Contribution of Increased Life Expectancy to Living Standards

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Abstract: The paper provides an analysis of the contribution of increasing life expectancy to living standards across countries. Building on an intertemporal utility framework and the literature on the value of statistical life, it analyzes contributions of economic growth and increasing life expectancy to welfare for 20 countries from 1870, offers an analysis with a near-global scope from 1950, and covers the adverse implications of a negative health shock (HIV/AIDS). Various measures of life expectancy are explored, and the implications of different methods of discounting are discussed.

Keywords: Welfare, development, economic growth, health, life expectancy, infant mortality, value of statistical life, discounting.

JEL Classification: I10, I15, I30, I31, J11, J17, O10, O11.

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Contents Page

Tables

Figures

Appendix Tables

I. Introduction

Improvements in health constitute an important aspect of the process of economic development. Health is valued in its own right, as it enables economic activities directly or through the acquisition of human capital, and as it enhances the enjoyment of wealth and income. The present paper aims to add to the understanding of the contribution of health to living standards globally, measuring improved health with increased life expectancy, and interpreting increased life expectancy as increasing the value of an individual's expected lifetime consumption.

Measuring the contribution of health to living standards, of course, is a complex and ambiguous task. Section II therefore prepares the ground, placing the present paper in the context of the literature on health and economic development, drawing on the literature on health as human capital, the macroeconomic literature on the interactions between health and macroeconomic variables like GDP per capita or economic growth, and the development accounting literature, interpreting health trends together with other development outcomes.

The analysis is broadly structured in three blocks. Sections III and IV prepare the ground, introducing the theoretical framework, and motivating the choice of parameters for the utility function, including by reference to the literature on the value of statistical life. A principal challenge arises from the fact that the bulk of the available evidence on valuations of mortality risks comes from a small number of high-income countries, whereas this paper aims for global coverage. In addition to reviewing the available evidence, the paper therefore also discusses whether alternative specifications yield plausible results when applied to low-income countries.

Section V presents estimates of the contribution of health to living standards in three settings. First, it discusses the experience of 20 (mainly economically advanced) countries from 1870. Second, it provides a near-global analysis of the contribution of increased life expectancy to living standards from 1950. Third, it adapts the framework to the study of the consequences of a negative health shock, using HIV/AIDS as an example.

One of the main characteristics of the analysis is the use of life expectancy, together with GDP per capita, as a determinant of living standards. Section VI takes this issue further, exploring alternative measures of life expectancy (e.g., population averages of remaining life expectancy) and analyzing alternative methods of calculating or approximating discounted life expectancy. Section VII concludes.

II. Context

The present paper relates to and builds on a longstanding economic literature on the contribution of health to living standards. It is useful to distinguish two branches of this literature – the theoretical work on health as human capital or health and development, and the empirical studies analyzing trends in health and other variables over time and interactions between health and other variables.

According to Grossman (1972), good health contributes to living standards both directly (as it enters the intertemporal utility function) and indirectly (as agents can invest in good health, which in turn affects income and consumption opportunities). The analysis of health as human capital also offers a rich framework for linking health to education and other types of human capital (Becker, 2007). In the development literature, improved health appears as a key development outcome, but also as an instrument, with poor health contributing to capability deprivation (Sen, 1999), and good health enhancing positive liberties and welfare (Dasgupta, 1990). Moreover, health outcomes carry information regarding the effectiveness of economic and political structures (Sen, 1993).

The perception of health as a key aspect of development has also motivated an empirical literature describing and analyzing health outcomes across countries or over time, and their relationship with other economic variables. Preston (1975, also see an updated analysis in Deaton (2003)) observed that life expectancy is positively correlated with income in a given year, but that life expectancy across countries had increased between 1930 and 1960. He attributes the bulk of this increase to "factors exogenous to a country's current level of income." Ram and Schultz (1979) stress the "large increases in the life expectancy of youth and adults in low-income countries." Easterlin (2000) highlights the contributions of economic growth, improved health, and other factors to the worldwide standard of living (but cautions against causal interpretations of the correlation between these indicators). Bourguignon and Morrison (2002) analyze trends in the global distribution of income and life expectancy, finding that inequality in longevity has declined "in the second half of the 20th century, perhaps mitigating the failure of income inequality to improve in the last decades." Easterly (1999) points out that health outcomes tended to increase with GDP per capita, but that most of the improvements could not be attributed to economic growth. Cutler, Deaton, and Lleras-Muney (2006) conclude that "between rich and poor countries, health comes from institutional ability and political willingness to implement known technologies, neither of which is an automatic consequence of rising incomes" (see also Deaton, 2006).

In the empirical growth literature of the 1990s, life expectancy or similar variables were typically included in growth regressions, motivated as a proxy for human capital. However, Temple (1999) observes that the "role [of these variables] is never justified by a well-articulated theory." Moreover, life expectancy is likely endogenous and correlated with the error term in these regressions (as, for example, implied by the findings of Cutler, Deaton, and Lleras-Muney (2006)), and attempts to adopt instrumental-variable techniques to overcome the endogeneity problem have not been fully successful (Weil, 2010).

The present paper most directly relates to the theoretical work on health as human capital and the empirical literature analyzing trends in health and other development indicators across countries. From the literature on health as human capital it takes the intertemporal utility function, which aggregates utility flows over a lifespan, and therefore provides a framework to assess the contributions of increases in income and of declining mortality to living standards. In other regards, it is in the tradition of development accounting exercises like Easterlin (2000) or Bourguignon and Morrison (2002), assessing trends in different development outcomes, bypassing issues of interdependencies and causality as discussed in Cutler, Deaton, and Lleras-Muney (2006), or Weil (2010).

This approach has been applied to studying the contribution of improved health to living standards over long periods of time (Usher (1980), Crafts (1997), and Nordhaus (2003)), typically finding that the contribution of declining mortality to living standards is of a similar order of magnitude as increases in income. Murphy and Topel (2006) conduct a similar exercise for the United States, but also discuss the role of different diseases and prospective gains from medical progress. Becker, Philipson, and Soares (2005) adopt this approach to study the evolution of world inequality, finding that "unlike income changes, longevity changes since 1960 reduced the disparity in welfare across countries." One recent addition to the literature, motivated by recent declines in life expectancy experienced in many African countries, are studies estimating the impact of HIV/AIDS on living standards (Crafts and Haacker (2004), Philipson and Soares (2005)).

III. Framework

Following authors like Usher (1973), Rosen (1988), Murphy and Topel (2006), and Becker, Philipson, and Soares (2005), the analysis is motivated by an intertemporal utility function of the form

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

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*, and ρ is the discount rate.[1]

The individual's budget constraint is

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

where y_t stands for the individual's income at time *t*, and r_t is the real interest rate faced by the individual at time *t*. (under perfect insurance, this moves in line with an individual's mortality rate). This framework allows for a rich analysis of implications of changes in mortality and earnings profiles, and has been put to good use in a number of studies analyzing the contribution of health to living standards over the life cycle (notably, Murphy and Topel, 2006).

For the analysis of the welfare implications of changes in mortality profiles across countries, however, it is necessary (owing to data constraints) to adopt a simplified version of this model (as in Usher (1973), and Becker, Philipson, and Soares (2005)), with

$$V(y^*, \{\mu_{s,t}\}, \rho, s) = u(y^*)\int_s^\infty e^{-\int_s^t (\rho+\mu_{s,v})dv} dt = u(y^*) LE(\{\mu_{s,t}\}, \rho, s) \, , \tag{3}$$

i.e., the lifetime utility of an individual who receives a certain permanent income y^* each year, and enjoys an expected (discounted) life expectancy LE .

For assessments of the contribution of improved health to living standards, y^* in Eq. (3) is then typically equated with GDP per capita, and LE with life expectancy. This simplified framework involves several departures from the richer framework sketched in Eqs. (1) and (2). First, it abstracts from changes in the profile of consumption over time which may occur in response to changes in the profile of mortality. While the bias introduced by this omission is small for marginal changes in the profile of mortality (as the envelope theorem applies), it may distort results for a non-incremental analysis. Second, the budget constraint in Eq. (2) is forward-looking, and the higher the rate of growth of y_t , the higher is an individual's level of y^* and thus V . Using GDP per capita as a proxy for y^* , in addition to well-known shortcomings (as noted by Becker, Philipson, and Soares (2005)), in a cross-country analysis, understates welfare in fast-growing economies. Third, a similar kind of myopia occurs when estimates of life

[1] Some of the studies we build on include additional factors in the utility function. Rosen (1988) accounts for leisure, Murphy and Topel (2006) allow for a direct link between health and utility.

expectancy are used as a proxy for $LE(\{\mu_{s,t}\}, \rho, s)$. The latter is conceived as forward-looking (based on *expected* mortality rates) in Eq. (3), whereas "life expectancy" typically is calculated as a summary indicator of *current* mortality rates.

Eq. (3) provides a framework for assessing the contributions of improving life expectancy to living standards, as

$$\frac{dV}{V} = \frac{y^* u'(y^*)}{u(y^*)} \frac{dy}{y} + \frac{dLE}{LE}, \tag{4}$$

i.e., growth in living standards is obtained as the weighted sum of the growth in income and the growth of life expectancy, with weights determined by the elasticity of the utility function.

Alternative, on may start from economic growth, and then add the contribution of increased life expectancy to living standards (see, for example, the adjusted growth rates offered by Crafts (1997) and Nordhaus (2003)). The variation in y^* equivalent (in terms of its impact on V) to a change in LE is

$$\left.\frac{dy^*}{y^*}\right|_{EQU} \equiv -\left.\frac{dy^*}{y^*}\right|_{dV=0} = \frac{u(y^*)}{y^* u'(y^*)} \frac{dLE}{LE}. \tag{5}$$

The increase in living standards z (a monotonous transformation of V) is then obtained as the sum in the increase in income and the income-equivalent of the increase in life expectancy, i.e.,

$$\frac{dz}{z} = \frac{dy^*}{y^*} + \frac{u(y^*)}{y^* u'(y^*)} \frac{dLE}{LE}. \tag{6}$$

For larger changes in income and life expectancy (e.g., when comparing data points over long periods), Eq. (3) defines the equivalent variation w in income that corresponds to a discrete change in life expectancy implicitly as

.
$$\frac{u(y^* + w)}{u(y^*)} = \frac{LE + \Delta LE}{LE}. \tag{7}$$

IV. Parameters

To apply the framework described in Section III, it is necessary to determine an appropriate functional form and choose parameters. Most of the available studies focus on the United States and other developed economies. In contrast, the applications below estimate the contributions of improved health to living standards across periods of time or across countries characterized by large differences in GDP per capita and life expectancies. It is therefore important that the specification yields sensible results over this large domain.

Two approaches that have been used to this end – calibrating the utility function based on micro-empirical evidence on the shape of preferences, and utilizing estimates of the value of statistical life. These approaches are related. To illustrate the link between the VSL and the theoretical framework, consider the case in which mortality is constant over time.[2] The value of statistical life (VSL) is most commonly estimated as the wage premium (i.e., equivalent variation $dy^*\big|_{EQU}$ in y^*) that compensates for higher mortality risk on the job. In this case, $VSL = \left.\frac{dy^*}{d\mu}\right|_{dV=0}$, and $LE = \frac{1}{\rho+\mu}$. Substituting into Eq. (5) yields

$$VSL \equiv \left.\frac{dy^*}{d\mu}\right|_{dV=0} = \frac{u(y^*)}{y^* u'(y^*)} y \cdot LE = \frac{y \cdot LE}{\gamma}, \tag{8}$$

i.e., the VSL is equal to (discounted) lifetime income, divided by the elasticity of the utility function γ. Owing to risk aversion, $\gamma < 1$, which implies that the VSL is always larger than the expected lifetime income. By rearranging Eq. (8), it is also possible to draw inferences regarding the shape of the utility function from the VSL, as

$$\frac{u(y^*)}{y^* u'(y^*)} = \frac{VSL}{yLE}. \tag{9}$$

One of the most influential study calibrating the utility function based on micro-empirical evidence is Murphy and Topel (2006), adopting a utility function of the form

$$u(y) = \frac{y^{1-\frac{1}{\sigma}} - y_0^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}}, \tag{10}$$

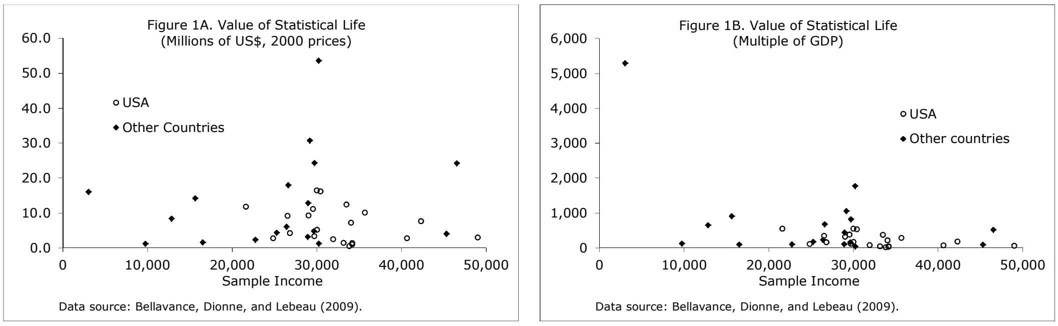
where σ is the intertemporal elasticity of substitution. This specification is sufficiently general for our purposes, as it encompasses different approaches that have been used in the literature. The parameters σ and y_0 can be calibrated based on evidence on the shape of the utility function, or estimates of the value of statistical life, as Eqs. (8) and (10) imply that

[2] For a temporary increase in mortality, and the wage premium over the corresponding period, the results are similar.

$$VSL = \frac{y \cdot LE}{\gamma} = \frac{1 - \left[\frac{y_0}{y}\right]^{1-\frac{1}{\sigma}}}{1 - \frac{1}{\sigma}} y \cdot LE \tag{11}$$

For example, Becker, Philipson, and Soares (2005) calibrate their parameters by reference to the literature on the value of health improvements (an earlier version of Murphy and Topel (2006)) and the econometric evidence on the parameter σ. Other authors assume that the VSL is proportional to $y \cdot LE$, either setting y_0 equal to zero (e.g., Crafts and Haacker (2004)) or proportional to the population average of income (Murphy and Topel (2006).

Figure 1. Value of Statistical Life Across Countries



For an analysis spanning countries with very different income levels, the empirical literature on the VSL across countries is relevant for setting the parameters of the utility function. Figure 1 summarizes estimates of the VSL compiled in a recent study by Bellevance, Dionne, and Lebeau (2009).[3] Several inconvenient truths emerge from the data. (1) The available evidence is dominated by empirical studies from the United States. (2) There is almost no evidence from low- and middle-income countries, and the one study available from a low-income country (India) is a massive outlier, at least when considering the VSL relative to income. (3) There is no apparent correlation between income and the VSL.

The empirical evidence regarding the VSL across countries is mixed. For example, Miller (2000) finds an income elasticity in the vicinity of one, while Viscusi and Aldy (2003) estimate the elasticity at about 0.5, and Bowland and Beghin (2001) suggest elasticities of the VSL with respect to income between 1.5 and 2.3. Estimates of the elasticity of the VSL appear to be sensitive to the underlying sample (see discussion in Viscusi and Aldy (2003), who also re-estimate earlier studies based on their dataset).

[3] Bellevance, Dionne, and Lebeau (2009) draw on Viscusi and Aldy (2003) for much of their sample, but add some more recent studies, and eliminate studies drawing on the same datasets.

Becker and Elias (2007) point at the role of influential observations, noting that the elasticity of the VSL estimated by Viscusi and Aldy (2003) changes to 1.15 if one outlier (the observation from India also identified in the discussion of Fig. 1) is removed from the sample.

One unsatisfactory aspect of the empirical literature on the VSL is the fact that it does not clearly identify the role of life expectancy (which, in light of Eq. (11), would be necessary to calibrate the parameters of the utility function). Notably, an estimate of the income elasticity of the VSL of one does not necessarily imply that the VSL is proportional to income (controlling for life expectancy). While empirical studies typically capture average mortality risk among the sample, this is not a good proxy for life expectancy.[4]

Alternatively, estimates of the value of statistical life can be obtained based on social valuations. Appelbaum (2011) reports valuations of life adopted by various U.S. government agencies in 2010 of between US$ 6 million and US$ 9.1 million. With a level of GDP per capita in 2010 of US$ 47,284 (IMF, 2011), this implies a value of statistical life in the range between 127 times GDP and 192 times GDP. Nordhaus (2003), motivated by earlier versions of these social/political valuations of life, adopts a value of statistical life of US$ 3 million, corresponding to 129 times GDP per capita in 1990 (US$ 23,198).

Against this background, the analysis offered here rests on the following assumptions:

(1) The value of statistical life is set at 130 times GDP per capita for the United States.

(2) The discount rate is set at 3 percent (in line with Becker, Philipson, and Soares (2005), and one of the variations in Nordhaus (2003)).

(3) The elasticity of the utility function with respect to income is constant (i.e., the parameter y_0 in Eq. 10 is set equal to zero). This choice avoids that valuations of life (relative to income) differ radically across low-income countries, and compared to high- and middle-income countries. (This point is discussed further below, and illustrated in Figure 2.)

(4) The relevant life expectancy underlying the social valuation of the value of statistical life is the discounted average remaining life expectancy. For the United States, undiscounted average remaining life expectancy was equal to 44.6 years in

[4] In the studies included by Bellevance, Dionne, and Lebeau (2009), average mortality risk differs by a factor of 34 between studies. Substituting demographic data for unavailable data on life expectancy from the VSL studies is problematic, as the composition of the sample – in terms of its age structure and other characteristics – may differ substantially from the overall population.

2005-10 (United Nations Population Division, 2011), and discounted average remaining life expectancy was equal to 22.0 years.[5]

(5) Using assumptions (1) and (4), and Eq. (9), the elasticity of the utility function can then be calculated as the ratio of discounted average life expectancy (22.0 years) and the value of statistical life relative to GDP per capita, i.e.,

$$\frac{y^* u'(y^*)}{u(y^*)} = \frac{22}{130} \approx 0.169,$$

implying a value of the parameter σ of 1.20 (see Eq. (10)).

(6) The state of health, LE, is proxied by discounted life expectancy at birth. Where available, discounted life expectancy is calculated accounting for infant mortality, otherwise, it is approximated on the basis of data on life expectancy alone.

(7) Consequently, the increase in living standards (Eq. (6) can be calculated as the rate of economic growth, plus 5.9 (i.e., the inverse of the elasticity) times the rate of growth of average discounted life expectancy. In our specification, this weight is constant across countries with different income levels.

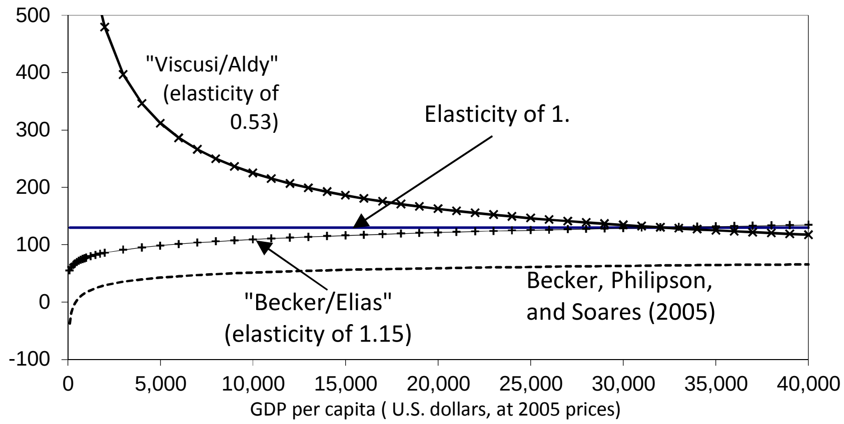
The value of statistical life of 130 times GDP per capita assumed in this calibration based on data for the United States is below the median (180 times income) of the studies covered by Bellevance, Dionne, and Lebeau (2009), but well within the range spanned by these studies, with 15 of 39 returning a lower estimate. Compared to the policy valuations for the United States quoted above, the VSL of 130 times GDP per capita, i.e. US$ 6.1 million in 2010, is at the lower end of the values of life adopted by government agencies (between US$ 6 million and US$ 9.1 million), and close to the level assumed by Nordhaus (2003), who also draws on policy valuations. Relative to the macroeconomic literature, the implied estimate of the parameter σ is at about the level accepted in the macroeconomic literature, as surveyed by Browning, Hansen, and Heckman (1999). The estimates of the VSL adopted here, however, are higher than those implied by the specification in Becker, Philipson, and Soares (2005), which are not directly based on VSL estimates.

Calculating discounted life expectancy is not a trivial exercise. While estimates of undiscounted life expectancy are available widely, the underlying survival tables (necessary for calculating discounted life expectancy precisely) are frequently unpublished. Depending on data availability, the present paper explores three different ways of calculating discounted life expectancy. (1) For the section covering 20 countries from 1870, discounted life expectancy is calculated based solely on available estimates

[5] This compares to an undiscounted life expectancy at birth of 78.2 years, and a discounted life expectancy at birth of 29 years.

of undiscounted life expectancy, which is interpreted deterministically (i.e., assuming that everyone survives to the same age).[6] (2) For the section covering 150 countries from 1950, and the discussion of the welfare costs of HIV/AIDS, discounted life expectancy is calculated also incorporating data on infant mortality (see Appendix for details). This avoids a source of bias arising from the fact that gains in life expectancy at birth in low-income countries disproportionately reflect declines in infant mortality or child mortality, carrying a high weight in discounted life expectancy, whereas increases in life expectancy in economically advanced countries tend to reflect improved survival at old age, which contributes little to *discounted* life expectancy. (3) Section VI discusses the possible bias introduced by these approximations, using precise estimates of discounted life expectancy based on detailed survival tables available for 1995 – 2010. This section also explores alternatives to life expectancy at birth as indicator of the state of population health.

Figure 2. 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.

For an analysis that captures the contribution of health to living standards globally (i.e. across countries with GDP per capita, in 2005 PPP dollars, ranging from about US$300 to US$ 83,000), the form of the utility function is a critical factor. Notably, different specifications of the utility function that have been proposed have widely divergent implications for the value of statistical life across countries with different levels of economic development. This point is illustrated in Figure 2, showing the implications of different elasticities of the VSL with respect to incomes (taking values of 0.53, 1.0, and 1.15, respectively), as well as the specification proposed by Becker, Philipson, and Soares (2005).[7] The curves representing different elasticities have been

[6] This is the same approach as adopted by Becker, Philipson, and Soares (2005).

[7] The study by Viscusi and Aldy (2003) and the comment in Becker and Elias (2007) are based on sample income, not GDP per capita. Mapping from sample income to GDP per capita is not necessarily 1-to-1. This

normalized to intersect at a VSL of 130 times GDP per capita and a level of GDP per capita of US$ 32,000 (in 2005 PPP dollars),[8] and controlling for average remaining life expectancy at 44.6 years (as above).

The three curves representing elasticities of 0.53, 1.0, and 1.15 differ little for levels of GDP per capita between US$25,000 and US$ $35,000, i.e., the countries dominating the available evidence on the value of statistical life. This may help explain the large variations in the estimates of the elasticity of the VSL with respect to income based on these studies. However, the estimates differ radically across low-income countries (broadly, countries with a level of GDP per capita between US$ 300 and US$ 2,000 (PPP, 2005 prices). For an elasticity of 0.53, as estimated by Viscusi and Aldy (2003), the value of statistical life (relative to GDP per capita) becomes very large in low-income countries. For example, for people located at the World Bank's poverty line of US$ 1.25 per day, the VSL becomes 960 times GDP per capita. Even elasticities in the vicinity of (but not equal to) 1 have large implications for the VSL relative to income across countries, as illustrated by the curve representing an elasticity of 1.15 (VSL of 69 times GDP per capita at US$ 1.25 per day).

The study by Becker, Philipson, and Soares (2005) is an outlier as it implies a lower VSL of 64 times GDP per capita at a level of GDP per capita of US$32,000, about one-half of the level assumed in the present study. Moreover, it assumes very large differences in the VSL across low-income countries, with a VSL of 30 times GDP per capita for GDP per capita at US$2,000 (PPP, 2005 prices), and negative utility of being alive below a level of GDP per capita of about US$430 (in 2005 prices).[9] Becker, Philipson, and Soares (2005) correctly observe that GDP per capita falls below this threshold in only one country in their dataset (Democratic Republic of Congo). However, their critical value is just below the World Bank's poverty line of 1.25 US$ per day (at 2005 prices), and

point, however, is not critical for the discussion of Fig. 2, as the variation in income across countries plausibly dominates discrepancies between GDP per capita and wage rates within countries.

[8] US$ 32,000 (in 2005 PPP dollars) correspond to the level of GDP per capita in the United States in 1990. This reference point was chosen because Becker, Philipson, and Soares (2005) use it as anchor for their analysis, and as many of the studies of wage/mortality trade-offs the literature on the VSL draws from date back to at least 1990.

[9] The value in Becker, Philipson, and Soares (2005) is US$353, at 1996 prices, from the Penn World Tables 6.1. The value of US$440 results from a transformation to 2005 prices based on data from the current World Development Indicators (World Bank, 2011). This transformation is not straightforward, but appears to be successful at the lower end of the income distribution – while Becker, Philipson, and Soares (2005) find that the only country with GDP per capita below the critical value of US$353 is the Democratic Republic of Congo (1994-97) in the Penn World Tables 6.1, the only countries with GDP per capita below US$440 in this period in the World Development Indicators database are the Democratic Republic of Congo and Liberia (the latter was not included in the Penn World Tables 6.1).

implies that 22.6 percent of the global population would have been better off dead in 2005.[10] Such Swiftian propositions for a large part of the populations of low-income countries are not plausible,[11] as they would imply death-seeking behavior among these people, and the absence of certain health-seeking behavior.[12]

Overall, our specification of the utility function reflects (1) that the bulk of the evidence on the VSL comes from high-income countries, and we therefore use a point estimate of the VSL consistent with this evidence as an anchor. (2) In the absence of solid empirical evidence, we adopt a utility function that implies an elasticity of the VSL with respect to income of one. This is based on the observation that even elasticities in the vicinity of one can result in large difference in the VSL across low-income countries. At the same time, of course, it is important to acknowledge that the empirical basis of our specification (and alternatives) is exceedingly weak as far as low-income countries are concerned.

V. Contribution of Increased Life Expectancy to Living Standards

A number of authors have estimated the contribution of increased life expectancy to living standards, including Crafts (1997) for a group of industrialized countries since 1870, Nordhaus (2003) and Murphy and Topel (2006) for the United States since 1900, Crafts (2007) for the United Kingdom, Becker, Philipson, and Soares (2005) with a near-global scope, and Soares (2009) for Latin America and the Caribbean.

These studies find that the contribution of increased life expectancy to living standards is substantial, and of a similar magnitude as the contributions of the growth of GDP per capita. For example, the estimates by Becker, Philipson, and Soares (2005) imply that increasing life expectancy accounted for 28 percent of the increase in global living standards between 1960 and 2000 (and 40 percent in the "poorest 50%

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[10] World Bank (2008) estimates that 25.2 of the global population fell below the poverty line of US$1.25 per day. The point estimate of 23.5 percent corresponding to the value at which the utility from being alive becomes negative in Becker, Philipson, and Soares (2005) was calculated using the World Bank's PovCalNet website (http://iresearch.worldbank.org/PovcalNet/povDuplic.html, accessed May 18, 2011).

[11] Swiftian preferences and propositions were introduced by Jonathan Swift in *A Modest Proposal* (1729), a satirical and provocative essay suggesting that the wretched Irish should sell their children as meat, to generate some income to improve their lot, spare their children a dismal life, and contain the spread of Papism.

[12] With a negative utility of being alive, individuals would not invest in life-extending measures, but may spend to reduce or avoid the disutility from being ill. Additionally, life-time utility could be positive even if current income is too low if the individual expects an increase in income. See, for example, Wagstaff and van Doorslaer (2003), and Preker and others (2004), for an analysis of health spending among the poor.

countries").[13] Murphy and Topel (2006) value the decline in mortality in the United States between 1900 and 1950 at about as "roughly equal to output of goods and services," but find that "gains after 1950 form a smaller share of income because other forms of productivity grew faster." Nordhaus (2003) estimates that "the value of improved health (…) grew at between 2.2 and 3.0 percent of consumption, whereas consumption grew at a rate of about 2.1 percent" in the United States between 1900 and 1995, also noting a slowdown the contribution of health improvements in the second half of the 20th century. Using similar methods, Crafts (2007) suggests that increased life expectancy contributed about the same as growth of GDP per capita to "augmented income" in the UK between 1870 and 2001.[14]

The present paper adds to these quantitative estimates in three directions. (1) It provides an analysis of the contribution of increased life expectancy to living standards from 1870 to 2009, focusing on today's industrialized economies (similar to Nordhaus (2003), Crafts (2007), and especially building on Crafts (1997)). (2) It provides a global analysis of the contributions of economic growth and increasing life expectancy to living standards for 1950 to 2009. This analysis is similar in scope to the study by Becker, Philipson, and Soares (2005), but differs from theirs in terms of the specification of the utility function and the method used to calculate discounted life expectancy. (3) We discuss the welfare costs of a major adverse health shock (HIV/AIDS) in a number of countries (building on work by Crafts and Haacker (2004) and Philipson and Soares (2005)).

The analysis builds on two principal data sources. Demographic and population estimates from 1950 are from United Nations Population Division (2011). For earlier years, estimates of life expectancy are those reported by Crafts (1997) and from other sources (see Appendix Table 1), and estimates of population size are from Maddison (2003). Data on GDP per capita for 1870 – 2001 are from Maddison (2003), and have been extended through 2009 using growth rates obtained from World Bank (2011) and, in a few cases, other sources (see Appendix). The Maddison dataset was chosen over alternative datasets (World Development Indicators, or Penn World Tables), as it allows a consistent analysis of long-term trends from 1870 in selected countries (for which data are available from Maddison (2003) only), and as for the present purposes the scope is wider than for the Penn World Tables.[15] For the post-1950 period, the coverage of the

[13] Based on Table 2 in Becker, Philipson, and Soares (2005). Calculated as value of life expectancy gains (in annual income), divided by sum of life expectancy gains and gains in GDP per capita.

[14] This relates to the "mortality age weighted" example in Crafts (2007). Aggregating over periods, the estimates by Crafts imply a rate of growth of GDP of 1.4 percent, and a contribution of increased life expectancy adding 1.5 percentage points to the growth of "augmented income" of 2.9 percent.

[15] The latest version of Penn World Tables (7.0) covers 189 countries and territories over the 1950-2009 period, but does not include complete series for many of them. Maddison (2003) offers estimates of GDP

analysis rises from 128 countries (88 percent of the global population) in 1950 to 143 countries by 1973 and 148 countries by 1990 (96 percent of the global population). (The differences in coverage are attributable to discontinuities in the data associated with the break-up of the Soviet Union, Yugoslavia, and Czechoslovakia.)

Using life expectancy at birth as an indicator for the state of health is not a trivial choice. Mortality may not move in line with morbidity, an issue that we abstract from in our theoretical framework, but that is taken up more explicitly by authors like Murphy and Topel (2005), Cutler and Richardson (1999), and in the theoretical framework of Grossman (1972). Moreover, life expectancy at birth is not a representative indicator of improvements in (remaining) life expectancy enjoyed across the population, and discounted life expectancy frequently can only be approximated from available data. Some of these issues will be taken up in Section VI.

The estimates reported below are based on Eq. (7), with the gain arising from increased life expectancy transformed into an annual contribution to living standards. The presentation of the estimates is similar to Eq. (6). In an environment with discrete changes in GDP and life expectancy, unlike in the incremental analysis Eq. (6) builds on, it is necessary to take account of the interaction effects. Our analysis reports the contributions of increased GDP and of life expectancy to living standards, without attributing the interaction effect to either of them.[16]

Growth in Living Standards, 20 Countries, 1870 – 2009

Table 1 summarizes estimates for a set of 16 advanced economies (14 European countries, plus United States and Canada), 3 emerging economies (Brazil, India, Mexico), and Japan, which starts out at a level of GDP per capita close to the latter group but catches up with the leading economies (see Appendix Table 1). To estimate the contribution of increasing life expectancy to living standards, discounted life expectancy has been approximated based on data on life expectancy alone, using the first method described in the Appendix.

per capita for 1973 for many countries, even if complete series are not available, which can be used to calculate period growth rates from 1973.

[16] For this reason, there can be small differences between the sum of the contributions of GDP growth and life expectancy, and the growth of living standards. These discrepancies are generally small, at around 1 percent of the increase in living standards for the industrialized countries, and up to 2 percent for the emerging economies covered in Table 1.

Table 1: Growth in Living Standards, 20 Countries, 1870-2009

	1870-1913				1913-1950			
	GDPpc growth	LE growth	LE contr.	LS growth	GDPpc growth	LE growth	LE contr.	LS growth
Australia	1.1	0.5	1.2	2.2	1.0	0.4	0.8	1.8
Austria	1.5	0.7	2.2	3.7	0.2	1.2	2.9	3.1
Belgium	1.1	0.5	1.4	2.5	0.7	0.8	1.8	2.5
Canada	2.3	0.5	1.3	3.6	1.3	0.7	1.5	2.9
Denmark	1.6	0.6	1.4	3.0	1.6	0.5	1.0	2.6
Finland	1.4	0.5	1.6	3.1	1.9	0.9	2.2	4.1
France	1.5	0.4	1.2	2.6	1.1	0.7	1.6	2.8
Germany	1.6	0.7	2.1	3.7	0.2	0.8	1.9	2.0
Italy	1.3	1.2	4.0	5.3	0.8	0.9	2.0	2.9
Netherlands	0.9	0.9	2.3	3.2	1.1	0.7	1.3	2.4
Norway	1.3	0.3	0.8	2.1	2.1	0.6	1.2	3.4
Spain	1.2	0.5	1.6	2.9	0.2	1.1	2.7	2.9
Sweden	1.5	0.5	1.3	2.8	2.1	0.6	1.2	3.3
Switzerland	1.7	0.6	1.5	3.2	2.1	0.7	1.6	3.7
United Kingdom	1.0	0.6	1.6	2.7	0.9	0.7	1.4	2.4
United States	1.8	0.4	1.0	2.8	1.6	0.7	1.6	3.2
Average, 16 countries	1.4	0.6	1.8	3.3	1.1	0.8	1.7	2.8
Brazil	0.3	0.3	1.1	1.4	2.0	1.3	4.0	6.1
India	0.5	0.0	0.1	0.6	-0.2	1.1	3.9	3.7
Japan	1.5	0.4	1.3	2.8	0.9	0.8	2.0	2.9
Mexico	2.2	1.1	4.1	6.4	0.8	1.4	4.3	5.2

	1950-1973				1973-2009			
	GDPpc growth	LE growth	LE contr.	LS growth	GDPpc growth	LE growth	LE contr.	LS growth
Australia	2.4	0.2	0.3	2.8	1.9	0.4	0.6	2.4
Austria	4.9	0.3	0.6	5.6	1.9	0.4	0.6	2.5
Belgium	3.5	0.3	0.5	4.0	1.7	0.3	0.6	2.2
Canada	2.8	0.3	0.5	3.3	1.5	0.3	0.5	1.9
Denmark	3.1	0.2	0.3	3.4	1.5	0.2	0.2	1.7
Finland	4.3	0.4	0.7	5.0	2.0	0.3	0.6	2.5
France	4.0	0.4	0.7	4.8	1.4	0.3	0.5	1.9
Germany	5.0	0.3	0.5	5.5	1.4	0.3	0.6	1.9
Italy	4.9	0.4	0.8	5.8	1.5	0.3	0.6	2.0
Netherlands	3.5	0.2	0.3	3.7	1.6	0.2	0.3	1.9
Norway	3.2	0.1	0.2	3.4	2.4	0.2	0.3	2.7
Spain	5.6	0.7	1.2	6.9	2.1	0.3	0.5	2.6
Sweden	3.1	0.2	0.4	3.4	1.4	0.2	0.3	1.8
Switzerland	3.1	0.3	0.5	3.6	0.7	0.3	0.4	1.2
United Kingdom	2.4	0.2	0.4	2.8	1.6	0.3	0.4	2.1
United States	2.5	0.2	0.4	2.9	1.6	0.2	0.5	2.0
Average, 16 countries	3.5	0.3	0.5	4.0	1.6	0.3	0.5	2.0
Brazil	3.7	0.8	1.8	5.6	1.5	0.6	1.2	2.6
India	1.4	1.4	4.1	5.7	3.7	0.7	1.8	5.2
Japan	8.1	0.9	1.6	9.8	1.8	0.3	0.7	2.3
Mexico	3.2	1.1	2.6	5.9	1.2	0.5	1.3	2.1

Sources: Author's calculations, based on data in Appendix Table 1. "GDPpc growth" stands for annual growth of GDP per capita (percent), "LE growth" for annual growth of life expectancy (percent), "LE contr." for the contribution of increassed life expectancy to the growth in living standards (percentage points), and "LS growth" for annual growth of living standards (percent).

For the 16 advanced economies, the picture is fairly similar. Overall, living standards improved by 2.9 percent annually between 1870 and 2009, reflecting a rate of growth of GDP per capita of 1.8 percent, and a contribution of increasing life expectancy of

1.1 percentage points annually.[17] The relative roles of GDP growth and improvements in life expectancy were reversed over the period covered. Before 1950, improvements in living standards were dominated by rising life expectancy (especially in the 1913-50 period, when it accounted for almost two-thirds of the overall gains). However, the rate of increase in life expectancy dropped sharply after 1950 (to less than one-half of the rate observed in 1870-1950). Meanwhile, economic growth accelerated especially in 1950-73. Consequently, increasing life expectancy contributed only about one-quarter to the rise in living standards in 1950-73 (when GDP growth was extraordinarily high) and one-third between 1973 and 2009. Apart from the first period, the contribution of life expectancy has been more even across countries than the contribution of GDP growth, this partly reflects war-related economic disruptions in a number of countries (notably Austria, Germany, and Spain) and subsequent catch-up growth.

For the initially less developed countries the picture is more heterogeneous. Japan stands out in terms of high growth rates of both GDP per capita and life expectancy, especially in the 1950-73 period, catching up with the leading economies economically and attaining the highest levels of life expectancy among the 20 countries covered from 1990. While India stagnated economically between 1913 and 1973, life expectancy doubled over this period, dominating the increases in living standards. Brazil and Mexico did not keep pace with the leading economies in terms of GDP growth, but experienced higher rates of growth of life expectancy, so that the improvements in living standards in these two countries are consistently among the highest of the 20 countries covered in Table 1.

Growth in Living Standards, 150 Countries, 1950 – 2009

The demographic estimates published by the United Nations Population Division (2011), and the wider country coverage by Maddison (2003) from 1950, enable a near-complete global analysis of the contribution of increasing life expectancy to living standards, summarized in Table 2 (a complete set of country estimates is provided in Appendix Table 2). The estimates in Table 2 are based on improved measures of discounted life expectancy (applying the third method described in the Appendix), also using data on infant mortality available from United Nations Population Division (2011).

[17] These averages are weighted by 1990 population levels. The results are robust regarding the base year for weighting. E.g., if 1870 population weights are used, the annual growth in living standards between 1870 and 2009 comes out at 3.0 percent, rather than 2.9 percent when 1990 weights are used.

Table 2: Growth in Living Standards, 150 Countries, 1950-2009

	1950-1973				1973-1990				1990-2009			
	GDPpc growth	LE growth	LE contr.	LS growth	GDPpc growth	LE growth	LE contr.	LS growth	GDPpc growth	LE growth	LE contr.	LS growth
North Africa	2.4	0.9	3.4	5.9	1.7	1.0	2.5	4.3	1.5	0.6	1.1	2.7
Sub-Saharan Africa	1.9	1.0	3.2	5.2	-0.8	0.4	1.6	0.7	1.0	0.4	0.7	1.8
Latin America/Caribbean	2.8	0.9	2.5	5.4	0.8	0.7	2.1	2.9	1.6	0.4	1.3	2.9
North America	2.5	0.2	0.7	3.2	1.9	0.3	0.7	2.6	1.3	0.2	0.4	1.6
Asia	2.6	1.5	4.5	7.2	3.5	0.7	2.0	5.5	5.4	0.4	1.2	6.6
Europe (excl. Eastern Europe)	4.3	0.4	1.8	6.2	2.0	0.3	0.9	3.0	1.2	0.3	1.1	2.3
Eastern Europe	n.a.	0.5	3.1	n.a.	0.6	0.0	0.8	1.4	0.7	0.1	0.6	1.3
Oceania	2.3	0.2	1.1	3.4	1.5	0.4	0.9	2.4	1.9	0.3	0.8	2.7
World	n.a.	1.0	3.5	n.a.	2.4	0.6	1.7	4.1	3.6	0.4	1.0	4.7
World (excl. Eastern Europe)	2.8	1.1	3.5	6.4	2.5	0.6	1.8	4.4	3.8	0.4	1.1	5.0
Low-income countries[2]	1.1	0.7	2.1	3.2	0.0	1.0	3.1	3.1	2.0	0.6	1.4	3.5
Low-middle income countries[1,2]	2.1	1.2	3.7	5.9	1.9	0.8	2.3	4.3	2.4	0.5	1.2	3.6
Upper-middle income countries[2]	3.1	0.9	3.0	6.2	0.8	0.7	2.2	3.0	1.9	0.4	1.0	2.9
High-income countries[2]	4.4	0.4	1.7	6.1	2.4	0.4	0.9	3.3	1.4	0.3	0.7	2.1
Bottom quartile 1950[1,2]	1.3	0.8	1.9	3.1	1.0	1.1	3.1	4.2	2.6	0.6	1.5	4.1
Top quartile 1950[2]	3.3	0.3	1.5	4.8	1.5	0.3	0.9	2.5	1.5	0.2	0.6	2.1
China	2.9	1.8	5.4	8.4	4.8	0.4	1.0	5.8	7.8	0.3	0.7	8.5
India	1.4	1.4	4.6	6.1	2.5	0.8	2.5	5.1	4.8	0.6	1.7	6.6
Russia	n.a.	0.3	2.4	n.a.	1.0	-0.1	0.0	1.0	0.3	0.0	0.3	0.5
South Africa	2.2	0.9	2.6	4.9	-0.3	0.8	2.3	2.0	1.3	-0.9	-2.0	-0.7

Sources: Author's calculations, based on Maddison (2003), United Nations Population Division (2011), and other sources, as documented in the Appendix. The underlying country estimates are provided in Appendix Table 2.
[1] Excluding China and India. [2] Excluding Eastern Europe.

The estimates for Europe (excluding Eastern Europe), North America, and Oceania echo the earlier findings for the 16 industrialized countries these groups largely overlap with. In these countries, improvements in living standards were dominated by increases in GDP, although increasing life expectancy did not play a negligible role. In North Africa, sub-Saharan Africa, and Latin America, increased life expectancy dominated improvements in living standards in 1950-90), partly reflecting low rates of economic growth in the 1973-90 period. In Asia, health improvements dominated the growth in living standards in 1950-73, but GDP growth was the largest contributor after 1973.

This pattern in the growth of life expectancy is consistent with a delayed health transition outside the most advanced economies (Riley (2001), chapter 1), and a delayed transmission or implementation of health knowledge and health technology (Deaton (2004), Acemoglu and Johnson (2007)). For the final period (1990-2009), the contribution of increasing life expectancy to living standards declined to about one-quarter of the total, and the economic growth exceeds the contribution from life expectancy in all regions but sub-Saharan Africa, North Africa, and the Middle East. This reflects an acceleration in growth, but also a slowdown in the rate of growth of life expectancy in most regions.

The differences in the role of life expectancy are correlated with the level of economic development. Outside the high-income countries, increased life expectancy is the largest contributor to living standards through 1990.[18] Economic growth exceeds the contribution of increased life expectancy for each income group in 1990-2009, but the share of the contribution of life expectancy declines with income. This ex-post country classification (using the World Bank's definition of income groups as of July 1, 2010), however, introduces a bias regarding the role of economic growth (growth in 1950-2009 is a key determinant of 2010 income levels). For this reason, we also divide countries by initial income. As expected, the difference in economic growth between the top quartile and the bottom quartile, by initial income, are smaller than the differences using the ex-post classification, but the findings regarding the role of life expectancy are similar to the discussion across (ex-post) income groups.

In two regions, developments diverge from this broad picture. In Eastern Europe, life expectancy stagnated in 1973-90 (and decline in Russia, Ukraine, and a number of other countries), and barely improved in 1990-2009 (the latter, however, reflects a drop in life expectancy in the early stages of the economic transition in many countries, followed by a recovery). As a crude illustration of the costs in terms of living standards of the Soviet experience and the subsequent transition, a comparison with Southern Europe is instructive. Life expectancy in Easter Europe (62.8 years) was at about the same level as in Southern Europe (62.3 years) in 1950, but fell behind by 2 years by 1973, 6 years by 1990 and 10 years by 2009. On top of the economic malaise, this drop in life expectancy (using Southern Europe as benchmark) is equivalent to an additional drop in GDP per capita of about one-third.[19]

In sub-Saharan Africa, the regional average masks highly divergent experiences regarding gains in life expectancy, owing to the impact of the HIV/AIDS epidemic. This is illustrated in Table 2 with the South African data. GDP per capita increased by 1.3 percent annually between 1990 and 2009. Meanwhile, life expectancy dropped from 61.5 years to 51.8 years, more than offsetting the economic gains, and resulting in an overall drop in living standards of 0.7 percent annually, and an accumulated 13 percent.

The Adverse Impact of a Large Health Shock: HIV/AIDS

One important application of the methods described and developed in this paper is the analysis of specific health developments. For example, Murphy and Topel (2006) estimate the value of a hypothetical decline in mortality from a range of diseases, and Crafts and Haacker (2004) and Philipson and Soares (2005) estimate the welfare costs of HIV/AIDS. Such assessments are more complex than the interpretation of trends in living standards provided earlier in this paper, as they require the identification of a

[18] We exclude China and India (shown separately in Table 2) from the discussion by income group. These two countries would dominate the lower-middle income countries, and the "bottom quartile 1950."

[19] Calculated based on the "loss" in life expectancy (70.2 years vs. 80 years), using Eq. (7).

counterfactual. The impact of HIV/AIDS serves well as an example for the contribution of the approach described and developed in the present paper to the analysis of health shocks and interventions, because it represents a very large recent health shock and has played a large role in the international development policy agenda. Table 3 summarizes estimates of the impact of HIV/AIDS on living standards for 11 countries with the highest absolute numbers of people living with HIV/AIDS (representing 64 percent of the global total of people living with HIV/AIDS as of 2009), building on estimates by the United Nations Population Division (2011), including a counterfactual "no AIDS" scenario.[20]

Table 3: Impact of HIV/AIDS, 11 Countries, 1990-2009

	2009			1990-2009						Accumulated through 2009	
	PLWH	HIV Prev.	HIV Deaths	GDPpc growth	LE growth	o/w HIV/AIDS	LE contr.	o/w HIV/AIDS	LS growth	Loss in LE (years)	Loss in LS (percent)
India	2,400,000	0.3	170,000	4.8	0.6	0.0	1.7	0.0	6.6	-0.5	-1.5
Kenya	1,500,000	6.3	80,000	0.2	-0.3	-0.4	-0.6	-0.9	-0.4	-5.9	-21.9
Mozambique	1,400,000	11.5	74,000	4.0	0.7	-0.6	2.8	-1.5	7.0	-7.1	-31.9
Nigeria	3,300,000	3.6	220,000	1.6	0.6	-0.2	2.1	-0.4	3.8	-2.8	-12.8
Russian Federation	980,000	1.0	50,000	0.3	0.0	-0.1	0.3	-0.1	0.5	-0.9	-2.7
South Africa	5,600,000	17.8	310,000	1.3	-0.9	-1.1	-2.0	-2.7	-0.7	-12.8	-49.6
Tanzania	1,400,000	5.6	86,000	1.7	0.6	-0.3	2.1	-0.6	3.9	-5.4	-19.6
Uganda	1,200,000	6.5	64,000	3.5	0.6	-0.1	2.1	0.0	5.7	-4.9	-20.3
United States	1,200,000	0.6	17,000	1.3	0.2	0.0	0.4	0.0	1.7	-0.5	-1.0
Zambia	980,000	13.5	45,000	0.3	0.0	-0.3	0.4	-0.6	0.7	-7.8	-36.8
Zimbabwe	1,200,000	14.3	83,000	-0.5	-1.2	-1.2	-2.7	-2.8	-3.2	-17.3	-67.1

Sources: UNAIDS (2010) and author's calculations, based on Maddison (2003), United Nations Population Division (2011), and other sources, as documented in the Appendix. "PLWH" stands for People living with HIV/AIDS, "HIV Prev." for HIV prevalence (in percent) between age 15 and 49, "GDPpc growth" stands for annual growth of GDP per capita (percent), "LE growth" for annual growth of life expectancy (percent), "LE contr." for the contribution of increassed life expectancy to the growth in living standards (percentage points), and "LS growth" for annual growth of living standards (percent). "Loss in LE" is the loss in life expectancy owing to HIV/AIDS as of 2009, "Loss in LS" is the corresponding loss in living standards.

The impact of HIV/AIDS on life expectancy is substantial. An HIV prevalence rate of 1 percent translated into a (population-weighted) average loss in life expectancy of 0.9 years as of 2009, and the loss in life expectancy exceeded 10 years in South Africa and Zimbabwe. The impact of HIV/AIDS more than offset gains in life expectancy from all other sources in 1990-2009 in Kenya, South Africa, and Zimbabwe, so that life expectancy declined in absolute terms. In these countries, the impact of HIV/AIDS on life expectancy was so strong that living standards overall declined, even after taking into account the impact of economic growth. Meanwhile, HIV/AIDS accounted for a loss in life expectancy of about one-half year in countries with relatively low HIV prevalence (India, United States).

One factor that is masked by the estimates in Table 3 is the impact of the response to HIV/AIDS. In 2009, HIV/AIDS-related deaths corresponded to 1.5 percent of people living with HIV/AIDS in the United States, but about 7 percent in India, Nigeria, and Zimbabwe, the difference presumably reflecting difference in the quality and accessibility of health services and specifically access to antiretroviral treatment. The

[20] The counterfactual "no AIDS" scenario does not include annual estimates. The annual data for 1990 and 2009 used in Table 3 were obtained by intrapolation from 5-year period estimates.

impact of HIV/AIDS, as it appears in Table 3, thus reflects the health consequences of HIV/AIDS as well as the mitigating impacts of health technological advances and the policy response to HIV/AIDS.

VI. Variations on Life Expectancy

This paper provides a framework for an integrated assessment of the contribution of economic growth and improving health to living standards. There are numerous limitations to this exercise, including the possibilities that GDP per capita is not a good indicator of material living standards in a country (e.g., if income is distributed unevenly), that life expectancy (at birth) is not a good indicator of the state of health (e.g., as it does not capture morbidity, and as life expectancy at birth is not a representative summary indicator of the health outlook across the population), and that an indicator of "living standards" based on GDP per capita and life expectancy alone may fall short in terms of describing the state of development and the quality of living standards across and within countries.

Even if one accepts the framework adopted in the present paper, setting aside these numerous challenges, life expectancy at birth is not a straightforward indicator of the state of health in a country, as a social valuation may apply weights across the population which are different from the ones implied by life expectancy at birth. Moreover, in the absence of detailed demographic cross-country data, calibrating indicators like discounted life expectancy poses challenges.

Life expectancy at birth is an attractive summary indicator of the state of health at it captures health expectations over the course of a life (for a more thorough discussion of this point, see Grimm and Harttgen, 2007). For the analysis of the current state of health of a country's population, however, it is not necessarily a good indicator, as it places all emphasis on a specific and small population sub-group (babies), and does not capture adequately the state of health across population groups. Notably, changes in the health outlook of old people carry a low weight in life expectancy at birth (as they are weighted by the probability of surviving through old age). For this reason, average remaining life expectancy, i.e., the age-specific remaining life expectancy, weighted by the population share of the respective age group, captures the state of health across the population better. Average remaining life expectancy, however, reflects both health and demographic factors (in countries with high birth rates, younger cohorts carry higher weight). One way to standardize remaining life expectancy is weighing by survival probabilities for the respective age, which is equivalent to normalizing the population structure to the one that would emerge with zero population growth (see Grimm and Harttgen (2007)).

Table 4. Different Perspectives on Life Expectancy (LE), 2005-10

	LE at Birth	LE, Survival Weighted	LE, Weighted by Pop. Age Structure	LE, Weighted by 1990-95 Pop. Age Structure	Discounted LE at Birth (exact)	Discounted LE at Birth (Approx. 1)	Discounted LE at Birth (Approx. 2)
			(Life Expectancy in Years, 2005-10)				
North Africa	71.9	38.9	48.0	50.3	28.0	29.4	27.9
Sub-Saharan Africa	52.9	34.1	41.9	42.3	23.0	26.4	24.2
Latin America/Caribbean	73.4	39.8	49.0	51.2	28.2	29.7	28.2
North America	78.2	41.3	44.7	46.0	29.2	30.2	29.0
Asia	69.2	38.2	44.6	46.9	27.3	29.1	27.4
Europe (excl. Eastern Europe)	78.5	41.4	42.7	44.3	29.2	30.1	29.0
Eastern Europe	69.6	37.7	38.7	40.7	27.8	29.2	27.9
Oceania	81.2	42.4	46.8	48.6	29.6	30.4	29.3
World	69.5	38.4	44.5	46.4	27.3	29.1	27.5
Low-income countries[2]	59.0	35.7	44.8	45.7	24.6	27.5	25.4
Low-middle income countries[1,2]	65.7	37.3	46.1	47.8	26.4	28.6	26.8
Upper-middle income countries[2]	72.2	39.3	47.7	50.0	28.0	29.4	28.0
High-income countries[2]	78.7	41.5	43.9	45.7	29.2	30.2	29.0
China	72.7	38.9	43.7	46.6	28.3	29.6	28.1
India	64.2	36.9	44.7	46.1	26.1	28.5	26.5
			(Average Annual Growth Rate, 1995-2000 to 2005-10)				
North Africa	0.48	0.23	-0.06	0.40	0.29	0.14	0.22
Sub-Saharan Africa	0.69	0.17	0.22	0.30	0.56	0.30	0.41
Latin America/Caribbean	0.44	0.24	-0.05	0.39	0.25	0.13	0.21
North America	0.20	0.20	0.04	0.33	0.06	0.05	0.06
Asia	0.40	0.19	-0.18	0.31	0.26	0.13	0.20
Europe (excl. Eastern Europe)	0.36	0.28	0.12	0.49	0.15	0.11	0.13
Eastern Europe	0.28	0.18	-0.20	0.30	0.15	0.09	0.14
Oceania	0.33	0.30	0.13	0.51	0.11	0.08	0.09
World	0.41	0.20	-0.09	0.34	0.26	0.14	0.20
Low-income countries[2]	0.79	0.23	0.24	0.42	0.60	0.31	0.43
Low-middle income countries[1,2]	0.48	0.16	-0.06	0.29	0.34	0.17	0.26
Upper-middle income countries[2]	0.32	0.17	-0.19	0.27	0.19	0.08	0.16
High-income countries[2]	0.31	0.26	0.04	0.45	0.12	0.09	0.10
China	0.26	0.15	-0.40	0.25	0.14	0.07	0.11
India	0.56	0.25	0.07	0.39	0.38	0.19	0.30

Sources: Author's calculations, United Nations Population Division (2011). Regional averages weighted by 1995 population.

[1] Excluding China and India. [2] Excluding Eastern Europe (to maintain consistency with Table 1).

Table 4 summarizes estimates of different measures of life expectancy, focusing on the period 1995-2010 for which sufficiently detailed demographic estimates are available across countries from United Nations Population Division (2011), distinguishing life expectancy at birth, average remaining life expectancy weighted by survival probability to the respective age, average remaining life expectancy weighted by the population share of the respective age group, and average remaining life expectancy weighted by the lagged population share of the respective age group. The comparing the latter two measures provides an indicator of how much changes in average remaining life expectancy over time are drive by changes in the population structure as opposed to improvements in health services and technologies.

In the 2005-2010 period, global life expectancy was 69 years, ranging from an average of 59 years for low-income countries to 79 years for high-income countries.[21] Between the 1995-2000 period and the 2005-10 period, life expectancy at birth increased by about 0.4 percent annually. In general, life expectancy increased faster in countries with lower income, this fact is consistent with findings by Bourguignon and Morrison (2002) or Becker, Philipson, and Soares (2005), suggesting that improving health contributes to a convergence in global living standards.

Survival-weighted life expectancy is much lower (as it includes older cohorts with low remaining life expectancy). The large gap in the growth rates of life expectancy at birth and of survival-weighted life expectancy for sub-Saharan Africa and North Africa and Middle East (to a lesser extent, also Latin America and Asia) is consistent with a larger role of reduced infant and child mortality in health improvements in these regions.

For life expectancy weighted by the population age structure, there is no clear pattern across regions of income groups, as the population in countries with higher life expectancy also tends to be older. Remarkably, by this measure, the average state of health of the (aged) population of high-income countries (43.9 years remaining) is somewhat worse than the state of health of the population of low-income countries (44.8 years remaining), and the state of health in several regions (Middle East and Northern Africa, Latin America and Caribbean, Asia, and Eastern Europe) is deteriorating, as health advances do not keep up with the health decay of an aging population.

This point is evident also from the rightmost column in Table 4, showing gains in average remaining life expectancy controlling for changes in the population structure, with growth rates around 0.35 for most regions. (The difference between the two rightmost columns then shows the impact of population aging.) It is worth noting that by this count, life expectancy in the economically advanced countries increases faster than life expectancy at birth, as much of the gains in life expectancy are concentrated at old ages in these countries.

Adopting discounted life expectancy – in line with the intertemporal utility framework motivating the analysis above – raises additional challenges. Calculating

[21] Among low-income countries, the variation in life expectancy is very high, ranging from 46 years (Central African Republic, Sierra Leone) to over 67 years (Bangladesh, Nepal). See Deaton (2006) and Preston (1975) for further discussion of life expectancy and economic development.

discounted life expectancy requires age-specific mortality rates which are not available across countries for most of the period studied here, and undiscounted life expectancy, as it does not carry information on the age profile of mortality, cannot easily be transformed into discounted life expectancy. To illustrate and explore this point, Table 4 provides 3 measures of discounted life expectancy at birth – calculated exactly based on age-specific mortality rates,[22] approximated treating life expectancy deterministically,[23] and treating life expectancy from age 1 deterministically, but explicitly accounting for infant mortality. The latter approach, adopted in most of the above analysis, takes into account that much of the asymmetries in mortality profiles across countries reflect differences in infant mortality, for which data are available about as widely as for life expectancy at birth.

At first sight, the different measures of discounted life expectancy (evaluated at a discount rate of 3 percent) are similar, ranging (for the global average) from 27.3 years to 29.1 years, compared to an undiscounted life expectancy of 69.5 years. This reflects the low weights of higher ages – less than 50 percent over age 23, and less than 10 percent over age 77. The error caused by treating life expectancy deterministically is much reduced by accounting for infant mortality – over 80 percent of the error is eliminated for the global average, and about two-thirds for sub-Saharan Africa. The discrepancies are more pronounced for growth rates.

The differences are more pronounced when growth rates are considered. Treating life expectancy deterministically results in an under-estimate of the growth rate of discounted life expectancy of about one-half in low- and middle-income countries, and of one-quarter in high-income countries. For each income group or region, this bias is not eliminated, but much reduced by making an explicit allowance for infant mortality. As a consequence, the bias in estimating the increase in discounted life expectancy in low- or middle-income countries, *relative* to high-income countries, is also much reduced.

These methodological findings have implications for two types of studies. A study of the contribution of increased life expectancy to living standards over long periods of time treating life expectancy deterministically (e.g., the long-term analysis from 1870-2009 offered in the present paper, and the related studies discussed above) underestimates the contribution of increased life expectancy in early stages of the health transition, when increases in life expectancy are dominated by declining infant mortality. Second, studies following this approach and taking a cross-country

[22] United Nations Population Division (2011) provides age-specific mortality by 5-year cohort. For calculating discounted life expectancy, mortality is assumed to be constant within age cohorts.

[23] I.e., if life expectancy is 72 years in a country, all citizens are assumed to live through age 72 and die at that age.

perspective (such as Becker, Philipson, and Soares, 2005), while obtaining plausible estimates for the United States and similar countries,[24] underestimate the contribution of increased life expectancy in less developed countries by a large margin, both absolutely and relative to high-income countries.[25]

VII. Conclusions

The objective of the paper is to analyze the contribution of improved health (or, more specifically, increasing life expectancy) to living standards globally. Increasing life expectancy, alongside with economic growth, is seen as increasing the value of lifetime consumption possibilities. A principal challenge arises from the fact that most of the microeconomic evidence on valuations of increments to life expectancy (or reduced mortality) comes from a small number of advanced economies. Extrapolating specifications based on this evidence to low-income countries may yield valuations of life in developing countries which are extremely high (e.g., when an elasticity of the VSL with respect to income of around 0.5 is adopted) or implausibly low, yielding Swiftian propositions (whereby a large proportion of the population of low-income countries, and about one-half of the inhabitants of sub-Saharan Africa would be better of dead) in some studies (Becker, Philipson, and Soares, 2005). Using the estimates available for high-income countries as an anchor, and with these implausible examples of extrapolations in mind, the present paper adopts an income elasticity of the value of statistical life of one, i.e., the value of statistical life is assumed to be proportional to income.

For 16 advanced economies, the paper suggests that living standards improved by 2.9 percent annually between 1870 and 2009, of which increasing life expectancy contributed 1.1 percentage points annually. Notably, rising life expectancy dominated the increase in living standards from 1870 to 1950. Subsequently, the contribution of life expectancy declined both in absolute terms and relative to income. For the larger sample, increased life expectancy dominated improvements in living standards in North Africa, sub-Saharan Africa, and Latin America in 1950-90 (partly as a consequence of low rates of economic growth in the 1973-90 period). In Asia, health improvements dominated the growth in living standards in 1950-73, but GDP growth was the largest

[24] For the United States, the bias caused by discounting life expectancy as a deterministic variable is only 15 percent in 1995-2005.

[25] The present discussion uses exact estimates (conditional on survival tables provided in United Nations Population Division (2011)) of life expectancy, available only from 1995, as a benchmark. However, it is plausible that the findings regarding the bias involved in discounting while interpreting life expectancy deterministically also occurs in earlier periods, as the role of infant mortality (and thus the source of the bias) in these periods was larger.

contributor after 1973. These findings underline the role of health in improving living standards, and are consistent with a delayed health transition outside the most advanced economies, and a delayed transmission or implementation of health knowledge and health technology. Conversely, the estimates of the impact of HIV/AIDS illustrate the large adverse consequences of a negative health shock.

Life expectancy at birth is not an unambiguous indicator of the state of population health. The present paper explores the role of aggregation and discounting. If population averages of (remaining) life expectancy are used as a health indicator, the role of health is not straightforward, as advances in health technologies are offset by a depreciation of health capital owing to demographic change and population aging. Average remaining life expectancy in a number of countries has therefore been declining. Regarding discounting, it is not always possible to calculate discounted life expectancy (which is called for by the utility framework adopted here) exactly, owing to lack of age-specific mortality rates across countries. Where only the most common health indicators are available, it is critical to explicitly account for infant mortality, in addition to undiscounted life expectancy. Otherwise, if life expectancy is treated deterministically, the estimate of the growth of discounted life expectancy in developing countries (where infant mortality plays a large role) is too low by about one-half, and the resulting estimates of the contribution of increased life expectancy to living standards are therefore heavily biased downwards.

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Appendix

For the period 1950-2009, data on life expectancy, infant mortality, and population size are from United Nations Population Division (2011). Data on GDP per capita are based on Maddison (2003), extended through 2009 using data from World Bank (2011). In some cases, GDP data were unavailable from World Bank (2011), and estimates from IMF (2011) were used. This regards Myanmar, Taiwan Province of China, and Zimbabwe (all years), Afghanistan (2001-02), Bahrain (2009), Kuwait (2008-09), and Oman (2009).

For the years before 1950, data on GDP per capita and population sizes are from Maddison (2003). Most data on life expectancy for this period are from Crafts (1997), augmented by data around 1870 for Brazil, Mexico, and India from Arriaga (1968) and Das Gupta (1971). The dataset for the analysis for 20 countries, 1870-2009, is provided in Appendix Table 1.

Appendix Table 1: GDP per Capita and Life Expectancy, 20 Countries, 1870-2009

	1870	1913	1950	1973	1990	2009	1870	1913	1950	1973	1990	2009
	GDP per capita (US$, 1990 prices)						Life Expectancy at Birth (Years)					
Australia	3,273	5,157	7,412	12,878	17,106	25,034	48	59	69	72	77	82
Austria	1,863	3,465	3,706	11,235	16,905	22,096	32	42	66	71	75	81
Belgium	2,692	4,220	5,462	12,170	17,197	22,220	40	50	67	72	76	80
Canada	1,695	4,447	7,291	13,838	18,872	23,580	43	53	68	73	77	81
Denmark	2,003	3,912	6,943	13,945	18,452	23,501	46	58	70	74	75	79
Finland	1,140	2,111	4,253	11,085	16,866	22,463	37	46	65	71	75	80
France	1,876	3,485	5,271	13,114	18,093	21,679	42	50	66	73	77	81
Germany	1,839	3,648	3,881	11,966	15,929	19,511	36	49	67	71	75	80
Italy	1,499	2,564	3,502	10,634	16,313	17,944	28	47	65	72	77	82
Netherlands	2,757	4,049	5,996	13,082	17,262	23,173	39	56	71	74	77	80
Norway	1,432	2,501	5,463	11,246	18,466	26,457	49	57	72	74	77	81
Spain	1,207	2,056	2,189	7,661	12,055	16,458	34	42	62	73	77	81
Sweden	1,662	3,096	6,739	13,493	17,695	22,569	46	57	71	75	78	81
Switzerland	2,102	4,266	9,064	18,204	21,482	23,580	41	52	69	74	78	82
United Kingdom	3,190	4,921	6,939	12,025	16,430	21,421	41	53	69	72	76	80
United States	2,445	5,301	9,561	16,689	23,201	29,472	44	52	68	72	75	78
Average, 16 countries	2,091	3,864	6,506	13,634	19,145	24,331	39	50	67	72	76	80
Brazil	713	811	1,672	3,882	4,923	6,628	27*	31	50	60	66	73
India	533	673	619	853	1,309	3,198	25*	25	37	51	58	65
Japan	737	1,387	1,921	11,434	18,789	21,471	37	44	60	73	79	83
Mexico	674	1,732	2,365	4,845	6,119	7,373	24*	30	49	63	71	77

Sources: For GDP, Maddison (2003), updated to 2009 by author using World Bank (2011). For life expectancy, Crafts (2007), United Nations Population Division (2011), Arriaga (1968), and Das Gupta (1971). Average is weighted by population, using data from Maddison (2003) and United Nations Population Division (2011).
* Data relate to 1872 (Brazil), 1895 (Mexico), and 1871-1880 (India).

Discounted life expectancy, depending on data availability, can be calculated or approximated in various ways. Where only data on life expectancy at birth LE are available, and a discount rate δ is adopted, discounted life expectancy LED_A is frequently approximated as

$$LED_{A,0} = \frac{1-e^{-\rho \cdot LE_0}}{\rho}, \tag{A1}$$

with $\rho = -\ln(1-\delta)$. Where complete survival tables are available, (undiscounted) life expectancy by age can be calculated exactly. As some specifications of life expectancy adopted in the present paper involve weighing remaining life expectancy across the population, it is convenient to calculate life expectancy recursively from age-specific mortality rates. To illustrate how this is obtained, consider first *undiscounted* life expectancy at age x,

$$LE_X = (1-\mu_x)\cdot(LE_{X+1}+1)+\mu_x\left[\frac{\mu_x+(1-\mu_x)\cdot\ln(1-\mu_x)}{(\ln(1-\mu_x))^2}\right], \tag{A2}$$

where μ_x stands for mortality at age This is exact except for the (unknown) timing of deaths within periods (assumed constant within the period).

Similarly, discounted life expectancy LED_X can be calculated recursively as

$$\begin{aligned} LED_X &= (1-\mu_x)\cdot\left[(1-\delta)\cdot(LED_{X+1})-\frac{\delta}{\ln(1-\delta)}\right] \\ &+\mu_x\left[\frac{1-(1-\delta)\cdot(1-\mu_x)+(1-\delta)\cdot(1-\mu_x)\cdot\ln((1-\delta)\cdot(1-\mu_x))}{(\ln((1-\delta)\cdot(1-\mu_x)))^2}\right], \end{aligned} \tag{A3}$$

the first line of which contains the contribution to life expectancy of those surviving beyond age x, and the second line the allowance for those expected to die at age x.

Where only undiscounted life expectancy at birth and infant mortality are available, the method described by Eq. (A1) can be refined, first transforming Eq. (A2) to obtain undiscounted life expectancy at age 1, i.e.,

$$LE_1 = \frac{1}{1-\mu_x}\left[LE_0-\mu_x\left[\frac{\mu_x+(1-\mu_x)\cdot\ln(1-\mu_x)}{(\ln(1-\mu_x))^2}\right]\right]-1, \tag{A4}$$

then approximating discounted life expectancy at age 1 using Eq. (A1), with

$$LED_{A1} = \frac{1-e^{-\rho \cdot LE_1}}{\rho}, \tag{A5}$$

Discounted life expectancy at birth can then be obtained using Eq. (A3), substituting LED_{A1} from Eq. (A5) for LED_{X+1}.

Appendix Table 2. Growth in Living Standards, 150 Countries, 1950-2009

	1950-1973				1973-1990				1990-2009			
	GDPpc growth	LE growth	LE contr.	LS growth	GDPpc growth	LE growth	LE contr.	LS growth	GDPpc growth	LE growth	LE contr.	LS growth
Afghanistan	0.3	1.1	4.5	4.8	-0.8	0.9	3.4	2.6	4.6	0.7	2.3	7.1
Albania	3.6	1.0	3.7	7.4	0.5	0.3	1.1	1.6	2.6	0.4	1.0	3.6
Algeria	2.4	1.2	3.7	6.2	1.3	1.2	4.4	5.7	0.8	0.4	1.2	2.0
Angola	2.3	1.2	4.6	7.1	-4.0	0.4	1.6	-2.5	3.2	1.1	3.7	7.0
Argentina	2.1	0.4	1.1	3.2	-1.2	0.4	1.2	-0.1	2.9	0.3	0.8	3.7
Armenia	n.a.	0.6	1.4	n.a.	-0.1	-0.2	0.0	0.0	2.1	0.5	1.2	3.3
Australia	2.4	0.2	0.5	2.9	1.7	0.4	0.8	2.5	2.0	0.3	0.6	2.6
Austria	4.9	0.3	1.3	6.3	2.4	0.4	1.0	3.4	1.4	0.3	0.6	2.0
Azerbaijan	n.a.	0.6	1.5	n.a.	0.3	-0.1	0.3	0.6	3.5	0.4	1.8	5.3
Bahrain	3.2	2.1	7.3	10.8	-0.4	0.5	1.7	1.4	1.5	0.2	0.5	1.9
Bangladesh	-0.4	-0.6	-1.5	-1.8	1.5	2.5	7.6	9.2	3.6	0.7	2.5	6.2
Belarus	n.a.	0.4	2.0	n.a.	1.9	-0.1	0.0	1.9	3.1	-0.1	0.1	3.2
Belgium	3.5	0.3	1.0	4.6	2.1	0.3	0.8	2.8	1.4	0.3	0.5	1.9
Benin	-0.1	1.2	4.6	4.5	0.5	0.9	3.1	3.6	1.1	0.7	2.2	3.3
Bolivia	0.9	0.7	2.3	3.3	-0.4	1.3	4.5	4.1	1.7	0.6	2.0	3.7
Botswana	5.2	0.8	2.7	8.1	6.3	0.8	2.4	8.9	3.0	-1.0	-1.8	1.1
Brazil	3.7	0.8	2.6	6.4	1.4	0.6	2.2	3.7	1.6	0.5	1.4	3.0
Bulgaria	5.2	0.7	2.7	8.1	0.3	0.0	0.3	0.6	2.2	0.1	0.3	2.5
Burkina Faso	1.6	1.4	7.1	8.8	0.5	0.8	3.0	3.6	1.6	0.6	2.0	3.7
Burundi	1.9	0.6	2.2	4.2	1.6	0.3	1.0	2.6	-1.2	0.4	1.3	0.1
Cambodia	2.0	0.0	-0.6	1.4	0.5	2.2	7.9	8.5	3.9	0.6	1.9	5.8
Cameroon	1.8	1.0	3.6	5.4	1.2	0.7	2.1	3.4	0.0	-0.3	-0.6	-0.6
Canada	2.8	0.3	0.9	3.8	1.8	0.3	0.8	2.6	1.2	0.2	0.4	1.6
Cape Verde	0.7	0.7	2.5	3.2	5.1	1.0	3.1	8.4	4.0	0.7	1.8	5.8
Central African Republic	0.4	1.3	5.0	5.3	-1.0	0.6	2.0	1.0	-0.9	-0.2	-0.4	-1.3
Chad	-0.4	0.9	3.0	2.6	-0.2	0.7	2.3	2.1	2.4	-0.2	-0.5	2.0
Chile	1.3	0.7	2.4	3.7	1.4	0.8	2.7	4.1	3.5	0.4	0.8	4.2
China	2.9	1.8	5.4	8.4	4.8	0.4	1.0	5.8	7.8	0.3	0.7	8.5
Colombia	2.1	1.1	2.2	4.4	1.9	0.6	0.9	2.8	1.4	0.4	0.5	1.9
Comoros	2.0	0.9	3.4	5.5	-1.5	0.7	2.1	0.5	-1.1	0.4	0.9	-0.2
Congo, Rep.	2.2	1.2	3.2	5.5	0.7	0.2	2.5	3.2	0.5	0.0	1.4	1.8
Costa Rica	3.5	0.9	3.9	7.5	0.6	0.6	0.8	1.3	2.6	0.2	0.1	2.7
Côte d'Ivoire	2.6	0.8	2.5	5.2	-1.9	0.7	1.8	-0.1	-0.8	0.1	0.5	-0.3
Croatia	n.a.	0.7	2.9	n.a.	n.a.	0.2	2.5	n.a.	0.9	0.3	0.7	1.6
Czech Republic	n.a.	0.3	3.0	n.a.	n.a.	0.1	0.7	n.a.	1.5	0.4	0.6	2.2
Denmark	3.1	0.2	1.2	4.3	1.7	0.1	0.5	2.1	1.3	0.2	0.8	2.1
Djibouti	1.7	1.2	2.4	4.1	-2.4	0.8	1.0	-1.4	-0.5	0.6	0.4	-0.1
Dominican Republic	3.0	1.3	0.7	3.7	1.2	0.7	0.3	1.5	3.7	0.4	0.5	4.2
DRC	1.7	0.7	4.6	6.4	-2.7	0.3	2.9	0.1	-4.0	0.1	1.9	-2.1
Ecuador	2.5	1.0	4.1	6.7	1.0	0.9	2.3	3.3	1.4	0.5	1.3	2.7
Egypt, Arab Rep.	1.5	0.9	3.0	4.6	4.0	1.0	2.8	6.9	2.2	0.8	1.4	3.7
El Salvador	2.0	1.2	3.5	5.5	-0.6	0.9	3.6	3.0	2.0	0.4	2.6	4.7
Equatorial Guinea	3.0	0.8	3.7	6.8	2.3	0.8	3.1	5.5	15.5	0.4	1.3	17.1
Estonia	n.a.	0.4	3.0	n.a.	1.3	-0.1	2.9	4.2	2.0	0.4	1.4	3.5
Ethiopia	2.2	1.2	2.0	4.2	-0.8	0.4	-0.1	-0.9	2.5	1.1	0.9	3.5
Finland	4.3	0.4	4.4	8.9	2.5	0.3	1.5	4.0	1.5	0.3	3.6	5.2
France	4.0	0.4	1.2	5.2	1.9	0.3	0.7	2.6	1.0	0.3	0.5	1.5
Gabon	3.8	1.4	1.3	5.1	-2.4	1.3	0.7	-1.7	-1.2	0.0	0.5	-0.7
Gambia, The	2.2	1.2	4.8	7.1	-0.8	1.5	4.1	3.2	1.1	0.5	0.3	1.4
Georgia	n.a.	0.6	4.5	n.a.	1.4	0.2	5.2	6.7	-1.8	0.2	1.5	-0.3
Germany	5.0	0.3	1.7	6.8	1.7	0.3	0.6	2.3	1.1	0.3	0.7	1.7
Ghana	1.0	1.0	1.1	2.1	-1.6	0.7	0.9	-0.7	2.6	0.6	0.6	3.2

Appendix Table 2. Growth in Living Standards, 150 Countries, 1950-2009

	1950-1973				1973-1990				1990-2009			
	GDPpc growth	LE growth	LE contr.	LS growth	GDPpc growth	LE growth	LE contr.	LS growth	GDPpc growth	LE growth	LE contr.	LS growth
Greece	6.2	0.5	3.4	9.8	1.6	0.4	2.3	3.9	2.4	0.2	1.8	4.2
Guatemala	1.9	1.1	1.3	3.3	-0.4	0.8	1.2	0.8	1.0	0.7	0.4	1.4
Guinea	2.0	0.5	3.4	5.5	0.6	1.3	2.7	3.3	0.9	1.0	1.9	2.9
Guinea-Bissau	5.0	0.7	2.0	7.1	-0.6	0.7	4.6	4.0	-1.6	0.5	3.5	1.9
Haiti	-0.2	1.2	2.9	2.7	0.2	0.8	2.6	2.8	-1.8	0.6	1.9	0.1
Honduras	1.0	1.3	5.3	6.3	0.8	1.2	2.7	3.5	1.2	0.5	2.0	3.3
Hong Kong, China	5.2	0.7	4.5	9.9	5.5	0.4	3.7	9.3	2.5	0.3	1.3	3.8
Hungary	3.6	0.5	1.7	5.3	0.8	0.0	0.4	1.3	1.7	0.3	0.8	2.5
India	1.4	1.4	4.6	6.1	2.5	0.8	2.5	5.1	4.8	0.6	1.7	6.6
Indonesia	2.6	1.6	5.9	8.6	3.1	0.9	2.8	6.0	3.1	0.5	1.5	4.6
Iran, Islamic Rep.	5.1	1.7	7.3	12.8	-2.6	0.8	3.2	0.5	3.4	0.8	2.1	5.6
Iraq	4.5	2.1	7.5	12.4	-2.5	0.7	2.1	-0.4	-4.5	0.0	0.3	-4.3
Ireland	3.0	0.4	1.1	4.2	3.2	0.3	0.7	4.0	4.0	0.4	0.6	4.7
Israel	5.5	0.3	0.8	6.4	1.8	0.3	0.7	2.5	1.7	0.3	0.6	2.3
Italy	4.9	0.4	1.5	6.5	2.5	0.4	1.0	3.6	0.5	0.3	0.6	1.1
Jamaica	5.1	0.9	2.6	7.8	-0.8	0.1	0.6	-0.2	0.3	0.1	0.4	0.7
Japan	8.1	0.9	2.4	10.6	3.0	0.4	0.9	3.8	0.7	0.3	0.4	1.1
Jordan	1.6	1.3	4.8	6.5	2.8	0.7	2.0	4.8	2.1	0.2	0.6	2.7
Kazakhstan	n.a.	0.7	2.0	n.a.	-0.2	0.3	1.2	1.0	1.5	0.0	0.5	2.0
Kenya	1.7	1.1	3.8	5.6	0.7	0.6	1.8	2.5	0.2	-0.3	-0.6	-0.4
Korea, Rep.	5.8	1.3	3.5	9.6	6.8	0.7	1.3	8.2	4.3	0.6	0.4	4.7
Kuwait	-0.3	1.0	2.3	1.9	-8.3	0.4	1.7	-6.7	4.1	0.1	0.8	4.9
Kyrgyz Republic	n.a.	0.7	1.7	n.a.	-0.2	0.5	3.0	2.8	-0.8	0.1	3.4	2.5
Lao PDR	1.0	0.5	1.8	2.8	1.1	0.9	0.0	1.1	3.5	1.1	0.7	4.2
Latvia	n.a.	0.4	2.6	n.a.	1.4	-0.1	0.8	2.2	0.2	0.3	0.7	0.9
Lebanon	1.1	0.8	3.1	4.3	-2.8	0.3	3.3	0.4	4.7	0.3	-2.8	1.7
Lesotho	3.4	0.9	3.8	7.3	2.7	1.0	0.0	2.6	2.7	-1.2	5.2	8.0
Liberia	1.4	1.0	4.1	5.6	-2.0	0.0	4.4	2.3	-2.4	1.4	1.2	-1.2
Libya	9.3	1.1	2.5	12.1	-4.4	1.4	0.1	-4.3	-0.2	0.5	0.3	0.1
Lithuania	n.a.	0.5	3.7	n.a.	0.8	0.0	2.3	3.1	0.8	0.1	4.2	5.1
Macedonia, FYR	n.a.	1.1	2.4	n.a.	n.a.	0.3	2.4	n.a.	0.1	0.2	2.4	2.5
Madagascar	0.8	1.0	2.7	3.6	-2.1	0.7	1.3	-0.8	-0.6	1.4	0.7	0.1
Malawi	2.5	0.7	3.1	5.6	-0.1	0.7	3.9	3.8	2.1	0.6	2.4	4.6
Malaysia	2.2	0.8	3.1	5.4	4.2	0.4	3.0	7.3	3.4	0.3	0.4	3.9
Mali	1.1	0.9	3.7	4.8	1.4	1.2	1.8	3.2	1.6	0.7	0.6	2.3
Mauritania	3.2	1.1	3.6	6.9	-0.3	0.8	2.0	1.8	1.2	0.2	1.1	2.3
Mauritius	1.7	1.2	4.3	6.1	4.0	0.5	1.4	5.4	3.7	0.3	2.1	5.9
Mexico	3.2	1.1	3.4	6.7	1.4	0.7	3.5	4.9	1.0	0.4	1.9	2.9
Moldova	n.a.	0.5	4.9	n.a.	0.8	0.2	1.3	2.2	-3.2	0.1	2.8	-0.5
Mongolia	3.0	1.2	7.2	10.4	2.6	0.4	1.9	4.5	1.1	0.6	1.9	3.0
Morocco	0.7	1.0	4.6	5.3	2.5	1.1	2.2	4.8	1.8	0.6	0.8	2.6
Mozambique	2.2	1.3	3.6	5.9	-3.0	0.4	4.1	0.9	4.0	0.7	3.8	8.0
Myanmar	2.0	2.0	0.5	2.6	1.4	0.6	0.4	1.9	6.6	0.6	0.4	7.0
Namibia	2.1	1.3	0.5	2.6	-0.4	0.7	0.6	0.3	2.0	0.1	0.6	2.7
Nepal	1.0	0.9	4.9	5.9	1.5	1.2	2.7	4.3	1.9	1.2	2.1	4.0
Netherlands	3.5	0.2	0.6	4.0	1.6	0.2	1.4	3.1	1.6	0.2	4.6	6.2
New Zealand	1.7	0.2	3.6	5.4	0.7	0.3	1.0	1.7	1.1	0.3	2.1	3.3
Nicaragua	2.6	1.4	0.5	3.1	-4.0	0.9	0.3	-3.7	1.0	0.7	0.5	1.5
Niger	-0.4	0.1	5.9	5.4	-1.6	0.4	5.0	3.3	-0.2	1.4	0.9	0.6
Nigeria	2.7	1.0	3.2	6.0	-1.0	0.3	0.9	-0.2	1.6	0.6	0.5	2.1
Norway	3.2	0.1	4.7	8.0	3.0	0.2	1.7	4.7	1.9	0.3	1.2	3.1
Oman	7.5	1.6	3.0	10.7	4.1	1.6	1.2	5.3	1.3	0.2	0.6	2.0

Appendix Table 2. Growth in Living Standards, 150 Countries, 1950-2009

	1950-1973				1973-1990				1990-2009			
	GDPpc growth	LE growth	LE contr.	LS growth	GDPpc growth	LE growth	LE contr.	LS growth	GDPpc growth	LE growth	LE contr.	LS growth
Pakistan	1.7	1.4	0.8	2.5	3.1	0.6	0.5	3.6	2.2	0.4	0.8	3.0
Panama	3.5	1.0	3.6	7.3	0.3	0.5	3.2	3.5	3.4	0.2	1.9	5.3
Paraguay	1.1	0.2	1.8	2.9	2.9	0.2	1.2	4.0	-0.1	0.3	0.8	0.6
Peru	2.5	1.1	2.8	5.4	-1.7	1.0	0.3	-1.4	3.0	0.6	0.8	3.9
Philippines	2.7	0.5	2.0	4.8	0.7	0.3	1.7	2.4	1.6	0.2	0.7	2.3
Poland	3.5	0.8	3.5	7.1	-0.3	0.0	1.7	1.4	3.8	0.4	0.7	4.6
Portugal	5.4	0.6	4.8	10.5	2.5	0.5	2.0	4.6	1.4	0.3	1.1	2.6
Qatar	1.6	1.0	1.8	3.4	-10.4	0.5	0.8	-9.6	2.7	0.3	0.5	3.2
Romania	4.8	0.6	2.5	7.4	0.1	0.0	0.4	0.4	1.5	0.3	0.8	2.3
Russian Federation	n.a.	0.3	2.4	n.a.	1.0	-0.1	0.0	1.0	0.3	0.0	0.3	0.5
Rwanda	1.0	0.5	1.9	2.9	1.5	-1.8	-5.1	-3.8	2.0	2.7	8.0	10.1
Saudi Arabia	7.2	1.5	5.5	13.1	-1.1	1.3	4.1	3.0	-0.2	0.4	1.0	0.8
Senegal	0.2	0.6	2.2	2.4	0.2	1.4	4.2	4.4	0.9	0.5	1.6	2.5
Sierra Leone	2.2	1.0	4.0	6.3	-0.3	0.3	1.4	1.0	-2.8	1.0	3.7	0.8
Singapore	4.4	0.7	2.3	6.8	5.3	0.5	1.2	6.5	3.5	0.4	0.6	4.2
Slovak Republic	n.a.	0.5	2.3	n.a.	n.a.	0.1	0.4	n.a.	2.2	0.3	0.6	2.8
Slovenia	n.a.	0.4	1.7	n.a.	n.a.	0.3	0.7	n.a.	2.1	0.4	0.8	2.9
South Africa	2.2	0.9	2.6	4.9	-0.3	0.8	2.3	2.0	1.3	-0.9	-2.0	-0.7
Spain	5.6	0.7	2.0	7.7	2.7	0.3	0.9	3.7	1.7	0.3	0.5	2.1
Sri Lanka	0.8	1.0	3.1	3.9	2.9	0.5	1.6	4.5	4.0	0.4	0.9	4.9
Sudan	-0.2	0.7	2.4	2.2	-0.3	0.7	2.4	2.1	3.7	0.8	2.3	6.1
Swaziland	5.1	0.9	3.2	8.5	0.4	1.0	3.5	3.9	1.0	-1.1	-2.6	-1.6
Sweden	3.1	0.2	0.6	3.6	1.6	0.2	0.5	2.1	1.3	0.2	0.4	1.7
Switzerland	3.1	0.3	0.9	4.0	1.0	0.3	0.6	1.6	0.5	0.3	0.5	1.0
Syrian Arab Republic	2.2	1.3	4.9	7.2	2.1	0.8	2.6	4.7	2.1	0.3	0.9	3.0
Taiwan Province of China	6.7	1.0	2.1	8.9	5.3	0.4	1.1	6.5	4.1	0.3	1.5	5.6
Tajikistan	n.a.	0.7	3.5	n.a.	-1.9	0.2	1.5	-0.4	-2.6	0.3	0.8	-1.9
Tanzania	1.4	0.8	3.4	4.9	-0.5	0.3	2.7	2.2	1.7	0.6	0.5	2.2
Thailand	3.7	0.9	5.1	9.0	5.5	1.0	2.4	8.0	3.1	0.1	1.1	4.2
Togo	2.7	1.4	1.9	4.6	-1.9	0.7	0.8	-1.1	-1.4	0.3	0.2	-1.3
Trinidad and Tobago	3.8	0.6	3.7	7.6	0.4	0.3	4.1	4.5	4.9	0.1	1.2	6.1
Tunisia	3.0	1.1	1.4	4.5	2.4	1.2	4.1	6.7	3.4	0.4	2.5	5.9
Turkey	3.4	0.4	2.3	5.7	2.7	1.2	1.4	4.2	1.9	0.8	0.9	2.8
Turkmenistan	n.a.	0.7	4.0	n.a.	-1.7	0.3	-1.2	-2.8	3.0	0.2	2.1	5.2
Uganda	0.9	1.2	2.2	3.1	-2.0	-0.4	0.1	-1.9	3.5	0.6	-0.2	3.4
Ukraine	n.a.	0.4	6.0	n.a.	1.2	0.0	2.0	3.2	-1.8	-0.1	0.7	-1.2
United Arab Emirates	2.0	1.7	0.6	2.7	-3.7	0.6	0.7	-3.1	2.3	0.3	0.5	2.8
United Kingdom	2.4	0.2	2.6	5.1	1.9	0.3	1.1	3.0	1.4	0.3	2.1	3.6
United States	2.5	0.2	0.7	3.1	2.0	0.3	0.7	2.6	1.3	0.2	0.4	1.7
Uruguay	0.3	0.2	0.6	0.9	1.6	0.3	1.2	2.8	2.2	0.3	0.6	2.9
Uzbekistan	n.a.	0.6	2.1	n.a.	-1.1	0.3	1.1	0.0	1.3	0.1	0.5	1.8
Venezuela, RB	1.5	0.9	3.0	4.6	-1.4	0.5	1.5	0.0	0.9	0.2	0.5	1.4
Vietnam	1.0	0.9	3.1	4.2	1.3	1.8	5.5	6.9	5.7	0.7	1.8	7.5
Zambia	2.1	0.9	3.0	5.1	-1.5	-0.3	-0.8	-2.3	0.3	0.0	0.4	0.7
Zimbabwe	3.2	0.7	2.2	5.4	-0.3	0.5	1.6	1.3	-0.5	-1.2	-2.7	-3.2

Source: Author's calculations, based on Maddison (2003), United Nations Population Division (2011), and data sources, as explained in Appendix. "GDPpc growth" stands for annual growth of GDP per capita (percent), "LE growth" for annual growth of life expectancy (percent), "LE contr." for the contribution of increassed life expectancy to the growth in living standards (percentage points), and "LS growth" for annual growth of living standards (percent).