Contribution of Increased Life Expectancy to Living Standards

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Abstract:
The paper assesses the contribution of increased life expectancy to living standards in the context of economic development. For today's industrialized countries, increased life expectancy has played a major part in raising living standards over the last century, although the contribution has slowed down after 1950. For developing countries cross-country data available from 1950, the slowdown in the contribution of health gains to living standards has occurred later, consistent with a delayed dissemination of health innovations. As a result of the adverse impact of HIV/AIDS, living standards in many African countries have fallen in recent years, with declines in life expectancy more than offsetting economic gains.

JEL classification numbers: I10, I30, I31, N37, O10

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I. Introduction

The paper analyzes and quantifies the contribution of changes in life expectancy to living standards in various settings, adopting a model in which agents are endowed with an intertemporal utility function, and expected lifetime utility depends on anticipated incomes and survival probabilities. In this framework, changes in life expectancy can be evaluated using income as a meter, by calculating the change in income that is equivalent – in terms of its impact on lifetime utility – to the change in life expectancy. This transformation enables an analysis of changes in living standards owing to changes in income and health. We apply the model in three different contexts, (1) updating earlier work on the contribution of increasing life expectancy to living standards in leading industrialized countries since 1870, (2) extending the analysis to essentially all countries globally from 1950, (3) and reviewing the impact of a major health shock (HIV/AIDS) in a number of countries.

Our analysis builds on a substantial body of literature on the value of statistical life[1] and applied work to assess the contribution of increased life expectancy to living standards. The analytical framework goes back to Schelling (1968), an informal analysis that established the principle that inferences regarding valuations of life can be made based on incremental changes in mortality risks, and the amounts individuals are prepared to pay or forfeit to avoid such risks. This concept has been formalized in microeconomic papers by Mishan (1971), Jones-Lee (1974), and Arthur (1981), using a framework in which lifetime utility derives from the expected utility of future consumption streams, discounted and weighted by survival probabilities.

More directly, our paper relates to studies using estimates of the value of statistical life in a macroeconomic context, in order to assess the contributions of increased life expectancy (as well as economic growth) to the growth of living standards. The earliest contributions in this direction were those by Usher (1973, 1980), the recent contributions most relevant in our context include Nordhaus (2003), Crafts (2007, 2005, and 1997), dealing with the role of increasing life expectancy during industrial development), and Murphy and Topel (2006). Bourguignon and Morrison (2002) and Becker, Philipson, and Soares (2005) have addressed aspects of the contribution of improved health to living standards in the post-WWII period across a broader set of countries. A spin-off from this literature has been motivated by the experience of increased mortality owing to HIV/AIDS in many countries, the most comprehensive studies in this direction are Crafts and Haacker (2003, 2004) and Philipson and Soares (2005).

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[1] The "value of statistical life" extrapolates valuations of incremental changes in mortality to an estimate of the implied valuation of life. For example, if an increment in mortality of 0.2 percent is associated with a salary that is US$10,000 higher than the salary for an otherwise equivalent employment, the value of statistical life is $500,000.

Against this background, the present paper adds value in several areas. First, it argues that some approaches to studying the contribution of life expectancy to living standards are not well-suited for studying large changes in life expectancy, or assessing changes in life expectancy across countries with large differences in income per capita, and proposes a method that is more robust in this regard. Second, we provide comprehensive estimates of the roles of economic growth and increased life expectancy across a large number of countries. (This partly updates earlier work, but also adds to it in terms of scope and in light of the noted methodological differences.) Third, we provide the most comprehensive analysis of the impact of HIV/AIDS – a major health shock that has resulted in substantial declines in life expectancy in a number of countries – on living standards available so far (as far as the literature drawing on the value of statistical life is concerned), including a discussion of the consequences of the scaling-up of antiretroviral treatment.

Section 2 introduces our theoretical framework, and motivates our choice of parameters for the intertemporal utility function. Section 3 discusses the contribution of increased life expectancy in 17 industrialized countries in 1870-2006, and for a larger group of 136 countries for the 1950-2006 period. Section 4 analyzes the adverse impacts of HIV/AIDS across countries. Section 5 concludes.

II. Theoretical Framework and Choice of Parameters

We first describe the analytical framework and the functional form of the model adopted in our analysis. Second, we populate the parameters of the model, drawing on the on the empirical literature estimating the value of statistical life and other approaches. Third, we show how to apply the model to studying the contribution of changes in life expectancy to living standards.

Analytical Framework

Our analytical framework derives from a straightforward microeconomic model of consumption, in which an individual values consumption and life expectancy according to the lifetime utility function

$$U[\{c_t\},\{\mu_{s,t}\},\rho,s]=\int_s^{\infty} u(c_t)e^{-\int_s^t(\rho+\mu_{s,v})dv}dt\,, \tag{1}$$

where $\{c_t\}$ denotes the individual's consumption stream over time, *s* stands for the individual's initial age, $\{\mu_{s,t}\}$ is the set of time-varying mortality rates of an individual with initial age *s* at time *t*, with $t\in[s,\infty)$, ρ gives the discount rate, and $u(...)$ has the usual properties, with $u'(...)>0$ and $u''(...)<0$.

The individual's budget constraint is

$$\int_s^\infty c_t e^{-\int_s^t r_v dv} dt = \int_s^\infty y_t e^{-\int_s^t r_v dv} dt = \int_s^\infty y^* e^{-\int_s^t r_v dv} dt\,, \tag{2}$$

where y_t stands for the individual's income at time *t*, r_t is the real interest rate at time *t*, and y^* is the constant income stream that yields the same present discounted value as the (possibly time-varying) income stream $\{y_t\}$. Let $\{c_t^*\}$ be the consumption stream that maximizes (1), subject to (2), and $V = U[\{c_t^*\},\{\mu_{s,t}\},\rho,s]$. The solution to the optimization problem implies a link between V and *y**, say, $\frac{dV}{dy^*} = \lambda$, derived from the Lagrange multiplier associated with the lifetime budget constraint. The incremental change in y^* that would have the same effect on V as an incremental change in the mortality pattern $\{\mu_{s,t}\}$ then is equal to

$$dy^* = \frac{-1}{\lambda}\int_s^\infty u(c_t^*)\int_s^t d\mu_{s,v} dv\, e^{-\int_s^t (\rho+\mu_{s,v})dv} dt\,.^2 \tag{3}$$

In the macroeconomic literature on the contribution of changes in life expectancy to living standards, it is customary to impose several restrictions on the framework outlined above. First, instead of considering trajectories $\{c_t^*\}$, it is assumed that lifetime utility can be described in terms of a "permanent" consumption level c^*. Eq. (1) then reduces to

$$V(\{\mu_{s,t}\},c^*,\rho,s) = u(c^*)\int_s^\infty e^{-\int_s^t (\rho+\mu_{s,v})dv} dt\,, \tag{4}$$

where the first term on the right-hand side in Eq. (4) represents the utility flow. The integral in Eq. (4) represents life expectancy (discounted by the rate of time preference, and equal to actual life expectancy in the special case of $\rho = 0$), which we will denote as *LE*. Eq. (4) can therefore be rearranged as

$$V(\{\mu_{s,t}\},c^*,\rho,s) = u(c^*)LE(\{\mu_{s,t}\},\rho,s)\,, \tag{5}$$

[2] To obtain Eq. (3), we utilize the envelope theorem.

$$\text{with} \quad LE(\{\mu_{s,t}\},\rho,s)=\int_s^{\infty} e^{-\int_s^t(\rho+\mu_{s,v})dv}dt\,, \tag{6}$$

i.e., lifetime utility is represented as the utility flow from permanent income (or the consumption level consistent with it), multiplied by (discounted) life expectancy.

This restriction implies that the analysis misses out on some of the subtleties of the intertemporal allocation of consumption, and interactions between changes in mortality profiles and consumption patterns. However, our analysis covers a large number of countries for which only limited demographic and economic data are available, which does not support a more sophisticated approach. As we use GDP per capita as proxy for c^*, it should be noted that we (crudely) capture the most important link between income, life expectancy, and consumption – as incomes are spread over a longer time span, they translate into a lower level of c^* for given income. This is reflected in GDP per capita as it represents an average across the population (including those too old or too young to generate income).

The second type of restrictions we impose regards the structure of preferences. A functional form that will turn out convenient in terms of identifying the value of statistical life based on model parameters (and model parameters based on empirical evidence on the value of statistical life) is the one adopted by Murphy and Topel (2006), which is also sufficiently general to encompass different specifications adopted in studies by Crafts and Haacker (2003, 2004), Philipson and Soares (2005), and Crafts (1997). In this framework, the utility flow from consumption is determined by

$$u(c)=\frac{c^{1-\frac{1}{\sigma}}-c_o^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}}, \tag{7}$$

where c_0 presents a level of extreme poverty below which the utility flow from consumption c becomes negative, and $\sigma=-\frac{u'(c)}{cu''(c)}$, the elasticity of substitution, is assumed constant. For reasons that will become apparent further below, we transform the utility function, using

$$u(c)=c^{\frac{1}{\gamma}}-c_o^{\frac{1}{\gamma}}, \tag{8}$$

which, apart from a linear transformation, is identical to the Murphy and Topel (2006) specification, with $\gamma=\frac{\sigma}{\sigma-1}$.

The framework above is sufficient to estimate the contribution of growing consumption and life expectancy to living standards. It is, however, useful, to transform the model to use consumption rather than utility as a meter for improving living standards (this will allow us to directly assess the contribution of health improvements, alongside with economic growth, to living standards). To this end, it is necessary to express the gains or costs associated with changes in mortality patterns and life expectancy in terms of equivalent changes in consumption. Using Eq. (8) to substitute for $u(c^*)$ in Eq. (5), and differentiate, we obtain

$$dV = \frac{1}{\gamma}(c^*)^{\frac{1}{\gamma}-1} LEdc^* + \left((c^*)^{\frac{1}{\gamma}} - c_o^{\frac{1}{\gamma}} \right) dLE\,. \tag{9}$$

Setting *dV* equal to zero in Eq. (9), and solving for *dc**, first yields the *compensating* variation in income as

$$\left.\frac{dc^*}{c^*}\right|_{dV=0} = -\gamma \frac{(c^*)^{\frac{1}{\gamma}} - c_o^{\frac{1}{\gamma}}}{(c^*)^{\frac{1}{\gamma}}} \frac{dLE}{LE}\,. \tag{10}$$

The variation in consumption that is *equivalent* to a change in life expectancy is then obtained by reversing the sign on the right-hand side in Eq. (10), i.e.

$$\left.\frac{dc^*}{c^*}\right|_{EQU} = \gamma \frac{(c^*)^{\frac{1}{\gamma}} - c_o^{\frac{1}{\gamma}}}{(c^*)^{\frac{1}{\gamma}}} \frac{dLE}{LE}\,. \tag{11}$$

In Eq. (11), the multiplier that determines the percentage change in income equivalent to some percentage change in life expectancy consists of two parts – the parameter γ and a term that depends on the level of income relative to income level c_0. Specifically, for large levels of c^* (relative to c_0), or very low levels of c_0, the multiplier approaches γ, whereas it declines to zero (or below zero) as c^* approaches (or falls below) c_0.

It is useful to link Eq. (11) to the concept of the value of statistical life, to benefit from the empirical evidence in this regard. Most of this literature interprets the value of statistical life as the incremental change in income that compensates for an incremental change in mortality (normalized in terms of the valuation of one statistical death).

To integrate mortality in our analysis, we define average mortality μ as the constant level of mortality that corresponds to the same level of life expectancy as the time-variant mortality profile $\{\mu_t\}$. This is related to life expectancy through

$$LE = \int_0^\infty e^{-\mu t} dt = \frac{1}{\mu}, \tag{12}$$

i.e., the average mortality rate is equal to the inverse of life expectancy. Substituting for life expectancy in Eq. (11) gives the compensating variation in income as

$$\frac{dc^*}{c^*} = \gamma \frac{(c^*)^{\frac{1}{\gamma}} - c_o^{\frac{1}{\gamma}}}{(c^*)^{\frac{1}{\gamma}}} \frac{d\mu}{\mu}, \tag{13}$$

$$dc^* = \left[\gamma \frac{(c^*)^{\frac{1}{\gamma}} - c_o^{\frac{1}{\gamma}}}{(c^*)^{\frac{1}{\gamma}}} LE \cdot c^* \right] d\mu . \tag{14}$$

From Eq. (14) and the definition of the value of statistical life, denoted below as *VSL*, it follows that

$$VSL = \gamma \frac{(c^*)^{\frac{1}{\gamma}} - c_o^{\frac{1}{\gamma}}}{(c^*)^{\frac{1}{\gamma}}} LE \cdot c^*, \tag{15}$$

i.e., the value of statistical life is equal to the product of a term reflecting the shape of the utility function and expected lifetime consumption $LE \cdot c^*$. Starting from estimates of the value of statistical life, and making allowances for the sample levels of income and remaining life expectancy, it is therefore possible to draw inferences regarding the structure of preferences.

Choice of Parameters

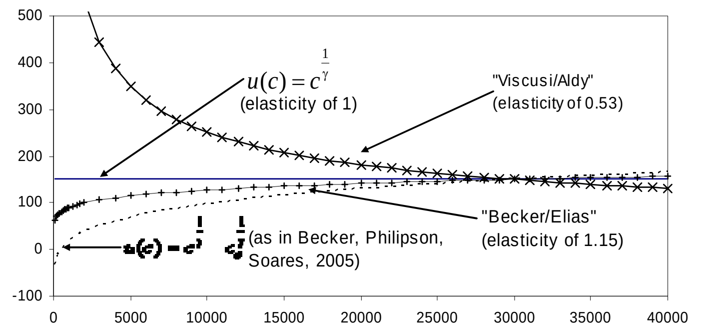
The principal challenge in finding an appropriate functional form and parameters arises from the fact that we wish to apply our analysis to the study of changes in life expectancy over long periods of time (back to 1870 or 1950, depending on the context) and a large number of countries, including low-income countries, whereas the empirical evidence on the value of statistical life largely comes from high-income countries, covering the last few decades. Thus, in drawing on the available evidence, we encounter problems similar to those associated with out-of-sample projections in an econometric context.

It is useful to distinguish three approaches to estimating or calibrating the value of statistical life across countries. First, a number of empirical “meta analyses” relate available estimates of the value of statistical life from individual studies to a range of explanatory variables. An early attempt in this direction was Miller (2000), finding an elasticity of the value of statistical life with respect to GDP per capita (or GNP per capita) close to one (estimates range from 0.85 to 1.0 across specifications). Bowland and Beghin (2001), however, estimate elasticities between 1.5 and 2.3. Viscusi and Aldy (2003), assembling the most comprehensive dataset and survey of the literature to date, estimate the elasticity at 0.5-0.6. However, Becker and Elias (2007) observed that the estimates by Viscusi and Aldy (2003) critically depend on three related observations from one low-income country. When these are excluded from the sample, Becker and Elias (2007) estimate the elasticity of the value of statistical life with respect to income at 1.15.

The second approach is associated Murphy and Topel (2006), who adopt a specification of the form $u(c^*) = (c^*)^{\frac{1}{\gamma}} - c_o^{\frac{1}{\gamma}}$ (see also Eqs. (7) and (8)). The income level below which utility turns negative, c_0, depends on the economic and social context; for their analysis of the contributions of improved health standards to living standards over time, Murphy and Topel (2006) scale it in line with GDP per capita, so that the value of statistical life across the population – for a given distribution of income – is proportional to GDP per capita. Becker, Philipson, and Soares (2005), and Philipson and Soares (2005), use the same functional specification as Murphy and Topel (2006), but assume that the utility function is the same across countries irrespectively of the level of GDP per capita over time or across countries, with a level of c_0 of US$353 in 1996 U.S. dollars (sourced from Penn World Tables 6.1).

A third approach is used by Crafts (1997), and Crafts and Haacker (2003, 2004), as well as in earlier work by Usher (1973, 1980). For the analysis of changes in living standards over long periods of time (Crafts, 1997) or across countries with large differences in income levels, they specify the value of statistical life as proportional to income, which would correspond to setting c_0 equal to zero in Eqs. (7) and (8).

Figure 1. Value of Statistical Life for Different Specifications and Income Levels
(Multiples of GDP per capita)



Source: Author's calculations. Elasticity refers to elasticity of VSL with respect to GDP per capita.

To illustrate the implications of adopting the different approaches, Figure 1 illustrates the value of statistical life according to different specifications. To facilitate comparisons, we use a value of statistical life of 150 times GDP per capita for a level of GDP per capita of US$30,000 as an anchor, reflecting that the bulk of evidence comes from high-income countries.[3]

[3] In the dataset assembled by Viscusi and Aldy (2003), 31 observations were from the United States. Of the 21 studies from outside the United States, only 5 were from countries with a level of GDP per capita below US$10,000 (including the three observations from India that were identified as problematic by Becker and Elias (2007).

Figure 1 shows that the different specifications used in the literature differ radically regarding the value of statistical life in low- and middle-income countries (applying PPP exchange rates and 2005 prices, low-income countries broadly populate the range between US$500 and US$2,000, and middle-income countries the bracket between US$2,000 and US$20,000). The horizontal line represents a model in which the elasticity of the VSL is equal to one, i.e., the VSL is proportional to GDP per capita. The curves labeled "Becker/Elias" and "Aldy/Viscusi" illustrate the implications of adopting different elasticities. For an elasticity of the VSL with respect to GDP per capita of 1.15 (as estimated by Becker and Elias, 2007), the VSL is 100 times GDP per capita at GDP per capita of US$2,000, and 81 times GDP per capita at GDP per capita of US$500 (corresponding to one of the poorest countries worldwide). For the elasticity of 0.53 (as estimated by Viscusi and Aldy, 2003),[4] the corresponding values are 536 times GDP per capita (of US$2,000) and 1028 times GDP per capita (of US$500).

Regarding the specification adopted by Becker, Philipson, and Soares (2005),[5] we find that the VSL (relative to GDP per capita) is fairly constant across high-income countries, but that it drops off steeply across middle-income countries (between 40 and 120 times GDP per capita) and especially for low-income countries (between 0 and 40 times GDP per capita). These radical assumptions are puzzling, especially as they are apparently not motivated by any evidence from low-income countries, but based on econometric evidence solely from the United States.[6]

In light of the discussion above, we adopt a specification with an income elasticity of 1, in line with earlier work by Usher (1973, 1980), Crafts (1997), Crafts and Haacker (2004),

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[4] The specification by Viscusi and Aldy also includes other variables, which we do not capture and which might be correlated with GDP per capita.

[5] For our presentation in Figure 1, we normalized the specification by Becker, Philipson, and Soares (2005) so that the curves intersect at a level of GDP per capita of US$30,000. We also set the value of GDP per capita at which the VSL equals zero at US$500 (about the lowest level of GDP per capita in our sample, at 2005 prices) rather than US$353 (in 1996 dollars, terms-of-trade adjusted, from Penn World Tables 6.1), about the lowest level in their sample. The curvature of the utility function in Figure 1 is consistent with Becker, Philipson, and Soares (2005).

[6] Another problematic aspect of the specification adopted by Becker, Philipson, and Soares (2005) is the implication that a large number of people in low-income countries obtain negative utility from being alive. Although the mapping between the different data sources is difficult, it appears that the value of US$353 (in 1996 dollars, terms-of-trade adjusted, from Penn World Tables 6.1) below which utility turns negative is close to the $1-a-day poverty line (in 2005 dollars, at PPP) used in Chen and Ravallion (2008), who estimate that 39 percent of the population of Africa were living at or below that income level. The Becker, Philipson, and Soares (2005) proposition of negative utility from being alive below a certain income level also appears inconsistent with evidence on well-being from low-income countries, see Deaton (2006).

and Murphy and Topel (2006).[7] This reflects that our analysis covers a large number of countries, including low-income countries. Assuming a value of the elasticity substantially different from one would imply that health-income tradeoffs are radically different in low-income countries as compared with high-income countries, and we do not see a basis to support this assumption. Choosing between a value of the elasticity in the close vicinity of one or equal to one, we adopt the latter, as it yields a particularly straightforward interpretation of the VSL and the contribution of increasing life expectancy to living standards.

For c_0 equal to zero (i.e., an elasticity of the VSL with respect to income of 1), Eqs. (15) becomes

$$VSL = \gamma LE \cdot c^*, \qquad (16)$$

or, equivalently,

$$\gamma = \frac{VSL}{LE \cdot c^*}, \qquad (17)$$

providing a straightforward mapping between estimates of the VSL and the parameter γ.

This, however, requires that remaining life expectancy and the level of permanent consumption are known, which is problematic in case of the employment-based estimates of the value of statistical life. For this reason, we adopt as an anchor the value of statistical life of US$ 6.9 million reportedly used by the U.S. Environmental Protection Agency for policy analyses in 2008 (Borenstein, 2008). This relates to a level of GDP per capita (US$ 43,541 (IMF, 2008), which we use as measure of permanent consumption c^*, and an average remaining life expectancy across the U.S. Population of about 44 years.[8] The value of statistical life thus corresponds to 158 times GDP per capita. Dividing by average remaining life expectancy yields an estimate of the parameter γ of 3.6.

Parameterizing our model based on actual life expectancy, in light of Eq. (6), implies setting the discount rate for lifetime utility to zero, whereas other studies apply a positive discount rate. This reflects the fact that our analysis is based on data on actual life expectancy, which cannot be transformed into discounted life expectancy without additional

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[7] There is a slight difference to the approach by Murphy and Topel (2005). They adopt a positive value c_0, but scale it in line with average income per capita. Thus, in their framework, changes in the income distribution (but not the average level of income) have implications that our simpler model does not capture.

[8] The remaining life expectancy was calculated by the author based on projections of the U.S. population by age for 2008 from United States Bureau of Census, Population Division (2008) and estimates of life expectancy by age for the 2005-2010 period from United Nations Population Division (2009b). The latter have not been adjusted, as 2008 is close to the midpoint of the 2005-2010 period.

data (survival curves) or assumptions. However, owing to the way in which we determine the parameter γ, our estimates of the contributions of increasing life expectancy to living standards are robust to the choice of the discount rate.[9] A shortcoming that remains is that we cannot adequately distinguish the consequences of increases in infant or child mortality on one hand (where discount

Among earlier studies, Nordhaus (2003) adopts a similar approach, using a value of statistical life of US$3 million (129 times GDP per capita),[10] based on 1990 income and prices, based on the VSL used in policy evaluations by the U.S. government. Using working men at age 40 as a benchmark (as most empirical studies of the value of statistical life are based on working-age men), and assuming a remaining life expectancy of 40 years,[11] this implies a value of the parameter γ of 3.2.[12] Using more precise estimates of remaining life expectancy for males at age 40 (35.1 years, according to NCHS (1997)) would result in a estimate of the parameter γ of 3.7. As the value of statistical life adopted by Nordhaus is derived from a value adopted by U.S. agencies for policy evaluations, the average remaining life expectancy for the total U.S. population (43.8 years in 1990, according to data from United States Bureau of Census (1992) and NCHS (1997)), which would translate into a value for the parameter γ of 3.0.

Another important source of data are the studies of the value of statistical life compiled and analyzed by Viscusi and Aldy (2003), including 28 studies for the United States and 22 studies from other countries for which sufficient summary data are available for our purposes. For the United States, the median value of statistical life (across studies, relative to the average income for the respective sample) is 234, for other countries it is 287, and for the combined dataset, the median value of statistical life is 257 times sample income. Finding an appropriate value for the remaining life expectancy for the Viscusi/Aldy (2003) dataset is difficult, as the estimates of the value of statistical life relate to different years (and

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[9] Adopting a positive discount rate would imply that remaining (discounted) life expectancy is lower than the 44 years used in our calibration, and the parameter γ would be correspondingly larger. As increments to life expectancy would also be discounted (and thus be smaller than changes in actual life expectancy), so that estimates of the contribution of increments in life expectancy to living standards come out similarly. However, assumptions about discounting matter if declines in mortality are concentrated among the young in some countries, and the old in others. This is a problem common to all studies based on deterministic life expectancy (the present one, also Becker, Philippson and Soares (2005)). An example for a study based on survival curves – which can address this problem – is Crafts and Haacker (2003, 2004), using data available only for a fraction of the period under consideration in the present paper.

[10] Author's calculation, based on a value of $23,208 for U.S. GDP per capita in 1990 from IMF (2009).

[11] More precisely, he uses an average mortality rate of 0.025, the remaining life expectancy is obtained as the inverse of this number.

[12] Author's calculation, as Nordhaus uses a different specification.

countries). If a value of remaining life expectancy of around 40 is assumed, then a value of statistical life of 257 times sample income would imply a parameter γ of about 6.4. While our choice for the value statistical life (158 times GDP per capita) is lower than the median for these studies, it is well within the range spanned by them, with 8 studies for the U.S. and 6 studies from other countries returning lower values.

An alternative source of evidence on the value of statistical life are empirical studies targeting parameters of the utility function in econometric studies, either on a microeconomic or macroeconomic level. Browning, Hansen, and Heckman (1999) concludes that the elasticity of substitution is "a bit" larger than 1 (see our discussion of the parameter σ in Eq. (7)). This would be consistent with estimates of the value of statistical life as those suggested by the discussion above. However, Murphy and Topel (2006) also point at evidence from macro-econometric studies suggesting a lower level of σ, which cannot easily be reconciled with our framework with $c_0 = 0$, but is less problematic in Murphy and Topel's framework. Becker, Philipson, and Soares (2005) adopt a value of γ of 5 and a positive value of the parameter c_0, which would imply a VSL of 192 times GDP per capita for the United States (assuming a remaining life expectancy of 44 years).

For our macroeconomic approach, it is important to be explicit about aggregation issues. We measure the impact of HIV/AIDS on living standards through its impact on life expectancy at birth. Some of the theoretical and applied literature (e.g., Arthur (1981), Rosen (1988), Cutler and Richardson (1998, 1999), and Murphy and Topel (2006)) emphasizes the age-dependence of the value of statistical life – the shorter the remaining life span, the lower the utility derived from it. Some researchers (e.g., Crafts and Haacker (2004), or Philipson and Soares (2005)) therefore base their estimates of the impacts of HIV/AIDS on living standards on suitably weighted population averages, with Crafts and Haacker (2004) assigning equal weights across individuals, and Philipson and Soares (2005) deriving the weights from the remaining lifetime utility of each individual. Our focus on life expectancy at birth reflects two considerations. First, we deal with some weak data environments, and life expectancy at birth is one of the most commonly available indicators of the state of health across countries. Second, the composition of the population also reflects other demographic factors (notably birth rates), whereas our primary interest is the analysis of the consequences of declining mortality.

Contribution of Changes in Life Expectancy to Living Standards

With $c_0 = 0$, it follows from Eq. (9) that

$$V = (c^*)^{\frac{1}{\gamma}} LE , \tag{18}$$

which implies that the growth of living standards is equal to $\frac{1}{\gamma}$ times the growth rate of consumption, plus the growth rate of life expectancy. As we would like to connect to available estimates of economic growth, it is useful to apply a monotonous transformation. Raising both sides of Eq. (18) to the power of γ, we obtain a measure $\bar{V} = V^{\gamma}$ of living standards that is linear in (y^*), i.e.,

$$\bar{V} = (c^*)LE^{\gamma}. \tag{19}$$

The contributions of growth of income and of life expectancy to living standards can then be represented as

$$\frac{d\bar{V}}{\bar{V}} = \frac{dc^*}{c^*} + \gamma\frac{dLE}{LE}, \tag{20}$$

i.e., the rate of growth of living standards is equal to the rate of growth of consumption, plus the growth rate of life expectancy, weighted by parameter γ.

As most applications are based on data describing discrete (and sometimes large) changes in the underlying variables, it is useful to show under which circumstances the framework based on incremental changes $dc*$ and dLE may be applied to discrete data, without introducing significant bias. From Eq. (18), it follows that

$$\frac{\Delta\bar{V}}{\bar{V}} = \left[1+\frac{\Delta c^*}{c^*}\right]\left[1+\frac{\Delta LE}{LE}\right]^{\gamma} - 1. \tag{21}$$

By Taylor expansion, the term involving LE can be represented as

$$\left[1+\frac{\Delta LE}{LE}\right]^{\gamma} = 1+\gamma\frac{\Delta LE}{LE} + \gamma(\gamma-1)\left[\frac{\Delta LE}{LE}\right]^{2} + higher\ order\ terms, \tag{22}$$

so that discrete changes can be approximated by

$$\frac{\Delta\bar{V}}{\bar{V}} = \frac{\Delta c^*}{c^*} + \gamma\frac{\Delta LE}{LE}, \tag{23}$$

provided that the cross term $\frac{\Delta c^*}{c^*}\frac{\Delta LE}{LE}$, and the higher-order terms involving $\frac{\Delta LE}{LE}$ are small. For larger changes in the underlying variables, it would be possible to calculate the changes in living standards explicitly as the change in the value of $\bar{V} = (c^*)LE^{\gamma}$, although it would then not be possible to clearly attribute the overall change to either (c^*) or LE.

One important application of our approach regards settings in which the principal area of interest are the implications for living standards of certain health events or interventions, for example the benefits of a health investment under consideration or – an area which we will discuss in some detail below – the welfare implications of increased mortality owing to a major epidemic like HIV/AIDS. In these cases, our framework yields a simple way of deriving the welfare costs exactly (conditional on our framework and parameters applied) as

$$\left.\frac{\Delta\overline{V}}{\overline{V}}\right|_{y^*=const.} = \left[1+\frac{\Delta LE}{LE}\right]^{\gamma} - 1. \qquad (24)$$

One important advantage of the approach to estimating the contributions of changes in GDP per capita and life expectancy summarized in Eqs. (20), (23) and (24) is robustness when applied over large changes in GDP per capita or life expectancy, which is an advantage compared to linearized models (e.g., Nordhaus (2003), Crafts (2001), Cutler and Richardson (1999). From Eq. (18) or (19), the variation in consumption that is equivalent to a change in mortality μ or life expectancy LE is

$$dc^* = -\left[\frac{\gamma c^*}{\mu}\right] d\mu \text{ or} \qquad (25)$$

$$dc^* = \left[\frac{\gamma c^*}{LE}\right] dLE\,. \qquad (26)$$

The terms inside the squared brackets do not remain constant as life expectancy, mortality rates, or the level of consumption change. A linearized approach assuming constancy of the terms inside the square brackets in Eqs. (25) and (26) therefore produces biased estimates, but does not offer advantages in terms of simplifying the analysis.

III. Contribution of Increased Life Expectancy to Living Standards

Our model provides a framework for analyzing the contributions of increasing life expectancy to living standards over time and across countries. We first apply this to study the contribution of increased life expectancy to living standards since 1870 for a group of industrialized countries, and then extend the analysis to a larger set of 136 countries for a shorter period (from 1950).

The study that is, in terms of scope and methodology, closest to the framework adopted in the present paper, is Crafts (1997), which applies a reduced form similar to Eq. (23), covering 16 countries for the years 1870-1992.[13] Other notable studies covering long periods of time are Nordhaus (2003), covering the years 1990-95 for the United States, attributing a monetary value to a life year gained (or, in an alternative approach, to an increment in mortality), and Crafts (2005, 2007), which applies an approach similar to Nordhaus's to the United Kingdom for the years 1870-2001. Becker and others (2005) cover 96 countries over the period 1960-2000, focusing on the role of health improvements in the evolution of world inequality.

Table 1 reports our findings regarding the implications of growth in GDP per capita and in life expectancy for living standards for a set of 17 countries, based on Eq. (23) and source data summarized in Appendix Tables 1 and 2. It builds on (and partly replicates) the analysis by Crafts (1997), extending the final period to 2007 and increasing the country coverage by one. However, the weight of changes in life expectancy (parameter γ) underlying the estimates in Table 1 has been updated in line with our discussion above.

The estimates summarized in Table 1 illustrate the crucial role of both increases in GDP per capita and in life expectancy in increasing living standards since 1870. Over the entire period, the contributions of growth in GDP per capita and life expectancy (both at 1.8 percentage points) were roughly even.[14] Over time, however, the relative contributions of growth in GDP per capita and in life expectancy, respectively, have changed. Until about 1950, the most important source of improvements in living standards were improvements in longevity, especially over the years 1913-1950, where it contributed 3.0 percentage points to an annual rate of growth of living standards of 4.1 percent.[15] The relative roles of GDP growth and improvements in public health in raising standards were reversed in the second half of the 20th century, when improvements in life expectancy slowed down, contributing only about 1 percentage point to the growth of living standards, while GDP growth accelerated, notably between 1950 and 1973.

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[13] Crafts (1997) also considers the impact of changes in hours worked (imputing a value of leisure), an issue that is beyond the scope of our study. As data on hours worked were unavailable for Spain, his summary tables (unlike ours) exclude Spain.

[14] Based on unweighted averages of GDP per capita and life expectancy (Appendix Tables 1 and 2).

[15] Acemoglu and Johnson (2007) discuss innovations in public health from a macroeconomic perspective. Deaton (2006) provides a more extensive discussion of convergence and divergence of health and income indicators.

Table 1. Contributions of GDP per Capita and Life Expectancy to Living Standards, 17 Countries, 1870-2007

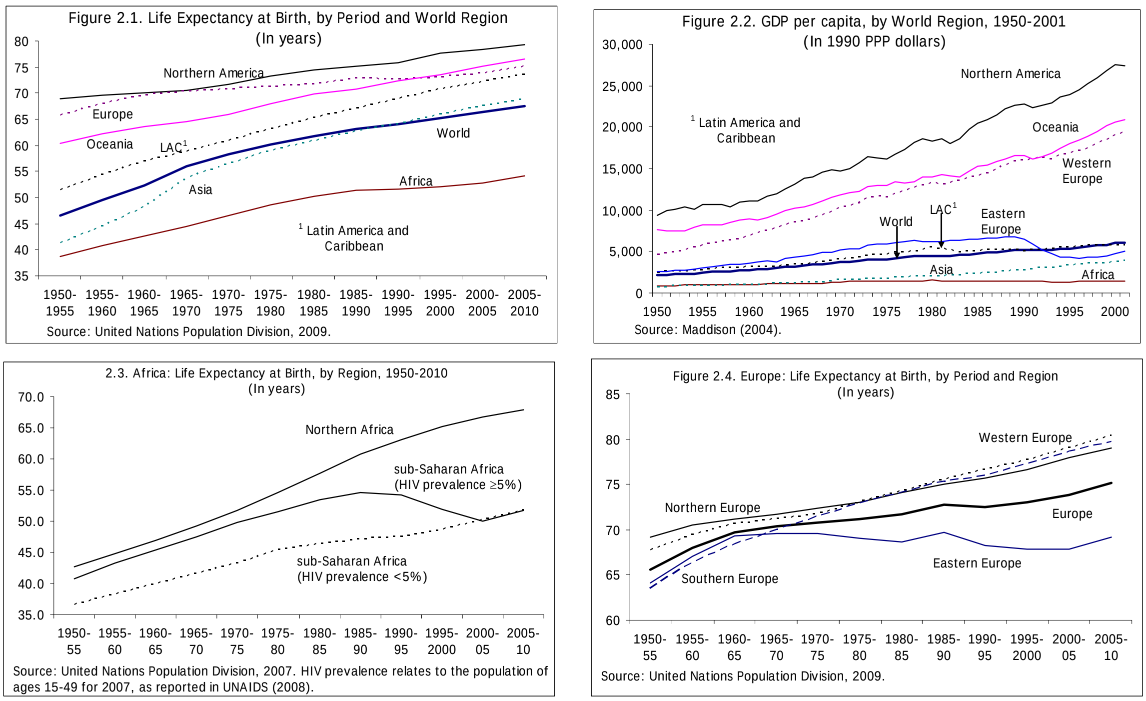
	1870-1913				1913-1950			
	GDP per capita	Life Expectancy	Life Expectancy	Living standards	GDP per capita	Life Expectancy	Life Expectancy	Living standards
	(Rate of growth)	(Rate of growth)	(Contribution to growth in living standards)	(Rate of growth)	(Rate of growth)	(Rate of growth)	(Contribution to growth in living standards)	(Rate of growth)
Australia	1.1	0.5	1.8	2.8	1.0	0.4	1.6	2.6
Austria	1.5	0.7	2.5	3.9	0.2	1.2	4.4	4.6
Belgium	1.1	0.5	1.8	2.9	0.7	0.8	3.1	3.8
Canada	2.3	0.5	1.8	4.1	1.3	0.7	2.7	4.1
Denmark	1.6	0.6	2.0	3.6	1.6	0.6	2.1	3.6
Finland	1.4	0.5	2.0	3.5	1.9	1.0	3.6	5.5
France	1.5	0.4	1.6	3.0	1.1	0.8	2.8	3.9
Germany	1.6	0.7	2.6	4.2	0.2	0.9	3.2	3.4
Italy	1.3	1.2	4.5	5.8	0.8	0.9	3.3	4.2
Japan	1.5	0.4	1.6	3.0	0.9	1.0	3.7	4.5
Netherlands	0.9	0.9	3.1	4.0	1.1	0.7	2.5	3.6
Norway	1.3	0.3	1.3	2.6	2.1	0.7	2.4	4.5
Spain	1.2	0.5	1.8	3.1	0.2	1.2	4.2	4.4
Sweden	1.5	0.5	1.9	3.3	2.1	0.6	2.3	4.4
Switzerland	1.7	0.6	2.1	3.7	2.1	0.8	2.8	4.9
United Kingdom	1.0	0.6	2.2	3.2	0.9	0.7	2.6	3.5
United States	1.8	0.4	1.4	3.2	1.6	0.8	2.9	4.5
Average	1.4	0.6	2.1	3.5	1.2	0.8	3.0	4.1

	1950-1973				1973-2007			
	GDP per capita	Life Expectancy	Life Expectancy	Living standards	GDP per capita	Life Expectancy	Life Expectancy	Living standards
	(Rate of growth)	(Rate of growth)	(Contribution to growth in living standards)	(Rate of growth)	(Rate of growth)	(Rate of growth)	(Contribution to growth in living standards)	(Rate of growth)
Australia	2.4	0.1	0.5	2.9	2.0	0.4	1.4	3.4
Austria	4.9	0.3	1.1	6.1	2.1	0.4	1.4	3.5
Belgium	3.5	0.2	0.9	4.4	1.9	0.4	1.3	3.2
Canada	2.8	0.2	0.9	3.7	1.8	0.3	1.1	2.9
Denmark	3.1	0.2	0.6	3.7	1.8	0.2	0.7	2.5
Finland	4.3	0.3	1.0	5.3	2.4	0.3	1.3	3.7
France	4.0	0.4	1.4	5.4	1.7	0.3	1.2	2.9
Germany	5.0	0.2	0.7	5.7	1.6	0.4	1.4	2.9
Italy	4.9	0.4	1.4	6.4	1.8	0.4	1.3	3.2
Japan	8.1	0.6	2.2	10.2	2.1	0.4	1.3	3.5
Netherlands	3.5	0.1	0.4	3.9	1.8	0.2	0.9	2.7
Norway	3.2	0.1	0.4	3.6	2.7	0.2	0.9	3.6
Spain	5.6	0.6	2.1	7.7	2.5	0.3	1.2	3.7
Sweden	3.1	0.2	0.6	3.7	1.8	0.2	0.9	2.7
Switzerland	3.1	0.3	1.0	4.1	0.8	0.3	1.1	2.0
United Kingdom	2.4	0.2	0.6	3.1	2.0	0.3	1.1	3.0
United States	2.5	0.1	0.5	3.0	1.9	0.3	1.0	2.9
Average	3.9	0.3	1.0	4.9	1.9	0.3	1.1	3.1

Source: Author's calculations. For data sources, see Appendix Tables 1 and 2. Averages are weighted by population size.

The contribution of GDP growth to living standards appears to be more variable than the contribution of increased life expectancy, with standard deviation of 1.4 and 1.0, respectively (across countries and periods). The impact of conflict-related disruptions is apparent in the data on GDP per capita (low growth in Austria, Germany, and Spain, 1913-1950). Another notable outlier is the period of rapid growth in Japan between 1950 and 1973, when GDP per capita grew six-fold, or at a yearly rate of just over 8 percent (also partly reflecting preceding conflict-related disruptions). Meanwhile, the growth of life expectancy does not show outliers of a similar magnitude as those observed for growth rates GDP per capita, which may reflect the prominent role of cross-country diffusion of health innovations as opposed to country-specific factors.

Figure 2. Life Expectancy and GDP per Capita, Major World Regions, 1950-2010



A limitation of the analysis of long-term trends going back as far as 1870 is that macroeconomic and health data are available for a small and relatively homogenous set of countries. We therefore proceed with an analysis of trends income and health trends since 1950, where data are available for a much larger group of countries. Figure 2 summarizes trends for major world regions in life expectancy (1950-2010, from United Nations Population Division, 2009b) and GDP per capita (1950-2001, from Madison (2004). On this level of aggregation, life expectancy increased steadily, with the exception of the "bump" in the trajectory of life expectancy for Europe in 1990-95 (Figure 2.1). Life expectancy in Africa did not increase in line with the global average, and decelerated further after 1985.

Similar to life expectancy, GDP per capita has increased across world regions throughout the post-1950 period (Figure 2.2). The most significant deviations from trends in the global average occur among regions with relatively low initial levels of GDP per capita, including the sharp decline in GDP per capita of about one-third in Eastern Europe between 1989 and 1996, the relatively high rates of growth in Asia, especially after 1973, and the increasing gap between Africa and the rest of the world, especially the persistent stagnation in Africa after 1980 (with a rebound in recent years).

Figure 2.3 illustrates the role of the ongoing HIV/AIDS epidemic in trends in life expectancy in Africa. In sub-Saharan Africa, life expectancy declined substantially in countries with high HIV prevalence, and continued to increase at a slightly lower rate in countries with lower HIV prevalence. Meanwhile, North Africa (with very low rates of HIV prevalence, and also much higher levels of life expectancy at the outset) experienced substantial increases in life expectancy.

Figure 2.4 breaks down trends in life expectancy by sub-region in Europe. Notably, the “bump” in life expectancy in Europe observed earlier can be attributed to a decline in life expectancy concurrent with the economic contraction in the early 1990s. Perhaps more significant are the longer-term discrepancies between Eastern and Southern Europe – while life expectancies in Eastern and Southern Europe were on a similar level and appeared to catch up with other European regions between 1950 and 1965, life expectancy stagnated in Eastern Europe since 1965, fluctuating at about the same level for the next 25 years (while life expectancy increased by 7 years in Southern Europe), followed by the noted decline in the early 1990s.

To take this analysis further, we build a more comprehensive country-level dataset, covering 145 countries. For life expectancy, our data are based on United Nations Population Division, and cover the years 1950-2007.[16] For GDP per capita, the data from Maddison (2004), extending to 2001 only, were complemented by data from World Bank (2009), extending the series to 2007 and transforming the data into US$ at PPP exchange rates and 2005 prices.

Our estimates of the contribution of growth of GDP per capita and life expectancy, respectively, to living standards are summarized in Table 2, showing population-weighted averages by major world region, as well as estimates for a group of large countries (by population size), and four smaller countries with high rates of HIV prevalence. In light of our previous discussion, we distinguish North Africa and sub-Saharan Africa, and show estimates for Eastern Europe separately.

[16] Annual data were obtained by intrapolation from the 5-year averages reported in United Nations Population Division (2009b).

Table 2. Contributions of GDP per Capita and Life Expectancy to Living Standards, Selected Countries and Regions, 1950-2007

(1) GDP per capita (annual rate of growth); (2) Life expectancy (annual rate of growth);
(3) Life expectancy (contribution to annual growth in living standards); (4) Living standards (annual rate of growth)

	1950-1973				1973-1990				1990-2007			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Bangladesh	-0.4	0.9	3.2	2.8	1.5	1.1	4.0	5.5	3.5	1.2	4.2	7.7
Brazil	3.7	0.8	2.9	6.6	1.4	0.6	2.2	3.6	1.6	0.5	1.8	3.4
China,P.R.: Mainland	2.9	2.2	7.8	10.6	4.8	0.4	1.5	6.3	7.5	0.4	1.5	9.0
India	1.4	1.4	5.2	6.6	2.5	0.8	3.0	5.6	4.7	0.5	1.8	6.5
Indonesia	2.6	1.4	4.9	7.5	3.1	1.3	4.7	7.7	2.9	0.8	2.9	5.8
Mexico	3.2	1.1	4.1	7.3	1.4	0.7	2.6	3.9	1.5	0.4	1.5	3.1
Nigeria	2.7	0.7	2.4	5.1	-1.0	0.5	1.7	0.6	1.4	0.4	1.4	2.8
Pakistan	1.7	0.9	3.1	4.8	3.1	0.5	2.0	5.0	2.4	0.5	1.9	4.3
Philippines	2.7	1.0	3.8	6.4	0.7	0.7	2.4	3.2	1.7	0.5	1.9	3.7
Russia	n.a.	0.4	1.4	n.a.	1.0	-0.1	-0.3	0.7	0.4	-0.2	-0.6	-0.2
South Africa	2.2	0.9	3.4	5.6	-0.3	0.7	2.7	2.4	1.5	-0.9	-3.4	-1.9
Vietnam	1.0	1.1	4.0	5.0	1.3	1.5	5.4	6.7	5.8	0.8	2.8	8.6
Botswana	5.2	0.8	2.9	8.1	6.3	0.7	2.7	9.0	3.4	-1.0	-3.6	-0.3
Namibia	2.1	1.3	4.8	6.9	-0.4	0.8	2.9	2.5	2.4	-0.1	-0.5	2.0
Swaziland	5.1	0.9	3.3	8.4	0.4	1.1	4.0	4.4	1.1	-1.5	-5.6	-4.5
Zambia	2.1	0.9	3.2	5.3	-1.5	0.1	0.3	-1.2	0.0	-0.8	-2.9	-2.9
North Africa	2.8	1.0	3.5	6.2	1.3	1.1	3.8	5.1	1.4	0.6	2.0	3.4
Sub-Saharan Africa	2.1	0.9	3.2	5.3	-0.9	0.5	1.9	1.1	0.9	0.1	0.4	1.3
Latin America and	2.7	0.9	3.1	5.8	0.7	0.6	2.3	3.0	1.8	0.4	1.6	3.4
North America	2.5	0.2	0.7	3.2	1.9	0.3	1.1	3.0	1.7	0.3	1.0	2.7
Asia	4.4	1.6	5.7	10.1	2.6	0.6	2.3	4.9	3.5	0.5	1.7	5.2
Eastern Europe	n.a.	0.5	1.7	n.a.	n.a.	0.0	0.0	n.a.	1.0	0.0	0.1	1.0
Europe[1]	4.1	0.4	1.3	5.4	2.0	0.3	1.2	3.2	1.6	0.3	1.1	2.7
World[1]	2.9	1.1	3.8	6.7	1.3	0.5	1.9	3.2	1.9	0.4	1.3	3.2
Low initial income[2]	2.1	1.2	4.3	6.4	2.5	0.8	3.0	5.5	3.2	0.5	1.7	4.9
High initial income[2]	3.3	0.5	1.6	5.0	1.4	0.4	1.5	2.9	1.5	0.3	1.1	2.6

Sources: Author's estimates and calculations, based on data from Maddison (2004), World Bank (2009), and United Nations Population Division (2009b). Averages are weighted by population size. Former member states of the USSR are assigned to Eastern Europe. Aggregates exclude former Yugoslavia and successor states. A full set of country-level estimates is available in Appendix Table 3.

[1] Excluding Eastern Europe.

[2] "Low initial income" includes 58 countries with GDP per capita in 1950 at or below US$ 1,656 (2005 prices, PPP), "high initial income" represents 61 countries with GDP per capita in 1950 above that level.

Regarding global trends, the findings from our comprehensive sample are different from those presented earlier for a sample dominated by major industrialized economies. Improvements in life expectancy played a major part in rising living standards in the 1950-73 period, contributing 3.9 percentage points to an overall growth rate of 6.6 percent. However, the contribution of increased life expectancy declines in subsequent periods (to 1.9 percentage points in 1973-90, and 1.3 percentage points in 1990-2007). This point become clearer when the sample is divided by initial income (in 1950). Consistent with our earlier findings, improvements in life expectancy played a secondary role (compared to GDP growth) in raising living standards in the more advanced economies since 1950. For the countries starting out with lower income, the pattern changes between periods – improvements in life expectancy are the dominant factor driving increases in living standards from 1950 to 1973. However, the contribution of economic growth increased subsequently, while the growth of life expectancy slowed down, so that economic growth became the dominant factor in improving living standards after 1990. This pattern would be consistent with a delayed dissemination of major health innovations in developing countries, which had already resulted in major increases in life expectancy in leading economies before 1950, but still resulted in pronounced improvements in developing countries between 1950 and 1973.[17]

Globally, much of the recent acceleration in economic growth can be attributed to an acceleration in growth in Asia, notably in China and India (which dominate the population-weighted average for Asia, and also carry considerable weight on the global scale). Regarding the (cor)relation of GDP growth and growth in life expectancy, we note that periods of strong growth in individual countries – e.g., China (1973-90 and 1990-2007, India (1990-2007), Vietnam (1990-2007), or Botswana (1973-1990) – were not characterized by high rates of growth of life expectancy, suggesting that there is no simple causal relationship, going either way, between GDP per capita and life expectancy.[18]

The country-level estimates also allow us to interpret developments in regions or countries where life expectancy evolved notably differently from global trends. For Eastern Europe, we see that improvements in life expectancy essentially played no role since 1973, with a contribution to the growth of living standards of 0.0 percentage points in 1973-1990 and 0.1 percentage points in 1990-2007, and life expectancy actually declined in key economies in the region (Russia and Ukraine, see Appendix Table 3) both in 1973-1990 and in 1990-2007.

The other significant adverse health event identified above is the impact on life expectancy of the evolving HIV epidemic, notably in sub-Saharan Africa, which results in a stagnation in average life expectancy in the region in 1990-2007 (an increase of 0.1 percent only). However, in line with the wide discrepancies in HIV prevalence in the region, the impact of HIV/AIDS is also very uneven, and the average masks very serious declines in life expectancy in some countries, while life expectancy increased in others. For 5 countries with high HIV prevalence included in Table 2, the increases in mortality and associated declines in life expectancy were of a magnitude to wipe out any increases in living standards owing to increased GDP per capita since 1990, and in one case, the impact of declining life expectancy since 1990 was enough to wipe out any improvements in living standards achieved since 1973.

IV. Impact of HIV/AIDS

In light of the magnitude of the declines in life expectancy caused by HIV/AIDS in many countries, it can be argued that it represents the most significant international adverse health

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[17] For context, see Acemoglu and Johnson (2007) and Deaton (2006).

[18] This point is further elaborated by Deaton (2003), also providing a comprehensive discussion of related literature, and Deaton (2006).

shock recorded since the 1950s (when the data and estimates compiled by United Nations Population Division start). Without diminishing the roles of other – more chronic – health conditions in development, this means that to understand changes in living standards in many countries affected by HIV/AIDS since about 1990, it is necessary to take account of the reversals in health outcomes which have occurred as a consequence of the epidemic.

As the study of the impact of HIV/AIDS involves the analysis of extreme changes in life expectancy, and a number of countries with high HIV prevalence are low-income countries, it also represents a robustness test of the different approaches used to analyze the implications for living standards of changes in mortality or life expectancy. The impact of HIV/AIDS on living standards has been analyzed previously by Jamison, Sachs, and Wang (2001), Crafts and Haacker (2003, 2004), and Philipson and Soares (2005).

Jamison, Sachs, and Wang (2001) adopt a linearized approach similar to Nordhaus (2003). As observed above, this is problematic when applied to large changes in life expectancy – if a one percent decline in life expectancy represents a decline in living standards equivalent to 3.6 percent of GDP per capita, a decline in life expectancy in excess of 28 percent – when a linearized approach is used – would correspond to a loss exceeding GDP per capita, which obviously does not make sense. Jamison, Sachs, and Wang (2001) get around this problem by focusing on year-to-year changes, comparing the growth rate of GDP with a growth rate including an imputation for the loss in life expectancy, but their approach would need to be modified to assess losses accumulated over a number of years. Crafts and Haacker (2003, 2004) therefore adopt a non-linear approach close to the one used in the present paper.

Philipson and Soares (2005) apply the framework of Becker, Philipson and Soares (2005) to the impact of HIV/AIDS. As argued above, the specification adopted by Becker, Philipson and Soares (2005) is problematic when applied to low-income countries, and this is particularly relevant for a study such as theirs focusing on sub-Saharan Africa. As a consequence, their estimates of welfare costs of HIV/AIDS, for similar changes in mortality, can differ widely across countries .[19] For example, the welfare losses owing to HIV/AIDS (in percent of GDP per capita) for an 18-year old are the same (19 percent) for Equatorial Guinea (where life expectancy is reduced by 3 percent) as in Chad (where life expectancy is reduced by 7 percent), reflecting higher GDP per capita in Equatorial Guinea; a loss in life expectancy of 14 percent in Tanzania reduces living standards for an 18-year-old by “only” 10 percent; and HIV/AIDS – in the (Becker,) Philipson, and Soares framework – is welfare-enhancing in the Democratic Republic of Congo as GDP per capita there is so low that the utility of being alive is negative. As argued above, we find the wide variations in the relative

[19] Philippson and Soares (2005) report the “value of AIDS eradication” (*y*), whereas we focus on the costs of the impact of HIV AIDS (*x*), with $y = -\frac{x}{1+x}$.

valuation of health across low-income countries (to the point at which life becomes unworthy of living) proposed by Philipson and Soares (2005) (and Becker, Philipson and Soares (2005)) implausible, and these examples illustrate our point.

To identify the impact of HIV/AIDS, we compare life expectancy (for 2000-2005) to counterfactual estimates of life expectancy, excluding the impact of HIV/AIDS, both from United Nations Population Division (2009). There is one ambiguity to be aware of – we would like to differentiate between the impact of HIV/AIDS and the consequences of increased access to treatment. Access to antiretroviral treatment took off in many countries towards the end of the 2000-05 period, which means that our data understate the impact of HIV/AIDS. The fact that we average across the period only mitigates, but does not eliminate this source of bias. As a measure of the health impact of HIV/AIDS, we focus on life expectancy at birth.[20]

Table 3 summarizes our estimates of the impacts of increased mortality owing to HIV/AIDS on living standards for selected countries. For sub-Saharan Africa, life expectancy at birth has declined by 10 percent relative to a no-AIDS scenario, from 55.6 to 50.0 years, translating into a loss in living standards equivalent to 32 percent of GDP. For some of the countries with very high HIV prevalence, the losses are much more pronounced, exceeding 50 percent of GDP for Botswana, Lesotho, Malawi, Swaziland, Zambia, and Zimbabwe. These losses may appear extreme at first sight. It is important, however, to recognize that the underlying changes in mortality and life expectancy are extremely large, as well. For many countries in sub-Saharan Africa, HIV/AIDS has reversed gains in life expectancy that had occurred over several decades. Meanwhile, the consequences of HIV/AIDS for living standards are not negligible for some countries with lower HIV prevalence rates. For example, in Ethiopia, with an estimates HIV prevalence rate of about 2 percent, a loss in life expectancy of 2.4 years translates in to a welfare loss equivalent to 15 percent of GDP, and for Thailand (HIV prevalence: 1.4 percent), life expectancy declines by 2.2 years, corresponding to a loss in living standards equivalent to 11 percent of GDP.

Whereas Table 3 summarizes the overall impact of HIV/AIDS on living standards, Table 4 relates economic growth and changes in life expectancy (overall and owing to HIV/AIDS) over the period 1990-2005, in which the impact of HIV/AIDS on mortality escalated in many countries. For sub-Saharan Africa overall, HIV/AIDS has been a drag on the growth rate of living standards. While GDP per capita increased at a modest rate of 0.9 percent annually, life expectancy stagnated, so that living standards improved at a rate of 1.2 percent annually. However, the modest role of health improvements masks two development going in opposite directions –improvements in public health which made a substantial positive contribution to

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[20] More extensive studies also use life expectancy at age 15 (Crafts and Haacker, 2004) or at age 18 (Philippson and Soares, 2005). Crafts and Hacker(2004) also provide average across ages based on survival curves (but weighing individuals equally), Philippson and Soares (2005) apply weights based on remaining life expectancy.

living standards (2.2 percent annually), which were largely wiped out by the adverse impact of HIV/AIDS (–2.0 percent annually).

For the countries with high HIV prevalence, living standards have been declining in the period since 1990. Whereas the growth rate of GDP per capita ranged from 0.9 percent to 3.9 percent annually for Botswana, Lesotho, Namibia, South Africa, and Swaziland, living standards declined by between 2.1 percent and 5.8 percent annually. In Zimbabwe, which has undergone a severe economic contraction in the latter part of the period, the adverse impact of increasing mortality on living standards was three times larger than the (direct) impact of the economic contraction.[21]

Table 3. Impact of HIV/AIDS on Living Standards (Levels), Selected Countries

Country	HIV Prevalence	Life Expectancy		Welfare Loss
	(In percent of population, age 15-49, end-2007)	(In Years, without AIDS, 2000-05)	(In Years, actual, 2000-05)	(Level change by 2000-05, in percent of GDP)
Sub-Saharan Africa	5.2	55.6	50.0	-31.6
Botswana	24.9	67.8	48.2	-70.8
Dem. Rep. of Congo	n.a.	49.3	47.7	-11.3
Ethiopia	2.1	54.9	52.5	-14.8
Kenya	6.1-8.1	60.5	51.7	-43.3
Lesotho	23.4	61.2	46.0	-64.3
Malawi	12.3	61.5	50.1	-52.4
Mozambique	12.2	52.9	47.6	-31.7
Namibia	15.3	68.3	56.7	-48.8
Nigeria	3.2	49.2	46.7	-16.8
South Africa	18.2	63.6	53.1	-47.9
Swaziland	26.4	63.2	46.1	-67.8
Tanzania	6.4	59.2	52.0	-37.2
Zambia	15.0	53.4	41.6	-59.2
Zimbabwe	19.0	64.5	41.2	-80.1
Thailand	1.4	70.4	68.2	-10.6
Russia	1.1	64.9	64.8	-0.6
Ukraine	1.5	68.1	67.7	-2.0
Brazil	0.6	71.6	71.0	-3.0
Haiti	2.2	61.7	59.6	-11.9
Honduras	0.7	72.5	70.9	-7.6

Source: UNAIDS (2008), United Nations Population Division (2009), and author's calculations.

Meanwhile, HIV/AIDS played a significant negative role in evolving living standards even in the countries with HIV prevalence between 0.6 percent and 2.1 percent (see Table 3)

[21] Our analysis is only concerned with measuring the direct contribution of changes in income and life expectancy to living standards, but we do not analyze causes of such changes, or the relation between economic variables and health indicators. For Zimbabwe, it can plausibly be argued that the erosion in health services associated with the economic crisis contributed to the severe impact of HIV/AIDS on mortality.

included in Table 4. One disconcerting aspect of the estimates in Table 4 is the extent to which the impact of HIV/AIDS appears to be related to the level of economic development. In an number of low-income countries covered (e.g., Haiti, Malawi, Ethiopia), HIV/AIDS had a disproportionally large impact on the growth of life expectancy, whereas the impact of HIV/AIDS in Brazil appears very small (arguably reflecting an early and comprehensive health sector response and near-complete access to antiretroviral treatment.

Table 4. Impact of HIV/AIDS on the Growth of Living Standards, Selected Countries

Country	Growth of GDP per capita	Growth in Life Expectancy	Of which: HIV/ AIDS	Growth in Living Standards	Of which: HIV/ AIDS
	(In percent, annual average, 1990-2005)	(In percent, annual average, 1990-2005)	(In percent, annual average, 1990-2005)	(In percent, annual average, 1990-2005)	(In percent, annual average, 1990-2005)
SSA	0.9	0.1	-0.6	1.2	-2.0
Botswana	3.9	-1.7	-2.0	-2.1	-7.2
Dem. Rep. of Congo	-5.0	-0.1	-0.1	-5.3	-0.5
Ethiopia	0.7	0.9	-0.2	4.0	-0.8
Kenya	0.0	-0.8	-0.8	-2.8	-3.0
Lesotho	1.4	-2.0	-2.3	-5.8	-8.3
Malawi	0.9	-0.2	-1.8	0.1	-6.6
Mozambique	5.0	-0.1	-1.5	4.5	-5.6
Namibia	1.8	-1.1	-1.8	-2.1	-6.4
Nigeria	2.0	-0.1	-0.7	1.7	-2.6
South Africa	0.9	-1.2	-1.5	-3.4	-5.3
Swaziland	1.3	-1.8	-2.1	-5.0	-7.5
Tanzania	1.6	0.4	-0.5	3.2	-1.8
Zambia	-1.2	-1.0	-1.1	-4.7	-4.1
Zimbabwe	-2.5	-2.2	-2.2	-10.4	-7.8
Thailand	3.6	0.0	-0.1	3.5	-0.3
Russia	-0.5	-0.3	-0.1	-1.7	-0.4
Ukraine	-2.4	-0.2	-0.1	-3.2	-0.3
Brazil	1.1	0.5	0.0	2.9	-0.1
Haiti	-1.6	0.6	-0.2	0.6	-0.7
Honduras	1.1	0.4	-0.2	2.4	-0.7

Source: Authors calculations, based on data from IMF (2009), World Bank (2009), and United Nations Population Division (2009b).

The very large adverse impacts of HIV/AIDS across countries imply that the positive impacts of efforts to extend access to antiretroviral treatment can be very large as well, and we will offer some estimates to illustrate this point. Our analysis is based on data on the delay in the progression of the disease and of death achieved by treatment. As a reference point, we use estimates included in WHO (2008), which can be considered as estimates of the impact of HIV/AIDS in the absence of treatment.[22] Accordingly, an HIV/AIDS-related death results in about 48 life years lost (47 years in middle-income countries, 49 years in low-income countries, which – in the absence of country-level estimates, we will use as benchmark for our analysis. Our benchmark for the potential impact of antiretroviral treatment is based on United Nations Population Division (2009a), suggesting that antiretroviral treatment increases survival by a mean of 16 years.[23]

On the country level, the potential impact of a treatment program depends on many other factors – the state of the health system, the financial resources of the government (complemented by donor financing), treatment coverage rates, and the types of treatment being available. These factors we cannot adequately capture here – our calculation therefore provides a somewhat artificial illustration of the implications of full access to treatment. In this case, the estimates for the impact of HIV/AIDS and treatment on life years lost imply that treatment, at an assumed coverage rate of 100 percent, could mitigate the impact of HIV/AIDS on life expectancy by one-third (16 years, divided by 48 years).[24]

Table 5 shows that the benefits from comprehensive access to treatment are substantial. For Sub-Saharan Africa as a whole, comprehensive treatment mitigates the impact of HIV/AIDS on living standards by the equivalent of 9.6 percent of GDP, which translates into a gain from treatment equivalent to 14 percent of GDP (relative to a situation with no access to treatment). In seven countries, the gains that can be achieved through comprehensive access to treatment exceed the equivalent of 20 percent of GDP, and exceed the equivalent of 50 percent of GDP in one case. The bad news is that the costs of HIV/AIDS remain very substantial, even in a comprehensive treatment scenario. A welfare improvement equivalent to 50 percent of GDP is fantastic, but not so much if it raises living standards by 50 percent from a level at which they are depressed by 68 percent to a level at which they are reduced by "only" 51 percent (see Table 5 for Swaziland).

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[22] The data relate to 2004, a year in which access to treatment was still low in many low- and middle-income countries, and mortality among people receiving treatment (most of whom had initialed it over the preceding few years) was low.

[23] Based on an estimated mean survival time of 19.3 years after initiation of treatment, and 3.2 years without treatment, both from the time a person develops the full symptoms of AIDS.

[24] As the underlying data for 2000-2005 from United Nations Population Division (2009b) are not clean estimates of the impact of HIV/AIDS excluding treatment, our estimates of the impact of treatment include a small downward bias.

Table 5. Living Standards and Antiretroviral Treatment

	Full Impact of HIV/AIDS Loss in...		Comprehensive Treatment Loss in...		Difference "Treatment" vs. "Full Impact"[1]	Gains from Treatment[1]
Country	Life Expectancy	Living Standards	Life Expectancy	Living Standards	Living Standards	Living Standards
	(Years)	(Percent of GDP)	(Years)	(Percent of GDP)	(Percent of GDP)	(Percent of GDP)
Sub-Saharan Africa	-5.6	-31.6	-3.7	-22.0	9.6	14.0
Dem. Rep. of Congo	-1.6	-11.3	-1.1	-7.6	3.6	4.1
Ethiopia	-2.4	-14.8	-1.6	-10.1	4.7	5.6
Kenya	-8.8	-43.3	-5.9	-30.8	12.5	22.1
Lesotho	-15.2	-64.3	-10.1	-47.9	16.3	45.7
Malawi	-11.5	-52.4	-7.6	-38.0	14.4	30.3
Mozambique	-5.3	-31.7	-3.5	-22.1	9.6	14.0
Namibia	-11.6	-48.8	-7.7	-35.1	13.7	26.8
Nigeria	-2.4	-16.8	-1.6	-11.4	5.4	6.4
South Africa	-10.5	-47.9	-7.0	-34.4	13.5	25.9
Swaziland	-17.1	-67.8	-11.4	-51.1	16.7	52.0
Tanzania	-7.2	-37.2	-4.8	-26.2	11.0	17.6
Zambia	-11.8	-59.2	-7.8	-43.5	15.6	38.3

Source: Author's calculations, based on United Nations Population Division (2009b). Table 5 does not provide estimates for Botswana, where the impact of antiretroviral treatment in the 2000-05 data already is pronounced, and Zimbabwe, where the impact of HIV/AIDS appears to interact with the economic crisis.

[1] "Difference 'Treatment vs. Actual'" is expressed in terms of the costs of HIV/AIDS (relative to a counterfactual with no AIDS). "Gains from Treatment" are defined relative to the reduced level of living standards in the absence of treatment, and calculated as 100 times "Difference 'Treatment vs. Actual,'" divided by (100 minus the percentage loss in living standards from "impact of HIV/AIDS" scenario).

In addition to an assessment of the welfare gains associated with comprehensive access to treatment, our analysis also offers insights regarding the roles of prevention programs. The impact of HIV/AIDS on life expectancy is largely proportional to HIV incidence. A decline in the number of new infections by 10 percent (using an analysis similar to the one illustrated in Table 5) would therefore increase living standards across sub-Saharan Africa by the equivalent of 4 percent of GDP, and between 1 percent of GDP and 14 percent of GDP among the countries covered in Table 5. A decline in the number of new infections by one-third would have an impact equal to the effect of a comprehensive treatment illustrated in Table 5. More generally, prevention and treatment programs complement each other, and attaining reductions in HIV incidence may be a prerequisite for sustaining high treatment coverage rates. Combining a the two examples (a 50 percent reduction in HIV incidence, and full access to treatment) would reduce the impact of HIV/AIDS on life expectancy by two-thirds, and result in gains in living standards (relative to unchanged incidence and no treatment) equivalent to 29 percent of GDP across sub-Saharan Africa, and between 8 percent of GDP and 121 percent of GDP among the countries covered in Table 5.

V. CONCLUSIONS

The present paper covers some methodological ground regarding measuring the contributions of increased life expectancy to living standards, based on the literature on the value of statistical life and its macroeconomic interpretations, and discusses the contribution of increased life expectancy to living standards in three different contexts.

Methodologically, we build an explicit framework that – we argue – has certain advantages compared to other recent studies, as it provides a reduced form well-suited for analyzing periods characterized by substantial changes in life expectancy. One objective of our analysis is a meaningful analysis of changes in life expectancy on a global scale, including in low-income countries, and we address some shortcomings in the existing literature in this direction as well.

Regarding the contributions to living standards of increased life expectancy over a long period of economic development in 17 of toady’s leading industrialized economies, we find that the contributions of increased incomes and improved health to living standards were roughly even over the 1870-2006 period. The relative importance of increasing income and improved health, however, have shifted after 1950. While improvements in living standards were primarily driven by improved health before 1950, growing GDP per capita accounted for most of the improvements since then. Further, improvements in health showed less volatility and appeared to follow a common trend across countries, suggesting that the factors driving health improvements are different from factors driving GDP growth, and that there is no simple relationship between GDP per capita and health attainments.

Based on a larger sample of 136 countries from 1950, we find that improvements in life expectancy played a major part in rising living standards in the 1950-73 period, but the contribution of increased life expectancy declines in subsequent periods. This pattern would be consistent with a delayed dissemination of health innovations which already had a major impact in the leading industrialized countries between 1913 and 1950. The most recent acceleration in the growth of GDP per capita globally (1990-2006) can be attributed to an acceleration in growth in Asia, notably in China and India. Periods of strong growth in individual countries were not characterized by high rates of growth of life expectancy, reinforcing our earlier point that suggesting that there is no simple causal relationship, going either way, between GDP per capita and life expectancy.

The analysis of the adverse impact of HIV/AIDS – which already showed as an extraordinary health development in our analysis of global trends – suggests that living standards have fallen in many countries in sub-Saharan Africa, with losses in life expectancy more than offsetting any gains in GDP per capita, and that the average losses to living standards in sub-Saharan Africa may be as high as 38 percent of GDP. One feature of our analysis that is new relative to earlier work is a discussion of the implications of improved access to treatment and of HIV prevention for the impact of HIV/AIDS. We find that improved access to treatment (an assumed coverage rate of 80 percent) does mitigate the adverse impacts of HIV/AIDS, but only at a rate that would correspond to a successful prevention of 18 percent of new infections.

We see the principal shortcomings of the approach adopted in the present study in two areas. First, our measure of the contributions of increased income and increased life expectancy is based entirely on outputs of the development process and of other (e.g. health) factors. The perspective is thus one of accounting for changes in living standards, without addressing factors driving the changes in income or life expectancy. To obtain a fuller accounting of the role of increased income or higher life expectancy to living standards, it would therefore be necessary to gain a better understanding of the interactions between income ad health, and of factors that may be driving both. The limited evidence in this direction that we present in the present study suggests that this would be a complex exercise.

Second, while the approach taken in the present study has clear advantages compared to other approaches addressing ht e contribution of health to living standards, as it is based on an explicit microeconomic framework, the weak evidence regarding the underlying estimates of the value of statistical life is a matter of concern for our purposes. Notably, most of the empirical literature is based on data from industrialized countries and a few middle-income countries. Adapting such estimates to a global scale, as we do, therefore corresponds to out-of-sample projection, implying that the margin of error of our estimates is large.

VI. References

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Appendix Table 1. GDP per Capita, 17 Countries, 1870-2007
(constant 2005 international dollars, at purchasing power parity)

	1870	1913	1950	1973	2007
Australia	4,350	6,853	9,850	17,114	32,735
Austria	2,974	5,533	5,917	17,936	35,537
Belgium	3,911	6,131	7,936	17,683	33,399
Canada	2,486	6,525	10,699	20,304	36,260
Denmark	2,754	5,378	9,545	19,171	34,905
Finland	1,575	2,918	5,879	15,323	33,324
France	2,634	4,893	7,402	18,414	31,625
Germany	3,047	6,044	6,430	19,827	33,181
Italy	2,221	3,798	5,188	15,755	28,682
Japan	1,020	1,918	2,656	15,812	31,689
Netherlands	4,311	6,330	9,376	20,455	36,956
Norway	2,581	4,506	9,845	20,266	49,359
Spain	1,984	3,379	3,599	12,595	28,536
Sweden	2,360	4,398	9,574	19,168	34,090
Switzerland	3,301	6,698	14,231	28,582	37,581
United Kingdom	4,716	7,274	10,258	17,777	33,717
United States	3,412	7,399	13,346	23,296	43,102
Average (unweighted)	2,920	5,293	8,337	18,793	34,981

Sources: World Bank (2009) for 2007; authors calculations, based on Maddison (2004) and World Bank (2009) for earlier years.

Appendix Table 2. Life Expectancy at Birth, 17 Countries, 1870-2007

	1870	1913	1950	1973	2007
Australia	48.0	59.1	69.6	71.7	81.3
Austria	31.7	42.2	65.7	70.5	79.7
Belgium	40.0	49.6	67.5	71.4	79.4
Canada	42.6	52.5	69.1	73.1	80.5
Denmark	45.5	57.7	71.0	73.6	78.1
Finland	36.5	46.2	66.3	70.7	79.3
France	42.0	50.4	66.5	72.4	80.9
Germany	36.2	49.0	67.5	70.6	79.6
Italy	28.0	47.2	66.0	72.1	81.0
Japan	37.0	44.4	64.0	73.3	82.5
Netherlands	38.9	56.1	72.1	74.0	79.7
Norway	49.3	57.2	72.7	74.4	80.4
Spain	33.7	41.8	63.9	72.9	80.6
Sweden	45.8	57.0	71.8	74.7	80.7
Switzerland	41.0	52.2	69.2	73.8	81.6
United Kingdom	41.3	53.4	69.2	72.0	79.2
United States	44.0	51.6	69.0	71.3	79.0
Average (unweighted)	38.5	49.6	66.1	72.1	80.1

Sources: Crafts (1997) for 1870-1973, World Bank (2009) for 2007.

Appendix Table 3. Contributions of GDP per Capita and Life Expectancy to Living Standards, 145 Countries, 1950-2007
(1) GDP per capita (annual rate of growth); (2) Life expectancy (annual rate of growth);
(3) Life expectancy (contribution to annual growth in living standards); (4) Living standards (annual rate of growth)

	1950-1973				1973-1990				1990-2007			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Afghanistan, I.R. of	0.3	1.1	4.0	4.3	-0.8	0.8	2.8	2.0	2.1	0.3	1.2	3.3
Albania	3.6	1.1	3.9	7.5	0.5	0.4	1.3	1.8	2.4	0.4	1.3	3.6
Algeria	2.4	1.2	4.3	6.7	1.3	1.2	4.3	5.5	0.8	0.5	1.7	2.5
Angola	2.3	1.2	4.3	6.7	-4.0	0.6	2.1	-1.9	3.1	0.6	2.1	5.3
Argentina	2.1	0.4	1.4	3.5	-1.2	0.3	1.3	0.0	2.9	0.3	1.0	3.9
Armenia	n.a.	0.6	2.2	n.a.	-0.1	-0.2	-0.8	-0.8	2.9	0.4	1.5	4.4
Australia	2.4	0.2	0.6	3.0	1.7	0.4	1.5	3.1	2.2	0.3	1.2	3.4
Austria	4.9	0.3	1.2	6.2	2.4	0.4	1.4	3.9	1.6	0.3	1.2	2.8
Azerbaijan, Rep. of	n.a.	0.6	2.3	n.a.	0.3	0.0	0.1	0.3	2.9	0.4	1.3	4.2
Bahrain, Kingdom of	3.2	1.1	3.9	7.2	-0.4	0.7	2.6	2.2	3.0	0.3	1.2	4.1
Bangladesh	-0.4	0.9	3.2	2.8	1.5	1.1	4.0	5.5	3.5	1.2	4.2	7.7
Belarus	n.a.	0.4	1.6	n.a.	1.9	-0.1	-0.3	1.6	2.7	-0.1	-0.5	2.2
Belgium	3.5	0.3	0.9	4.5	2.1	0.3	1.2	3.3	1.7	0.3	0.9	2.7
Benin	-0.1	1.1	4.1	4.0	0.5	0.8	2.9	3.4	1.1	0.7	2.7	3.8
Bolivia	0.9	0.7	2.6	3.5	-0.4	1.3	4.7	4.3	1.6	0.6	2.3	3.9
Botswana	5.2	0.8	2.9	8.1	6.3	0.7	2.7	9.0	3.4	-1.0	-3.6	-0.3
Brazil	3.7	0.8	2.9	6.6	1.4	0.6	2.2	3.6	1.6	0.5	1.8	3.4
Bulgaria	5.2	0.6	2.0	7.2	0.3	0.0	0.1	0.4	2.3	0.1	0.5	2.8
Burkina Faso	1.6	1.2	4.2	5.8	0.5	0.7	2.4	2.9	1.8	0.6	2.2	4.0
Burundi	1.9	0.6	2.3	4.2	1.6	0.3	1.2	2.9	-1.4	0.4	1.4	0.0
Cambodia	2.0	0.2	0.8	2.8	0.5	1.8	6.5	7.0	4.2	0.6	2.1	6.4
Cameroon	1.8	1.0	3.6	5.4	1.2	0.9	3.2	4.4	0.0	-0.4	-1.5	-1.5
Canada	2.8	0.3	1.1	3.9	1.8	0.3	1.2	3.0	1.6	0.2	0.8	2.4
Cape Verde	0.7	0.9	3.2	3.9	5.1	0.8	2.8	7.9	3.7	0.5	1.6	5.4
Central African Rep.	0.4	1.3	4.8	5.2	-1.0	0.7	2.4	1.4	-1.0	-0.3	-1.1	-2.1
Chad	-0.4	0.9	3.3	2.8	-0.2	0.7	2.4	2.2	2.6	-0.3	-1.0	1.7
Chile	1.3	0.7	2.6	3.8	1.4	0.8	3.0	4.4	3.9	0.4	1.4	5.3
China,P.R.: Mainland	2.9	2.2	7.8	10.6	4.8	0.4	1.5	6.3	7.5	0.4	1.5	9.0
China,P.R.:Hong Kong	5.2	0.9	3.2	8.4	5.5	0.4	1.4	6.9	2.9	0.4	1.4	4.3
Colombia	2.1	1.1	3.9	6.1	1.9	0.6	2.1	4.1	1.6	0.4	1.3	2.9
Comoros	2.0	0.9	3.3	5.3	-1.5	0.8	2.9	1.4	-1.1	0.8	3.0	1.9
Congo, Republic of	2.2	1.4	5.0	7.2	0.7	0.3	1.2	2.0	0.1	-0.6	-2.1	-2.1
Costa Rica	3.5	0.9	3.2	6.7	0.6	0.6	2.2	2.7	3.0	0.3	0.9	3.9
Côte d'Ivoire	2.6	1.4	5.0	7.7	-1.9	0.8	3.0	1.1	-0.9	0.0	-0.1	-1.1
Croatia	n.a.	0.7	2.6	n.a.	n.a.	0.2	0.7	n.a.	1.2	0.3	1.2	2.4
Czech Republic	n.a.	0.3	1.1	n.a.	n.a.	0.2	0.6	n.a.	1.9	0.3	1.2	3.1
Democratic Republic of	1.7	0.7	2.4	4.1	-2.7	0.4	1.4	-1.3	-4.5	0.0	0.0	-4.6
Denmark	3.1	0.2	0.7	3.8	1.7	0.1	0.4	2.1	1.9	0.2	0.9	2.8
Djibouti	1.7	1.2	4.5	6.1	-2.4	0.8	2.8	0.4	-1.0	0.5	1.7	0.7
Dominican Republic	3.0	1.4	4.9	7.9	1.2	0.7	2.5	3.8	3.8	0.4	1.5	5.3
Ecuador	2.5	1.0	3.7	6.2	1.0	0.9	3.2	4.2	1.1	0.5	1.9	3.0
Egypt	1.5	0.9	3.4	4.9	4.0	1.1	4.1	8.1	2.0	0.6	2.3	4.3
El Salvador	2.0	1.3	4.6	6.6	-0.6	0.8	2.8	2.2	2.4	0.5	1.9	4.3
Equatorial Guinea	3.0	0.8	2.9	5.9	2.3	0.8	2.9	5.2	17.5	0.4	1.5	19.0
Estonia	n.a.	0.4	1.5	n.a.	1.3	-0.1	-0.3	1.0	3.3	0.3	0.9	4.2
Finland	4.3	0.3	1.2	5.5	2.5	0.4	1.3	3.8	2.1	0.3	1.2	3.3
France	4.0	0.4	1.5	5.5	1.9	0.3	1.2	3.1	1.3	0.3	1.2	2.5
Gabon	3.8	1.3	4.8	8.6	-2.4	1.3	4.7	2.3	-1.2	-0.1	-0.2	-1.4
Gambia, The	2.2	1.1	4.1	6.2	-0.8	1.2	4.1	3.3	0.9	0.5	1.8	2.7
Georgia	n.a.	0.6	2.1	n.a.	1.4	0.2	0.7	2.2	-1.7	0.1	0.3	-1.3
Germany	5.0	0.3	1.0	6.0	1.7	0.4	1.3	3.0	1.4	0.3	1.2	2.5
Ghana	1.0	0.7	2.5	3.5	-1.6	0.7	2.7	1.1	2.4	0.0	-0.1	2.3
Greece	6.2	0.5	1.8	8.0	1.6	0.4	1.3	2.9	2.7	0.2	0.5	3.3
Guatemala	1.9	1.2	4.4	6.3	-0.4	0.8	3.0	2.6	1.2	0.7	2.6	3.8
Guinea	2.0	0.7	2.4	4.4	0.6	1.1	3.9	4.4	0.9	1.0	3.7	4.5
Guinea-Bissau	5.0	0.8	2.8	7.7	-0.6	0.8	3.0	2.4	-2.4	0.5	1.7	-0.7
Haiti	-0.2	1.3	4.6	4.5	0.2	0.8	2.8	2.9	-2.0	0.6	2.3	0.3

Appendix Table 3. Contributions of GDP per Capita and Life Expectancy to Living Standards, 145 Countries, 1950-2007
(1) GDP per capita (annual rate of growth); (2) Life expectancy (annual rate of growth);
(3) Life expectancy (contribution to annual growth in living standards); (4) Living standards (annual rate of growth)

	1950-1973				1973-1990				1990-2007			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Honduras	1.0	1.3	4.6	5.6	0.8	1.2	4.3	5.1	1.5	0.5	1.8	3.3
Hungary	3.6	0.5	1.8	5.4	0.8	0.0	0.0	0.9	2.2	0.3	1.1	3.3
India	1.4	1.4	5.2	6.6	2.5	0.8	3.0	5.6	4.7	0.5	1.8	6.5
Indonesia	2.6	1.4	4.9	7.5	3.1	1.3	4.7	7.7	2.9	0.8	2.9	5.8
Iran, I.R. of	5.1	1.0	3.7	8.9	-2.6	0.9	3.2	0.6	3.8	0.6	2.2	5.9
Iraq	4.5	1.8	6.4	10.9	-2.5	0.5	1.8	-0.7	-5.8	0.3	1.2	-4.6
Ireland	3.0	0.4	1.3	4.3	3.2	0.3	1.0	4.3	5.3	0.4	1.3	6.6
Israel	5.5	0.5	1.8	7.3	1.8	0.4	1.3	3.0	1.8	0.3	1.2	3.0
Italy	4.9	0.4	1.6	6.6	2.5	0.4	1.3	3.9	1.0	0.3	1.1	2.2
Jamaica	5.1	0.9	3.2	8.3	-0.8	0.2	0.6	-0.2	0.6	0.0	0.2	0.8
Japan	8.1	0.9	3.2	11.2	3.0	0.4	1.6	4.6	1.2	0.3	1.0	2.1
Jordan	1.6	1.3	4.8	6.4	2.8	1.0	3.5	6.3	1.9	0.5	1.7	3.6
Kazakhstan	n.a.	0.7	2.5	n.a.	-0.2	0.3	1.1	0.9	1.6	-0.2	-0.6	1.0
Kenya	1.7	1.2	4.3	6.0	0.7	0.6	2.2	2.9	0.2	-0.6	-2.2	-1.9
Korea	5.8	1.3	4.7	10.5	6.8	0.9	3.2	10.0	4.7	0.6	2.3	7.0
Kuwait	-0.3	1.0	3.5	3.2	-8.3	0.6	2.0	-6.3	4.9	0.2	0.8	5.7
Kyrgyz Republic	n.a.	0.7	2.7	n.a.	-0.2	0.5	1.6	1.4	-1.4	0.1	0.5	-1.0
Lao People's Dem.Rep	1.0	0.5	1.7	2.7	1.1	0.9	3.1	4.2	3.3	1.0	3.7	7.1
Latvia	n.a.	0.4	1.3	n.a.	1.4	-0.1	-0.3	1.1	1.6	0.2	0.8	2.4
Lebanon	1.1	0.8	3.0	4.2	-2.8	0.3	1.0	-1.9	4.3	0.3	1.0	5.3
Lesotho	3.4	0.9	3.2	6.7	2.7	0.9	3.4	6.1	3.2	-1.5	-5.3	-2.1
Liberia	1.4	1.1	3.9	5.3	-2.0	0.4	1.4	-0.6	-2.9	1.0	3.7	0.8
Libya	9.3	1.1	3.9	13.2	-4.4	1.5	5.2	0.8	-1.1	0.5	1.9	0.8
Lithuania	n.a.	0.5	1.9	n.a.	0.8	0.0	-0.1	0.7	1.6	0.1	0.2	1.8
Macedonia, FYR	n.a.	1.1	3.9	n.a.	n.a.	0.3	1.2	n.a.	-0.1	0.2	0.8	0.7
Madagascar	0.8	1.0	3.7	4.5	-2.1	0.7	2.6	0.5	-0.6	1.0	3.5	2.9
Malawi	2.5	0.7	2.5	4.9	-0.1	0.9	3.3	3.3	1.7	0.4	1.4	3.2
Malaysia	2.2	1.3	4.8	7.0	4.2	0.6	2.2	6.4	3.9	0.3	1.2	5.1
Mali	1.1	0.3	1.2	2.3	1.4	0.7	2.5	3.9	1.3	0.7	2.4	3.6
Mauritania	3.2	0.7	2.7	5.9	-0.3	0.8	2.8	2.5	1.5	0.1	0.4	1.9
Mauritius	1.7	1.3	4.6	6.3	4.0	0.5	2.0	5.9	3.9	0.2	0.9	4.7
Mexico	3.2	1.1	4.1	7.3	1.4	0.7	2.6	3.9	1.5	0.4	1.5	3.1
Moldova	n.a.	0.5	2.0	n.a.	0.8	0.2	0.8	1.6	-3.2	0.1	0.3	-2.9
Mongolia	3.0	1.2	4.4	7.4	2.6	0.7	2.6	5.2	1.0	0.5	1.8	2.8
Morocco	0.7	1.1	3.8	4.5	2.5	1.1	4.0	6.5	1.6	0.6	2.2	3.9
Mozambique	2.2	1.3	4.7	6.9	-3.0	0.4	1.6	-1.4	4.1	0.6	2.0	6.1
Namibia	2.1	1.3	4.8	6.9	-0.4	0.8	2.9	2.5	2.4	-0.1	-0.5	2.0
Nepal	1.0	1.0	3.4	4.4	1.5	1.2	4.3	5.8	1.8	1.2	4.4	6.2
Netherlands	3.5	0.1	0.5	4.0	1.6	0.2	0.8	2.5	1.9	0.2	0.8	2.6
New Zealand	1.7	0.2	0.6	2.3	0.7	0.3	1.0	1.7	1.5	0.4	1.3	2.8
Nicaragua	2.6	1.4	4.9	7.5	-4.0	0.8	3.0	-1.0	1.2	0.8	2.7	3.9
Niger	-0.4	0.2	0.6	0.2	-1.6	0.5	1.7	0.1	-0.3	1.2	4.2	3.9
Nigeria	2.7	0.7	2.4	5.1	-1.0	0.5	1.7	0.6	1.4	0.4	1.4	2.8
Norway	3.2	0.1	0.5	3.6	3.0	0.2	0.7	3.6	2.3	0.3	1.0	3.3
Oman	7.5	1.6	5.8	13.3	4.1	1.7	6.0	10.1	1.3	0.5	1.8	3.1
Pakistan	1.7	0.9	3.1	4.8	3.1	0.5	2.0	5.0	2.4	0.5	1.9	4.3
Panama	3.5	1.0	3.6	7.1	0.3	0.5	1.7	2.0	3.2	0.3	0.9	4.1
Paraguay	1.1	0.2	0.9	2.0	2.9	0.2	0.7	3.5	0.0	0.3	1.1	1.1
Peru	2.5	1.2	4.2	6.6	-1.7	1.0	3.5	1.8	2.9	0.6	2.3	5.2
Philippines	2.7	1.0	3.8	6.4	0.7	0.7	2.4	3.2	1.7	0.5	1.9	3.7
Poland	3.5	0.8	2.8	6.3	-0.3	0.1	0.2	0.0	3.9	0.3	1.2	5.1
Portugal	5.4	0.7	2.6	8.1	2.5	0.5	1.8	4.4	1.8	0.3	1.2	3.0
Romania	4.8	0.7	2.4	7.2	0.1	0.0	0.1	0.1	1.7	0.2	0.9	2.5
Russia	n.a.	0.4	1.4	n.a.	1.0	-0.1	-0.3	0.7	0.4	-0.2	-0.6	-0.2
Rwanda	1.0	0.6	2.1	3.1	1.5	-1.5	-5.4	-4.0	1.4	2.1	7.6	9.0
Saudi Arabia	7.2	1.5	5.4	12.6	-1.1	1.3	4.8	3.6	-0.1	0.4	1.6	1.5
Senegal	0.2	0.6	2.3	2.5	0.2	1.0	3.7	3.9	1.0	0.4	1.4	2.4

Appendix Table 3. Contributions of GDP per Capita and Life Expectancy to Living Standards, 145 Countries, 1950-2007
(1) GDP per capita (annual rate of growth); (2) Life expectancy (annual rate of growth);
(3) Life expectancy (contribution to annual growth in living standards); (4) Living standards (annual rate of growth)

	1950-1973				1973-1990				1990-2007			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Sierra Leone	2.2	0.7	2.6	4.8	-0.3	0.5	1.8	1.4	-3.4	0.9	3.2	-0.2
Singapore	4.4	0.7	2.6	7.0	5.3	0.4	1.5	6.8	4.0	0.4	1.5	5.5
Slovak Republic	n.a.	0.5	1.9	n.a.	n.a.	0.1	0.4	n.a.	2.5	0.2	0.9	3.4
Slovenia	n.a.	0.4	1.3	n.a.	n.a.	0.3	0.9	n.a.	2.7	0.4	1.4	4.1
South Africa	2.2	0.9	3.4	5.6	-0.3	0.7	2.7	2.4	1.5	-0.9	-3.4	-1.9
Spain	5.6	0.7	2.6	8.2	2.7	0.3	1.1	3.9	2.2	0.3	1.0	3.2
Sri Lanka	0.8	1.0	3.5	4.3	2.9	0.5	1.6	4.6	4.0	0.4	1.3	5.3
Sudan	-0.2	0.6	2.3	2.1	-0.3	0.6	2.2	1.9	3.7	0.6	2.1	5.8
Swaziland	5.1	0.9	3.3	8.4	0.4	1.1	4.0	4.4	1.1	-1.5	-5.6	-4.5
Sweden	3.1	0.2	0.7	3.8	1.6	0.2	0.8	2.4	1.8	0.2	0.8	2.6
Switzerland	3.1	0.3	1.2	4.3	1.0	0.3	1.1	2.1	0.6	0.3	1.0	1.7
Syrian Arab Republic	2.2	1.1	4.0	6.2	2.1	1.0	3.6	5.7	2.0	0.5	1.8	3.8
Tajikistan	n.a.	0.7	2.5	n.a.	-1.9	0.2	0.7	-1.1	-3.4	0.3	1.1	-2.3
Tanzania	1.4	0.7	2.7	4.1	-0.5	0.4	1.4	0.9	1.4	0.4	1.5	2.9
Thailand	3.7	0.8	2.9	6.6	5.5	0.8	2.7	8.2	3.5	0.0	-0.1	3.4
Togo	2.7	1.1	3.8	6.5	-1.9	0.8	2.7	0.8	-1.5	0.4	1.6	0.0
Trinidad and Tobago	3.8	0.6	2.1	5.9	0.4	0.3	0.9	1.3	5.6	0.0	0.1	5.7
Tunisia	3.0	1.1	4.0	7.0	2.4	1.2	4.4	6.8	3.4	0.5	1.6	5.1
Turkey	3.4	1.4	5.2	8.5	2.7	0.7	2.6	5.2	2.5	0.6	2.3	4.7
Turkmenistan	n.a.	0.7	2.6	n.a.	-1.7	0.3	1.3	-0.4	2.5	0.2	0.6	3.1
Uganda	0.9	1.2	4.4	5.3	-2.0	-0.3	-1.2	-3.3	3.3	0.4	1.4	4.8
Ukraine	n.a.	0.4	1.4	n.a.	1.2	0.0	-0.1	1.1	-1.3	-0.1	-0.5	-1.8
United Arab Emirates	2.0	1.3	4.7	6.7	-3.7	0.9	3.2	-0.5	2.5	0.4	1.4	3.9
United Kingdom	2.4	0.2	0.8	3.2	1.9	0.3	1.0	2.9	1.9	0.3	1.0	3.0
United States	2.5	0.2	0.7	3.2	2.0	0.3	1.1	3.0	1.7	0.3	1.0	2.7
Uruguay	0.3	0.2	0.7	1.0	1.6	0.3	1.1	2.7	2.1	0.3	1.0	3.1
Uzbekistan	n.a.	0.7	2.4	n.a.	-1.1	0.3	1.1	0.0	0.7	0.1	0.2	0.9
Venezuela, Rep. Bol.	1.5	0.9	3.3	4.9	-1.4	0.4	1.5	0.1	1.1	0.2	0.8	1.9
Vietnam	1.0	1.1	4.0	5.0	1.3	1.5	5.4	6.7	5.8	0.8	2.8	8.6
Zambia	2.1	0.9	3.2	5.3	-1.5	0.1	0.3	-1.2	0.0	-0.8	-2.9	-2.9
Zimbabwe	3.2	0.7	2.6	5.7	-0.3	0.5	1.6	1.3	-3.1	-1.9	-6.8	-9.9

Source: Author's calculations, based on World Bank (2009), United Nations Population Division (2009b), and Maddison (2004). Data on GDP per capita are based on World Bank (2009), but were augmented with data from individual IMF staff reports were series were incomplete (i.e., for Afghanistan, Albania, Belarus, Indonesia, Iraq, Malaysia, Mali, Mongolia, Namibia, Oman, Paraguay, Poland, United Arab Emirates, Venezuela, and Zimbabwe).