the review of income and wealth

Review of Income and Wealth
Series 60, Number 2, June 2014
DOI: 10.1111/j.1475-4991.2012.00524.x

THE GDP VALUE OF TWENTIETH-CENTURY HEALTH IMPROVEMENTS IN DEVELOPED ECONOMIES: INITIAL ESTIMATES FOR ENGLAND

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Economists are aware that conventional measures of national income do not capture everything that is important to individuals. In particular, the value of huge improvements in health over the twentieth century has gone uncalculated. Usher and Nordhaus have emphasized the virtues of including mortality improvements in some form of extended national income measure. This article therefore sets out a methodology that can be used to calculate the value of mortality and morbidity improvements. The results for England indicate that the value of health improvements in developed economies have added at least 0.3 percent per annum to twentieth-century GDP growth rates. The results demonstrate that those interested in understanding improvements in economic welfare need to pay much more attention to improvements in health.

JEL Codes: I12, I15, O47

Keywords: extended national income, morbidity, mortality, twentieth century

1. Introduction

The economic performance of a nation is usually measured as the change in national income per head. It is widely known, however, that this approach excludes a large number of different aspects of the standard of living that people value. One aspect that is at best poorly included is the reduction in mortality and morbidity that has been an important feature of development since 1900 (Usher, 1980; Nordhaus, 2002; Crafts, 2005; Murphy and Topel, 2005; Hickson, 2009). This article will, for the first time, set out a methodology by which we can assess the value of reductions in mortality and morbidity as a proportion of GDP. It will also apply this methodology to England and Wales for the period 1900–2000.[1]

Improvements in health have clearly made a major difference to the standard of living. DeLong (2000) highlights the value of twentieth-century health gains by considering how much material wealth would be necessary to compensate an individual going back to the health conditions in 1890. "Given the absence in 1890 of modern inoculations, modern antibiotics, and other technologies of the past century, it is hard to argue that anything less than an astronomical income back in

Note: I would like to thank Nick Crafts for all his help, Tim Leunig for his generous and invaluable support with this article, and as ever, Frank Hickson. Thanks also to two very helpful anonymous referees. Financial support from the Economic and Social Research Council and the British Academy is gratefully acknowledged.

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[1]England and Wales will be summarized as England throughout the article.

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1890 could compensate" (DeLong, 2000, p. 22). Not only can we cure any number of diseases, such as tuberculosis, but we can now vaccinate people so that they do not suffer from numerous diseases in the first place. For those conditions that we cannot cure, such as diabetes, the treatments that are available today are much more effective than was the case in the past. Even simple medicines, such as painkillers and antibiotics, have had life-transforming effects for many, in both the developed and the developing world.

The idea that we should include improvements in healthcare in measures of economic performance goes back to the work of Usher (1980). He claimed that "statistics of economic growth may be seriously misleading as indicators of whether people are becoming better off in the course of time if changes in longevity are not taken into account" (Usher, 1980, p. 228). Nordhaus (2002) built on Usher's work, with claims that twentieth-century improvements in health have provided a substantial contribution to standards of living, and that "the economic value of increases in longevity in the last hundred years is about as large as the value of measured growth in non-health goods and services" (Nordhaus, 2002, pp. 37–38). Existing research only considers reduction in mortality (or increases in life expectancy), despite the importance of taking into account the health quality of these additional life-years (often referred to as morbidity). Some scholars argue that only valuing mortality improvements overstates health gains because it does not account for the increased burden of chronic illness in older ages.[2] For completeness, and to better assess the accuracy of using mortality as a proxy for overall health, this article sets out a methodology for evaluating reductions in morbidity that is similar in approach to that outlined by Nordhaus (2002) for mortality.

As well as setting out the methodology in this article, we apply it to England between 1900 and 2000. England is chosen because it has particularly good data for the entire century. It would be possible to apply this methodology to other countries, but in many cases data constraints would limit such studies to the post-war era. We find that the value of improved health provides at least an additional 0.3 percent per annum GDP growth over the century, with mortality improvements accounting for virtually all of this additional growth, since morbidity improvements only account for 0.01 percent. There is no reason to believe that this figure would be dramatically different for any other developed country.

In Section 2 we consider the conceptual issues associated with measuring health in terms of extended national income. Section 3 provides an outline of the methodology. This comprises the existing mortality measure and our novel morbidity measure, and an outline about how these are combined to provide an original health measurement methodology. In Section 4 we apply the methodology to the data for twentieth-century England. In Section 5 we discuss the implications of the results in terms of what the original methodology lends to the existing literature, the significance of the results, and the magnitude of health gains.

[2]See, for example, Kramer (1980) and Gruenberg (1977): they connect medical improvements (such as the introduction of penicillin, aureomycin, terramycin, etc.) with the postponement of death, rather than with a genuine improvement in health. Consequently, instead of diminishing disease and enriching life, the twentieth-century products of medical developments have served to prolong disease and increase the proportion of the population suffering from disabling and chronic illnesses. Thus, according to pessimists, not accounting for this increased duration of chronic illness overstates health benefits.

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2. Theory

The key point that is accounted for by the methodology is that the same annual GDP per capita with a long life should be recognized as a higher living standard that that income with a short life (Crafts, 2005). For example, an economy in which the population has a GDP per capita of $20,000, with lives that are short and in poor health, would be ranked the same as people having income of $20,000, with a long and healthy life, by existing national income measures (Nordhaus, 2002).[3]

The concept, nature, and methodology of calculating GDP goes back to Simon Kuznets. Kuznets never intended GDP to be an indicator of general well-being. He fully recognized the limitations of focusing only on market activities, and excluding non-market activities, such as household production and voluntary work. A further limitation is that, by measuring marketed output at market prices, GDP also excludes quality improvements. This issue was partially addressed in the U.S. context by the Boskin Commission (Boskin *et al.*, 1998). And since the 1990s the U.S. Bureau of Labor Statistics has calculated hedonic GDP to account for quality improvements. Furthermore, as societies become richer, the proportion of a lifetime that is spent undertaking paid work has fallen. The length of the typical working week has declined, holidays entitlements have increased, and the retirement age has fallen as a proportion of life expectancy. There have been short periods of time in which these have not been true, but over the twentieth century the amount of leisure time available to those in the labor force has increased nearly fourfold. The proportion of people who live to retirement has increased sevenfold, and the average length of retirement has increased fivefold (Fogel, 2004). These important gains in welfare are not captured in national income.

Improvements in healthcare are included in changes in GDP only when they occur as a market transaction. Thus, a new surgical procedure that leads more people to seek treatment will appear as a rise in national income, valued by the cost of providing the service if delivered by the public sector, or the market price if the procedure is produced and sold by the private sector. In contrast, a new and improved surgical procedure that replaces an existing one will not change national income unless it also raises the cost. And a new procedure, or medicine, that is as effective or more effective and costs less, will reduce GDP, even though it will clearly increase the standard of living. Accurate measurement of improvements in quality continues to be an important objective. In 2002 the European Commission required member states to take more account of quality changes when measuring public sector health output (Castelli *et al.*, 2007).[4]

Most economists recognize that the national accounts are imperfect measures, especially when considering quality and welfare. Mamalakis (1996) highlights the need for much more research to be carried out before reliable versions of the

[3]Dollars used here represent a hypothetical value. Dollars used in the Results and Discussion sections of the article represent current (2012) U.S. dollar prices.

[4]Castelli *et al.* (2007) contains a comprehensive list of items that ought to be included to measure quality more accurately. Moreover, the authors highlight the difficulties associated with defining healthcare outputs, attaching values to the outputs, and obtaining relevant data (in the twenty-first century). These difficulties are exacerbated for the study of the twentieth century. As such, the methodology used here represents a simplified approach to accounting for quality changes.

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missing blocks that bridge the System of National Accounts variables with economic and total welfare can be built. Okun (1971) presents important considerations about the need for national accounts to reveal more about redistribution so that we can evaluate "the extent to which our society fulfils its egalitarian objectives" (Okun, 1971, p. 133). Hulten (2001) provides a useful warning about overextending the boundaries of national income measures, especially beyond the realms of the market economy, with an insurmountable list of everything that correlates with the production of goods and services and affects economic welfare; whilst also acknowledging the primary objective of national income measurement and the contentiousness of including non-marketed welfare gains.

Rather than outline a superior System of National Accounts measure, the article will provide an indication of the order of magnitude of these gains in health over the long run using the System of National Accounts as an insightful index. Whilst we recognize that the System of National Accounts was not designed to account for quality improvements, we measure a Fisherian or utility based System of National Accounts, which accounts for health gains. This consideration does of course have some justification, in that the System of National Accounts includes the cost of medical care, but no direct measure of the return in terms of the quality of healthcare. As well as Nordhaus (2002) and others using this approach to value long run mortality gains, Cutler *et al.* (2006) have used GNP as a basis for calculating the return on healthcare spending. They make a conservative estimate that 50 percent of health gains are attributable to healthcare spending. Other factors that have influenced improvements in health over the twentieth century constitute education, public health measures and laws, and general advances in technology.[5]

The extended national accounts methodology used here conceptualizes gains in health as an imputation for a change in the environment; because improved health has largely been a result of the accumulation of knowledge on how to cure and prevent diseases that affect all individuals (rich and poor, educated and uneducated). As such, the results presented below are not double counting any factors already included in System of National Accounts measures.

3. Methodology

3.1. *Mortality*

Usher (1980) proposed a method for imputing national income measures to account for increases in life expectancy. Nordhaus (2002) refined this measure and outlined the "willingness to pay for improved mortality" approach used in this article. Equations (1) to (3) summarize this methodology (Nordhaus, 2002, pp. 13–16).[6] An individual is assumed to value consumption and health according to a lifetime utility function:

[5]See Cutler and Richardson (1999) for a more detailed consideration of other factors contributing to improved health. See Kitagawa and Hauser (1973) for an original study of the relationship between education and health. See Lleras-Muney (2005) for a more recent and detailed study about the effect of education upon health.

[6]Equations (1) to (3) in the article are adapted from equations (1) to (6) in Nordhaus (2002, pp. 13–16).

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$$V[c_t;\theta;\rho;\mu_t]=\int_{\theta}^{\infty}u(c_t)e^{-\rho(t-\theta)}S[\mu_t]dt, \tag{1}$$

where $V[c_t; \theta, \rho, \mu]$ is the value at time t of the consumption stream, now and in the future, faced by an individual of age θ; $u(c_t)$ is the stream of instantaneous utility or felicity of consumption; ρ is the pure rate of individual time preference;[7] $S(\mu_t)$ is the set of survival probabilities; and μ_t is the set of mortality rates. The key assumption here is that utility is a function of the expected value of consumption weighted by the probability of survival. Nordhaus (2002) also assumed that an individual will choose a consumption annuity that yields constant consumption during the individual's lifetime, $c_t = c^*$, in line with the lifecycle model of consumption.

$$V[c_t;\theta,\rho,\mu_t]=\frac{u(c^*)}{(\rho+\mu)}. \tag{2}$$

Nordhaus (2002) further highlights that an individual faces a trade-off between health and wealth,[8] and hence the relative value of consumption and mortality:[9]

$$\frac{dc^*}{d\mu}=\frac{-u(c^*)}{[u'(c^*)(\rho+\mu)]}. \tag{3}$$

Nordhaus (2005, p. 376) makes two normalizations in order to simplify the discussion without loss of generality: first, the simplification produced by selecting a goods metric utility function, which provides a metric in which utility is measured in terms of goods at the equilibrium, which implies that $u'(c^*) = 1$; second, the implication that there is no utility after death and as such zero is the utility at which the individual is indifferent between life and death (Nordhaus, 2005, p. 377).

Following this methodology, the additional life-years (due to improved mortality) need to be valued. We value additional life-years by estimating the amount that society would be willing to pay for reduced mortality. Estimates about this value range widely: from less than \$100,000 to several million dollars (Dillingham,

[7]The time preference is assumed to be exponential in order to provide a simple initial estimate. Although it is possible that hyperbolic discounting might be more pertinent, considerations about the precise magnitude of time preference, over such a long time horizon and with more intangible intertemporal choices are the subject of another article. For a detailed review of time discounting and time preference, see Frederick *et al.* (2002).

[8]Trade-offs between health and wealth represent an important decision for individuals and policy makers. However, there are a limited number of studies that actually consider the utility of health and wealth empirically. See Levy and Nir (2012) for a theoretical and empirical consideration of a function that provides a good description for the utility of health and wealth. Also important is the inequality that exists in all developed countries, often referred to as the health/wealth gradient. There is a vast amount of literature that tries to establish the mechanisms which include education, ability to work, access, and also the purchase of healthcare, which is often shown to be among the least important, even in the U.S. Deaton (2002) provides a useful overview about the complexity of this health/wealth gradient. As a result, the methodology used here does not apply any kind of weighting to account for differing purchasing power and trade-off functions across the population.

[9]The assumptions made here are also likely to be oversimplified. Srinivasan (2005) highlights the implausibility of instantaneous felicity being independent of age and health status.

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TABLE 1
Twentieth-Century Value of a Statistical Life (VSL) Income Elasticities and Values, England ($ million)

Study	VSL Income Elasticity	VSL Value ($ million)
Costa and Kahn (2003)	1.6	1.20
Miller (2000)	1	1.21
Viscusi and Aldy (2003)	0.6	1.63

Notes: Costa and Kahn (2003) and Viscusi and Aldy (2003) values of statistical life values are calculated from Miller (2000). All $ values are in current (2012) U.S. dollar prices.

1985, p. 277).[10] We use Miller's (2000) "best estimate" value of a statistical life (VSL) as a conservative estimate, derived from some of the most robust U.K. studies.[11] To put this into context, our value of a statistical life estimate is about half as valuable as that used by Nordhaus (2005) for the U.S. over the twentieth century. We also include considerations about the changing income elasticity of demand for improved health over the twentieth century. Costa and Kahn (2003, p. 1) highlight that as an economy develops, the health and well-being of the population increases along with the demand for safety and the subsequent compensating wage differential. They estimate that between 1940 and 1980 the VSL increased by 300–400 percent, indicating a VSL income elasticity of between 1.5 and 1.7 (Costa and Kahn, 2003, p. 13). Conversely, Viscusi and Aldy (2003, p. 44) estimate income elasticity as being between 0.5 and 0.7. The large variation in estimated income elasticities in different meta-analyses may reflect differences in sample construction (Costa and Kahn, 2003, p. 13), as well as differing assumptions about the relationship between income and the demand for safety, and how this changes over the long run. These estimates of the value of a statistical life with differing elasticity and dynamic values over the twentieth century are presented in Table 1. They will be combined with death rate data in order to calculate the value of these extra life-years (in Section 4).

3.2. *Morbidity*

Cutler and Richardson (1999) outlined a health measure which we use to define morbidity in the article. Combining estimates of the share of people who are alive, the prevalence of people with particular conditions, and the quality of life for people with those conditions, Cutler and Richardson estimate quality of life as:[12]

[10]There is a vast literature that considers the value of a statistical life. See Jones-Lee (1989) for a comprehensive overview. For a more recent consideration about some of the most fundamental problems associated with valuing a statistical life, see Kniesner *et al.* (2007). See Miller (2000) for considerations about country variance. See Aldy and Viscusi (2008) for considerations about variance across age groups and cohort effects. For further considerations of age effects (and also the influence of health status), see Alberini *et al.* (2004). For one of the only studies to explicitly consider the value of a statistical life in developing countries, see Bowland and Beghin (2001).

[11]For the VSL studies upon which Miller's best estimate is based, see Ghosh *et al.* (1975), Jones-Lee *et al.* (1987, 1995), Maclean (1979), Marin and Psacharopoulos (1982), and Melinek (1974).

[12]Equation from Cutler and Richardson (1998).

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$$(4)\quad H_{t+k} = \Pr[\text{Alive at } t+k] \times \left(\sum\nolimits_d \Pr[\text{Condition } d \text{ at } t+k] \times [\text{QALY for } d \text{ at } t+k]\right).$$

This approach attaches quality adjusted life-year (QALY) weights to living with each of a range of particular conditions, and sums the probability of each condition multiplied by the quality adjusted life-year weight of the condition to give the value of health (Cutler and Richardson, 1999, p. 18). Changes in the value of health (largely as a result of improved quality adjusted life-year weights) can then be estimated by using a value of a statistical healthy life-year estimate. This is a function of the value of a statistical life adjusted for the burden of illness.

As outlined in equation (4), we estimate the burden of illness by combining data about the prevalence and quality of life of each illness. Prevalence data exist in some basic form for prominent illnesses over the twentieth century in England. However, data do not exist about the quality of life associated with different illnesses over the twentieth century in England, with the exception of a study by Hickson (2006). That study estimated a series of quality adjusted life-year weights for different illnesses and eras of the twentieth century in England. The methods were based on a study by Murray and Lopez (1996) that pioneered an approach for estimating illness quality of life for countries where these data do not exist. Both entail an expert study to determine the likely burden of different illnesses, and the final result is generated through arriving at expert consensus. Quantitative studies about the historical quality of life are limited: in addition to Murray and Lopez (1996) and Hickson (2006), Cutler and Richardson (1999) have calculated quality adjusted life-year weights for the U.S. from 1970 to 1990. It is noteworthy that the quality adjusted life-year weights generated by Hickson (2006) are of a similar magnitude to those generated by both Cutler and Richardson (1999) and Murray and Lopez (1996) for comparable illnesses and eras.

None of these three studies estimate quality adjusted life-year weights for a broad sample of illnesses. When trying to account for all diseases, a number of assumptions have to be made. This detracts from the precision of the results. In fact, all that can be said with certainty is that the overall results presented here are an underestimate. The biggest contention associated with this approach is how to proxy a broad morbidity state, such as infectious disease, with a limited number of estimates for specific infectious diseases, such as tuberculosis or influenza. This problem is compounded by changes in the classification of disease. For example, in 1900 there were about 160 causes of death associated with preceding illness. In 2000 a "Tabulation List for Morbidity" was published for the first time; it contained 298 different states of morbidity.[13] Because it is impossible to proxy all or even many diseases, the approach used here is to use a limited number of sample morbidity quality adjusted life-year weights, that are more pessimistic than the "average" disease burden in each of the three broad morbidity states: infectious, non-infectious, and disability. These are presented in Table 2. Section 4 generates

[13]The International Classification of Disease (ICD) is the coding system used to define all causes of mortality. It has been in use since 1900 and is updated (to include a more sophisticated array of entries) every 10 years. The ICD became substantially more detailed after the World Health Organization (WHO) assumed responsibility for managing this system in 1948.

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TABLE 2
Twentieth-Century Quality Adjusted Life-Year Weights (QALY) for Broad Morbidity Categories, England

Morbidity State	(QALY)
Infectious	0.68
Non-infectious	0.56
Disabilities	0.50

Source: Hickson (2006).

TABLE 3
Twentieth-Century Value of a Statistical Healthy Life-Year (VSHLY) Values for Broad Morbidity Categories, England ($ million)

	VSL ($ million)				VSHLY ($ million)		
Morbidity	C&K	M	V&A	QALY	C&K	M	V&A
Infectious	1.20	1.21	1.63	0.68	0.82	0.82	1.11
Non-infectious				0.56	0.67	0.67	0.91
Disability				0.50	0.60	0.61	0.82

Notes: See Table 1 for VSL values; see Table 2 for QALY values; VSHLY is calculated as the VSL adjusted for the QALY (VSL*QALY).
All $ values are in current (2012) U.S. dollar prices.
C&K, Costa and Kahn (2003); M, Miller (2000); V&A, Viscusi and Aldy (2003).

significant results, which provide some reassurance for this approach. The key message is that, even at a lower bound estimate, the results are significant.

In Table 2 we present the quality adjusted life-year weight as a number that is a fraction of one. Any value between zero (which represents death) and one (which represents full health) is the fraction of a life-year lived. A mild illness or disability would achieve a score near to 1, such as 0.9 or 0.8. For a severe illness the quality adjusted life-year weight could be as low as 0.1. In addition to summarizing the quality of life for morbidity data, we use the quality adjusted life-year weights in Table 2 to adjust the value of a statistical life. This is necessary to value improvements in morbidity. Essentially we are reducing the value of a statistical life-year to represent the fraction of a year lived in less than full health. The results concerning the value of a statistical healthy life-year are presented in Table 3.

3.3. *Health (Mortality and Morbidity)*

The above considerations about the value of improvements in mortality (equations (1)–(3)) and morbidity (equation (4)) will be combined in a single measure of health (equation (5)). The result is a novel methodology that considers the magnitude and value of improvement in health, in terms of additional life-years due to improvements in mortality and the quality of those additional life-years by also considering morbidity.

$$\frac{dc^*}{d\mu+\lambda}=\frac{-u(c^*)}{(\rho+[\mu+\lambda])}. \tag{5}$$

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In equation (5), $u(c^*)$ = the goods value of life and c^* = consumption (cf. equation (1)); μ represents the set of mortality rates; λ = the morbidity consideration outlined in equation (4), thus $\mu + \lambda$ accounts for the population who are alive, and their probability of living with a certain illness and the corresponding quality of life burden of that illness; and ρ = the pure rate of individual time preference. Finally, it should be noted that the left-hand side of equation (5) is greater than zero because individuals are likely to forego some consumption in return for improved health. The results of applying this methodology to the data for twentieth-century England are outlined below.

4. Results

We value health improvements by first calculating the monetary value of reduced mortality. This is summarized in Table 4, where the decline in the death rate (referred to as mortality burden change) is valued. By applying the value of a statistical life to the number of additional life-years we can estimate the value of mortality improvements. The results in Table 4 are striking: estimates about the value of improved mortality range from \$840 billion to \$1.14 trillion. This equates to twentieth-century improvements in life expectancy being as valuable as all economic activity in England in the year 2000, as measured by GDP; or, as being many times more valuable than all economic activity for earlier years, such as 1900 and 1950 when GDP in England was approximately \$200 billion and \$350 billion, respectively.

Next we calculate the approximate value of improvements in morbidity. The first stage in Table 5 is the calculation of the change in illness prevalence adjusted by the corresponding quality of life illness burden for broad morbidity categories. This corresponds with equation (4) and is presented as morbidity burden change, in the second column in Table 5. The negative results for non-infectious diseases (−18802) and disability (−7976) are not surprising because there has been an increase in prevalence of these conditions over the twentieth century. This is not entirely the result of worse health: in many cases the reported prevalence of disease increases as more treatments become available, diagnostic capabilities improve, or awareness of the disease rises (Cutler and Richardson, 1998, p. 18). Likewise, improvements in medical technology enable people to live for longer, albeit with the disease. It is therefore especially noteworthy that the decline in infectious

TABLE 4

Willingness to Pay for Improved Mortality (WTP Mortality) Calculation, England, 1900–2000 ($ million)

Mortality	Mortality Burden Change	VSL ($ million)			WTP Mortality ($ million)		
		C&K	M	V&A	C&K	M	V&A
Σ mortality	678875	1.20	1.21	1.63	814650	821439	1106566

Notes: Mortality burden change calculated from Office for National Statistics (2003); see Table 1 for VSL values.

All $ values are in current (2012) U.S. dollar prices.

C&K, Costa and Kahn (2003); M, Miller (2000); V&A, Viscusi and Aldy (2003).

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TABLE 5

Willingness to Pay for Improved Morbidity (WTP Morbidity) Calculation, England, 1900–2000 ($ million)

Morbidity State	Morbidity Burden Change	VSHLY ($ million)			WTP Morbidity ($ million)		
		C&K	M	V&A	C&K	M	V&A
Infectious	51594	0.82	0.82	1.11	42307	42307	57269
Non- infectious	–18802	0.67	0.67	0.91	–12597	–12597	–17110
Disability	–7976	0.60	0.61	0.82	–4786	–4865	–6540
Σ morbidity	24816				24924	24845	33619

Notes: Morbidity burden change calculated from Hickson (2006); see Tables 2 and 3 for VSHLY calculation.

All $ values are in current (2012) U.S. dollar prices.

C&K, Costa and Kahn (2003); M, Miller (2000); V&A, Viscusi and Aldy (2003).

TABLE 6

Willingness to Pay for Improved Health (WTP Health) Calculation, England, 1900–2000 ($ billion)

Quality Adjusted Life Expectancy	WTP Mortality ($ billion)			WTP Morbidity ($ billion)			WTP Health ($ billion)		
	C&K	M	V&A	C&K	M	V&A	C&K	M	V&A
Σ mortality + Σ morbidity	815	821	1106	25	25	34	840	846	1140

Notes: WTP QALE is calculated as the sum of WTP mortality + WTP morbidity; for these calculations see Tables 4 and 5.

All $ values are in current (2012) U.S. dollar prices.

C&K, Costa and Kahn (2003); M, Miller (2000); V&A, Viscusi and Aldy (2003).

morbidity has outweighed the increase in non-infectious and disability related morbidity, albeit with a small number of additional life-years, relative to the size of the population. The overall result is an improvement in the morbidity burden by 24,816 life-years. Next we apply the value of a statistical healthy life-year to these 24,816 additional healthy life-years in order to estimate the monetary value of improved morbidity over the twentieth century. This is presented in the final row of Table 5 and is estimated to be worth at least $24 billion.

Following equation (5), the results presented in Table 5 are combined with the equivalent for mortality (from Table 4), in order to estimate the value of overall health gains. This result, in Table 6, is shown to be in the region of $1 trillion. One of the noteworthy features in Table 6 is the size of the mortality gain versus morbidity. This is driven by three factors. First, for morbidity we make lower bound assumptions to generate defendable (lower bound) results in the absence of detailed morbidity data. Second, the value of a statistical life is greater than the value of a statistical healthy life-year. Third, twentieth-century trends in mortality have been overwhelmingly positive. In England, life expectancy increased from 46 years in 1900 to 78 years in 2000 (Office for National Statistics, 2006). This trend has not been as positive for morbidity. Overall morbidity has improved, but there have been increases in the prevalence of chronic diseases and disabilities.

The final stage of estimating the value of health gains includes the use of a chain Fisher quantity index to calculate real GDP growth rates. Fisherian growth

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TABLE 7

Compound Average Annual Rates of Fisherian Growth, England, 1900–2000 (%)

	WTP Health Growth			Fisherian Growth (GDP + WTP Health)		
GDP Growth	C&K	M	V&A	C&K	M	V&A
1.8	0.3	0.3	0.4	2.1	2.1	2.2

Notes: GDP growth calculated from Maddison (2001); see Table 6 for WTP calculation. C&K, Costa and Kahn (2003); M, Miller (2000); V&A, Viscusi and Aldy (2003).

requires the result presented in Table 6 to be summed with national income. Table 7 outlines the compound average growth rate of: GDP, the value of health improvements, and the sum of these two, which equates to Fisherian growth. The most noteworthy point from Table 7, and the message of the article, is the magnitude of health gains. The lower bound estimates in Table 7 indicate that health improvements have added at least 0.3 percent per annum to compound average annual GDP growth.

5. Discussion

By developing a novel methodology, we have generated more comprehensive results about the value of health gains. What is most noteworthy is that increases in chronic diseases and disabilities have been outweighed by health improvements associated with the virtual elimination of infectious diseases over the twentieth century. This has generated an overall improvement in morbidity which provides a very small (+0.01 percent), but crucially, positive contribution to improvements in mortality (which add at least 0.3 percent to per annum GDP growth). This is a significant result, showing that only valuing life expectancy does not lead to an overestimate of the value of health gains. In fact, the results presented here indicate that mortality is a very good proxy for valuing health improvements, at least in twentieth-century England.

It is reasonable to assume that other developed countries have experienced similar health gains. Developed countries tend to have similar health profiles because they have experienced the transformation in health, referred to as the "epidemiological transition."[14] This is associated with substantial improvements in life expectancy and a shift in the cause of illness from infectious to chronic diseases. Figure 1 summarizes this transformation. For developing countries, however, it is not possible to use the results for England to draw any inferences. Not only are these countries at an earlier stage of the epidemiological transition, but there is also a much greater degree of heterogeneity among them.

By generating estimates about the magnitude of health gains for developed economies, the article provides a contribution to the existing literature about the value of improved mortality, particularly the findings of Usher (1980) and

[14]Omran (1971) defined the epidemiological transition as the transformation of the mortality pattern from a world dominated by infectious and acute diseases to one dominated by chronic and degenerative diseases.

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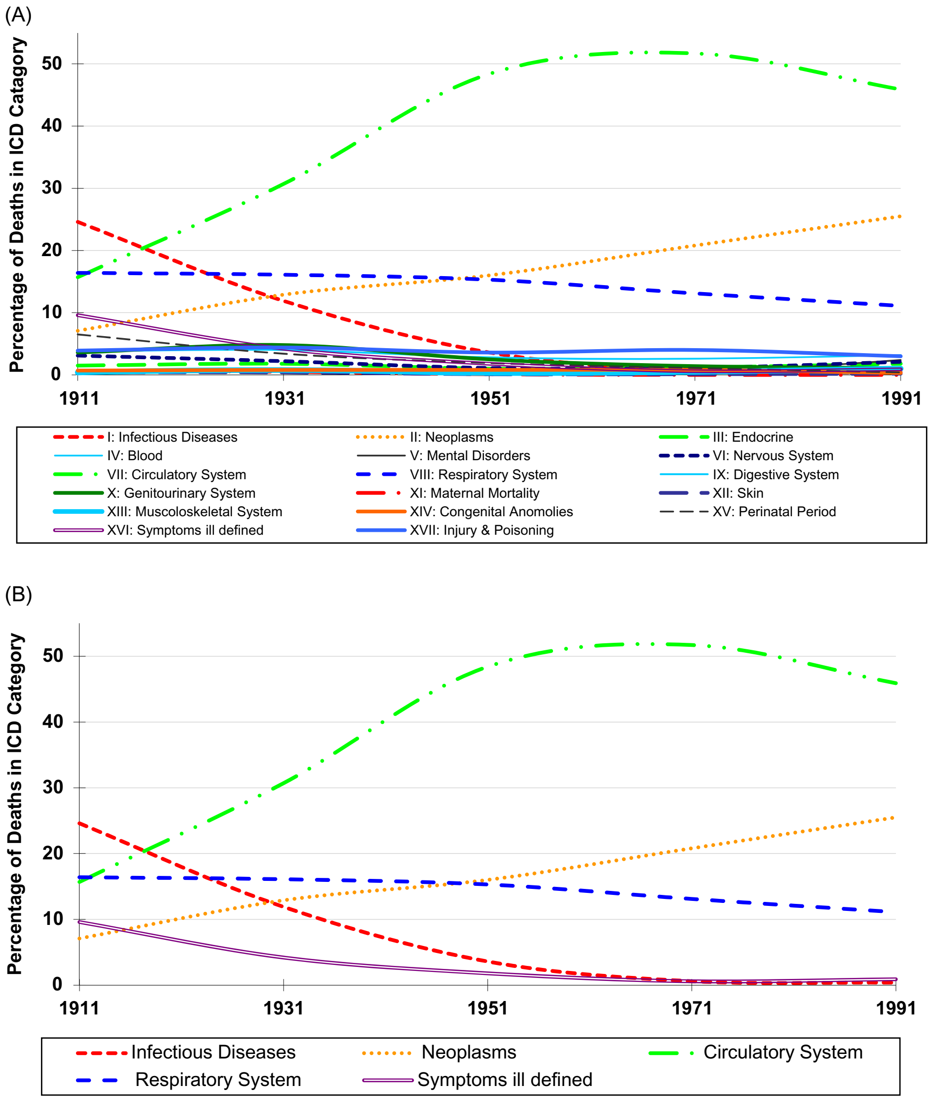

Figure 1. Percentage of deaths in International Classification of Disease (ICD) categories, England, 1911–91: (a) percentage of total deaths in each ICD category; (b) percentage of deaths in the five most prevalent ICD categories

Source: Charlton and Murphy (1997, p. 44). In order to make comparisons over time it is necessary to bridge the various coding systems that have been used (from ICD1 in 1901 to ICD9 since 1979). In the statistics used here, from Charlton and Murphy, historical data have been converted to their ICD9 equivalents.

Nordhaus (2002), discussed above, although the results presented here do not generate such valuable results as Nordhaus (2002). By multiplying the per annum growth rates in Table 7 by 100, we find the value of increased health over the twentieth century to add about 25 percent to non-health goods and services, rather

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than the 100 percent identified by Nordhaus. However, the results presented here are lower bound estimates and the U.S. has higher national income and subsequent value of a statistical life, which accounts for a significant proportion of the difference.

Although smaller in magnitude, the results of the article corroborate similar studies. Hickson (2009) conducted an equivalent study for Japan. The results concur with Nordhaus (2002), showing that longevity gains were as valuable as non-health goods and services over the course of the twentieth century. Like the U.S., Japan has higher national income and a greater value of a statistical life than England. Also, like Nordhaus's work, the Japan study calculated a mid range and not lower bound estimate. Crafts (2005) valued improved mortality in the U.K. since 1870: as in the U.S. and Japan studies, he estimates that the (mid range value) improvements in mortality have been about as valuable as the growth in national income. The results of the article also substantiate these existing mortality-only studies by indicating the likely accuracy of using mortality as a proxy for overall health.

Owing to the tentative nature of this study, there are aspects that could benefit from a more precise approach. Many of these problems are insurmountable (and not just within the confines of this article), but still ought to be recognized. The most obvious features for improvement are the methodological variables. We have used lower bound estimates to try to enhance the reliability of the findings. However, the value of a statistical life, the value of a statistical healthy life-year, and especially the quality adjusted life-year weights would benefit from being more precise and universally acceptable. Although verging on the impossible, it would be ideal to employ a much greater number of morbidity state quality adjusted life-year weights. This would certainly increase the magnitude of the results and reiterate the key message of the article: that twentieth-century health gains have been extremely valuable in developed countries, and that only valuing life expectancy does not lead to an overestimate about the value of these health gains.

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