The Relationship Between Health and Growth: When Lucas Meets Nelson-Phelps*

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Abstract

This paper revisits the relationship between health and growth in light of modern endogenous growth theory. We propose an unified framework that encompasses the growth effects of both, the accumulation and the level of health. Based on cross-country regressions where we instrument for both variables, we find that a higher initial level and a higher rate of improvement in life expectancy, both have a significantly positive impact on per capita GDP growth. Then, restricting attention to OECD countries, we find supportive evidence that only the reduction in mortality below age forty generates productivity gains, which in turn may explain why the positive correlation relationship between health and growth in cross-OECD country regressions is weaker over the contemporary period.

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1 Introduction

Can health explain cross-country differences in levels and growth rates of income? This question is of primary importance, in particular in current debates on the costs and benefits of new health programs. For example, whether health should or should not have a positive impact on growth, will have an obvious impact on the public support for or against implementing more universal health coverage programs. While left-leaning politicians would still advocate such programs even if they are not shown to be growth-enhancing, these programs would clearly gain consensus if, as it has been shown elsewhere for education, improving health is yet another way to increase a country's growth potential.

Basic economic intuition supported by partial empirical evidence, suggests that health should somehow matter for growth. First, individuals with higher life expectancy are likely to save more, and savings in turn feed back into capital accumulation and therefore into GDP growth as shown for instance by Zhang, Zhang and Lee (2003). Second, individuals with higher life expectancy are likely to invest more (or to have their parents invest more) in education, which in turn should be growth-enhancing[1]. In an environment marked by low child mortality, parents are likely to choose a low level of fertility[2], which limits the growth in total population and supports per capita GDP growth. Finally, and more directly, healthier individuals are typically more productive, better at adapting to new technologies and more generally to changing situations.

A convenient way to address the relationship between health and growth, it to look at health as a particular form of human capital (see Weil (2009)). Then, drawing on the parallel between health and education, one can distinguish be-

[1] Kremer and Miguel (2004) as well as Jayachandran and Lleras-Muney (2009) provide convincing microeconomic evidence that better health increases human capital investments.

[2] See Lee(2003) and Galor (2005) for a discussion of the demographic transition. Using a large panel of countries, Murtin (2009) displays empirical evidence that child mortality has had a significant positive effect on the crude birth rate over the twentieth century.

tween two basic approaches. A first approach, based on Mankiw-Romer-Weil (1992) and Lucas (1988), would view health as a regular factor of production. Accordingly, output growth should be correlated, if any, with the *accumulation* of health, in particular with the increase in life expectancy in a country or region. A second approach, based on Nelson and Phelps (1966), would argue that a higher *stock* of health spurs growth by facilitating technological innovation and/or technological adoption. Accordingly, productivity growth should be positively correlated with the *level* of health, in particular with the initial or the average level of life expectancy in a country or region over a given period.

In the recent literature on health and growth, two papers exemplify these two approaches, and these two papers lead to somewhat opposite policy conclusions. First, Acemoglu and Johnson (2008), henceforth AJ, follow a Lucas-type approach and regress income growth on the increase in life expectancy between 1940 and 1980, using a very clever instrument for the growth in life expectancy. Namely, AJ exploit the wave of health innovations that occurred as of the 1950s and affected all countries worldwide: more precisely, they use the pre-intervention distribution of mortality from 15 diseases and the dates of global interventions to construct a country-varying instrument for life expectancy. Then, when regressing per capita GDP growth on the growth in life expectancy over the 1940-1980 period, AJ find that improvements in life expectancy over that period have no significant effect on total GDP, increases the rate of population growth, and thus reduces per capita GDP significantly. Second, a contemporaneous paper by Lorentzen, McMillan and Wacziarg (2008), henceforth LMW, adopts a Nelson-Phelps approach and regresses per capita GDP growth on the average child and adult mortality rates over the period 1960-2000. LMW use 17 instruments for these two mortality indicators: a malaria ecology index - originally developed by Sachs et al. (2004) - which captures the exogenous portion of malaria incidence, 12 climate variables, and four geographic features of countries, which are unlikely to be affected by human activity and more particularly by income levels. LMW then find a strong effect of mortality rates on income growth[3]. In particular, they find that adult mortality alone can account for all of Africa's growth shortfall over the 1960-2000 period[4].

This note tries to reconcile the Lucas and Nelson-Phelps approaches by proposing an unified framework for analyzing the relationship between health and growth. We first propose a theoretical framework that embeds both, the Lucas and Nelson-Phelps ingredients. There, individuals live for two periods, unless they die after their first period of life. At birth, individuals benefit from past education investments by previous generations (these are embodied in their initial productivity level), but at the same time individuals can improve upon their initial productivity by themselves investing in human capital. The extent to which they will benefit from such human capital investments in the future, depends upon the probability of surviving until the old age, and this probability in turn reflects the current health level in the economy. A main implication of the model is that both, the level and the increase in health can matter for growth.

Moving to the empirical analysis, we provide unambiguous support to the effect that (improved) health is growth-enhancing[5]. In particular, combining the AJ and the LMW instruments, we show that, in cross-country regressions, per capita GDP growth is significantly affected by both the initial level and the

[3] Weil (2009) and Ashraf et al. (2008) adopt an intermediate stance. They respectively estimate and simulate the macroeconomic impact of improvements in health observed at a microeconomic level, and argue that health effects are small or only observed in the long run. However, their analysis fails to account for one of the most important channel, which is reduction in fertility. As demonstrated by Young (2005), this effect can have powerful consequences on productivity growth as it mitigates the Malthusian effect of extended longevity.

[4] In addition, LMW disentangle the negative effects of mortality on investment and human capital accumulation from its positive effect on the fertility rate, and they find that investment and fertility are the strongest channels underlying the positive effect of health on growth.

[5] While an exhaustive review of the literature is well beyond the scope of this note, we refer the reader to Bloom et al. (2004) and Weil (2007) who derive a similar conclusion.

accumulation of life expectancy. This finding holds over both, the 1940-1980 and the 1960-2000 periods. In doing so, we also explain AJ's correct finding that the increase in life expectancy over the period between 1940 and 1980 shows not significantly positive correlation with (per capita) GDP growth in a Lucas-type regression where per capita GDP growth is regressed on the growth of life expectancy over that period. Our explanation hinges on the observed convergence in life expectancy across countries over that period. Namely, the higher the initial level of life expectancy at the beginning of the period, the lower the increase in life expectancy during the period. This implies that if one regresses per capita GDP growth over the increase in life expectancy during the period 1940-1980, the regression coefficient also captures the negative correlation between the increase in life expectancy and its initial level since this latter term is typically omitted from a Lucas-type regression.

We then look more closely at the relationship between health and growth across OECD countries, using cross-country panel regressions. We find a significant and positive impact of health on growth between 1940 and 1980, but this relationship tends to weaken over the contemporary period, say from 1960 onwards. We interpret this finding as reflecting an age-specific productivity effect of health. Indeed, as of 1960, most of the growth in life expectancy at birth appears to be related to a reduction in mortality at old age, but we find that it is mostly the decrease in the mortality of individuals aged forty or less that matters for growth.

The paper is structured as follows. Section 2 outlays the theoretical framework. Section 3 describes the data and the empirical methodology. Section 4 presents the empirical results from global cross-country and then from cross-OECD panel regressions. Section 5 concludes by summarizing our results and then suggesting avenues for future research.

2 Theoretical framework

In this section we develop a simple model where the accumulation and level of health both matter for growth. In this model, the expected life expectancy of each individual impacts on her investment in human capital, and human capital in turn affects both, final output and its rate of productivity growth.

2.1 Basic setup

More formally, consider an economy populated by a continuum of overlapping generations of (at most) two-period lived individuals. Each period bring a mass one of young individuals, but not all of them survive until their old age: the level of health at date t is captured by the probability $(1-\delta_t)$ that any individual born at date t will indeed survive up to date $t+1$. This probability which captures life expectancy will affect individuals' investment in human capital at date t.

All individuals born at date t (call them "t-individuals") start with the same initial productivity A_t^y when young and end up with the same productivity A_{t+1}^o when and if they get old. We allow for intergenerational knowledge externalities, whereby:

$$A_t^y = (A_t^o)^\theta, 0 < \theta < 1 \tag{1}$$

When $\theta = 0$, the model is of pure Mankiw-Romer-Weil nature, with growth being influenced by the accumulation of human capital and health, not their level. In the polar case where $\theta = 1$, we are back to a pure Nelson-Phelps framework where only the levels of human capital and health affect (long-run) growth.

When young, a t-individual t decides how to divide her time between work and education (or human capital investment). In line with Mincer's specification of the marginal value of human capital, we assume that h units of time devoted to education at date t multiply individual productivity by the factor $e^{\sigma h}$ at date $t+1$, where σ is a positive coefficient that reflects the efficiency of the education system. Thus, if h_t denotes the equilibrium investment in human capital of t-individuals, we have:

$$A^o_{t+1} = A^y_t e^{\sigma h_t} \tag{2}$$

Suppose people have logarithmic utility of consumption each period, they discount next period's utility at the rate ρ and have a survival probability δ_t. Assuming that each period an individual is paid a fixed proportion of her current productivity, t-individuals will choose h_t to

$$\max_{h_t} \{ \ln [A^y_t(1-h_t)] + \frac{1-\delta_t}{1+\rho} \ln \left[A^y_t e^{\sigma h_t} \right] \}$$

By first order conditions, this immediately yields:

$$h_t = 1 - \frac{1+\rho}{\sigma(1-\delta_t)} \tag{3}$$

Not surprisingly, the equilibrium level of human capital investment increases with the current level of life expectancy $(1-\delta_t)$, and thus so will individual productivity growth $A^o_{t+1}/A^y_t = e^{\sigma h_t}$.

2.2 Aggregate productivity growth

However what we are estimating in the empirical section, is not individual, but aggregate productivity growth. In this model, average income per capita (counting current education spending as part of aggregate income) at date t is given by[6]:

$$y_t = \frac{1}{2-\delta_{t-1}}[A_t^y + (1-\delta_{t-1})A_t^o] \tag{4}$$

Using (1) and (5), we thus get the following expression for aggregate productivity growth between dates t and $t+1$:

$$G_t = \frac{(A_{t+1}^o)^\theta + (1-\delta_t)A_{t+1}^o}{(A_t^o)^\theta + (1-\delta_{t-1})A_t^o}\frac{2-\delta_{t-1}}{2-\delta_t} \tag{5}$$

Now using (2), we can reexpress this aggregate productivity growth rate G_t as a function G of $A_{t-1} := A_{t-1}^o, h_{t-1}, h_t, \delta_{t-1}, \delta_t$, namely:

$$G_t = \frac{A_{t-1}^{\theta^3} e^{\sigma\theta(h_t+\theta h_{t-1})} + (1-\delta_t)A_{t-1}^{\theta^2} e^{\sigma(h_t+\theta h_{t-1})}}{A_{t-1}^{\theta^2} e^{\sigma\theta h_{t-1}} + (1-\delta_{t-1})A_{t-1}^{\theta} e^{\sigma h_{t-1}}}.\frac{2-\delta_{t-1}}{2-\delta_t} \tag{6}$$

where $h_t = 1 - \frac{1+\rho}{\sigma(1-\delta_t)}$ and $h_{t-1} = 1 - \frac{1+\rho}{\sigma(1-\delta_{t-1})}$ by (3).

2.3 Growth and the level and increase in life expectancy

Now suppose we start from the benchmark level of health $(1-\delta)$ such that the equilibrium human capital investment is equal to zero[7], and from the benchmark steady state productivity $A = 1$[8], and then use a linear approximation to assess the effects on aggregate productivity growth between dates t and $t+1$ of increasing health a little as of date $t-1$. We have:

Proposition 1 *Up to first order approximation, the rate of aggregate productivity growth* $g = G(A_{t-1}, h_{t-1}, h_t, \delta_{t-1}, \delta_t)$ *around* $(1, 0, 0, \delta, \delta)$ *is equal to*

$$g \simeq \beta_A(1-A) + \theta\beta_h h_{t-1} + \beta_h \Delta h_{t-1},$$

[6] Here we are making use of the fact that the total pool N_t of active individuals in period t comprises: (i) the mass one of all young individuals at date t; (ii) the mass $(1-\delta_{t-1})$ of old survivors from the previous period. Thus $N_t = 2 - \delta_{t-1}$

[7] Namely $0 = 1 - \frac{1+\rho}{\sigma(1-\delta)}$ or $\delta = 1 - \frac{1+\rho}{\sigma}$

[8] The above productivity growth and knowledge spillover equations imply that when $h = 0$, productivity growth remains stationary at $A = 1$ if starting from $A = 1$.

where: (i) $\Delta h_{t-1} = h_t - h_{t-1}$; *(ii)* $\beta_A = \theta(1-\theta)\frac{\theta+1-\delta}{2-\delta}$; *(iii)* $\beta_h = \sigma\frac{\theta+1-\delta}{2-\delta}$.

Proof. See Appendix. ■

Thus both the level and increase in human capital, and therefore *both the level and increase in life expectancy, impact on aggregate productivity growth.* [9].

3 Empirical analysis

In this section, we present the empirical methodology, the data, and then we present and discuss the empirical results.

3.1 Empirical methodology

The above theoretical framework predicts that growth in GDP per capita should depend both, upon the initial level of life expectancy and also upon its variation over time. In line with the model, we shall estimate the equation:

$$\Delta \log y_i = a + b\Delta \log \mathrm{LE}_i + c \log \mathrm{LE}_{i,0} + u_i \tag{7}$$

where $\Delta \log y_i$ is the growth of the log of per capita GDP in country i over a given time period, $\Delta \log \mathrm{LE}_i$ is the growth in the log of life expectancy in that country over the same period, $\log \mathrm{LE}_{i,0}$ is the level of life expectancy in country

[9] Note however that this model predicts stagnation in long run steady-state except when $\theta = 1$ which corresponds to the pure Nelson-Phelps case. To see this, note that when h and δ are constant over time (which is the case in steady state), we have:

$$G = \frac{A^{\theta^3} e^{\sigma\theta(1+\theta)h} + (1-\delta)A^{\theta^2} e^{\sigma(1+\theta)h}}{A^{\theta 2} e^{\sigma\theta h} + (1-\delta)A^{\theta} e^{\sigma h}}.$$

Now let us reason by contradiction and suppose that $G > 1$. Then we would have: $A \longrightarrow \infty$ over time, so that whenever $\theta < 1$:

$$G = \frac{A^{\theta^3-\theta^2} e^{\sigma\theta(1+\theta)h} + (1-\delta)e^{\sigma(1+\theta)h}}{e^{\sigma\theta h} + (1-\delta)A^{\theta-\theta^2} e^{\sigma h}} \longrightarrow 0,$$

a contradiction with our assumption that $G > 1$. Now, using $G = 1$ we can solve for the steady state level of A.

i at the beginning of the period, and u_i is a residual term. This equation embeds the Lucas approach in one assumes that $c = 0$, as well as the pure Nelson-Phelps approach which corresponds to $b = 0$. Each regression shown in this section, will be run with first the Lucas-type restriction $c = 0$, then with the Nelson-Phelps restriction $b = 0$, and then without any restriction (i.e with $b \neq 0$ and $c \neq 0$).

Following AJ and LMW, we will provide both OLS and IV estimations for all our regressions, and our cross-country regressions will span the two periods 1940-1980 and 1960-2000. Measuring growth over a forty years time span enables us to reduce measurement errors affecting growth in GDP per capita or in life expectancy[10]. This measurement errors problem is typically magnified when using panel fixed-effects estimators as argued by Hauck and Wacziarg (2009). Hence our emphasis on cross-country regressions[11]. However, when restricting attention to OECD countries, we shall exploit the time dimension and run panel regressions using ten years time spans in order to avoid potential small sample size issues.

3.2 Data and summary statistics

In this paper we exploit three databases: the AJ data, which include 47 developed and developing countries and are used by the authors to investigate the relationship between log GDP per capita and log life expectancy between 1940 and 1980[12]; LMW data cover 96 countries over the period 1960-2000. The per

[10]In all regressions, annualized growth in GDP per capita stands for the log of per capita GDP at the end of the period minus the log of pper capita GDP at the beginning of the period, divided by the length of the period. This differs from average annual growth rates.

[11]As shown by AJ, a cross-country regression run over the 1940-1980 period provides qualitatively the same results than a panel fixed-effects approach using a ten years time span over the same period.

[12]In the AJ database, per capita GDP data are drawn from Maddison (2003), life expectancy data are taken from various United Nations Demographic Yearbooks and League of Nations reports (see the appendix of their NBER working paper). The AJ instrument, namely 1940 predicted mortality caused by the diseases treated in the 1950s and the 1960s, combines mortality data by disease and dates of interventions for disease eradication from an impressive collection of sources, including the League of Nations, United Nations, WHO Epidemiological Reports, National Academy of Sciences as well as various academic sources.

capita GDP data, the child and adult mortality rates, the life expectancy data, as well as various sources for their 17 instrument variables, are all drawn from the World Bank's World Development Indicators (2004) data set[13]; the OECD (2009) health database provides information on life expectancy at various ages (0, 40, 60 and 80 years) across OECD countries from 1960 onwards.

Table 1 summarizes the two main sample data we use in our empirical analysis, drawn respectively from AJ and LMW. The Table shows the average GDP per capita and average life expectancy respectively among high-income countries and among low/middle-income countries from the AJ sample over the period 1940-1980, and from the LMW sample over the period 1960-2000.[14] Not surprisingly, we see that over each of these two time intervals, high-income countries have achieved larger gains in GDP per capita and smaller increases in life expectancy than low/middle-income countries. For example, the increase in per capita GDP in high-income countries has been three times as large as in low and middle-income countries between 1940 and 1980, and about seven times larger in the LMW sample between 1960 and 2000[15]. In contrast, life expectancy has increased by 9.2 years in high-income countries and by 19.8 years in low and middle-income countries between 1940 and 1980. Also, after 1960, the low/middle income countries have witnessed a larger average increase in life expectancy than the high-income countries.

[13] As quoted from LMW, the malaria ecology index combines "the presence of different mosquito vector types and the human biting rate of the different mosquito vectors" (Sachs et al. 2004). LMW add eleven climate variables borrowed from the Koeppen-Geiger climate zones classification: tropical rainforest climate, its monsoon variety, tropical savannah climate, steppe climate, desert climate, mild humid climate with no dry season, mild humid climate with a dry summer, mild humid climate with a dry winter, snowy-forest climate with a dry winter, snowy-forest climate with a moist winter and highland climate. Finally, they add a variable measuring the proportion of land with more than five days of frost per month in winter, as well as the following geographical variables: the distance of a country's centroid from the equator, the mean distance to the nearest coastline, the average elevation, and the log of land area.

[14] In the LMW sample, life expectancy has been defined as the non-weighted average of male and female life expectancy. There is a 0.88 correlation between the log of life expectancy variables across LMW and AJ samples in 1980.

[15] The sample of low/middle income countries is about three times larger in LMW, and on average these countries are poorer than in the AJ sample in 1960.

TABLE 1 *HERE*

3.3 Cross country OLS regressions

We first perform cross country OLS regressions, using the LMW sample over the 1960-2000 period, and the results are shown in Table 2. There, we first reproduce the LMW methodology and results in columns I and II.[16] Regressing annualized per capita GDP growth, in percentage points, on the level of health as measured by the average child and adult mortality rates over the 1960-2000 period, we find a negative correlation coefficient between growth and these mortality indicators. If we believe the estimates in column II, adding up the effects of child and adult mortality as well as cross-country convergence, accounts for a growth gap of 2.35 percentage points[17]. Next, columns III and IV show that the regression coefficients are not significantly affected when substituting child and adult mortality rates in 1960 for their average values over the period, in other words when moving to a more standard Nelson-Phelps approach. This result is not so surprising as mortality rates evolve slowly over time: for example, the correlation between the 1960 adult mortality rate and its grand average over the 1960-200 period is equal to 0.93. Columns V and VI focus on a different explanatory variable, namely the log of life expectancy, while still adopting a Nelson-Phelps approach. Doing so makes the analysis more comparable with that in AJ, which similarly looks at life expectancy rather than mortality rates. Qualitatively, choosing life expectancy rather than mortality indicators

[16] See LMW, page 93, Table 4, column 1.

[17] With respectively 50 and 17 deaths per 1000 adults in Sub-Saharan Africa and high-income countries, and accounting for the LMW normalization of adult mortality, the latter variable vehicles a gap of 5x(0.5-0.17)=1.65 percentage points of annualized growth all along the period. As Sub-Saharan 1960 infant mortality was about 150 deaths per 1000 births, versus roughly 20 in developed countries, infant mortality implies a gap of 20.85x(0.150-0.20)=2.7 percentage points of growth. On the contrary, the convergence effect would imply a catch-up of about 1.03x(log(7820/1090))=2 percentage points. The combined effect of convergence, adult and child mortality therefore amounts to a growth gap of 1.65+2.7-2=2.35 percentage points.

for health, does not seem to make a big difference since we find that initial 1960 log of life expectancy[18] is significantly and positively correlated with per capita GDP growth. In addition, the magnitude of the regression coefficient is broadly comparable to what we obtain using mortality rates instead.[19] Columns VII and VIII introduce the Lucas/Mankiw-Romer-Weil approach, whereby one regresses annualized per capita GDP growth over the annualized growth in life expectancy. We find a non-significant coefficient on the growth in life expectancy variable, even after controlling for initial log GDP per capita. In substance, this result is consistent with AJ's findings of a non-positive correlation between growth in life expectancy and per capita GDP growth, even though here we look at different time periods. Last, columns IX and X combine the Lucas and Nelson-Phelps effects, and the results showed in these columns embody our main conclusion (which we shall again obtain when in the following IV regressions): in cross-country regressions with both OECD and non-OECD countries, there is a strong, positive and highly significant correlation between per capita GDP growth and both the initial level and the growth rate of life expectancy over the period.

TABLE 2 HERE

Table 3 tests the robustness of the above results to the AJ data sample over the 1940-1980 period. Again, we present three regressions which capture respectively the Lucas, Nelson-Phelps and our combined approach to the relationship between health and growth. We perform this set of regressions, first on the overall cross country sample, and then only for low and middle-income countries. The first and fourth columns reproduce the AJ result (in their Table 3, panel

[18]Similar results obtain if we simply use life expectancy as our health variable.

[19]Indeed, a twenty years gap in life expectancy between a developed country (70 years in 1960 life expectancy) and a Sub-Saharan African country (40 years) would entail a 6.53 x log(70/40)=3.6 percentage points gap in growth rates. Convergence would imply a catch-up of 2 percentage points. Thus, overall, we can explain up to a 1.6 percentage points growth gap.

B, columns 3 and 4). The comparison between columns 1 and 2 or between columns 4 and 5, shows that the Lucas and Nelson-Phelps approaches lead to different conclusions on the country samples, as they respectively suggest a negative and a positive correlation between (improved) life expectancy and (per capita GDP) growth, where both correlations are significant. When combining the two approaches, that is, when regressing (per capita) GDP growth on both the initial level and the increase in life expectancy over the period, we find that: (i) both the accumulation and initial level in life expectancy are positively associated with income growth; ii) the magnitude of the correlation between growth and the initial level of life expectancy overwhelms that obtained when following a pure Nelson-Phelps approach. In fact, the combined approach corrects for biases arising from the omitted variable problems in *both* the pure Lucas and pure Nelson-Phelps strategies, as witnessed by the substantial increase in explained variance when regressing growth over both, the level of and increase in life expectancy.

TABLE 3 *HERE*

The magnitude of the regression coefficients, suggests an important effect of health on growth: for instance, starting at 65 years of life expectancy in 1940 (which corresponds to the average developed country) rather than 45 years (the average among developing countries) implies a difference in average per capita GDP growth of 0.075xlog(65/45)=2.8 percentage points between 1940 and 1980. The effect of initial life expectancy thus plays in favor of the developed countries. On the other hand, the average growth in life expectancy over that period has been much faster in developing countries, which in turn gives developing countries a per capita GDP growth advantage equal to 3.58xlog(19.8/9.2)=2.7 percentage points. Our combined approach allows us to disentangle the effects of life expectancy on growth, with the initial level effect being mostly beneficial to developed countries, and the health accumulation effect being mostly beneficial to developing countries[20].

3.4 Instrumentation

To address endogeneity issues, we combine the instrumentation procedures used by AJ and LMW and the results are displayed in Table 4. Since we introduce two explanatory variables on the right hand side of our "combined" regressions, we needs at least two instruments. AJ use predicted mortality as a natural instrument for growth in life expectancy between 1940 and 1980 (column 1). Now, to instrument for the initial level of log life expectancy, one could use the Malaria Ecology index developed by Sachs et al. (2004), as shown on column 2, and then in the regression combining the Lucas and Nelson-Phelps effects it is natural to combine the above two instruments (which we do in column 3). Then, one can add the sixteen climatic and geographical variables used by LMW in order to increase statistical robustness of first-stage regressions (column 4). Importantly, Table 4 also reports F-statistics and Shea's R^2 statistics from first-stage regressions. All statistics are high with for instance F-tests p-values below 0.01, thereby indicating that the robustness of our first-stage regressions is strong. In addition, when using additional instruments as in column 4, we can run a Hansen-J test of overidentifying restrictions, which is robust to the presence of heteroskedasticity and autocorrelation. As a result, we fail to reject the null hypothesis of the joint exogeneity of our instrumental variables, which in turn suggests that our geographical and climate variables operate through the life expectancy channel to impact per capita GDP growth[21].

[20] Our main finding remains unchanged by the inclusion of initial log GDP per capita. Indeed, we estimated the following equation (with $R^2 = 0.62$): $\Delta \log y_i = b + 4.02^{***} \Delta \log \mathrm{LE}_i + 0.094^{***} \log \mathrm{LE}_{i,0} - 0.005^{**} \log y_{i,0} + u_i$. Coefficients pertaining to life expectancy are only marginally modified.

[21] Acemoglu et al. (2001) suggest that geographical and climatic variables affect institutions, which in turn affect growth. But this would have led to a rejection of joint exogeneity of our instruments, which is not the case.

Moving to the 1960-2000 period, predicted mortality is no longer a convenient instrument as many global health interventions occurred in the 1950s. But climatic and geographical variables remain available as a relevant set of instrumental variables (column 5), while Malaria Ecology can still serve as an instrument for initial life expectancy (column 6). The full set of LMW instruments (Malaria Ecology plus climatic and geographical variables) can then be used in the combined regression (column 7). As before, the first-stage regressions are valid as shown by high Shea-R^2 and F-test statistics, and the regression of column 7 pass the Hansen-J test of joint exogeneity of instruments.

Now let us briefly describe the results in Table 4. Column 1 reproduces the AJ result[22] and confirms the significant and negative coefficient on the growth in life expectancy found in former OLS regressions. Similarly, the IV approach validates the result drawn from the Nelson-Phelps approach, namely that of a significant and positive impact of initial life expectancy as shown in column 2. Next, instrumenting the combined regression in columns 3 and 4, confirms our previous results from combined OLS regressions (in column 4 the higher number of instruments strengthens the first-stage regression). Turning to the more recent 1960-2000 period, we find qualitatively identical results: combining the Lucas and Nelson-Phelps approaches offers a strong support for a positive effect of both the initial life expectancy and its growth on per capita GDP growth.[23]

TABLE 4 *HERE*

These results provide further support to the idea that health is good for growth. Both effects (level and accumulation) encompassed in our combined

[22] See their Table 9, panel B, column 1. For the sake of consistency between samples across columns 1-2-3, one country has been excluded from the original AJ sample, hence our estimate (1.35) differs slightly from AJ estimate (1.32).

[23] Interestingly, the coefficients of initial life expectancy are almost identical across columns 6 and 7, meaning that the instrumentation procedure has eliminated the omitted variable bias of OLS regressions.

approach are found to be strong in magnitude. As already emphasized by LMW, initial differences in health have heavily contributed to Africa's growth shortfall, as a gap of thirty years of life expectancy with respect to the health frontier in 1960 entails a gap in per capita GDP growth of 1.1 percentage points. But this figure falls short of accounting for the HIV/AIDS impact, which has in some countries lowered life expectancy to the standards of the 1950s. Thus, while developed countries have experienced an average increase of 9.2 years in life expectancy between 1960 and 2000, South Africa has suffered a decrease of 1.4 years over the same period, which, if we believe our regression coefficients, should account for an additional growth gap of 0.6 percentage point compared to developed countries[24].

3.5 What is missed in the pure Lucas and Nelson-Phelps approaches

Our above analysis provides evidence to the effect that achieving higher life expectancy has a positive significant effect on per capita GDP growth: first, improving health standards increases *current* productivity growth (the Lucas/MRW effect); second, higher contemporary health standards improve *future* productivity growth (the Nelson-Phelps effect). Compared to pure Nelson-Phelps regressions, we find a higher magnitude for the (overall) effect of health on per capita GDP growth. And the conclusions from our combined regressions differ even more radically from what is suggested by pure Lucas-type regressions: these regressions show either non-significant or significantly negative correlations between per capita GDP growth and the growth in life expectancy, thereby suggesting that health should have no significantly positive impact on per capita

[24] As South Africa starts from 49.2 years of life expectancy in 1960 and ends at 47.8 in 2000, while an average developed country displays respectively 68.3 and 77.5 years, this entails a growth gap equal to 1.52x(log(77.5/68.3)-log(47.8/49.2))/40=0.6 annual percentage points of growth.

GDP growth. In this subsection we explain why pure-Lucas type regressions do not show significantly positive coefficients, but why this cannot be directly interpreted as reflecting the absence of a positive effect of health on growth.

Key to understand the absence of positive and significant coefficients when regressing per capita GDP growth on the growth in life expectancy while omitting initial life expectancy on the right hand side of the growth regressions, is the convergence in life expectancy phenomenon, a well-know fact nicely analyzed by Becker et al. (2005). Thus Figure 1 points at a stunning convergence effect of the initial 1940 log of life expectancy on the growth in life expectancy over the period 1940-1980.

FIGURE 1 *HERE*

Then, suppose that, in line with our above model, growth is truly affected by both, the initial level of health at the beginning of the period and by the improvement of health over the period. Thus the relationship between health, its accumulation, and per capita GDP growth, may still be captured by regression equation (7). But now, let us also factor in the convergence in life expectancy phenomenon. From an econometric point of view, convergence in life expectancy can be captured through a linear regression of the form:

$$\Delta \log \mathrm{LE}_i = -\frac{1}{\rho} \log \mathrm{LE}_{i,0} + v_i, \tag{8}$$

where v_i is an error term.

Now, plugging (8) into (7) yields:

$$\begin{aligned} \Delta \log y_i &= a + b\Delta \log \mathrm{LE}_{i,0} + c(-\rho \Delta \log \mathrm{LE}_i - \rho v_i) + u_i \\ &= a + (b - c\rho)\Delta \log \mathrm{LE}_{i,0} + u_i - c\rho v_i \end{aligned} \tag{9}$$

In this equation, the coefficient of $\Delta \log \mathrm{LE}_i$ picks up not only the effect of life expectancy accumulation b but also the negative correlation between the accumulation of health (the improvement in life expectancy) and the initial level of health (or initial level of life expectancy). If the convergence coefficient ρ is sufficiently high, it can lead to a negative sign for the coefficient $(b - c\rho)$ in the Lucas-type regression of per capita GDP growth on the accumulation of life expectancy. Obviously, this negative sign is spurious : even if both the initial level and the accumulation of life expectancy on income growth have positive effects $(b, c > 0)$, it is possible to end up with a negative coefficient $(b - c\rho < 0)$ if ρ is sufficiently large.

Coming back to our numerical regression exercise, estimating the above convergence equation (8) over the period 1940-1980 for the overall cross-country sample, yields:

$$\Delta \log \mathrm{LE}_i = -0.015^{***} \log \mathrm{LE}_{i,0} + v_i, \text{ with } R^2 = 0.90 \tag{10}$$

Initial differences in life expectancy can thus explain 90% of further differences in growth of life expectancy. The fact that this negative correlation is large suggests that *both* the Lucas and the Nelson-Phelps approaches underestimate the effects of (improved) life expectancy on productivity growth, as *both* are contaminated by an omitted variable bias. However, this bias turns out to be smaller in the pure Nelson-Phelps approach[25]. Moving to the combined regression equation (7) thus generates estimates that are greater than those obtained in pure Nelson-Phelps regressions, and it overturns the negative results drawn from Lucas-type regressions.

That the initial level as well as the accumulation of human capital should matter for per capita GDP growth, has been stressed by others before us, for

[25] From Table 3 one has $b = 3.65$, $c = 0.076$ and $1/\rho = 0.015$. This conveys a negative omitted variable bias in the Lucas approach equal $-c\rho = -5.06$, and a negative omitted variable bias in the Nelson-Phelps approach equal to $-b/\rho = -0.55$. This is consistent with our estimates in Table 3.

example by Krueger and Lindhal (2001) who focus on the relationship between growth and education. Here we are pushing the same idea when analyzing the relationship between growth and health. Indeed what our discussion in this subsection illustrates, is that ignoring either of the two (level and accumulation) effects might generate potentially misleading policy conclusions, especially when explanatory variables display significant degrees of autocorrelation[26].

3.6 Growth and life expectancy by age in OECD countries

Let us first perform the same regressions as before but restricting attention to OECD countries, over the 1940-1980 period. Our findings are summarized in Table 5, which shows the results from the pure Lucas, from the pure Nelson-Phelps, and from the combined approach, respectively from OLS and IV regressions[27]. As shown in columns 1 and 4 (Lucas-type regressions), growth in life expectancy has a positive impact upon productivity growth in OECD countries. A simple look at Figure 1 clearly illustrates the positive correlation between these two variables, whereas this correlation used to be negative in Lucas-type regressions involving the whole cross-country sample. Next, columns 2, 3, 5 and 6 (Nelson-Phelps-type regressions) with initial log GDP per capita being added in columns 3 and 6, show a negative correlation between initial life expectancy and per capita GDP growth. This in turn captures a convergence effect, as this correlation becomes insignificant when initial log GDP per capita is introduced as a control variable. Last, our combined approach displayed on columns 4 and 7 confirms what we already obtained in the corresponding columns in Table 4,

[26] In theory, one could make the same case for average years of schooling inside growth regressions. However, as shown by Morrisson-Murtin (2009), convergence in education has been too weak over the 1960-2000 period to generate such bias.

[27] As before we chose predicted mortality to instrument for growth in life expectancy and a reduced set of geographical and climatic variables to instrument for initial life expectancy. Indeed, seven climatic variables have been excluded as no OECD country displayed the corresponding climate chatacteristics. As before, all regressions exhibit strong first-stage relationships and the joint exogeneity of instruments is validated in columns 6 to 8.

namely both the initial level of and the growth in life expectancy matter for per capita GDP growth.

TABLE 5 *HERE*

However, in unreported regressions we found that the correlations between productivity growth and the level and growth rate in life expectancy, weaken if we restrict attention to the post-1960 period. This is not surprising: first, cross-OECD differences in life expectancy are too small in 1960 to generate significant coefficients when regressing (per capita GDP) growth over the level and growth in life expectancy over the post-1960 period. Indeed, in 1960, 24 OECD countries out of 28 would show a life expectancy at birth which lies between 67.6 and 73.4 years[28]. Second, the coefficient on growth in life expectancy in the combined regression, was found to be significant only at 10% over the 1960-1990 period, and it is insignificant over the period between 1960 and 2000 when controlling for initial log of per capita GDP. We interpret this finding as evidence that the relationship between health and growth has weakened after 1960, and that not all of the post-1960 gains in life expectancy have had a significant impact on productivity growth. More precisely, we hypothesize that gains in life expectancy at young age and during active life matter more than gains in life expectancy at old-age.

To test this latter hypothesis, we use the OECD (2009) health database and exploit its panel dimension to increase the sample size and thereby improve statistical robustness. This comes at the cost of loosing the former instrumentation procedure, as all of our instruments that are relevant over that period are time-constant. However, all former IV estimates were relatively close to their OLS counterparts, which in turn suggests that OLS regressions already reflect

[28] Differences were relatively much starker in 1940: within the set of 22 OECD countries available both in 1940 and 1960, the coefficient of variation of life expectancy was equal to 11.5% in 1940 versus 6.9% twenty years later.

the causal effects we are trying to uncover. Besides, we can rely on GMM for an instrumentation with lagged explanatory variables.

Thus, Table 6 regresses the log of per capita GDP on variables measuring life expectancy at various ages (respectively at age 0, 40, 60 and 80). The retained time span is ten years and all regressions include time effects. As the results in Table 6 show, each explanatory variable in isolation comes out significant except life expectancy at 80 years when introducing fixed-effects. However, when regressing growth in per capita GDP on all life expectancy variables simultaneously, we find that life expectancy at age equal or older than 40 years is not significant. In other words, only gains in life expectancy *below* 40 years are significantly correlated with per capita GDP growth.

TABLE 6 *HERE*

Finally, Table 7 replicates the former regressions using the SYS-GMM estimator as described by Blundell-Bond (1998). In order to reduce the autocorrelation of residuals and eliminate potentially non-stationary components, here we first-differentiates the dependent and explanatory variables, regressing decennial growth in per capita GDP on growth in life expectancy over a ten years period[29], controlling for time dummies and country fixed effects. We still get the same conclusions, namely that reduced mortality between age zero and forty has a positive and significant impact on per capita GDP growth[30]. Our results are in line with the empirical microeconomic literature showing that better health at young age has long-term consequences in terms of workers productivity[31].

[29] We use log life expectancy lagged 20, 30 and 40 years as instrumental variables. All results remain identical when using variables in levels rather than in difference, but in the former case specification tests detect autocorrelation in residuals.

[30] The latter regression correctly rejects the null hypothesis of zero first-order correlation of first-differenced residuals, and correctly accepts the null hypothesis of zero second-order autocorrelation. A Hansen test of overidentifying restrictions validates the null hypothesis of joint exogeneity of instruments. As underlined by Roodman (2009), the number of instruments has been reduced in order to avoid the instruments proliferation problem that leads to Hansen statistics overestimation.

[31] See Behrman-Rosenzweig (2004) and Black et al.(2007).

TABLE 7 HERE

4 Conclusion

In this paper we argued that combining the Lucas (1988) and Nelson-Phelps (1966) approaches to human capital, improves our understanding of the relationship between health and growth. We first provided a simple model where both the initial level and the accumulation of health matters for growth. Then, in our empirical analysis we contrasted the results from combined regression (where per capita GDP growth is regressed over both, the initial level of and the growth in life expectancy) with results from regressions which embody only one of these two factors. In particular, having both initial level and accumulation of health effects on the right hand side of the regression equation, allows us to disentangle the effects of health on growth from spurious correlations driven by the convergence in life expectancy, whereby higher initial levels of life expectancy are negatively correlated with the growth of life expectancy in a country over a given period. Combining the instruments for health in Acemoglu-Johnson (2008) and those in Lorentzen et al.(2008), we find that better life expectancy, in the sense of both higher levels or positive accumulation, is definitely growth-enhancing. Then looking more closely at mortality rates by age groups in OECD countries, we find that reducing mortality, especially below age 40, is also growth-enhancing.

We see this as a first step in the analysis of the impact of health on productivity growth. A natural next step will be to try and uncover the particular channel -fertility decisions, adaptive abilities, innovative potential- whereby (improved) health enhances per capita growth and innovation.

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A Proofs

Proof of Proposition 1
We first compute first derivatives of G at $(1,0,0,\delta,\delta) = X$. We have

$$\frac{\partial G}{\partial \delta_t}(X) = -\frac{1}{2-\delta} + \frac{2-\delta}{(2-\delta)^2} = 0 = \frac{\partial G}{\partial \delta_{t-1}}(X);$$

Next:

$$\begin{aligned}\frac{\partial G}{\partial A_{t-1}} &= \frac{\theta^3 + (1-\delta)\theta^2}{2-\delta} - \frac{1}{2-\delta}(\theta^2 + (1-\delta)\theta) \\ &= (\theta-1)\theta\frac{\theta+1-\delta}{2-\delta} < 0.\end{aligned}$$

Then

$$\begin{aligned}\frac{\partial G}{\partial h_t} &= \sigma\frac{\theta+1-\delta}{2-\delta} > 0; \\ \frac{\partial G}{\partial h_{t-1}} &= \theta\frac{\partial G}{\partial h_t} - \frac{1}{2-\delta}\sigma(\theta+1-\delta) = (\theta-1)\frac{\partial G}{\partial h_t}.\end{aligned}$$

Therefore

$$g \simeq \beta_A(1-A) + \beta_h[h_t + (\theta-1)h_{t-1}]$$

where

$$\begin{aligned}\beta_A &= (\theta-1)\theta\frac{\theta+1-\delta}{2-\delta} < 0; \\ \beta_h &= \sigma\frac{\theta+1-\delta}{2-\delta}.\end{aligned}$$

This establishes the proposition.

B Figures

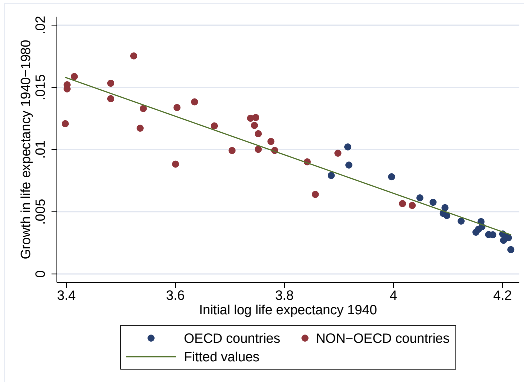

Figure 1: Convergence in Log Life Expectancy 1940-1980

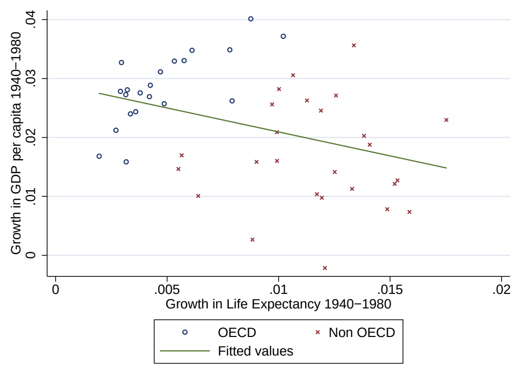

Figure 2: Growth in Log GDP per Capita and in Log Life Expectancy 1940-1980

Table 1 Descriptive Statistics

	Acemoglu-Johnson sample			Lorentzen-McMillan-Wacziarg sample		
	1940	1980	1940-1980	1960	2000	1960-2000
Developed countries						
GDP per capita	5 715	15 150	+ 9 435	7 820	22 802	+14 982
Life expectancy at birth	65.1	74.3	+9.2	68.3	77.5	+9.2
N	22	22	22	25	25	25
Developing countries						
GDP per capita	2 050	5 190	+3 140	2 033	4 315	+2 282
Life expectancy at birth	44.5	64.3	+19.8	47.6	59.9	+12.3
N	25	25	25	71	71	71

Table 2 – Nelson-Phelps versus Lucas Growth Regressions 1960-2000 – OLS Estimates

	Lorentzen-McMillan-Wacziarg results		Nelson-Phelps variant				Acemoglu-Johnson/Lucas approach		Combined approach	
	I	II	III	IV	V	VI	VII	VIII	IX	X
	Dependent Variable: Annual Growth in Log GDP per capita (in percentage points)									
Average adult mortality 1960-2000	-2.89*	-5.06***								
	(1.47)	(1.38)								
Average infant mortality 1960-2000	-11.61**	-20.85***								
	(4.54)	(4.55)								
Initial adult mortality 1960			-1.81	-4.12***						
			(1.53)	(1.51)						
Initial infant mortality 1960			-8.84***	-13.72***						
			(3.37)	(3.75)						
Initial log life expectancy 1960					3.42***	6.53***			4.15***	7.82***
					(0.48)	(0.87)			(0.49)	(0.93)
Growth in life expectancy 1960-2000							0.70	28.63	124.4***	154.25***
							(45.72)	(46.40)	(44.7)	(38.3)
Initial log GDP per capita 1960		-1.03***		-0.84***		-1.02***		0.40***		-1.14***
		(0.19)		(0.21)		(0.23)		(0.13)		(0.22)
R^2	0.40	0.57	0.27	0.37	0.31	0.44	0.00	0.06	0.37	0.54
N	94	94	94	94	96	96	96	96	96	96

note: robust standard errors; *** (respectively ** and *) represents significance at 1% (resp. 5% and 10%)

Table 3 – Impact of Life Expectancy on per capita GDP Growth 1940-1980 - OLS Estimates

	All Countries			Low & Middle Income Countries		
	Lucas	Nelson-Phelps	Both	Lucas	Nelson-Phelps	Both
	I	II	III	IV	V	VI
	Dependent Variable: Annual Growth in Log GDP per capita					
Growth in Log Life Expectancy	-0.81***		3.58***	-1.17***		3.15***
	(0.26)		(0.61)	(0.38)		(0.60)
Initial Log Life Expectancy		0.020***	0.075***		0.030***	0.075***
		(0.004)	(0.008)		(0.005)	(0.008)
N	47	47	47	36	36	36
R^2	0.13	0.31	0.56	0.16	0.41	0.61

note: robust standard errors; *** (respectively ** and *) represents significance at 1% (resp. 5% and 10%)

Table 4 - Impact of Life Expectancy on Income Growth - All Countries, IV Estimates

	1940-1980				1960-2000		
	Lucas	Nelson-Phelps	Both	Both	Lucas	Nelson-Phelps	Both
	I	II	III	IV	V	VI	VII
	Dependent Variable: Annual Growth in Log GDP per capita[1]						
Growth in Log Life Expectancy[2]	-1.35***		2.45	3.65***	0.25		1.42**
	(0.37)		(1.74)	(0.98)	(0.71)		(0.72)
Initial Log Life Expectancy[2]		0.033***	0.057**	0.076***		0.046***	0.044***
		(0.012)	(0.025)	(0.015)		(0.006)	(0.005)
N	46	46	46	45	90	90	90
R^2	0.08	0.19	0.54	0.52	0.00	0.26	0.35
Shea R^2 (Δ log LE)	0.49	-	0.20	0.66	0.52	-	0.56
Shea R^2 (log LE_0)	-	0.21	0.26	0.70	-	0.42	0.80
First-stage F-statistics (Δ log LE)	44.7	-	25.8	17.2	10.5	-	9.11
corresponding p-value	0.00	-	0.00	0.00	0.00	-	0.00
First-stage F-statistics (log LE0)	-	15.2	52.1	21.6	-	75.2	50.5
corresponding p-value	-	0.00	0.00	0.00	-	0.00	0.00
Hansen-J test p-value	-	-	-	0.44	0.00	-	0.24
Set of Instruments	AJ[3]	ME[4]	AJ[3]+ME[4]	AJ[3]+LMW[5]	LMW[5]	ME[4]	LMW[5]+ME[4]

note: all growth variables calculated as long differences. Robust standard errors.

[1]Taken from Maddison (2003) for 1940-1980 and from World Bank (2004) for 1960-2000

[2]Taken from Acemoglu-Johnson (2007) for 1940-1980 and from World Bank (2004) for 1960-2000

[3]Taken from Acemoglu-Johnson (2007)

[4]Malaria Ecology developed by Sachs et al. (2004)

[5]Sixteen climatic and geographical instruments taken from Lorentzen et al. (2008)

Table 5 – Health and Growth in OECD Countries 1940-1980

	OLS				IV estimates			
	Lucas	Nelson-Phelps		Both	Lucas	Nelson-Phelps		Both
	I	II	III	IV	V	VI	VII	VIII
	Dependent Variable: Annual Growth in Log GDP per capita							
Annual Growth in Log Life Expectancy	2.00***			5.58***	2.51***			6.99***
	(0.47)			(1.49)	(0.48)			(1.40)
Initial Log Life Expectancy		-0.037**	0.007	0.125***		-0.041**	-0.004	0.159**
		(0.015)	(0.021)	(0.032)		(0.016)	(0.026)	(0.029)
Initial Log GDP per capita			-0.011*	-0.011**			-0.008	-0.012**
			(0.005)	(0.004)			(0.006)	(0.005)
N	21	21	21	21	20	20	20	20
R^2	0.52	0.37	0.47	0.73	0.51	0.36	0.45	0.71
Shea R^2 (Δ log LE)	-	-	-	-	0.29	-	-	0.82
Shea R^2 (log LE_0)	-	-	-	-	-	0.80	0.53	0.65
First-stage F-statistics (Δ log LE)	-	-	-	-	4.73	-		3.52
corresponding p-value	-	-	-	-	0.04	-		0.05
First-stage F-statistics (log LE0)	-	-	-	-	-	26.62	54.49	12.01
corresponding p-value	-	-	-	-	-	0.00	0.00	0.00
Hansen-J test p-value	-	-	-	-	-	0.40	0.57	0.48
Set of Instruments	-	-	-	-	AJ[1]	LMW[2]	LMW[2]	AJ[1]+LMW[2]

note: all growth variables calculated as long differences. Robust standard errors.

[1]Taken from Acemoglu-Johnson (2007)

[2]Malaria Ecology index from Sachs et al. (2004) plus four climatic and five geographical instruments taken from Lorentzen et al. (2008)

Table 7 – GDP per capita and log life expectancy by age - OECD countries 1960-2000 (decennial time span)

	Pooled OLS					Panel Fixed-Effects				
	I	II	III	IV	V	VI	VII	VIII	IX	X
	Dependent variable: Log GDP per Capita									
Log of Life Expectancy at Birth	7.19***				10.72***	4.40***				8.57***
	(0.55)				(2.78)	(0.54)				(1.27)
Log of Life Expectancy at 40		4.84***			-2.77		2.45***			-1.63
		(0.92)			(4.70)		(0.72)			(0.50)
Log of Life Expectancy at 65			3.51***		-1.44			1.47***		-0.86
			(0.68)		(2.80)			(0.52)		(1.83)
Log of Life Expectancy at 80				2.73***	1.75**				0.54	-0.16
				(0.48)	(0.82)				(0.39)	(0.51)
Time Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed-effects	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
R^2	0.77	0.66	0.67	0.69	0.79	0.73	0.61	0.59	0.52	0.69
N	125	120	120	113	113	125	120	120	113	113
N countries	28	28	28	28	28	28	28	28	28	28

source: Life expectancy by age: OECD Health data (2008); GDP per capita: World Bank (2004)

Table 8 - GDP per capita and log life expectancy by age - OECD countries 1960-2000
SYS-GMM Estimates (decennial time span)

	SYS-GMM				
	I	II	III	IV	V
	Dependent variable: Growth in Log GDP per Capita				
Growth in Life Expectancy at Birth	2.88***				9.46**
	(1.08)				(4.41)
Growth in Life Expectancy at 40		3.62*			-5.37
		(1.88)			(8.02)
Growth in Life Expectancy at 60			2.02**		2.61
			(0.84)		(4.79)
Growth in Life Expectancy at 80				0.09	-0.78
				(0.55)	(0.68)
Time Dummies	Yes	Yes	Yes	Yes	Yes
Country fixed-effects	Yes	Yes	Yes	Yes	Yes
N	97	90	90	82	82
N countries	28	27	27	27	27
N instruments	13	13	13	13	13
Arellano-Bond 1st order correlation (p-value)	0.20	0.25	0.22	0.07	0.05
Arellano-Bond 2nd order correlation (p-value)	0.99	0.61	0.42	0.36	0.84
Hansen-J test	0.18	0.3	0.39	0.64	0.88

source: Life expectancy by age: OECD Health data (2008); GDP per capita: World Bank (2004)