect based on the estimated effect of education on own mortality found in individual-level data.

However, our estimates are comparable to those from aggregate cohort data. For example, Deaton and Paxson (2001) estimate the effect of higher education attainment rates on the log odds of dying over the 1-year horizon, using a panel of aggregate birth cohorts from the U.S. The data are obtained from the Current Population Surveys and from the Berkeley Mortality Database (now Human Mortality Database) and restricted to a sample of individuals aged 25-85 for the period 1975-95. Observations are assembled in cohort-age-gender cells, and regressions are run separately for each gender. In the middle panel of their Table 4.7, they report coefficients from OLS regressions of the log odds of dying on the proportion of the cohort with at least 16 years of education, controlling for mean income.[50] We use these estimated coefficients along with data from other sources to compute an elasticity of the 1-year mortality rate with respect to higher education attainment rates. This elasticity is found to be 0.33 for men and 0.28 for women.[51] These compare to indirect estimates of 0.25 for men and 0.34 for women for the elasticity of the 1-year mortality rate with respect to higher education attainment rates implied by our results when applied to the U.S. for the relevant period.[52] Since Deaton and Paxson (2001) do not address the issue of inverse causality and study contemporaneous effects, one could argue that it would be more pertinent for the purpose of comparison, to use the coefficient obtained from a less demanding regression, i.e. excluding longevity forecasts, which would then imply a tertiary education estimated coefficient of 0.05. In this case, our indirect elasticity estimates equal 0.34 for men and 0.46 for women. Finally, it should be noted that the cohort-level data in Deaton and Paxson (2001) are in fact aggregate data rather than individual-level ones, and can therefore encompass external effects along with the internal channel. To

Cutler et al. (2009), equal to .0018, the mean ${}_{10}q$=.0559 given in the legend of the same Table, and yrs= 11.1 for the U.S. in 1990 from the LGSS data (the mean of yrs is not reported by the authors).

[49] Here, we apply the procedure explained in a previous footnote when presenting the comparison to Elo and Preston (1996). We simulate the elasticity of life expectancy at birth with respect to 5-years mortality rate, ${}_5q$, of the age groups 25-64 using the 5x10 U.S. life tables for 1990-99 for the total population, which equals .0605. Hence $(\partial_5 q/\partial yrs)/({}_5q/yrs) = \beta/[(\partial\pi/\partial_5 q)/(\pi/{}_5q)] = .546$, for $\hat{\beta} = .033$. Using instead $\hat{\beta} = .026$ (our lowest point estimate, from column (1) of Table 7) ,we obtain 0.43, 20% higher than the Cutler et al. (2009) estimate.

[50] We were unable to compare our results to estimates based on individual level data reported in Table 4.4 of Deaton and Paxson (2001) because they come out of logit estimation and we would thus also need to know the mean values of all their independent variables and all estimated coefficients so as to compute the marginal effect of years of education for comparison with our results. This information is however missing in that paper, as is unfortunately also the case with other potentially relevant papers.

[51] We obtain these as $(\partial q/\partial edu)/(q/edu) = \gamma(1-q)edu$ using the procedure applied to Elo and Preston (1996) explained in footnote 43. Here, edu measures the proportion of individuals with at least 16 years of education in each cell age-cohort. Deaton and Paxson (2001) do not provide information about the mean values of education or mortality. We compute the estimate using the coefficients from their Table 4.7 (1.502 for men and 1.782 for women) along with higher education attainment in the U.S. for ages 25 and older averaged over 1975-95 from LGSS (.224 for men and .159 for women), and the 1-year mortality rate averaged across the relevant age groups for 1975-95 obtained from the cohort 1×1 death rates (.0301 for men and .0174 for women.)

[52] We use the coefficient from column (7) of Table 2 and the simulated elasticity of life expectancy at birth with respect to 1-year mortality of 25-84 age groups (from the U. S. 1×1 life tables for 1985) equal to .147 for men and .109 for women.

summarize, we note that while our estimates are higher than those based on micro-data for individuals, they do not appear to be very different than these cohort-based estimates of the health impact of education[53].

The estimated size of the coefficient on the higher education variable is too large to impute it solely to the direct individual internal channel. Could it then be the case that this coefficient is capturing some of the other indirect channels through which education can impact on health, reviewed in section 2? We believe that this cannot plausibly be the case, since higher education estimates appear robust to the inclusion of control variables arguably capturing all the main alternative channels through which education might be related to longevity. In light of all this, we are confident that the significance of higher education for longevity rests on the presence of a direct external channel through which education improves health outcomes at the aggregate level. Unfortunately, our results do not allow us to measure the exact size of the external effect of education on health.

Moreover, the analysis does not clarify through which channel the externality operates. However, one could interpret our results as evidence of a role of higher education in improving the effectiveness with which health related information is disseminated in society. To see this consider the fact that the coefficient on higher education falls systematically once the density of physicians is included in the regression. In general, the density of physicians is a significant and robust determinant of longevity. It is also highly collinear with higher education. Thus, it is useful to verify how the explanatory power of the latter is affected by the presence of physicians per capita as a competing determinant of life expectancy. To the extent that physicians help absorb and disseminate medical or health-related information across and within countries, in addition to their role as a rival health input, including this measure should diminish the impact otherwise captured by higher education measures. Indeed this is the case. Introducing physicians dampens the impact of higher education on life expectancy, consistent with the fact that these two variables are highly collinear. Finally, since we are attributing all of the impact of physicians to its direct rival role in the health production function, we are likely understating the overall effect of health-related knowledge[54], so that we could be underestimating the importance of the knowledge externality we are focusing on in this paper.

7 Conclusion

This paper belongs to a strand of the recent literature that addresses the determinants of longevity. As compared to this literature, our contribution is that we provide evidence for the existence of positive external effects of

[53]This is the case, even though we include a number of explanatory variables other than education and income and consider country-level data for a large cross-section of countries that are often very different from the U.S.

[54]Physicians may play two theoretically distinct roles in promoting health improvements: first, they provide rival services to patients acting as a direct rival input into the health production function; second, they are facilitators of health-related knowledge absorption and dissemination. The implication of the latter fact for our empirical analysis is that, if higher education affects longevity through an external channel as it favors the flow of knowledge in general and of health-related knowledge in particular, then its role should be partially captured by the physicians measure. Thus, our estimate of the education externality when also accounting for a measure of physicians could be viewed as a lower bound for the externality.

education on longevity.[55] We argue that the estimated effect of higher education on longevity controlling for literacy rates, can provide evidence of an external role of education once one addresses the endogeneity and omitted variables problems. To this effect, we make innovative use of forecasts made by UN demographers in 1973 regarding expected country-specific longevity around 2000. Our approach goes a long way towards taking into account the endogeneity of higher education suggested by theory. It also allows us to control for a number of otherwise omitted factors affecting future longevity. For instance, we control for initial life expectancy averaged over the same period as higher education to capture all otherwise omitted variables affecting end-of-period life expectancy whose positive effect might have been attributed in their absence to higher education.

The main contribution of this paper is the finding of a causal external effect of education on life expectancy. We find that the separate estimated impact of tertiary education on longevity is too large to rest exclusively on the internal channel, which provides evidence of external effects of education. More specifically, we find a direct effect of tertiary education on longevity that is at least three percent based on the specifications reported in Table 2. To illustrate the importance of these estimates, we note that a three percent estimated elasticity of life expectancy with respect to higher educational attainment implies that those acquiring tertiary education would gain at least an additional seventy years of life if the internal channel was the only one at work. It follows that the external channel is present as well. Moreover, comparing our estimates of the impact of education to micro-estimates reinforces this inference providing further evidence supporting an external channel through which education impacts upon longevity, beyond the effect of own education at the individual level. The above result contributes to three lines of research.

First, we suggest that education may play a more important role for health outcomes than previously thought. As explained at some length in the introduction, education is in fact already considered an important determinant of health but only at the level of the household. While it is possible to find papers mentioning external effects of education on health, a careful reading reveals that these effects typically concern transmission from parents to their children. What we have established in this paper is therefore that a greater investment in education will improve health not only through this internal channel, but also through the positive external effects that average education exerts. This is a potentially important finding and at the same time calls for further scrutiny given the limitations of cross-country aggregate data.

Second, a large body of empirical work coming out of labor economics and macro growth (summarized in Krueger and Lindahl, 2001, and Psacharopoulos and Patrinos, 2004) has studied the possibility of externalities arising from education on income. This should not come as a surprise since endogenous growth theory models dating back to Lucas (1988) and Romer (1990) assign a central role to human capital externalities in the process of economic growth. Moreover, "the significant open question ... whether the social returns to human capital

[55] This is the case even though we interpret the basic literacy coefficient as not adding to the external effect and allow the tertiary education coefficient to be interpreted as capturing both internal and external effects.

investment substantially exceed the private return" (Topel 1999, p. 2973) has been raised by a number of economists going back to Becker (1975) and Heckman and Klenow (1997). At the same time, although the debate is still open, there appears to be accumulating evidence suggesting the absence of such externalities[56], with the exception of Rauch (1993) and Moretti (2004).[57] This presents a challenge for a large class of important theoretical models built on the premise of human capital externalities. We point out that in assessing social returns, health status should be viewed as a separate component of welfare in addition to income, and show that education externalities for this important component of welfare can be important even when these have not been shown to matter for the other component of welfare typically studied by macroeconomists.[58]

Finally, the results presented in this paper suggest that there is scope for studying the determinants of welfare growth as a concept that is closely related but distinct from economic growth. Non-income factors are shown to be important for explaining variations in life expectancy across countries. Policy implications may be important. For instance, our findings suggest that investing in health-related inputs might be crucial for welfare growth even if the effect of health on economic growth is small as in Weil (2007), or non-existent as in Acemoglu and Johnson (2008). While the latter authors hold that their "estimates exclude any positive effects of life expectancy on GDP per capita" (p. 3), they acknowledge that, consistent with Becker, Philipson, and Soares (2005), "[*health*] interventions have considerably improved overall welfare" (p. 4). Our analysis highlights the crucial role that educational policies may play in enhancing welfare, since it gives evidence of the role that education plays in influencing the health component of welfare. We propose that human capital externalities are likely to be important determinants of a broader concept of welfare growth that goes beyond the standard concept of economic growth.

[56] Acemoglu and Angrist (2000) find "small social returns ... that are not significantly different from zero" and Cohen and Soto (2007) concur stating that "*the* effect of schooling is close to the typical micro Mincerian return *which* suggests the absence of externalities to education." Pritchett (2001) documents relatively low returns to education in a growth context and so do Bils and Klenow (2000) who find that "the channel from schooling to growth is too weak to plausibly explain more than one-third of the observed relation between schooling and growth." Finally, Ciccone and Peri (2006) find "no evidence of significant average-schooling externalities" for US cities.

[57] Rauch (1993) estimates a large social rate of return suggesting externalities for average education on wages in the context of US cities. Moretti (2004) finds some evidence of spillovers after estimating social returns to higher education at the city level.

[58] Our findings provide evidence of a form of increasing returns to scale in education as far as longevity is concerned, whereby tertiary education appears to be no less important than basic literacy. This contrasts with evidence on the determinants of economic growth pointing to decreasing returns to scale in education, with basic education being the single most important factor for income growth and higher education having little or no impact (see Sala-i-Martin, Doppelhofer and Miller 2004).

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Table 1: List of countries in the dataset

Country	Avg Life Expectancy†	Country	Avg Life Expectancy†
Algeria	70.3	Korea	75.7
Argentina	73.9	Malawi	40.8
Australia	78.9	Malaysia	72.7
Austria	78.0	Mali	47.7
Bangladesh	61.5	Mexico	74.4
Bolivia	63.1	Mozambique	42.6
Brazil	69.7	Myanmar	59.5
Cameroon	47.2	Netherlands	78.0
Canada	78.8	New Zealand	78.1
Chile	76.9	Norway	78.6
Colombia	71.5	Pakistan	63.2
Costa Rica	77.6	Panama	74.4
Cyprus	78.3	Paraguay	70.4
Denmark	76.5	Peru	69.3
Ecuador	73.4	Philippines	69.5
Egypt	70.1	Portugal	76.2
Finland	77.5	Singapore	77.9
France	78.8	Spain	78.9
Ghana	56.8	Sri Lanka	73.6
Greece	78.2	Sudan	55.9
Guatemala	66.2	Sweden	79.6
Haiti	50.8	Switzerland	79.7
Honduras	67.4	Tanzania	47.2
Iceland	78.8	Thailand	69.7
India	62.8	Tunisia	72.4
Indonesia	65.9	Turkey	68.1
Iran	69.5	Uganda	45.7
Ireland	76.9	United Kingdom	77.6
Israel	78.3	Unites States	76.7
Italy	79.2	Uruguay	74.3
Jamaica	71.1	Venezuela	73.0
Japan	80.9	Zambia	38.4
Jordan	70.7	Zimbabwe	40.7
Kenya	49.2		

†: This is the end of period average life expectancy from 1995 to 2004.

Table 2: Explaining 1995-2004 average life expectancy levels with BL higher education attainment rates.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Higher education	0.030***	0.030**	0.033***	0.031***	0.035***	0.043***	0.037***
	(0.011)	(0.012)	(0.012)	(0.011)	(0.011)	(0.013)	(0.013)
Initial income	0.017	0.018	0.014	0.018	0.009	0.002	-0.013
	(0.018)	(0.019)	(0.021)	(0.021)	(0.019)	(0.021)	(0.021)
Female literacy	0.029	0.030	0.036	0.038	0.075**	0.088***	0.092***
	(0.047)	(0.040)	(0.041)	(0.042)	(0.034)	(0.028)	(0.028)
Sanitation	0.007	0.008	-0.001	-0.004	-0.019	-0.028	-0.028
	(0.029)	(0.031)	(0.036)	(0.036)	(0.032)	(0.028)	(0.031)
AIDS	-0.029***	-0.029***	-0.028***	-0.030***	-0.022***	-0.018***	-0.016***
	(0.005)	(0.004)	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)
Pharmaceuticals	0.018**	0.018**	0.016*	0.014*	0.011	0.005	0.002
	(0.008)	(0.008)	(0.009)	(0.008)	(0.009)	(0.008)	(0.008)
Longevity forecast	0.878***	0.893***	0.937***	1.013***	0.928***	1.230***	1.073***
	(0.189)	(0.301)	(0.327)	(0.345)	(0.304)	(0.297)	(0.291)
Initial life expectancy		-0.018	-0.059	-0.107	-0.405	-0.715**	-0.700**
		(0.214)	(0.227)	(0.237)	(0.266)	(0.279)	(0.280)
Government stability			0.085	0.073	0.014	0.031	0.047
			(0.109)	(0.113)	(0.102)	(0.094)	(0.095)
Conflict				-0.043	-0.050	-0.075**	-0.061**
				(0.029)	(0.034)	(0.034)	(0.029)
Health system efficiency					0.358**	0.460***	0.453***
					(0.156)	(0.140)	(0.133)
Maximum temperature						0.130**	0.125**
						(0.057)	(0.054)
Maximum humidity						0.183**	0.189**
						(0.082)	(0.084)
Physicians							0.029*
							(0.016)
Constant	0.039	0.038	-0.107	-0.236	1.216	-0.075	0.625
	(0.745)	(0.755)	(0.844)	(0.849)	(0.913)	(0.845)	(0.764)
Observations	67	67	67	67	67	67	67
adjusted R^2	0.865	0.862	0.862	0.862	0.885	0.899	0.903

Notes: *** p<0.01, ** p<0.05, * p<0.1 Heteroskedasticity-consistent finite sample standard errors in parentheses. All variables (except Conflicts and Health System which lie between zero and one) are in natural logarithms so that the reported estimates are elasticities of life expectancy with respect to each explanatory variable. We estimate an OLS regression of average life expectancy over 1995-2004 on higher education averaged over the period from 1961 to 1980. This has an IV interpretation and is equivalent to explaining the deviations of actual life expectancy relative to its 1973 forecast, by the exogenous component of higher education. Initial income and initial life expectancy are measured by their 1961-80 time average. Conflict is an average over the period under study from 1961 to 2004, geographic variables are time invariant, and the remaining explanatory variables are average levels over 1961-95, subject to availability.

Table 3: Explaining 1995-2004 average life expectancy levels with CS higher education attainment rates.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Higher education	0.025**	0.027**	0.029**	0.026**	0.031**	0.033**	0.027*
	(0.011)	(0.011)	(0.013)	(0.013)	(0.014)	(0.014)	(0.015)
Initial income	0.016	0.002	-0.002	0.002	-0.004	-0.003	-0.017
	(0.019)	(0.020)	(0.023)	(0.024)	(0.025)	(0.025)	(0.027)
Female literacy	0.076	0.049	0.052	0.054	0.097**	0.127***	0.125***
	(0.057)	(0.052)	(0.052)	(0.052)	(0.042)	(0.044)	(0.042)
Sanitation	0.004	-0.002	-0.010	-0.014	-0.021	-0.019	-0.024
	(0.026)	(0.025)	(0.030)	(0.030)	(0.028)	(0.029)	(0.029)
AIDS	-0.026***	-0.026***	-0.025***	-0.027***	-0.020***	-0.017***	-0.015***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)
Pharmaceuticals	0.015*	0.012*	0.011	0.008	0.006	0.002	0.001
	(0.008)	(0.007)	(0.008)	(0.007)	(0.008)	(0.008)	(0.009)
Longevity forecast	0.838***	0.646**	0.671**	0.759**	0.656**	0.867***	0.674**
	(0.208)	(0.270)	(0.291)	(0.298)	(0.266)	(0.283)	(0.292)
Initial life expectancy		0.246	0.219	0.168	-0.129	-0.399*	-0.367*
		(0.163)	(0.176)	(0.185)	(0.200)	(0.210)	(0.212)
Government stability			0.083	0.081	0.031	0.025	0.049
			(0.122)	(0.125)	(0.108)	(0.111)	(0.109)
Conflicts				-0.036	-0.041	-0.060	-0.036
				(0.037)	(0.041)	(0.040)	(0.036)
Health system efficiency					0.312**	0.393***	0.377***
					(0.137)	(0.132)	(0.124)
Maximum temperature						0.123**	0.108*
						(0.060)	(0.058)
Maximum humidity						0.106	0.101
						(0.065)	(0.066)
Physicians							0.032**
							(0.016)
Constant	0.052	0.109	0.005	-0.173	1.269	0.420	1.307
	(0.763)	(0.754)	(0.838)	(0.819)	(0.901)	(0.901)	(0.943)
Observations	62	62	62	62	62	62	62
adjusted R^2	0.881	0.882	0.881	0.880	0.899	0.904	0.908

Notes: *** p<0.01, ** p<0.05, * p<0.1 Heteroskedasticity-consistent finite sample standard errors in parentheses. All variables (except Conflicts and Health System which lie between zero and one) are in natural logarithms so that the reported estimates are elasticities of life expectancy with respect to each explanatory variable. We estimate an OLS regression of average life expectancy over 1995-2004 on higher education averaged over the period from 1961 to 1980. This has an IV interpretation and is equivalent to explaining the deviations of actual life expectancy relative to its 1973 forecast, by the exogenous component of higher education. Initial income and initial life expectancy are measured as their 1961-80 time average. Conflict is an average over the period under study from 1961 to 2004, geographic variables are time invariant, and the remaining explanatory variables are average levels over 1961-95, subject to availability. The sample is down to 62 countries. Relative to the countries presented in Table 1, Iceland, Israel, Pakistan, and Sri Lanka are missing, and Zimbabwe is excluded.

Table 4: Explaining 1995-2004 average life expectancy levels with LGSS higher education attainment rates of 20-24 years old.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Higher education	0.045**	0.034**	0.035**	0.035**	0.030*	0.026	0.028*
	(0.019)	(0.016)	(0.017)	(0.017)	(0.015)	(0.016)	(0.016)
Initial income	0.044***	0.015	0.016	0.016	0.019	0.018	-0.006
	(0.015)	(0.017)	(0.018)	(0.020)	(0.021)	(0.020)	(0.021)
Female literacy	-0.009	-0.083	-0.089	-0.089	-0.051	-0.064	-0.052
	(0.062)	(0.060)	(0.061)	(0.062)	(0.048)	(0.056)	(0.054)
Sanitation	0.027	0.016	0.020	0.020	0.010	0.011	0.014
	(0.041)	(0.038)	(0.041)	(0.041)	(0.036)	(0.037)	(0.038)
AIDS	-0.021***	-0.017***	-0.017***	-0.017***	-0.016***	-0.016***	-0.014**
	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Pharmaceuticals	0.006	-0.003	-0.002	-0.001	-0.004	-0.012	-0.013
	(0.008)	(0.007)	(0.007)	(0.007)	(0.009)	(0.013)	(0.013)
Longevity forecast	0.809***	0.201	0.176	0.171	0.218	0.321	0.194
	(0.211)	(0.230)	(0.219)	(0.253)	(0.264)	(0.334)	(0.318)
Initial (61-95) life expectancy		0.841***	0.868***	0.873***	0.512	0.484	0.417
		(0.282)	(0.256)	(0.307)	(0.361)	(0.425)	(0.429)
Government stability			-0.051	-0.051	-0.094	-0.070	-0.024
			(0.092)	(0.090)	(0.093)	(0.098)	(0.099)
Conflicts				0.002	-0.033	-0.059	-0.034
				(0.044)	(0.047)	(0.063)	(0.060)
Health system efficiency					0.280*	0.300*	0.271
					(0.152)	(0.168)	(0.167)
Maximum temperature						-0.016	-0.005
						(0.084)	(0.084)
Maximum humidity						0.085	0.112
						(0.107)	(0.109)
Physicians							0.035**
							(0.014)
Constant	0.222	-0.064	0.028	0.034	1.081	0.477	1.219
	(0.858)	(0.759)	(0.861)	(0.841)	(1.035)	(1.026)	(0.883)
Observations	58	58	58	58	58	58	58
adjusted R^2	0.863	0.886	0.885	0.882	0.889	0.887	0.891

Notes: *** p<0.01, ** p<0.05, * p<0.1 Heteroskedasticity-consistent finite sample standard errors in parentheses. All variables (except Conflicts and Health System which lie between zero and one) are in natural logarithms so that the reported estimates are elasticities of life expectancy with respect to each explanatory variable. We estimate an OLS regression of average life expectancy over 1995-2004 on age-specific higher education attainment averaged over the whole period of availability from 1970 to 2000. This is equivalent to explaining deviations of actual life expectancy relative to its 1973 forecast. Initial income is measured as its 1961-80 time average, Conflict is an average over the period under study from 1961 to 2004, geographic variables are time invariant, and the remaining explanatory variables are average levels over 1961-95, subject to availability. The sample is down to 58 countries. Relative to the sample of countries shown in Table 1, Algeria, Iceland, Israel, Jamaica, Myanmar, Sudan, Tunisia and Venezuela are missing, and Jordan is excluded.

Table 5: Explaining 1995-2004 average life expectancy levels with LGSS higher education attainment rates of 20-29 years old.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Higher education	0.042*	0.042*	0.042*	0.038*	0.037*	0.036*	0.032*
	(0.021)	(0.022)	(0.022)	(0.022)	(0.019)	(0.019)	(0.018)
Initial income	0.034*	0.032	0.031	0.038*	0.040*	0.037*	0.017
	(0.018)	(0.019)	(0.020)	(0.021)	(0.021)	(0.021)	(0.025)
Female literacy	-0.001	-0.006	-0.004	0.004	0.039	0.052	0.058
	(0.060)	(0.053)	(0.055)	(0.056)	(0.044)	(0.041)	(0.040)
Sanitation	0.022	0.021	0.020	0.017	-0.001	0.001	0.002
	(0.039)	(0.040)	(0.044)	(0.045)	(0.038)	(0.037)	(0.037)
AIDS	-0.024***	-0.024***	-0.024***	-0.026***	-0.016***	-0.015***	-0.014**
	(0.006)	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)
Pharmaceuticals	0.008	0.007	0.007	0.003	-0.002	-0.011	-0.012
	(0.008)	(0.008)	(0.009)	(0.009)	(0.012)	(0.014)	(0.014)
Longevity forecast	0.856***	0.809***	0.817**	0.916**	0.839***	1.077***	0.929***
	(0.212)	(0.301)	(0.324)	(0.351)	(0.310)	(0.329)	(0.317)
Initial life expectancy		0.059	0.051	-0.023	-0.512	-0.698**	-0.663**
		(0.221)	(0.223)	(0.245)	(0.306)	(0.317)	(0.318)
Government stability			0.017	0.022	-0.080	-0.055	-0.017
			(0.127)	(0.128)	(0.109)	(0.112)	(0.108)
Conflicts				-0.054	-0.101**	-0.131**	-0.108*
				(0.043)	(0.042)	(0.054)	(0.055)
Health system efficiency					0.547***	0.587***	0.546***
					(0.151)	(0.156)	(0.163)
Maximum temperature						0.097	0.095
						(0.075)	(0.076)
Maximum humidity						0.137	0.159
						(0.101)	(0.103)
Physicians							0.028*
							(0.014)
Constant	0.066	0.068	0.035	-0.152	1.954**	0.676	1.183
	(0.892)	(0.898)	(1.039)	(1.055)	(0.861)	(0.905)	(0.858)
Observations	58	58	58	58	58	58	58
adjusted R^2	0.860	0.857	0.854	0.854	0.894	0.898	0.900

Notes: *** p<0.01, ** p<0.05, * p<0.1 Heteroskedasticity-consistent finite sample standard errors in parentheses. All variables (except Conflicts and Health System which lie between zero and one) are in natural logarithms so that the reported estimates are elasticities of life expectancy with respect to each explanatory variable. We estimate an OLS regression of average life expectancy over 1995-2004 on age-specific higher education attainment averaged over 1970-90. This has an IV interpretation and is equivalent to explaining the deviations of actual life expectancy relative to its 1973 forecast, by the exogenous component of higher education. Initial income is measured as its 1961-80 time average, Conflict is an average over the period under study from 1961 to 2004, geographic variables are time invariant, and the remaining explanatory variables are average levels over 1961-95, subject to availability. The sample is down to 58 countries. Relative to the sample of countries shown in Table 1, Algeria, Iceland, Israel, Jamaica, Myanmar, Sudan, Tunisia and Venezuela are missing, and Jordan is excluded.

Table 6: Explaining 1995-2004 average life expectancy levels with higher education enrolment rates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Higher education	0.049***	0.050***	0.054***	0.052***	0.046***	0.045***	0.037**
	(0.015)	(0.013)	(0.015)	(0.015)	(0.015)	(0.014)	(0.016)
Initial income	0.002	-0.006	-0.012	-0.008	-0.008	-0.007	-0.012
	(0.020)	(0.018)	(0.022)	(0.023)	(0.023)	(0.022)	(0.022)
Female literacy	0.002	-0.012	-0.008	-0.005	0.033	0.050	0.062
	(0.058)	(0.046)	(0.049)	(0.049)	(0.043)	(0.037)	(0.038)
Sanitation	0.019	0.016	0.006	0.004	-0.008	-0.014	-0.015
	(0.033)	(0.034)	(0.037)	(0.037)	(0.035)	(0.034)	(0.035)
AIDS	-0.026***	-0.025***	-0.024***	-0.026***	-0.021***	-0.018***	-0.018***
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)	(0.004)
Pharmaceuticals	0.018**	0.017**	0.014*	0.012	0.010	0.005	0.003
	(0.007)	(0.007)	(0.008)	(0.007)	(0.008)	(0.008)	(0.008)
Longevity forecast	0.810***	0.679**	0.720**	0.780**	0.731**	0.954***	0.896***
	(0.189)	(0.296)	(0.320)	(0.340)	(0.307)	(0.309)	(0.304)
Initial life expectancy		0.154	0.115	0.077	-0.167	-0.380	-0.414
		(0.193)	(0.206)	(0.223)	(0.241)	(0.265)	(0.265)
Government stability			0.111	0.102	0.042	0.045	0.047
			(0.109)	(0.113)	(0.103)	(0.098)	(0.100)
Conflicts				-0.029	-0.039	-0.058*	-0.053*
				(0.028)	(0.031)	(0.033)	(0.030)
Health system efficiency					0.293**	0.365***	0.373***
					(0.129)	(0.126)	(0.123)
Maximum temperature						0.102*	0.103**
						(0.051)	(0.050)
Maximum humidity						0.131	0.140
						(0.082)	(0.084)
Physicians							0.019
							(0.016)
Constant	0.452	0.516	0.349	0.243	1.276	0.199	0.550
	(0.712)	(0.731)	(0.811)	(0.817)	(0.802)	(0.795)	(0.765)
Observations	67	67	67	67	67	67	67
adjusted R^2	0.877	0.876	0.877	0.876	0.891	0.897	0.897

Notes: *** p<0.01, ** p<0.05, * p<0.1 Heteroskedasticity-consistent finite sample standard errors in parentheses. All variables (except Conflicts and Health System which lie between zero and one) are in natural logarithms so that the reported estimates are elasticities of life expectancy with respect to each explanatory variable. We estimate an OLS regression of average life expectancy over 1995-2004 on higher education averaged over the period from 1961 to 1980. This has an IV interpretation and is equivalent to explaining the deviations of actual life expectancy relative to its 1973 forecast, by the exogenous component of higher education. Initial income and initial life expectancy are measured as their 1961-80 time average. Conflict is an average over the period under study from 1961 to 2004, geographic variables are time invariant, and the remaining explanatory variables are average levels over 1961-95, subject to availability.

Table 7: Explaining 1995-2004 average life expectancy levels with BL average years of higher education.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Higher education	0.026**	0.027**	0.029**	0.028**	0.031***	0.038***	0.033***
	(0.010)	(0.011)	(0.011)	(0.010)	(0.009)	(0.012)	(0.011)
Initial income	0.021	0.023	0.020	0.024	0.015	0.009	-0.008
	(0.017)	(0.018)	(0.020)	(0.020)	(0.018)	(0.019)	(0.020)
Female literacy	0.032	0.035	0.041	0.043	0.080**	0.094***	0.098***
	(0.046)	(0.039)	(0.041)	(0.041)	(0.033)	(0.028)	(0.028)
Sanitation	0.005	0.006	-0.003	-0.005	-0.020	-0.030	-0.029
	(0.028)	(0.031)	(0.036)	(0.036)	(0.032)	(0.028)	(0.031)
AIDS	-0.029***	-0.029***	-0.028***	-0.030***	-0.023***	-0.019***	-0.017***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)
Pharmaceuticals	0.018**	0.018**	0.016*	0.013	0.011	0.004	0.002
	(0.008)	(0.008)	(0.009)	(0.008)	(0.009)	(0.008)	(0.008)
Longevity forecast	0.890***	0.923***	0.970***	1.043***	0.962***	1.275***	1.105***
	(0.190)	(0.300)	(0.325)	(0.344)	(0.304)	(0.303)	(0.294)
Initial life expectancy		-0.041	-0.084	-0.130	-0.424	-0.744**	-0.725**
		(0.215)	(0.226)	(0.236)	(0.268)	(0.285)	(0.285)
Government stability			0.086	0.074	0.015	0.034	0.050
			(0.110)	(0.114)	(0.103)	(0.096)	(0.096)
Conflicts				-0.043	-0.050	-0.073**	-0.059*
				(0.029)	(0.035)	(0.035)	(0.030)
Health system efficiency					0.353**	0.454***	0.448***
					(0.157)	(0.141)	(0.133)
Maximum temperature						0.130**	0.125**
						(0.058)	(0.055)
Maximum humidity						0.184**	0.190**
						(0.083)	(0.084)
Physicians							0.031*
							(0.016)
Constant	0.040	0.042	-0.100	-0.231	1.192	-0.092	0.645
	(0.770)	(0.776)	(0.860)	(0.864)	(0.916)	(0.855)	(0.760)
Observations	67	67	67	67	67	67	67
adjusted R^2	0.864	0.861	0.861	0.861	0.884	0.898	0.902

Notes: *** p<0.01, ** p<0.05, * p<0.1 Heteroskedasticity-consistent finite sample standard errors in parentheses. All variables (except Conflicts and Health System which lie between zero and one) are in natural logarithms so that the reported estimates are elasticities of life expectancy with respect to each explanatory variable. We estimate an OLS regression of average life expectancy over 1995-2004 on higher education averaged over the period from 1961 to 1980. This has an IV interpretation and is equivalent to explaining the deviations of actual life expectancy relative to its 1973 forecast, by the exogenous component of higher education. Initial income and initial life expectancy are measured as their 1961-80 time average. Conflict is an average over the period under study from 1961 to 2004, geographic variables are time invariant, and the remaining explanatory variables are average levels over 1961-95, subject to availability.