Determinants of Public Health Outcomes: A Macroeconomic Perspective*

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Abstract

This paper investigates the nature of the aggregate production function of health services. We build a model to analyze the role of public policy in determining social health outcomes, taking into account households choices concerning education, health related expenditures and saving. In the model, education has a positive external effect on health outcomes. Next, we perform an empirical analysis using a data set covering 72 countries from 1961 to 1995. We find strong evidence for a dual role of education as a determinant of health outcomes. In particular, we find that society's tertiary education attainment levels contribute positively to how many years an individual should expect to live, in addition to the role that basic education plays for life expectancy at the individual household level. This finding uncovers a key externality of the educational sector on the ability of society to take advantage of best practices in the health service sector.

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JEL Classification: O30, O40

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1 Introduction

In the last few years a branch of literature has developed applying macroeconomic analysis methods to various issues related with social health status. A lot of attention has been paid to the link between health improvement and economic growth. Theoretical and empirical work has considered how human capital accumulation, health improvements and technological progress reinforce each other (e.g. van Zon and Muysken 2001, Blackburn and Cipriani 2002, Chakraborty 2004, Howitt 2005). Some papers have underscored the possibility of multiple development paths, which may explain poverty or low life expectancy traps (e.g. Galor and Mayer 2002, Chakraborty et al. 2005). Others are concerned with the possible role played by health in the persistence of income inequality (e.g. Becker et al. 2003, Deaton 2003). This paper also applies theoretical and empirical methods from macroeconomics, but to a rather different issue. We explore the determinants of social health status, paying attention to understand and quantify the role played by the different factors of an aggregate production function of health services.

We investigate the nature of the aggregate production function of health services. This implicit production function determines average life-expectancy in the economy. First, this has to account for direct inputs such as goods and services provided in the health sector and determinants of hygienic conditions. We consider two different types of explicit inputs, one rival and another non-rival. We assume purchases of rival inputs to be mostly driven by overall purchasing power of consumers as captured by real income per capita. Non-rival inputs to the health sector are pure public goods, affecting the environment in which households make their decisions. An example of this is sanitation.

Average health performance also depends on how well health-related knowledge is rooted in society. For instance preventive behavior results from knowledge of risks incurred with hazardous behavior. For the individual this knowledge is determined by his/her education and by access to appropriate information. The availability and the diffusion of this information is determined by the distribution of education across society. Education can therefore play two different roles in the aggregate production function of health services. First, the level of education of the household's head enhances the longevity of its members. It seems reasonable in fact that education affects crucial factors such as the understanding of treatments or feeding children healthily. Second, the average level of education in the economy improves its absorption capacity for health-related technology and ideas.

These two effects play conceptually different roles. The first one operates as a rival input, benefiting only household members. The second instead determines the capacity of the heath service sector to take advantage of best practices. This sector is a high-tech sector and experiences fast technological progress. Furthermore, efficient use of new medical technologies requires understanding of scientific findings. The sophisticated character of knowledge transmission and use in this sector suggests that higher education constitutes its crucial determinant. In contrast, we expect the role of education in enhancing household members longevity to exhibit strongly diminishing returns. Thus, primary education attainment levels should suffice to capture this latter role of education. On the other hand controlling for this, any additional effect resulting from the attainment of tertiary education can then be attributed to the second role of education discussed above.

In this paper we present a model where rational individuals choose their educational attainment, their savings, and their consumption of rival health-related inputs. In this model, educational choices affect future wages but also have external effects on health outcomes.

We then use data from 72 countries for the period from 1961 to 1995 to test the empirical validity of the theoretical model. Using initial period averages to explain end-period life expectancy and utilizing appropriate IV estimates, allows us to alleviate the inherent endogeneity problem concerning life-expectancy and education. To further address problems with capturing the direction of causality, we also consider beginning of period changes in the explanatory variables to explain end of period changes in life expectancy.

We find that primary and tertiary education have separate positive effects on life-expectancy. Our main finding, is that tertiary education has at least as great an impact as primary education on health outcomes across countries. This suggests the externality role of education in facilitating adoption of best practices in health is at least as important as the role of basic education that enhances health outcomes at the household level. This paper provides evidence of a form of increasing returns in education, concerning their role in the aggregate production function of health services. This result is particularly interesting because previous work has established that primary education is the single most important determinant of income growth, while higher education is found to have little explanatory power for this component of welfare (see Sala-i-Martin et al. 2004). Here, tertiary education is found to be an important determinant of a second component of welfare, health status.

The next section presents the model and the theoretical results. Data are described and discussed in section 3. Section 4 describes the empirical analysis and present the empirical results, while section 5 briefly concludes.

2 A model of education and health investment

Suppose that individuals can live for two periods. All individuals live during the first period. Each has a probability of surviving to the second period, $\pi \in (0,1)$. In the households' perception its members survival probability is an increasing function of health related rival inputs, m. We consider the isoelastic function retained by Chakraborty and Das (2005)

$$\pi = \begin{cases} \mu m^{\varepsilon} & \text{if } m < \left(\frac{\bar{\pi}}{\mu}\right)^{\frac{1}{\varepsilon}} \\ \bar{\pi} < 1 & \text{if } m \geq \left(\frac{\bar{\pi}}{\mu}\right)^{\frac{1}{\varepsilon}} \end{cases} \tag{1}$$

Our analysis focuses on the interesting case when $m < \left(\frac{\bar{\pi}}{\mu}\right)^{\frac{1}{\varepsilon}}$. We consider that the following is satisfied

Assumption 1 $\varepsilon \in (0,1)$ *: Perceived returns on rival inputs to health are decreasing.*

Remark. In the theory that we present the household does not internalize the effect of education on the survival probability. Although this extension would be conceptually appealing, it would make the problem untractable as it exacerbates the issue of endogenous discounting, making the problem non concave in general. Our simplifying assumption helps emphasize the external effect of education, whose importance in determining health outcomes is also the main empirical finding of this paper.

We assume that the effectiveness of health investment, m, in enhancing life expectancy μ, depends upon the average education level in the economy, $\bar{e}$, and on public health policy according to function $h = \zeta_1 H^{\delta} \ell^{1-\delta}$, $\delta \in (0,1)$, where H is the level of non-rival health related inputs and ℓ is an index of population density. The level of education in the labor force acts as a pure externality because it enhances life expectancy by facilitating the use and diffusion of best practices. Input h is a pure public good, affecting for instance the rate at which households are subject to diseases. We use a Cobb-Douglas specification

$$\begin{aligned} \mu &\equiv (\zeta_0 \bar{e})^{\kappa} \left(\zeta_1 H^{\delta} \ell^{1-\delta}\right)^{1-\kappa} \\ &\equiv \zeta \bar{e}^{\kappa} H^{\delta(1-\kappa)} \end{aligned} \tag{2}$$

where we have defined $\zeta \equiv \zeta_0^{\kappa} \zeta_1^{1-\kappa} \ell^{(1-\delta)(1-\kappa)}$, and assume $\kappa \in (0,1)$. This is the basic building block of our theoretical framework which we take to the data.

The household problem consists in choosing education, e, rival health related inputs, m, and savings, s, to maximize its expected intertemporal utility:

$$\max_{c_1, c_2, s, m, e} u(c_1) + \pi u(c_2)$$

taking into account its sub-period budget constraints:

$$(1-\tau) w [1 - (1-\tau_e) e] = c_1 + (1-\tau_m) p_m m + s \tag{3}$$

$$(1-\tau) [w (1 + g(e)) + Rs] = c_2 \tag{4}$$

Education is costly in terms of forgone first period income but increases second period labor income by $g(e)$ percent, where $g' > 0$ and $g'' < 0$. Savings earn a gross return R. Public policy affects the household budget in three ways. First, income is reduced by the income tax, at rate τ. Second, expenditure on rival health related inputs is subsidized at rate τ_m. Third, the opportunity cost of education as expressed in terms of forgone wage income, is reduced by a subsidy applied at rate τ_e.[1]

As Blanchard (1985) and Yaari (1965) we assume that annuity markets exist. The household considers as given the return on savings, R. Free entry in the insurance market implies zero profits, i.e. fair insurance premia so that:

$$R = \frac{1+r}{E(\pi)} \tag{5}$$

where r is the risk-free rate of interest and $E(\pi)$ denotes the average survival probability for the generation. In a symmetric equilibrium this price depends on the individual choice of health related inputs and of education (via 1 and 2).

Our analysis is restricted to the case of a small open economy, where pre-tax return on savings, r, wages, w, and medical inputs prices, p_m, are exogenous and assumed constant.[2] This simplification is useful to focus attention on the direct interactions between private investment in health and in education, and on the role of public policy.

2.1 The household's choice

Let us restate the problem in the following form:

$$\begin{aligned}\max_{s,m,e} & \, u\left((1-\tau)\, w\left[1-(1-\tau_e)\, e\right]-(1-\tau_m)\, p_m m - s\right) \\ & + \pi u\left((1-\tau)\left[w\left(1+g(e)\right)+Rs\right]\right)\end{aligned}$$

the first order conditions for an interior solution are:

$$u'(c_1) = \pi (1-\tau) R u'(c_2) \tag{s}$$

$$u'(c_1) = \frac{\pi'_m}{(1-\tau_m)\, p_m} u(c_2) \tag{m}$$

$$u'(c_1) = \pi \frac{g'(e)}{1-\tau_e} u'(c_2) \tag{e}$$

[1] Notice that first period gross labor income is w if no education is acquired. Gross income is reduced by we_0 if an education level e_0 is attained. The public subsidy decreases this cost by $\tau_e we_0$.

[2] These restrictions somehow frustrate the macroeconomic approach retained. For instance the wage could be endogenous on the number of surviving individuals.

Let us pursue the analysis for the case of isoelastic utility functions $u(c) = c^{1-\sigma}/(1-\sigma)$ and specify $g(e) = be^{\beta}$ with $\beta \in (0,1)$, and by adopting the following[3]

Assumption 2 $\sigma \in (0,1)$ *: Substitution effects dominate income effects.*
$\sigma > \varepsilon$ *: Perceived returns on health investment are not large enough to convince households to postpone consumption entirely to the second period.*

Then the first order conditions above become:

$$c_1^{-\sigma} = \pi (1-\tau) R c_2^{-\sigma} \qquad (s')$$

$$c_1^{-\sigma} = \frac{\varepsilon}{m} \frac{\pi}{(1-\tau_m) p_m} c_2^{1-\sigma}/(1-\sigma) \qquad (m')$$

$$c_1^{-\sigma} = \pi \frac{\beta b e^{\beta-1}}{1-\tau_e} c_2^{-\sigma} \qquad (e')$$

Combining (s') and (e') we get:

$$e = e^* \equiv \left(\frac{\beta b}{(1-\tau_e)(1-\tau) R} \right)^{\frac{1}{1-\beta}} \qquad (6)$$

Notice that education decreases with the net return on savings. This is due to the fact that education and savings are two competing means to transfer consumption to the second period.

Combining (m') and (s') we get:

$$c_2 = (1-\tau) R \frac{(1-\sigma)}{\varepsilon} (1-\tau_m) p_m m \qquad (7)$$

where we understand that $\sigma \in (0,1)$ is a necessary assumption for the problem to make sense. Then from (7) and (4), taking into account (6), we have:

$$s = \frac{1-\sigma}{\varepsilon} (1-\tau_m) p_m m - \frac{w}{R} \left(1 + b \left(\frac{\beta b}{(1-\tau_e)(1-\tau) R} \right)^{\frac{\beta}{1-\beta}} \right) \qquad (8)$$

Savings tend to increase with health related expenditure, m, given that $\sigma \in (0,1)$, and to decrease with the level and productivity of education, $g(e)$. Com-

[3] Chakraborty and Das (2005) retain these same assumptions.

bining (s') and (7):

$$c_1 = \frac{(1-\tau_m)\,p_m}{[(1-\tau)\,R]^{\frac{1-\sigma}{\sigma}}}\frac{1-\sigma}{\varepsilon}\pi^{-\frac{1}{\sigma}}m \tag{9}$$

so that c_1 is increasing and concave in m.[4]

Now we can obtain the solution in terms of the level of health related input, m. To do this we combine the budget constraint with desired consumption, c_1 and c_2, and education, e. First substitute for c_1 and s in (3) using (9) and (8) to get:

$$\begin{aligned}(1-\tau)\,w\,[1-(1-\tau_e)\,e] \quad = \quad & \frac{(1-\tau_m)\,p_m}{[(1-\tau)\,R]^{\frac{1-\sigma}{\sigma}}}\frac{1-\sigma}{\varepsilon}\pi^{-\frac{1}{\sigma}}m \\ & +(1-\tau_m)\,p_m m+(1-\tau_m)\,p_m\frac{1-\sigma}{\varepsilon}m \\ & -\frac{w}{R}\left(1+b\left(\frac{\beta b}{(1-\tau_e)\,(1-\tau)\,R}\right)^{\frac{\beta}{1-\beta}}\right)\end{aligned}$$

Define

$$\gamma_0 \equiv p_m\left(1+\frac{1-\sigma}{\varepsilon}\right) > p_m \quad \text{and} \quad \gamma_1 \equiv \frac{1-\sigma}{\varepsilon}p_m > 0 \tag{10}$$

and the maximized permanent disposable income, which takes into account the individually optimal investment in education (6), as[5]

$$y \equiv (1-\tau)\,w\left[1-(1-\tau_e)\,e^* + \frac{1+g\,(e^*)}{(1-\tau)\,R}\right] \tag{11}$$

Using (1), the solution is therefore defined implicitly by :

$$\Gamma\,(m) \equiv \gamma_0\,(1-\tau_m)\,m + \frac{\gamma_1\mu^{-\frac{1}{\sigma}}}{[(1-\tau)\,R]^{\frac{1-\sigma}{\sigma}}}\,(1-\tau_m)\,m^{-\frac{\sigma-\varepsilon}{\sigma}} - y = 0 \tag{12}$$

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[4] Although we have set up a problem with endogenous discounting, the objective function is concave in m. We know from (1) that π is concave in m, and we have established in (9) that c_1 is increasing and concave in m, in (7) that c_2 is increasing and linear in m. Thus $u\,(c_1)+\pi\,(m)\,u\,(c_2)$ is increasing and concave with respect to m.

[5] By definition of e^* we have that $(1-\tau)\,w\left[1-(1-\tau_e)\,e^*+\frac{1+g(e^*)}{(1-\tau)R}\right] = (1-\tau)\,w\,[1-(1-\tau_e)\,e]+\frac{w}{R}\left(1+b\left(\frac{\beta b}{(1-\tau_e)(1-\tau)R}\right)^{\frac{\beta}{1-\beta}}\right)$

Assumption 2, $\sigma > \varepsilon$, is necessary and sufficient for function $\Gamma(m)$ to be increasing and concave.

2.2 Macroeconomic interaction and the symmetric equilibrium

Let us now turn to the analysis of stationary symmetric equilibria. Symmetry implies that the average survival probability for generation t up to date $t+1$, used by insurers to compute the fair premium, equals individual survival probability

$$E_t(\pi) = \pi \tag{13}$$

To compute the survival probability we use the average education level in the older generation labor force, of size L_{t-1}, (i.e. $\bar{e}_{t-1}$) to account for the externality on the efficiency of the health service sector. Suppose that the fertility rate is n, and all individuals have offsprings, so that births, N, evolve according to $N_t = (1 + n_{t-1}) N_{t-1}$. The labor force at date t is composed of $L_t = N_t$ young and $L_{t-1} = \frac{\pi_{t-1}}{1+n_{t-1}} N_t$ old (educated) workers. At steady state e, s, prices and tax instruments are constant. In particular we have $\bar{e}_{t-1} = e = e_t$, and $L_{t-1} = \frac{\pi}{1+n} L_t$.

Recall the definition of survival probability (1) and (2). Considering only interior solutions ($\pi < \bar{\pi}$) and taking into account symmetry and stationarity we get

$$\pi = \zeta e^{\kappa} H^{\delta(1-\kappa)} m^{\varepsilon}$$

Then taking into account (6), (5) and (13)

$$\tilde{\pi}(m) \equiv \left(\frac{\beta b}{(1-\tau_e)(1-\tau)(1+r)} \right)^{\frac{\kappa}{1-\beta-\kappa}} \left(\zeta H^{(1-\kappa)\delta} m^{\varepsilon} \right)^{\frac{1-\beta}{1-\beta-\kappa}} \tag{14}$$

Combining (6), (14) and (5), (13) we obtain[6]

$$e^*(m) \equiv \left(\frac{\beta b \zeta H^{(1-\kappa)\delta} m^{\varepsilon}}{(1-\tau_e)(1-\tau)(1+r)} \right)^{\frac{1}{1-\beta-\kappa}} \tag{15}$$

[6] Conditions (14) and (15) together imply $\tilde{\pi} = (1-\tau)(1+r)(1-\tau_e) / \left[\beta b (e^*)^{\beta-1}\right]$.

This level of education is an increasing function of rival health related inputs, m, and of their efficiency in improving life expectancy, $\zeta H^{(1-\kappa)\delta}$, as well as of the productivity of education, βb, and of the educational subsidy, τ_e. Again we find that education is decreasing in the after-tax return on savings, $(1-\tau)(1+r)$, since education and savings are two competing technologies to transfer consumption to the second period of life. All these considerations are amplified by the strength of the externality, κ, due to average education of older workers on the efficiency of youngsters' health related investment.

Consider now the first two terms of the implicit function (12), defining the individually optimal level of health related investment, m. Substituting for the symmetric equilibrium return on savings, from (5) and (13), then for the survival probability (14), and taking into account the chosen level of e^*, from (15), we have

$$\begin{aligned} G(m) &\equiv \gamma_0 (1-\tau_m) m + \frac{\gamma_1}{[(1-\tau) R]^{\frac{1-\sigma}{\sigma}}} \pi^{-\frac{1}{\sigma}} (1-\tau_m) m \\ &= (1-\tau_m) m \left\{ \gamma_0 + \frac{\gamma_1}{[(1-\tau)(1+r)]^{\frac{1}{\sigma}}} \frac{\beta b (e^*)^{\beta-1}}{1-\tau_e} \right\} \end{aligned} \tag{16}$$

We can also rewrite permanent disposable income, (11), at the symmetric stationary equilibrium, first substituting for e using (6), next for R using (5) and (13), then for π using (14), finally exploiting the definition of e^* (15)

$$y(m) \equiv (1-\tau) w \left\{ 1 + \frac{\tilde{\pi}}{(1-\tau)(1+r)} + (1-\tau_e) \frac{1-\beta}{\beta} e^* \right\} \tag{17}$$

It is therefore possible to express the equilibrium decision about private health investment as being m^* that solves the following implicit function

$$\Gamma(m) \equiv G(m) - y(m) = 0 \tag{18}$$

Both functions $G(m)$ and $y(m)$ are increasing in m. We are however able to establish the following proposition under assumption 3.

Assumption 3 $\varepsilon + \beta + \kappa \leq 1$: *Global returns to rival health related inputs are decreasing.*

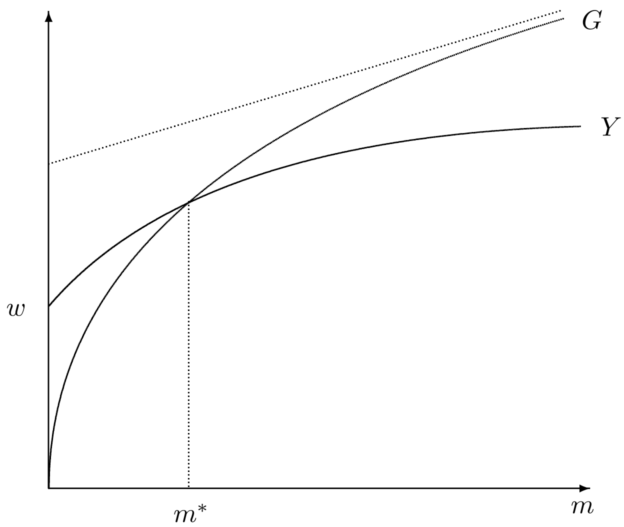

Figure 1: Determining private health investment in a symmetric equilibrium.

$\kappa < (1-\beta)(1-\sigma)$ *: Externality of education on the efficiency of health inputs is not too strong (e.g.* $\kappa \gtrsim 0$*). Sufficient condition for* $G' > 0$*and* $G'' < 0$.[7]

Proposition 1 *Equation (18) admits a unique, positive and finite, solution if assumptions 1 to 3 are satisfied.*

To prove the result we show in appendix A.1 that $G(m)$ and $y(m)$ are increasing and concave, that $y(0) > G(0) = 0$, but y' declines indefinitely towards zero while G' never falls below a positive lower bound. These conditions imply that the two schedules cross only once, as illustrated in figure 1.

We can use the system (14)-(18) to determine how single policy instruments affect consumption of rival health related inputs. This is equivalent to assuming the existence of lump sum taxes to finance public expenditure. We have the following result

Proposition 2 *If changes in policy instruments are financed, or rebated to households, through lump sum taxes and transfers:*

$$\frac{dm}{dH} > 0 \;\; ; \;\; \frac{dm}{d\tau_m} > 0 \;\; ; \;\; \frac{dm}{d\tau_e} > 0 \;\; ; \;\; \frac{dm}{d\tau} < 0$$

[7] The sufficient condition for $G' > 0$ is actually $\varepsilon < 1-\kappa/(1-\beta)$, which is however satisfied under this assumption and assumption 2.

For the proof see appendix A.2.

Consider first public health policy as summarized by H and τ_m. Provision of non-rival health inputs improves the efficiency of private health inputs and hence shifts upwards the demand curve for m. Conversely, a subsidy on purchases of private health inputs is tantamount to a downward shift in the supply curve for m. Both of these measures indirectly imply enhanced educational attainment (see equation 15). As far as the educational subsidy is concerned, cheaper education implies more education and this, by itself, makes permanent disposable income more sensitive to m. As a result it is individually efficient to consume more m. If moreover education has an external effect improving the efficiency of m (i.e. if $\kappa > 0$), then the response is much stronger as a result of macroeconomic interaction. We find complementarities between health and education, giving rise to multiplier effects.

Corollary 3 *Combining (14) and proposition 2 we get*

$$\frac{d\pi}{dH} >> 0 \quad ; \quad \frac{d\pi}{d\tau_m} > 0 \quad ; \quad \frac{d\pi}{d\tau_e} >> 0$$

2.3 Public policy

The analysis presented in this subsection does not lead to clear-cut results. This is not important for the empirical analysis, since we have no comparable cross-country data on public policy. The reader can skip this subsection.

The other macroeconomic constraint to be considered is the framing of individual choices and of public policy. From (18) and (14)-(15) we have established that individual choices depend on policy instruments τ_m, H, τ_e and τ. While explaining public policies is beyond the scope of this paper, we still need to restrict the possibilities set for policy intervention. In particular the scope of proposition 2 is limited because it assumes the feasibility of public lump-sum transfers. In practice in many countries education and health account for a substantial share of public and private expenditure. So any change in the amount of resources devoted to these sectors is likely to have first order effects on the rest of the economy, more so as public revenues are usually distortionary.

Since we focus on stationary equilibria, the public budget is assumed to be held balanced at each period. The public budget constraint equates current expenditure for generation t, on health and education, to income tax revenue levied on both generations:

$$\tau_m p_{mt} m_t L_t + H_t + \tau_e w_t e_t L_t = \tau \left\{ w_t \left[1 - (1-\tau_e) e_t\right] L_t + \left[w_t \left(1 + b e_{t-1}^{\beta}\right) + R_t s_{t-1} \right] L_{t-1} \right\}$$

Using the results obtained at the beginning of section 2.2, dividing the budget by the labor force of young workers and rearranging, public expenditure on health services per young worker is

$$\tau_m p_m m + \frac{H}{L} = w \left[\tau \left(1 - (1-\tau_e) e + \left(1 + b e^{\beta}\right) \frac{\pi}{1+n} \right) - \tau_e e \right] + \tau R s \frac{\pi}{1+n}$$

We express the public budget constraint in terms of per-youngster public deficit and in implicit form, with the help of equations (5), (13), (8) and the definition of e^* (15)

$$PB(m) \equiv \frac{H}{L} + \left[\tau_m - \tau (1-\tau_m) \gamma_1\right] p_m m - w \left[\tau (1-e^*) - (1-\tau) \tau_e e^*\right] = 0 \tag{19}$$

The first term accounts for expenditure for the provision of non rival health inputs. The second term accounts for the cost of subsidizing purchases of private health inputs. Specifically the first term in brackets is public expenditure on subsidies ($\tau_m p_m m$), while the second term in brackets takes into account the indirect positive impact on fiscal revenues from taxing savings due to enhanced life expectancy (i.e. increased m, see equation 8). The third term in (19) accounts for the income tax revenue from youngsters net of the transfer for education attainments. In fact the second terms in brackets includes direct education subsidy payments ($\tau_e w e^*$), but excludes money indirectly recovered through income taxation ($\tau \tau_e w e^*$). Hence it is legitimate and plausible to limit the analysis to the case where policy instruments are constrained to satisfy the following

Assumption 4 $\left[\tau_m - \tau (1-\tau_m) \gamma_1\right] p_m > 0$ *: Subsidizing purchases of rival health related inputs is not a self-financing policy.*
$w \left[\tau (1-e^*) - (1-\tau) \tau_e e^*\right] > 0$ *: Income tax revenue from youngsters is suffi-*

cient to finance educational subsidies.

To study the impact of an increase in, say, τ_m financed through an appropriate increase in the income tax rate, τ, one needs to consider how the system given by equations (18) and (19) adjusts. In this example we have

$$\begin{cases} \frac{\partial \Gamma}{\partial m}\frac{dm}{d\tau_m} + \frac{\partial \Gamma}{\partial \tau_m} + \frac{\partial \Gamma}{\partial \tau}\frac{d\tau}{d\tau_m} = 0 \\ \frac{\partial PB}{\partial m}\frac{dm}{d\tau_m} + \frac{\partial PB}{\partial \tau_m} + \frac{\partial PB}{\partial \tau}\frac{d\tau}{d\tau_m} = 0 \end{cases}$$

implying

$$\frac{dm}{d\tau_m} = \frac{\frac{\partial \Gamma}{\partial \tau}\left(\frac{\partial PB}{\partial \tau_m} / \frac{\partial PB}{\partial \tau}\right) - \frac{\partial \Gamma}{\partial \tau_m}}{\frac{\partial \Gamma}{\partial m} - \frac{\partial \Gamma}{\partial \tau}\left(\frac{\partial PB}{\partial m} / \frac{\partial PB}{\partial \tau}\right)}$$

Unfortunately, as it is shown in appendix A.3 it is impossible to determine analytically the sign of this expression. This is not a surprising result to the extent that the policy takes with one hand what it gives with the other. In general then the impact is ambiguous.

3 Data description

In this section, we describe the data set we have assembled to test our main hypotheses and take a first look at the relationship of health status with each of these inputs. The focus of our study, a country's health status, is measured by the average life expectancy at birth.

We employ a number of health output and health input variables from two sources. The *World Development Indicators* (WDI) 2002 database provides data on life expectancy at birth, physicians per thousand people, adult illiteracy rates[8], and sanitation[9]. We also obtained GDP per capita in PPP dollars, and tertiary education enrollment rates from the same database. Finally, we obtained primary and higher education attainment rates from the Barro and Lee (2001) dataset.

We were able to put together all the above series for 72 countries during the period 1961-1995. The list of counties is shown in Table A1 in the appendix.

[8] Defined as the percentage of individuals over 15 years of age who cannot, with understanding, read and write a short simple statement on their everyday life.

[9] Defined as the percentage of the population with access to improved sanitation facilities.

Table 1: Correlations

	LIFE	EDHA	EDBA	EDH	ILLI	SAN	PHYS	INC
LIFE	1							
EDHA	0.85	1						
EDBA	0.47	0.33	1					
EDH	0.88	0.94	0.36	1				
ILLI	-0.73	-0.73	-0.69	-0.74	1			
SAN	0.77	0.70	0.56	0.69	-0.66	1		
PHYS	0.89	0.87	0.39	0.91	-0.72	0.73	1	
INC	0.74	0.77	0.23	0.80	-0.59	0.65	0.86	1

Notes: We report cross-sectional correlations after averaging life expectancy over 1990 to 1995 and all remaining (potentially explanatory) variables for the period 1961 to 1995, except income for which we use its level at the beginning of the period. The sample size used here is 72 countries, except for illiteracy rates that is available for only 53 countries in this sample. All variables are in natural logarithms. LIFE is life expectancy, EDHA is higher education attainment rate, EDBA is primary education attainment rate, EDH is tertiary education enrollment rate, ILLI is the adult illiteracy rate as a percentage of the population over 15 years of age, SAN is the percentage of the population with access to improved sanitation facilities, PHYS is number of physicians per thousand people, INC is initial GDP per capita in constant $US.

However, the great majority of these series are not available annually; in some cases the data are exceedingly sparse in the time dimension. Because the cross-sectional dimension of the dataset is more complete and, more importantly, because of the inherent long-run nature of the relation under study, we chose to explore empirically the cross-sectional dimension of our dataset.

4 Empirical results

4.1 Preliminary evidence

In Table 1, we report basic correlations between our variables of interest. Our main hypothesis is that health inputs such us primary and higher education, sanitation, access to safe water, and physicians availability are related to health outcomes measured by life expectancy. Indeed, the correlations between life expectancy and higher education attainment rates or enrollment rates equal 85 and 88 percent respectively, while the correlation for basic education attainment rates equals 47 percent. An other (inverse) measure of basic education - the adult illiteracy rate - is also strongly correlated with life expectancy at minus 73 percent. All of these correlations are statistically significant with p-values below the one percent level. Sanitation and physicians are also strongly related with life expectancy with correlations of 77 and 89 percent respectively. However, nearly all of these health inputs are also strongly related to the level of real income per capita. This is especially true in the case of higher education attainment or enrollment rates and for physicians availability. Moreover, several of these inputs are highly correlated with each other raising a warning flag regarding a potential collinearity problem in the regression specifications that follow in the next subsection. Notably, the correlation between higher education attainment or enrollment rates with physicians is 87 and 91 percent respectively. As a robustness check for the importance of higher education we will thus consider specifications both with and without the apparently highly collinear physicians variable.

4.2 Cross-section regression results

We are well aware that there is a strong theoretical argument for endogeneity between life expectancy and tertiary education. While tertiary education should be expected to affect health outcomes, it can also be argued that individual decisions on tertiary education attainment depend on expected life expectancy so that it is plausible that longer life expectancy causes higher tertiary education levels. However, for the model we consider below, we fail to reject the null that tertiary education is exogenous with a p-value of 0.313[10] and the joint hypothesis that all explanatory variables are exogenous with a p-value of 0.742. This suggests that we could estimate the empirical model of life expectancy on secondary and primary education attainment rates, sanitation, physicians, and initial income with OLS. However, given that we have just about 70 observations

[10] Treating each explanatory variable as potentially endogenous and the remaining as exogenous, we also fail to reject the null that initial income is exogenous with a p-value of 0.534. Similarly, we cannot reject the null that primary education enrolment is exogenous with a p-value of 0.956. Nor, can we reject the null that physicians is exogenous with a p-value of 0.277, and finally we cannot reject the null that sanitation is exogenous with a p-value of 0.841.

and that the individual p-values for the null of exogeneity for each explanatory variable separately range from 0.277 for physicians to 0.956 for primary enrollment rates, we choose to be conservative regarding our inference of exogeneity, and estimate the model using IV in addition to OLS estimation. This serves to take into account possible endogeneity problems we have been unable to detect, and also acts as a robustness check for our OLS results.

Towards the goal of addressing potential endogeneity problems and establishing some evidence of temporal causation we consider: (i) Using lags of higher education and the other explanatory variables to explain end-period averages of life expectancy. Specifically, utilizing the average value of higher education and the other explanatory variables for 1961-75 to explain the average value of life expectancy over 1990-95. This takes care of endogeneity if individual decisions about higher education in 1961-75 are independent of life expectancy at birth for individuals born between 1990 and 1995. We present results based on this specification as the "Lags" model in columns two and five in Tables 2 and 3. (ii) Instrumenting the average of tertiary education over 1961-95 by its average value for 1961-75 to explain the average value of life expectancy over 1990-95. In the regression of each potentially endogenous explanatory variable[11] on all exogenous variables, the lag of each explanatory variable is shown to be strongly significant in determining the explanatory variable's period average, with p-values always below the one percent level of significance. We present results based on the IV specification in columns three and six in Tables 2 and 3.[12] (iii) We use log changes in the explanatory variables for the period 1961-75 to explain the log change in life expectancy for the period 1976-95. We also apply IV estimation to these variables in changes, instrumenting the log change in tertiary education over 1961-95 by its 1961-75 value. Results based on this approach are reported in Table 4.

Overall, we assess the link between health inputs and life expectancy with the "Lags" and "IV" models described above, and the"Period Avg" model where

[11] Even though we fail to reject the null of exogeneity for any of these variables and jointly for all of these variables, we are being conservative in allowing for the possibility that these could be endogenous and examine the robustness of the basic OLS results.

[12] We note here that for Sanitation (SAN) we typically have just a handful of observations for the whole period so we cannot instrument this variable with its lag.

we consider the average of the 1990-95 period life expectancy being explained by the 1961-95 average value of the explanatory variables. We report results for this model in columns one and four of Tables 2 and 3. In each case, we consider specifications with and without physicians, since this variable is highly collinear with higher education.[13] We also consider log changes of the variables in place of the levels and present estimation results from this exercise in Table 4. In this case, for the "Period Avg" model we consider the growth rate of life expectancy between 1976 and 1995 being explained by growth rates of the explanatory variables between 1961 and 1995, with results presented in the first and fourth columns of Table 4.

The dual effect of education on life expectancy is of primary interest to us. For this reason, we consider three different specifications with different pairs of measures for higher and basic education in Tables 2, 3, and 4. In specification one, we consider higher and primary attainment rates from the Barro and Lee database. We report the estimates from this specification in Table 2. In the second specification, results for which are reported in Table 3 we consider tertiary education enrollment rates along with the illiteracy rate, both taken from the WDI database. Finally, in Table 4, we consider log changes of education attainment levels.

In Model 1 of Table 2, we consider the impact of basic and higher education attainment rates as well as real income per capita and sanitation on the end-period (1990-95) average of life expectancy. We report results from Model 1 in the first three columns of Table 2. Irrespective of whether we consider the average value of the explanatory variables over the 1961-95 period, their average value at the beginning of the period, or instrument the former with the latter, higher education attainment rates consistently have a positive and significant impact on life expectancy which is always greater than the impact of primary education. The elasticity of life expectancy with respect to higher education is

[13] Physicians should have a dual role in determining health outcomes. On the one hand, this is a direct input into the health production function similar to any other medical input. On the other hand, they should have a role as vectors of knowledge facilitating medical technology absorption and the adoption of best practices. Including both tertiary education and physicians in the same specification should thus be expected to reduce the coefficient estimate of tertiary education to the extent these two variables are capturing the same concept. Thus, the coefficient estimate for tertiary education in these specifications should be seen as a lower bound of the importance of the knowledge externality we are focusing on in this paper.

Table 2: Cross-country life expectancy regressions

Specif. 1	**Model 1** *Period Avg*	**Model 1** *Lags*	**Model 1** *IV*	**Model 2** *Period Avg*	**Model 2** *Lags*	**Model 2** *IV*
INCOME	.033*** (1.75)	.039 (1.51)	.039** (2.01)	−.013 (−0.82)	−.008 (−0.36)	−.004 (−0.24)
EDHA	.072* (5.33)	.051* (3.45)	.063* (4.24)	.038* (3.47)	.027*** (1.69)	.036* (2.54)
EDBA	.048*** (1.95)	.041[1] (1.56)	.049*** (1.70)	.028 (1.31)	.019 (0.78)	.031 (1.21)
SAN	.080*** (1.82)	.101** (2.13)	.087** (2.07)	.066*** (1.84)	.098** (2.38)	.072** (2.12)
PHYS	—	—	—	.070* (4.29)	.068* (2.61)	.063* (3.06)
constant	3.349* (20.56)	3.307* (17.76)	3.278* (18.08)	3.908* (24.47)	3.834* (17.74)	3.805* (20.43)
Adj. R^2	78.8	75.3	78.7	82.8	77.9	82.5
Obs.	72	72	72	72	71	71

Notes: * p-value less than one percent, ** p-value less than five percent, *** p-value less than ten percent, [1]p-value=0.12. For the "Period Avg" models, we consider the average of the 1990-95 period life expectancy being explained by the averages of the 1961-95 period for the explanatory variables. For the "Lags" models, we consider again the average of the 1990-95 period life expectancy being explained in this case by the averages of the 1961-75 period for the explanatory variables. Finally, for the "IV" Models 1 and 2, we instrument the 1961-95 period averages for the explanatory variables using their average at the beginning of this period. All variables are in natural logs so that the reported estimates are elasticities of life expectancy with respect to each explanatory variable.

stable across the three methodologies ranging between 5.1 percent for the lags model to 6.3 percent for the instrumental variables estimation, and up to 7.2 percent for the period-averages model. Moreover, the estimated elasticity of life expectancy with respect to primary education ranges from 4.1 percent with a p-value of 0.12 for the lags model, to 4.9 and 4.8 percent and statistically significant at the ten percent level for the IV and period-averages models respectively. For the three specifications of Model 1, sanitation has a positive and consistently significant impact on life expectancy estimated about 10 percent.

In Table 2, we also take into account the fact that income can be a major determinant of health by including the initial period value of real income per capita. To the extent to which we control for public health inputs and education, real income per capita can serve isolate the effect of private health inputs purchases as it captures the consumer's purchasing power. Moreover, controlling for the effect of income helps isolate the effect of each of the other inputs not related to income. For the specifications in the first three columns, income has a positive impact on life expectancy, slightly below the elasticity of life expectancy with respect to primary education.

In columns four to six of Table 2, we report results for Model 2 which now includes physicians availability in addition to the two education variables, sanitation, and income per capita. Since physicians and higher education are highly collinear, with a correlation of 87 percent, introducing physicians dampens the impact of higher education on life expectancy. Still, this remains positive and significant, irrespective of whether we use period-averages, initial period averages, or instrument the explanatory variables, in columns four, five, and six respectively. The impact of higher education is stable across the three methodologies ranging between 2.7 percent for the lags model to 3.6 percent for the instrumental variables estimation and 3.8 percent for the period-averages model. Once again, the impact of primary education appears positive but is now statistically insignificant while sanitation still has a, somewhat reduced, positive and significant impact on life expectancy.

Physicians availability has a positive and strongly significant impact on life expectancy that remains stable at about seven percent in columns four to six, irrespective of the methodology pursued. To the extent that physicians facilitate the flow of health-related ideas a component of this health input could potentially be perceived as non-rival, a hypothesis that is supported by the dampening of the impact of higher education once the physicians availability variable is introduced in Model 2. Finally, once we account for physicians, income now has no impact on life expectancy.

Next, we consider a different (inverse) measure of basic education - the rate of illiteracy - along with tertiary education enrollment rates. In Table 3, we replicate the regression models estimated in Table 2, using now this alternative measures of basic and higher education. Conceptually, the illiteracy rate should measure an even more orthogonal component of education than primary attainment rates, relative to what is captured by our measures of tertiary education. In Table 3, tertiary education enrollment rates are shown to have a positive and statistically significant impact on life expectancy with elasticities ranging from a high of 8.5 percent down to 3.5 percent for the different models considered

Table 3: Cross-country life expectancy regressions

Specif. 2	**Model 1** *Period Avg*	**Model 1** *Lags*	**Model 1** *IV*	**Model 2** *Period Avg*	**Model 2** *Lags*	**Model 2** *IV*
INCOME	.039** (2.08)	.039*** (1.89)	.038** (2.12)	.006 (0.32)	.009 (0.37)	.004 (0.19)
EDH	.085* (4.98)	.068* (3.43)	.078* (4.36)	.055* (3.27)	.046** (2.21)	.035*** (1.82)
ILLI	$-.028^1$ (1.41)	$-.002$*** (-1.83)	$-.045$** (-1.98)	$-.021$ (-1.09)	$-.001$ (-1.22)	$-.039$*** (-1.79)
SAN	$.033^2$ (1.49)	$.033^3$ (1.47)	.025 (1.16)	.020 (0.99)	$.030^4$ (1.39)	.011 (0.53)
PHYS	—	—	—	.054* (3.34)	.053** (2.03)	.065* (2.85)
constant	3.65* (20.96)	3.71* (21.50)	3.76* (21.08)	4.03* (20.64)	4.02* (17.62)	4.19* (17.62)
Adj. R^2	79.8	76.9	79.8	82.0	78.6	81.9
Obs.	61	60	60	61	60	60

Notes: * p-value less than one percent, ** p-value less than five percent, *** p-value less than ten percent, [1]p-value=0.16, [2]p-value=0.12, [3]p-value=0.15, [4]p-value=0.17, [4]p-value=0.115. For the "Period Avg" models, we consider the average of the 1990-95 period life expectancy being explained by the averages of the 1961-95 period for the explanatory variables. For the "Lags" models, we consider again the average of the 1990-95 period life expectancy being explained in this case by the averages of the 1961-75 period for the explanatory variables. Finally, for the "IV" Models 1 and 2, we instrument the 1961-95 period averages for the explanatory variables using their average at the beginning of this period. All variables are in natural logs so that the reported estimates are elasticities of life expectancy with respect to each explanatory variable.

there. Illiteracy has a negative impact on life expectancy which can be statistically insignificant once physicians are introduced in the specification. The impact of sanitation remains positive but is not significant at conventional levels of significance, while the impact of physicians remains positive, significant, and of similar magnitude as previously. The estimated impact of income is positive but becomes statistically indistinguishable from zero once we introduce physicians in Model 2 presented in columns four to six.

Overall, we find that higher education matters significantly, and is more robust than primary education, sanitation, and even income. Using initial period averages to explain end-period life expectancy, allows us to establish that tertiary education is a significant and robust explanatory variable of end of period health output. This approach alleviates potential endogeneity problems and provides supporting evidence of a causality link from tertiary education to

Table 4: Cross-country life expectancy regressions

Specif. 1	**Model 1** *PeriodAvg*	**Model 1** *Lags*	**Model 1** *IV*	**Model 2** *PeriodAvg*	**Model 2a** *Lags*	**Model 2b** *Lags*	**Model 2** *IV*
INCOME	−.0002	−.001**	−.0003	−.0003	−.001**	−.001**	−.001[1]
	(−0.57)	(−1.98)	(−0.65)	(−0.85)	(−2.29)	(−2.04)	(−1.63)
EDHA	.055*	.025*	.068*	.047*	.025*	.025*	.069*
	(3.98)	(3.17)	(3.82)	(3.96)	(4.42)	(2.80)	(3.56)
EDBA	.060*	.032	.042	.058*	.042**	.017	.021
	(2.77)	(1.48)	(1.18)	(2.66)	(2.14)	(0.85)	(0.72)
YGROWTH	.030	−.015	−.029	.008	−.017	−.031	−.061
	(1.03)	(−0.81)	(−0.85)	(0.34)	(−0.86)	(−1.39)	(−1.49)
PHYS				.063**	.074**	.079*	.101*
				(2.34)	(2.48)	(3.09)	(2.63)
constant	.003	.009*	.004	.003	.007**	.009**	.006
	(0.81)	(2.69)	(0.94)	(0.89)	(2.55)	(2.37)	(1.49)
Adj. R^2	31.5	22.6	25.5	42.1	41.9	29.7	32.1
Obs.	66	66	66	63	63	52	50

Notes: * p-value less than one percent, ** p-value less than five percent, *** p-value less than ten percent, [1]p-value=0.104. All variables other than initial real income per capita are in log changes. YGROWTH is the growth rate of real income per capita. For the "Period Avg" models, we consider the growth rate of life expectancy between 1976 and 1995 being explained by growth rates of the explanatory variables between 1961 and 1995. For the "Lags" models, we consider again the growth rate of life expectancy between 1976 and 1995 being explained by growth rates of the explanatory variables between 1961 and 1975. Finally, for the "IV" Models 1 and 2, we instrument the 1961-95 period changes for the explanatory variables using their beginning of period averages. In Model 2a we do not use the beginning of the period change for physicians which allows us to use about 20% more observations. We do this in Model 2b for comparability of the sample with the IV Model 2. All variables are in natural logs so that the reported estimates are elasticities of life expectancy with respect to each explanatory variable.

health status (life expectancy).

As an additional methodology to remedy potential endogeneity problems facing tertiary education as a determinant of health status, we consider log changes of the variables instead of their log levels. This also serves as a robustness check for our main finding regarding the dual importance of education, and in particular the channel through which higher education affects life expectancy emphasized in this paper. We report estimates in Table 4.

The growth rate of higher education attainment levels has a positive impact on the end period growth rate in life expectancy for all seven specifications we consider below. It takes its highest value of about seven percent in the IV specifications reported in columns three and seven. The growth rate of primary education also has a positive effect which is now close to that for tertiary education but is statistically insignificant in several of the models we consider.

Looking at the negative coefficient estimates for initial income levels, there appears to be some evidence for convergence in life expectancy for countries that started with low real income per capita level. On the other hand, the growth rate of real income per capita does not seem to explain any of the gains in life expectancy. This suggests that any convergence that took place for initially low-income countries has not been the result of higher real income per capita growth, but likely due to changes in other determinants of public health in laggard countries. These other determinants would likely include public inputs like sanitation (which we cannot consider here directly in the absence of observations over time for this variable), and perhaps medical knowledge diffusion as emphasized in Papageorgiou, Savvides, and Zachariadis (2005).

5 Conclusion

We have presented a model where education can have external effects on life expectancy, beyond what can be expected from the impact of basic education on the individual household's health status. Our main results are as follows: a) Considering physicians per thousand inhabitants as an explanatory variable we find it extremely significant and robust. As a side effect, introducing this variable reduces the separate impact of tertiary education. b) Public health inputs such us sanitation have a positive impact on life expectancy. c) There is some evidence of convergence in life expectancy for countries that started off with low real income per capita levels in 1961 and this does not appear to be explained by faster output growth rates of initially poor countries, suggesting the possibility that faster technology absorption of initially laggard countries might actually be behind convergence. d) Education has a dual role in determining health oucomes, with both basic and higher education having positive impact on life expectancy. Moreover, the impact of higher education appears to be at least as important as the impact of basic education in determining life expectancy, suggesting the externality role of education in facilitating adoption of best practices in health is at least as important as the role of basic education enhancing health outcomes at the household level.

The last result is particularly interesting because growth regressions have established that primary education is the single most important determinant of income growth, while higher education is found to have little explanatory power (Sala-i-Martin, Doppelhofer and Miller 2004). Also microeconomic evidence suggests that primary education is more important than tertiary education in determining growth in income (e.g. Psacharopoulos 1994). Our findings suggest that tertiary education might be important for one component of welfare, health status, even if it's less important as a determinant of an other component of welfare, income per capita.

Bibliography

Aisa, R. and F. Pueyo (2004), "Endogenous longevity, health and economic growth: a slow growth for a longer life?" *Economics Bulletin*, Bulletin, 9(3), 1-10.

Bhargava, A., Jamison, D., Lauc, L. and C. Murray (2001), "Modeling the effects of health on economic growth," *Journal of Health Economics*, 20, 423-440.

Barro, R. (1996), "Health and Economic Growth," paper presented at the the Pan American Health Organization conference on Health, Human Capital and Economic Growth.

Barro, R. and J-W. Lee (1993), "International Comparisons of Educational Attainment," *Journal of Monetary Economics*, 32(3), 363-94.

Becker, G., Philipson, T. and R. Soares (2003), "The Quantity and Quality of Life and the Evolution of World Income Inequality," NBER Working Paper, No. 9765.

Blackburn, K. and G-P. Cipriani (2002), "A model of longevity, fertility and growth," *Journal of Economic Dynamics & Control*, 26 187-204.

Blanchard, O. (1985), "Debt , Deficits and Finite Horizons," *Journal of Political Economy* 93, 223-247.

Bloom, D., Canning, D. and J. Sevilla (2004), "The Effect of Health on Economic Growth: A Production Function Approach," *World Development*, 32(1), 1?13.

Castelló-Climent, A. and R. Doménech (2004), "Human Capital Inequality, Life Expectancy and Economic Growth," mimeo, Universidad Carlos III de Madrid.

Chakraborty, S. (2004), "Endogenous Lifetime and Economic Growth," *Journal of Economic Theory* 116, 119-137.

Chakraborty, S. and M. Das (2005), "Mortality, Human Capital and Persistent Inequality," *Journal of Economic growth*, forthcoming.

Chakraborty, S., Papageorgiou, C. and F. Pérez-Sebastían (2005) , "Disease and Development," paper presented at the Conference on Health, Demographics and Economic Development, Stanford University.

Commission on Macroeconomics and Health (2001), *Macroeconomics and Health: Investing in Health for Economic Development*, Geneva: World Health Organization.

Deaton, A; (2003), "Health, Inequality, and Economic Development", *Journal of Economic Literature* 41, 113-158.

Devlin, N. and P. Hansen (2001), "Health care spending and economic output: Granger causality," *Applied Economics Letters*, 8(8), 561-563.

Ehrlich, I. and H. Chuma (1990), "A Model of The Demand for Longevity and the Value of Life Extension," *Journal of Political Economy* 98, 761-782.

Fogel, R. (1994), "Economic Growth, Population Theory, and Physiology: The Bearing of Long-Term Processes on the Making of Economic Policy," *American Economic Review* 84, 369-95.

Fogel, R. (1997), "New Findings on Secular Trends in Nutrition and Mortality: Some Implications for Population Theory," in M. Rosenzweig and O. Stark (eds.), *Handbook of Population and Family Economics*. Amsterdam: Elsevier, 433-81.

Frankel, J.A. and D. Romer (1999), "Does Trade Cause Growth," *American Economic Review* 89, 379-99.

Galor, O. and D. Mayer-Foulker (2002), "Food for Thought: Basic Needs and Persistent Educational Inequality," paper presented at the the Pan American Health Organization conference on Health, Human Capital and Economic Growth, forthcoming in G. Lopez-Casasnovas, B. Rivera and L. Currais (eds.), *Health and Economic Growth: Findings and Policy Implications*. Cambridge, MA: MIT Press.

Grossman, M. (1972), "On the Concept of Health Capital and the Demand for Heath," *Journal of Political Economy* 80, 223-250.

Gupta, S., Verhoeven, M. and E. Tiongson (2001), "Public Spending on Health Care and the Poor," IMF working paper 01/127.

Hall, R. and C. Jones (1999), "Why Do Some Countries Produce so Much More Output Per Worker than Others?," *Quarterly Journal of Economics* 114, 83-116.

Hall, R. and C. Jones (2004), "The Value of Life and the Rise in Health Spending," NBER Working Paper Series, No. 10737.

Jamison, D., Lau, L. and J. Wang (2005), "Health's Contribution to Economic Growth in an Environment of Partially Endogenous Technical Progress," forthcoming in G. Lopez-Casasnovas, B. Rivera and L. Currais (eds.), *Health and Economic Growth: Findings and Policy Implications*. Cambridge, MA: MIT Press.

Kalemli-Ozcan, S. (2002) "Does the Mortality Decline Promote Economic Growth?", *Journal of Economic Growth*, 7, 411-439.

Neumayer, E. (2003), "Beyond income: convergence in living standards, big time," *Structural Change and Economic Dynamics*, 14, 275-296.

Nordhaus, W. (2002), "The Health of Nations: The Contribution of Improved Health to Living Standards," NBER working paper 8818.

Pritchett, L. and L. Summers (1996), "Wealthier is Healthier," *Journal of Human Resources*, 31(4), 841-868.

Papageorgiou, C., Savvides, A. and M. Zachariadis (2005), "International Medical R&D Spillovers," mimeo University of Cyprus.

Psacharopoulos, G. (1994) "Returns to investment in education: a global update," World Development, 22(9), 1325–1343.

Romer, P. (1990), "Endogenous Technological Change," *Journal of Political Economy* 98, S71-S96.

Sala-i-Martin, X., Doppelhofer, G. and R. Miller (2004), "Determinant of Long-term Growth: A Bayesian Averaging of Classical Estimates (BACE) Approach," *American Economic Review* 94(4), 813-835.

Stern M. (2003), "Endogenous Time Preference, Fertility, and Optimal Growth," Working Paper, Indiana University.

Thomas, D. and E. Frankenberg (2002), "Health, nutrition and prosperity: a microeconomic perspective," *Bulletin of the World Health Organization*, 80, 106-113.

Usher, D. (1973), "An Imputation to the Measure of Economic Growth for Changes in Life Expectancy," in M. Moss, ed., *The Measurement of Economic and Social Performance*, New York: NBER.

van Zon, A. and J. Muysken (2001), "Health and endogenous growth," *Journal of Health Economics*, 20, 169?185.

Weil, D. (2005), "Accounting for the Effect of Health on Economic Growth," paper presented at the Conference on Health, Demographics and Economic Development, Stanford University.

Yaari, M. (1965), "Uncertain lifetime, life insurance, and the theory of the consumer," *Review of Economic Studies* 32, 136-150.

Younger, S. (2001), "Cross-Country Determinants of Declines in Infant Mortality: A Growth Regression Approach," mimeo Cornell University.

A Appendix

Table A1: List of countries

Country	**Code**	**Avg Life Expectancy**[1]
Algeria	DZA	68.5
Argentina	ARG	72.1
Australia	AUS	77.5
Austria	AUT	76.3
Bangladesh	BGD	56.4
Belgium	BEL	76.6
Bolivia	BOL	59.4
Brazil	BRA	66.2
Cameroon	CMR	54.2
Canada	CAN	77.8
Chile	CHL	74.3
Colombia	COL	68.9
Costa Rica	CRI	75.8
Cyprus	CYP	76.8
Denmark	DEN	75.0
Ecuador	ECU	67.4
El Salvador	SLV	67.1
Finland	FIN	75.7
France	FRA	77.3
Germany	GER	75.6
Ghana	GHA	58.1
Greece	GRC	77.3
Guatemala	GTM	62.5
Haiti	HTI	53.4
Honduras	HND	65.3
Iceland	ICE	78.3
India	IND	60.2
Indonesia	IDN	62.9
Iran	IRN	65.8
Iraq	IRQ	59.6
Ireland	IRL	75.5
Israel	ISR	76.6
Italy	ITA	77.4
Jamaica	JAM	73.8
Japan	JAP	79.3
Jordan	JOR	69.5
Kenya	KEN	55.5

Table A1: List of countries cont.

Country	**Code**	**Avg Life Expectancy**
Korea	KOR	71.0
Malawi	MWI	43.4
Malaysia	MYS	71.2
Mali	MLI	44.3
Mauritius	MUS	70.1
Mexico	MEX	71.4
Mozambique	MOZ	43.8
Myanmar	MMR	55.3
Netherlands	NET	77.1
New Zealand	NZL	75.9
Norway	NOR	77.2
Pakistan	PAK	59.9
Panama	PAN	73.0
Paraguay	PRY	68.6
Peru	PER	66.8
Philippines	PHI	66.6
Portugal	PRT	74.1
Sierra Leone	SLE	35.2
Singapore	SGP	75.5
Spain	ESP	76.8
Sri Lanka	LKA	70.8
Sudan	SDN	53.1
Sweden	SWE	78.1
Switzerlannd	SWI	77.9
Tanzania	TZA	49.3
Thailand	THA	69.1
Tunisia	TUN	70.8
Turkey	TUR	67.2
Uganda	UGA	45.4
United Kingdom	GBR	76.2
Unites States	USA	75.5
Uruguay	URY	73.0
Venezuela	VEN	71.8
Zambia	ZMB	47.8
Zimbabwe	ZWE	53.6

[1]This is the end of period average life expectancy from 1990 to 1995.