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**Estimating 'Fisherian' National Income to Account for Twentieth Century Economic Welfare Gains
Generated by Improved Health: England & Wales**

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Abstract

Despite unprecedented health improvements in developed economies over the twentieth century there have been a limited number of attempts to quantify these developments in health (defined here as mortality and crucially also morbidity). The paper outlines the development of an original quantitative methodology that can measure historical levels of health in terms of additional economic growth, so that national income can be defined on a utility or 'Fisherian' basis to include health outputs. Current measures of national income or GDP only include the cost of health services, with no accounting for the return. An additional contribution of the paper is that the health measure comprises both prevalence and quality of life (from the perspective of the sufferer) indices for the entire twentieth century.

Although it is not possible to provide precise 'Fisherian' national income estimates, it is possible to highlight that at a lower bound estimate twentieth century health improvements in developed economies have added in excess of 1 percent growth to per annum GDP per capita if defined on a utility or 'Fisherian' basis to include health outputs. In addition to presenting a new methodology the results make some progress in filling a crucial historical void about the positive value of mortality and more originally morbidity gains during the twentieth century, despite an increase in the prevalence of chronic diseases. These 'Fisherian' national income estimates provide more sanguine conclusions about the value and contribution of health gains to economic welfare and as such substantiate Nordhaus (1999) and Cutler & Richardson (1999) who have emphasised the value of historical health improvements and the need to more accurately measure the associated economic welfare gains. The results of the paper are also pertinent for their optimism about the social productivity of health care spending.

Key words: please see the lexicon at the end of the paper for key words and definitions

1. Introduction

Since the late twentieth century there has been an increase in initiatives to try and measure health, which were partially inspired by concerns about the quality of the extra life years that have been generated by substantial gains in life expectancy over the twentieth century: in Britain life expectancy at birth increased from 46 years in 1900 to 78 years by 2000¹. Despite the significance of these historical health trends there have been a limited number of attempts to measure health retrospectively. To do this requires considerations about the burden of disability, disease and death, which have changed considerably during the twentieth century in economies that have undergone the epidemiological transition.

The need to consider health as a combination of mortality and morbidity has been well documented. The need to consider quality of life associated with mortality and morbidity has not. Simply considering reported levels of morbidity is misleading for any measure that is attempting to understand the health of a population beyond reported statistics about the number of doctor visit, efficacy of a therapy, prevalence of diseases and life expectancy. When consulting these measures the key concern is often related to the health related quality of life and therefore a measure that has this as its primary index is directly assessing the information, rather than making inferences from statistics. Second, because of a number of exogenous factors to health, there has been an increase in reporting of ill health or a social inflation of morbidity. These have all been well documented, for example: substitution effects, composition effects, time effects, more exacting health expectations and health ceilings, improved recognition and reporting, and even economic incentives, such as the availability of subsidised healthcare or disability payments. None of which tell us about the changing quality of life burden of diseases over time.

In recent years there has been an increase in efforts to understand the life quality significance of morbidity, through more studies attempting to consider functional ability, self perceived health/disability measures, limitation indices, days and years lost to ill health. All of which use some form of quality adjusted life year (QALY) index.

When considering historical quality of life, for which there are no QALYs, Cutler and Richardson have led the way with considerations about the quality of life associated with morbidity, through utilizing the American National Health Interview Survey since 1970². Despite the merits of this study it lacks considerations about health related quality of life for a long historical period because Cutler & Richardson are restricted by the start date of the NHIS. Murray's global burden of disease study is useful for the similar QALY constraints that are evident in countries without national health interview surveys³. Murray generated DALYs (inverse QALYs) across geography not time, but still faced similar constraints to those that are overcome here.

This paper provides an outline of an original methodology that was established to overcome the problems associated with measuring historical health and generate quantitative (monetary) estimates about the quality of life associated with morbidity gains in periods when QALY weights were non-existent. As such, the Quality Adjusted Life Expectancy (QALE) methodology that is outlined below is able to fill a void through generating quantitative estimates about the value of additional life years during historical periods. In the paper the value of health gains over the twentieth century in England and Wales will be calculated.

The QALE methodology supersedes many of the existing health measurement deficiencies and provides a unique historical health related quality of life measure. As well as filling this health measurement void the QALE also adheres to the general requisites of a good measure, i.e. it is coherently constructed, statistically reliable, sensitive, applicable, and valid. In addition to outlining a novel methodology the paper will also provide original estimates about the value of improved health in twentieth century England and Wales.

¹ Office of National Statistics / Government Actuaries Department (2006)

² Cutler & Richardson (1999)

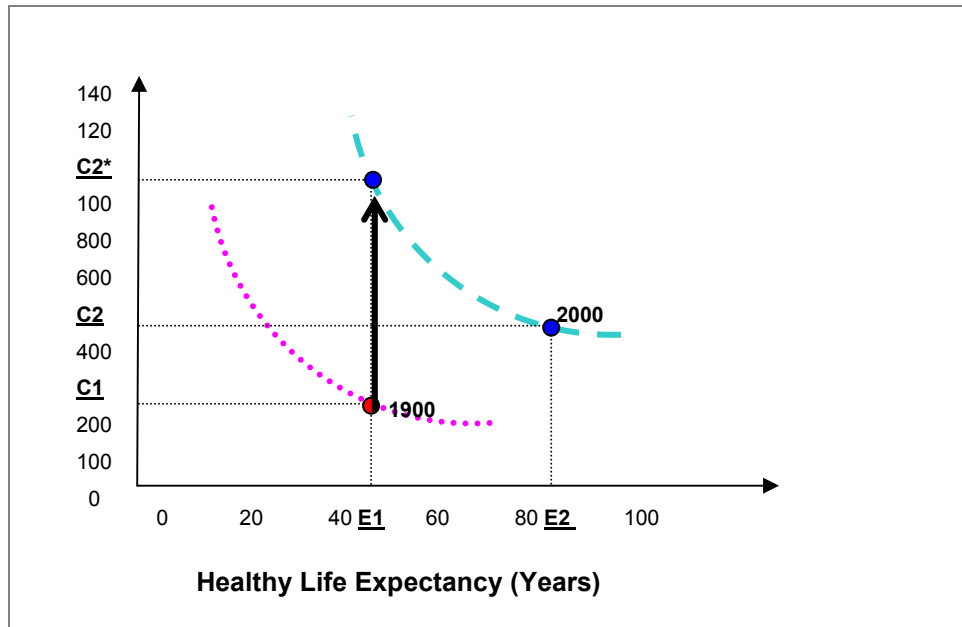
³ Murray & Lopez (1996)

In section 2 the QALE gain methodology will be explained. This comprises an outline of how WTP for mortality has been extended so that WTP morbidity can be gauged and how these two WTP measures are combined to create the QALE gain. This will also include a detailed explanation about how the QALY was estimated for key case study illnesses (blindness, breast cancer, stomach cancer and tuberculosis) and then extrapolated forward to include all twentieth century morbidity in England. This QALE methodology will then be applied to twentieth century England and Wales to estimate the value of improved health over the twentieth century, which are presented and discussed in section 3. Section 4 concludes.

2. Theory

The QALE is developed from the concept of willingness to pay (WTP), which currently only considers mortality, i.e. what an individual would be willing to forego in income for an increased probability of survival. The QALE has developed the concepts of WTP to include morbidity as well as mortality, i.e. what an individual would be willing to forego in income for an increased probability of survival with healthy life years. The indifference curve diagram below illustrates the basic notion of the WTP methodology.

Fig 1: Indifference curve diagram to illustrate the rationale of the WTP methodology



Consider a person observed initially at point 1900 and subsequently at point 2000: between 1900 and 2000 life expectancy has increased from E_1 to E_2 and income has increased from C_1 to C_2^* , not C_2 , as traditional measures would indicate. Point C_2^* is the height of the intersection of the indifference curve attained in 2000 with a vertical line at the value of life expectancy in 1900, whereby the individual maintains 2000 income with 1900 life expectancy. The difference between C_2 and C_2^* indicates the income value of increased life expectancy between 1900 and 2000 and the amount of income that an individual would be willing to pay for the improved health conditions of 2000, compared to 1900.

The WTP mortality approach used in this paper builds upon what was proposed by Usher and refined by Nordhaus⁴. This provides a method of measuring the gain in real income from improved life expectancy in the context of the life

⁴ Usher (1980) and Nordhaus (1999)

cycle consumption model. An individual is assumed to value consumption and health according to a lifetime utility function:

$$V[c_t; \theta, \rho, \mu_t] = \int_0^{\infty} u(c_t) e^{-\rho(t-\theta)} S[\mu_t] dt \quad (1)$$

Where $V[c_t; \theta, \rho, \mu_t]$ is the value at time t of the consumption stream, now and in the future, faced by an individual of age θ ; (c_t) is the stream of instantaneous utility; ρ is the pure rate of individual time preference; $S[\mu_t]$ 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. It is also assumed that the survival function is exponential, and therefore equation (1) becomes:

$$V[c_t; \theta, \rho, \mu_t] = \int_0^{\infty} u(c_t) e^{-(\rho+\mu)(t-\theta)} dt \quad (2)$$

This equation can be further simplified by assuming that the real interest rate faced by the individual is equal to the mortality adjusted rate of time preference $(\rho + \mu)$. Given these assumptions, an individual will choose a consumption annuity that yields constant consumption during the individual's lifetime, $c_t = c^*$. Integrating equation (2) yields a simpler outcome:

$$V[c_t; \theta, \rho, \mu_t] = \frac{u(c^*)}{(\rho + \mu)} \quad (3)$$

Equation (3) shows that the total utility value of consumption, discounted by a discount rate that equals the sum of the force of impatience and the force of mortality.

An individual will often face a trade-off between health and wealth. At age θ , changes in consumption and health yield:

$$\left. \begin{aligned} \frac{dV}{dc^*} &= \frac{u'(c^*)}{(\rho + \mu)} \\ \frac{dV}{d\mu} &= \frac{u(c^*)}{(\rho + \mu)^2} \end{aligned} \right\} \quad (4)$$

Hence, the trade-off between consumption and mortality:

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

It is then possible to further simplify through making two normalisations. First, utility is defined so that one unit of utility is one extra unit of the consumption good, by setting $u'(c^*) = 1$. Second, the pure rate of time preference is set equal to zero, such that when the utility of consumption is $u(c) = 0$, the individual is indifferent between life and death. This implies that there is zero utility after death. Given these assumptions, equation (5) can be reduced to:

$$\frac{dc^*}{d\mu} = Tu(c^*) \quad (6)$$

Where, T is life expectancy ($T=1/\mu$). The interpretation here is that a uniform change in mortality rates at every age will produce a welfare change equal to the number of years of life (T) times the goods value of life, $u(c^*)$.

The WTP morbidity approach used in this paper builds upon what was proposed by Cutler & Richardson⁵. Where health capital is defined as:

$$L \sum_{k=0}^{\infty} \frac{E_t[H_{t+k}]}{(1+r)^k} \quad (7)$$

Where H_t represents a person's quality of life in any year (scaled on a 0 to 1 basis, where 0 = death and 1 = perfect health) or the QALY. L represents the value of a year in perfect health and r is the real discount rate and k is the number of years of life.

After identifying health capital the next stage in the methodology is to consider the quality of life. The starting point for this (more complex) measurement is the probability that a person is alive or dead in each year of the future. This can be achieved through analysing life tables. These survival rates then need to be adjusted for the prevalence of disease. Quality of life weights also need to be attached to every condition and time period considered in the methodology. Hence, combining estimates of the share of the population who are still alive, at $t+k$, the prevalence of people with particular conditions, where d is the range of conditions a person could have, and the quality of life for people with those conditions, quality of life can be estimated as:

$$H_{t+k} = \Pr[\text{alive at } t+k] * \left(\sum_d \Pr = [\text{condition } d \text{ at } t+k] * [\text{QALY for } d \text{ at } t+k] \right) \quad (8)$$

The above WTP mortality and morbidity methodologies can be combined in a single methodology, the QALE. The result of combining the two above approaches is a methodology that considers the value of improvements in life expectancy and the value of these additional years from a health (or QALY) perspective. This QALE (quality adjusted life expectancy) methodology is expressed as:

$$QALE = \frac{dc^*}{d\mu + \lambda} = \frac{-u(c^*)}{(\rho + [\mu + \lambda])} \quad (9)$$

Where, $u(c^*)$ = the goods value of life and c^* = consumption. μ represents the set of mortality rates and $\lambda = \left(\sum_d \Pr \text{Condition } D \text{ at } t+k \right) * [\text{QALY for } D \text{ at } t+k]$, which is essentially the consideration for the health aspect of improved mortality rates, where d represents the range of possible health conditions. ρ = the pure rate of individual time preference. Finally, it should be noted that,

$$\frac{dc^*}{d\mu + \lambda} > 0$$

because individuals are likely to forego some consumption in return for improved healthy life years.

In this QALE approach, gains from improved mortality and morbidity are treated as an imputation for a change in the environment, because increased life expectancy has been largely a result of the accumulation of knowledge on how to cure and prevent diseases that affect all individuals (rich and poor, educated and uneducated), which is the reason that these improvements are not included in income measures and therefore not double counted by QALE imputations.

Once the WTP for mortality and morbidity or QALE has been calculated it is possible to append this value to national income measures, in order to provide a more vivid indication about the magnitude of health improvements, referred to as 'utility national income' or 'Fisherian' income. This is also desirable as it provides a more accurate account of

⁵ Cutler & Richardson (1999)

economic development compared to conventional Hicksian income measures. National income measures only include the costs or inputs of health care with no accounting for the output or benefits.

The notion of imputing national income measures to account for increases in life expectancy was initially proposed by Usher, who recognised the need to consider the value of maximising age specific mortality rates and societies' willingness to pay for this improvement⁶. These considerations have been developed in a limited number of studies, namely: Nordhaus⁷ for the USA between 1900 and 1995, Crafts⁸ for the UK between 1870 and 1998 and Hickson⁹ for twentieth century Japan. Despite their agreement with Usher's objectives of providing a more indicative national income estimate, none of these studies measure health per se, as they all utilise mortality (i.e. increased life expectancy) as a proxy for health.

This paper will indicate how the QALE supersedes existing willingness to pay methods in order to consider the value of increased life expectancy in a historical context (as has been accomplished in the Nordhaus, Crafts and Hickson 2002 studies) and also improved morbidity. Although this more comprehensive health measure can only yield estimates it is still superior, as these estimates provide a much more accurate indication about health than the more precise but less detailed WTP mortality only estimates. As well as providing important detail about the health related quality of life over time the QALE results will provide more comprehensive (utility based) results about economic development, through appending these results to national income for the twentieth century.

In this paper 'utility national income' (which is defined as the maximum amount that a nation can consume while ensuring that members of future generations can have expected lifetime utility the same as that of current generation), values improvements in quality adjusted life expectancy by considering the change in the population weighted average of age specific mortality rates multiplied by the estimated value of death averted in conjunction with the population weighted average of the morbidity burden multiplied by the estimated value of unhealthy life years averted. This is approximately equal to the increase in quality adjusted life expectancy times the value of an additional healthy life year.

In order to estimate a society's willingness to pay for reduced mortality it is necessary to establish the amount that a group of people (society) would be willing to pay for a reduction in the current period probability of death. Value of a Statistical Life (VSL) studies estimate the value of fatal risk reduction (through evaluating the amount that a society is willing to pay) in the expectation of saving one life (of an unidentified person) in the current period. There are three approaches that have been adopted to identify the VSL. First, is based on the implications of individuals' observed behaviour in production, e.g. risk compensating wage studies. Second, is based on the implications of individuals' observed behaviour in consumption, e.g. information concerning the time-inconsistency-safety trade offs involved in seat belt use, motorway speed decisions, the purchase and maintenance of smoke detectors for the home, etc. In contrast to these revealed preference approaches the third method elicits responses to questionnaires that involve asking a sample of individuals about their willingness to pay for various hypothetical changes in risk of fatality.

The majority of revealed preference studies have focused on risk compensating wage differentials or hedonic price studies. It is thought that this provides the most reliable estimate of individuals' willingness to pay for a reduced probability of death because labour market studies reflect actual behaviour, labour force decisions are repeated, and the variety of labour markets within and across countries and over time provides a rich choice of sample¹⁰.

⁶ Usher (1980)

⁷ Nordhaus (1999)

⁸ Crafts (2005)

⁹ Hickson (2002)

¹⁰ Nordhaus (1999)

There is a growing pool of evidence concerning premiums individuals are willing to pay to reduce the risk of death by small amounts. Estimates of the VSL range widely: from less than \$100,000 to several million dollars. Even the most credible VSL studies lack precision in consensus. This has led sceptics to claim that the variation in VSL estimates raises such doubts about their reliability that they are virtually redundant (for example, for a time this sceptical view was adopted by the UK Department of Transport). A more preferable approach is to identify the reasons for the large variation in VSL estimates and try to define what constitutes a reliable study.

Although it may never be possible to identify a universally accepted VSL (due to numerous issues: differing rates of individual marginal substitution, misinterpretation and aggregation of wage premiums, model misspecification, omitted variables and multicollinearity problems, to name a few) it is possible to identify an acceptable VSL, which is the approach here.

Miller (denoted as M in the tables below) provides a summary VSL 'best estimate' derived from applying a detailed and robust statistical analysis to the most reliable existing VSL studies (including revealed preference in consumption and production and contingent valuation) for the UK¹¹. The QALE will be applied to twentieth century England below and it is therefore desirable to use a UK specific VSL. Another appeal of adopting Miller's VSL is its versatility: it is possible to present the VSL as either an aggregate monetary estimate or as a VSL multiple. The latter is multiplied by GDP per capita, to yield a VSL estimate that accounts for the era it is considering. Due to the historical measurement objectives of the QALE, this approach is the best given that there are no historical VSL estimates for twentieth century England.

Another important consideration when valuing historical health with the QALE is the elasticity of the VSL over time. Costa & Kahn (denoted as C&K in the tables below) have claim that as an economy develops: income, the quantity of safety, and the health and well-being of the population also increases along with the demand for safety and the subsequent compensating wage differential¹². For example, they estimate that between 1940 and 1980 the VSL increased by 300 to 400 percent, rising from roughly 1 million (1990 \$) in 1940 to 5 million (1990 \$) in 1980 in the USA, which indicates a VSL income elasticity of between 1.5 and 1.7. Conversely, Viscusi & Aldy (denoted as V&A in the tables below) consider wage risk studies and estimates income elasticity as between 0.5 and 0.7¹³.

The implication of these different elasticities is the variance of the VSL relative to GDP and ought to be considered when valuing historical improvements in health. Costa & Kahn's results imply that as an economy develops increases in longevity or the VSL becomes more valuable (as the VSL increases 50-70 percent more than GDP because the VSL income elasticity they propose is 1.5-1.7 percent). Viscusi & Aldy's results claim that earlier increases in longevity were more valuable (as the VSL increases 50-70 percent less than GDP, because they propose that the VSL is inelastic by 0.5-0.7 percent). The implications of these theories is the relative magnitude of the VSL: if the VSL is income inelastic (Viscusi & Aldy) the value of the VSL is relatively large in earlier time periods, and the opposite is true for an income elastic VSL (Costa & Kahn), were the VSL becomes increasingly valuable as the twentieth century unfolds. The unitary elasticity (Miller) VSL estimates will lie between inelastic and elastic, respectively. These VSLs are presented in Table 1.

¹¹ Miller (2000)

¹² Costa & Kahn (2003)

¹³ Viscusi & Aldy (2003)

Table 1: Twentieth century VSL values

Study	VSL income elasticity	VSL value (1990 international \$)
Costa & Kahn (C&K) ¹⁴	1.6	0.64
Viscusi & Aldy (V&A) ¹⁵	0.6	1.18
Miller (M) ¹⁶	1	0.88

The VSL values presented in Table 1 will be combined with death rate data in order to calculate the value of these extra life years, which represents the value of improved life expectancy or the mortality gain. These results follow in section 3.

The Value of a Statistical Healthy Life Year (VSHLY) measurement follows the same rationale as the VSL, as it tries to establish the amount that a group of people (society) would be willing to pay for a reduction in the current period probability of ill health (instead of a death which is estimated by the VSL). The VSHLY will estimate the value of illness risk reduction in the expectation of saving one healthy life year (of an undefined person) in the current period, and therefore indicate society's willingness to pay for improved morbidity.

In contrast to the VSL literature, very little has been estimated about the VSHLY. Furthermore, existing initial attempts to consider some form of VSHLY tend to be abstract and generalised and do not consider an array of different illnesses.

Cameron and DeShazo (2004) who coined the term 'Value of Statistical Illness' (VSI), consider this as the rate of substitution between consumption and mortality/morbidity risk through evaluating the willingness to pay to avoid five (and only five) generalised mortality/morbidity states¹⁷. Although this provides an acceptable first effort to provide a more accurate VSI, there are noteworthy shortcomings. For example, the very general nature of the illness states and the void of considerations about the quality of life mean that the VSI is too generalised. Of greater concern is that some of the assumptions in their illness model seem arbitrary, e.g. the 6 year survival profiles. Finally, there is no indication about the change in the VSI, i.e. the associated trade-off costs as medical technology has advanced and the resultant improvement in the health/welfare quality of life associated with illness which is likely to have increased the value of the VSI over time.

A more general drawback of the majority of existing VSI methodologies is the assumptions that individuals are in one of two mutually exclusive states while alive: healthy or ill. The QALE methodology will provide a much more detailed and bespoke evaluation about the burden of illness.

The VSI (or VSHLY used here) is a function of the VSL adjusted for the QALY (VSL*QALY) for the associated illness and era under consideration. The VSL considers the value of a life year with 100 percent health and the QALY represents the necessary deduction for the value of a life year in less than perfect health. The VSHLY will deduct the according QALY fraction for the burden of morbidity. E.g. if the morbidity burden of tuberculosis in 1950 was 40 percent, an individual would only have gained 60 percent of a healthy life year (1 [full healthy life year] – 0.4 [morbidity burden] = 0.6 or 60 percent). The value of this healthy life year has been established above (it is the VSL) and this will be reduced by 40 percent for the morbidity burden in order to provide the VSHLY value.

¹⁴ Costa & Kahn (2003)

¹⁵ Viscusi & Aldy (2003)

¹⁶ Miller (2000)

¹⁷ See Cameron & DeShazo (2004): The five mortality/morbidity states that are considered: 1) shorter term morbidity with recovery, 2) longer term morbidity with recovery, 3) a combination of shorter term morbidity and premature mortality, 4) a combination of longer term morbidity and premature mortality, 5) immediate mortality.

In common with the VSL, the VSHLY component of the QALE methodology is versatile and enables alternative VSHLY indices to be used for those who feel that the VSHLY approach used here is too crude. Moreover, detailed sensitivity analysis of the VSL and VSHLY finds that the QALE gain results hold regardless of the value of the VSL or VSHLY for all reasonable approximations.

Once the VSHLY has been identified it is combined with morbidity burden data in order to calculate the value of these extra healthy life years, which represents the value of improved health or the morbidity gain. These results follow in section 3. However, unlike the death rate, the morbidity rate or burden information does not exist for twentieth century England. Therefore a significant contribution to knowledge of WTP morbidity is estimating this index.

In order to estimate the morbidity burden, the prevalence data for diseases has to be combined with a corresponding burden of illness index for the disease and era, which is referred to as a Quality Adjusted Life Year (QALY) in the paper. The QALY needs to be established in order to provide a standardised, numerical indication about the burden of morbidity across all illnesses and eras. Essentially the QALY is considering the portion of a healthy life year lost as a result of illness. The QALY will be presented as a number that is a fraction of one: where one represents a full healthy life year and anything between zero (which represents no healthy life year, i.e. death) and one is the fraction of a healthy life year lost to illness.

In order to establish the QALY for periods in history when this index does not exist and there is a void of compliant data it is necessary to approximate the QALY. Murray (1996) achieved this through conducting an expert study to determine (through a series of revealed preference exercises conducted by expert participants) the likely burden of different illnesses, where the final weight was generated through arriving at expert consensus. A similar value eliciting process can be carried out by an individual, through a detailed and consistent analysis of the pertinent literature and data, which is summarised (on the EuroQol spectrum) and applied to a series of independent revealed preference exercises. The latter is utilised here. Both of these approaches have their drawbacks in addition to the general disputation associated with QALYs. Sources of contention are similar for both methods and include: author biases which detract from objectivity (especially for the approach used here) and avoidance of issues such as adaptation and first hand understanding of quality of life burden of illnesses.

The QALY for tuberculosis, cancer and blindness has been estimated for the years 1900 and 2000, and will be gauged on a consistent spectrum (that can be utilised in the same way for all eras and illness), namely, EuroQol. The appeal of EuroQol is the simple ranking spectrum that it facilitates and the subsequent pellucid comparison it provides, through establishing a two dimensional information medium. EuroQol has been used in numerous studies that try to yield QALY weights for a variety of medical conditions.

The initial stage of estimating the QALY using the EuroQol matrix is to identify the most indicative and relevant health and welfare features of quality of life associated with morbidity during the twentieth century (for all illnesses). Five variables were selected: government initiatives and help, recognition and awareness, health developments, ability to lead a normal life, and pain and discomfort for diseases or status for disability), which represent the first set of EuroQol dimensions. Each of these variables was valued for tuberculosis, cancer and blindness in 1900 and 2000. The second set of EuroQol dimensions are the QALY ranks, which assess the performance of the health and welfare variables from a perspective of quality of life for the sufferer. There are six possible health and welfare ranks, which ranged from 1 (entire healthy life year) or complete quality of life to 0.167, which represents no quality of life¹⁸. By applying these rankings to the five health and welfare variables, EuroQol provides a standardised comparative analysis of tuberculosis, cancer and blindness during the twentieth century. The process of evaluation was to analyse an

¹⁸ The reason that the lowest score is not 0 is a result of the inherent assumption that any living state, regardless of how severe the burden of morbidity, is better than death. Hence, death is equal to 0 and perfect healthy life is equal to 1, it is theoretically possible to have a perfect healthy life but it is not possible to have an illness state that is worse than or equal to death.

extensive array of pertinent literature (primary data, patient and physician accounts, recommendations of contemporary experts, official reports, output of committees, comments and information from the British Medical Association, comments from charities and analysis of relevant media, and secondary sources) for tuberculosis, cancer and blindness during the twentieth century. This detailed literature review was compiled in order to provide an accurate profile about the living standards of the typical tuberculosis, cancer and blindness sufferer in 1900 and 2000, see Hickson (2006) for this conspectus. This profile information was then utilised to conduct independent revealed preference exercises ('visual analogue scale' [VAS], 'time trade off' [TTO], and 'standard gamble' [SG]), in order to identify and standardise an unbiased and consistent series of EuroQol ranks for tuberculosis, cancer and blindness in 1900 and 2000¹⁹. See Hickson (2006) for a detailed outline of the EuroQol methodology used here.

After the EuroQol has been utilised to generate a summary indication about the quality of life associated with tuberculosis, cancer and blindness in 1900 and 2000, this information is used in three independent revealed preference exercises (VAS, SG, TTO) in order to achieve independent consensus about the value of the QALY. The results of this are presented in Table 2, as 'Morbidity sample'. These 'Morbidity sample' QALYs are also utilised to represent profiles for broad morbidity states, referred to as 'Morbidity state' in Table 2: infectious (tuberculosis), non-infectious (cancer) and disability (blindness), to represent the aggregate epidemiological environment in twentieth century England and Wales. This is necessary to generate estimates about the aggregate QALE gain.

The QALY profiles are also important because of the foundation they provide for the wider morbidity calculations used in the aggregate QALE gain. In addition to cancer and blindness, tuberculosis is also considered in great detail. These sample morbidity states have been selected within the rationale of the epidemiological transition in an effort to optimise the accuracy of the results.

Tuberculosis was selected because it represents one of the most important infectious diseases that declined during the twentieth century in accordance with the epidemiological transition. The prominence of tuberculosis in the twentieth century enables more detailed quantitative considerations due to the availability of better data than alternative infectious diseases, for example, whooping cough and especially influenza.

One of the reasons for selecting breast cancer is the same as the appeal mentioned above for tuberculosis. Breast cancer was the most funded and researched cancer in twentieth century England, which facilitates a deeper insight into the quality of life features of this disease. Stomach cancer was utilised as a control for breast cancer and also to represent a more generic cancer, as far as possible. Breast and stomach cancer were also selected as their burden accords with the epidemiological transition, where debilitating diseases have increased to replace (and supersede) the decline in infectious diseases. This cancer trend is in contrast to the most prevalent twentieth century debilitating disease category, circulatory or cardiovascular diseases. The reason this has not been used is because of the decline of this disease from 50 percent of deaths in 1971 to 45 percent in 2000, which would bias the results²⁰.

Blindness was selected because it represents a significant twentieth century disability. All disabilities, including blindness, have inherent measurement problems for the QALE (largely because they are not usually resolved in death and therefore prevalence is harder to estimate compared to diseases). However, blindness has been well defined and documented over the twentieth century which makes it a preferable proxy disability compared to alternatives like paraplegia. Moreover, the quality of life burden of blindness was more severe than many alternative disabilities with good twentieth century data – e.g. deafness – and is therefore a more desirable sample.

¹⁹ The revealed preference exercises used here are three of the most common in this type of study. VAS is a method where the burden of different illness are rated on a (thermometer type) measurement scale, which is indexed from 0 (= death) to 100 (= perfect health). TTO identifies the trade off of life years for perfect health to avoid more life years with illness. SG evaluates the relationship between sickness and the level of risk acceptable to try and gain healthy life years. See Hickson (2006) for a detailed explanation and example of this process.

²⁰ Calculated from Office of National Statistics (2003)

Once the detailed historical QALY profiles have been constructed for these sample morbidity states, they are utilised to generate profiles for broad morbidity states: infectious (tuberculosis), non-infectious (cancer) and disability (blindness), to represent the aggregate epidemiological environment in twentieth century England. This is necessary to generate estimates about the aggregate QALE gain. The QALY weights used to represent infectious, non-infectious and disability in the aggregate QALE gain methodology are presented in Table 2.

Table 2: Twentieth century QALYs for morbidity samples and subsequent broad morbidity categories

Morbidity sample	QALY			Morbidity state	QALY
	low	mid	high		
Tuberculosis	0.4167	0.5833	0.7500	Infectious	0.4167
Breast cancer	0.4167	0.5833	0.7500	Non-infectious	0.3333
Stomach cancer	0.3333	0.5000	0.6667		
Blindness	0.3334	0.5000	0.6667	Disabilities	0.3334

The most noteworthy feature in Table 2 is that the QALY used for the broad morbidity states is equal to the low QALY for the sample morbidity. This is implemented to maintain the conservative stance of the aggregate QALE gain estimates presented here.

Once the QALY and the VSL have been identified, which has been achieved above, it is possible to calculate the VSHLY (VSL*QALY). This is achieved in Table 3.

Table 3: Twentieth century VSHLY (VSL*QALY) values for broad morbidity categories

Morbidity	VSL (1990 international \$)			QALY	VSHLY (1990 international \$)		
	C & K	V & A	M		C & K	V & A	M
Infectious	0.64	1.18	0.88	0.4167	0.27	0.49	0.37
Non-infectious				0.3333	0.21	0.39	0.29
Disability				0.3334	0.21	0.39	0.29

Table 3 provides the calculation of the VSHLY for the lower bound broad morbidity QALYs and the range of twentieth century VSLs that vary with income elasticity and were generated in Table 1.

In addition to utilising the lower bound QALYs and considering a range of VSL values, it is also desirable to apply an age weighting function as a further form of sensitivity analysis. There is evidence that the VSL and VSHLY are not constant across all age groups and therefore a more valuable approach for estimating society's willingness to pay would be a methodology that considers the potential for different ages to have varying values.

A practical method of age-weighting considers the relationship between age and efficiency, by reflecting an individual's social role. This form of age-weighting is provided by Murray, in his Global Burden of Disease study, and reflects the notion that greater importance needs to be attached to years of productive adult life²¹. It is noteworthy that this age weight function reduces the value of the QALE gain, because many mortality and morbidity gains in twentieth century England were at the youngest and oldest ages, which receive a lower weight on Murray's inverted u shaped age weighting function.

The drawbacks of using a static weighting function in a dynamic historical measurement need to be acknowledged. The ideal approach would apply a different set of age (and possibly gender) weights for different eras of the twentieth

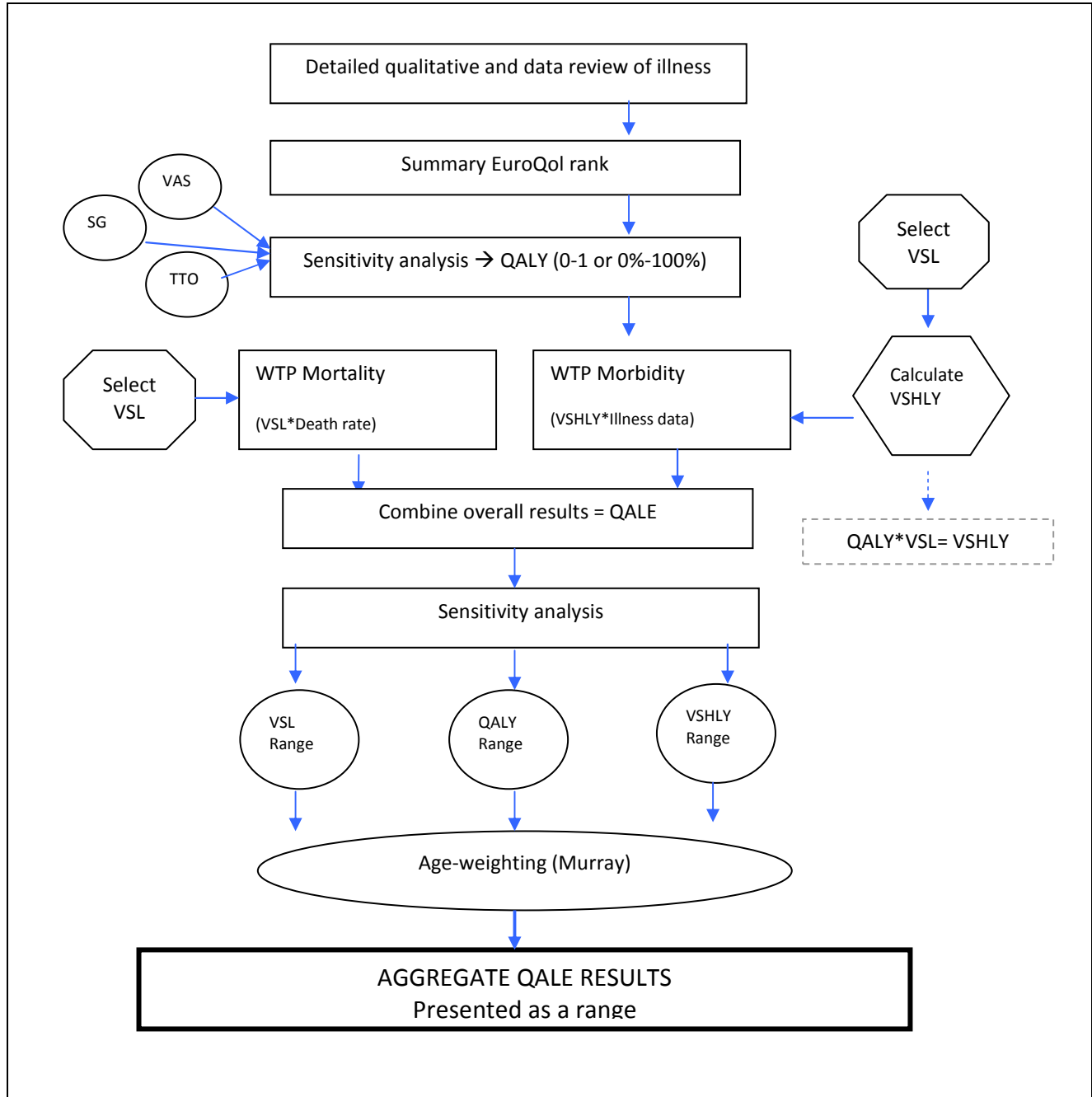
²¹ Murray & Lopez (1996)

century. As this option is not available in any of the existing literature, the Murray age-weighting will be utilised in order to provide a more accurate indication about the value of improved health, when standardised for age.

The data required to make mortality WTP adjustments to the conventional estimates of national income are population by age, death rates by age and the value of death averted (value of a statistical life). The data required to make morbidity WTP estimates are population by age, prevalence of a given disease, the burden of the disease (quality adjusted life year, QALY) and the value of ill health averted (value of a statistical healthy life year). These two calculations will then be combined to estimate the aggregate health improvement, namely QALE.

The QALE methodology is versatile enough so that just about any preferred age weighting function could be applied. This is also true for the VSL, QALY, and VSHLY values used in the QALE methodology. This is reiterated in Figure 2, which provides a summary of the Quality Adjusted Life Expectancy (QALE) methodological process. The facets of this measure have been outlined above. In the following section they will be utilised with England and Wales data to provide estimates about the value of improved health between 1900 and 2000.

Fig 2: Flow chart summary of QALE gain methodological process



3. Results and Discussion

This section of the paper reports the results of the worked example of the QALE methodology and considers the value of this model in light of the previous analysis. The worked example presented here will be for the aggregate QALE gain. This utilises the data presented above in Tables 1 to 3. The first stage of the QALE methodology is to identify the change in the mortality and morbidity burden. This change can then be valued (by the VSL and VSHLY, respectively) in order to generate the mortality and morbidity gains or WTP for improved mortality and morbidity. This is shown in Table 4. A simplified version of this process, for the age weighted aggregate QALE gain is shown in Table 5.

Table 4: Calculation of twentieth century aggregate QALE gain (un weighted): monetary value of 1900-2000 morbidity and mortality gains for different VSL weights (millions of 1990 international \$)

Morbidity state	Morbidity burden change	VSHLY			Morbidity gain		
		C&K	V&A	M	C&K	V&A	M
Infectious	51594	0.27	0.49	0.37	13930	25281	19090
Non- infectious	-31996	0.21	0.39	0.29	-6719	-12478	-9279
Disability	-7976	0.21	0.39	0.29	-1675	-3111	-2313
Sum of all morbidity gains for different VSL weights					5536	9692	7498

Mortality	Mortality burden change	VSL			Mortality gain		
		C&K	V&A	M	C&K	V&A	M
Mortality	15646	0.64	1.18	0.88	10013	18462	13768

Un weighted aggregate QALE gain								
Morbidity gain (sum)			Mortality gain			Aggregate QALE gain		
C&K	V&A	M	C&K	V&A	M	C&K	V&A	M
5536	9692	7498	10013	18462	13768	15549	28154	21266

Table 4 presents the mortality gain, aggregate morbidity gain and the corresponding aggregate QALE gain, which is the sum of the morbidity gains (for the broad morbidity states) and the mortality gain. These results are presented for the historical income elasticity VSLs and corresponding VSHLYs. As outlined above, the mortality gain is calculated as the fall in the death rate multiplied by the VSL and the morbidity gain is identified as: morbidity burden (prevalence*QALY) multiplied by the VSHLY (VSL*QALY). These results are expressed monetarily (1990 international \$). In this example, the mortality gain between 1900 and 2000 ranged from 10,013 to 18,462 and the aggregate morbidity gain ranged from 5,536 to 9,692 million 1990 international \$. The aggregate QALE gain, which is the sum of the mortality gain and aggregate morbidity gains, ranged from 15,549 to 28,154 million 1990 international \$.

Three points stand out from Table 4. First, the magnitude of these gains in quality adjusted life expectancy. Second, the constitution of these gains: mortality gains are always positive in the twentieth century and substantial whichever elasticity is assumed whereas morbidity gains were negative for non infectious and disability categories. Third and even more impressive is the value of the infectious morbidity gain, the positive nature of this result is expected because the advances (infectious disease elimination) of the epidemiological transition have been well documented. However the magnitude of this gain is not. Hence, the value of infectious disease declines is substantial enough to compensate the worsening in the morbidity burden associated with non infectious diseases and disabilities.

Another important point, which is not obvious from Table 4 are the improvements in the QALYs associated with all diseases, this is important because it reduced some of the negativity of non infectious disease and disability morbidity. Hence, the key driver of the negative QALE (for non infectious and disabilities) is the increase in the incidence and not a worsening in the quality of life associated with these morbidity categories.

These WTP and QALE gains have also been applied to Murray's age weighting function. The results are presented in Table 5.

Table 5: Twentieth century age weighted aggregate QALE gain: monetary value of 1900-2000 morbidity and mortality gains for different VSL weights (millions of 1990 international \$)

Morbidity state	Morbidity gain			Mortality gain			QALE gain		
	C&K	V&A	M	C&K	V&A	M	C&K	V&A	M
Infectious	10037	18215	13754				10037	18215	13754
Non- infectious	-6363	-11547	-8719				-6363	-11547	-8719
Disability	-1675	-3111	-2313				-1675	-3111	-2313
Mortality				6837	12606	9402	6837	12606	9402
Sum of all morbidity gains and mortality gain for different VSL weights:							8836	16163	12124

Table 5 makes the same considerations as Table 4, although only the summary results are shown here because of the intricacy of the mortality and morbidity gain calculation when they are done on an age specific basis. This includes the calculations made in Table 5 but instead of providing an aggregate mortality and morbidity gain, these calculations are disaggregated into eight age categories²². The key points to note from Table 5 are the decreases in the magnitude of the WTP mortality and morbidity and QALE gains. As has been mentioned above, this is because Murray's inverted u shaped age weight function values middle ages more than young and old. Table 5 therefore highlights that during the twentieth century a noteworthy proportion of WTP and QALE gains were generated by gains in health for the young and old. The extensiveness of this can be identified through considering the relationship between the un weighted and age weighted results, shown in the final row of Tables 4 and 5. The age weighted morbidity gain is about 60 percent lower than the un weighted equivalent, the age weighted mortality gain is about 30 percent lower and the age weighted aggregate QALE is about 40 percent lower than the un weighted aggregate QALE gain. The most important point in Table 5, is that even when an age weighting is applied the results about the value of health are still substantial.

²² The age groups considered in Murray's (2006) age weighting function are: 0-4, 5-14, 15-24, 25-34, 35-44, 45-654, 65-74, 75+

In order to further elucidate the magnitude of these results it is desirable to consider the values relative to economic growth, i.e. GDP. This is also desirable as it provides a rare quantitative approximation of the output of health service. Currently measures of GDP only consider the cost of the National Health Service (NHS), with no index for the output. Cost benefit considerations are made below Table 6, which reports and approximate estimate about what adjusted growth and the health output values were for twentieth century England.

Table 6: Twentieth century compound average growth rates of: GDP per capita and age weighted mortality gain, aggregate QALE gain, and 'Adjusted Growth' (percentage per annum)²³

GDP pc growth	Mortality gain growth			Morbidity gain growth			Aggregate QALE gain growth			'Adjusted Growth' (QALE + GDP pc)		
	C&K	V&A	M	C&K	V&A	M	C&K	V&A	M	C&K	V&A	M
1.4	1.0	1.8	1.4	0.3	0.5	0.4	1.3	2.3	1.8	2.7	3.7	3.2

Table 6 provides the compound average growth rate of GDP per capita, mortality, and the aggregate QALE gain for twentieth century England and Wales. Aggregate QALE gain growth equals the sum of mortality and morbidity gain growth. These results are generated by applying these gains (identified in Table 5) to a compounding formula, in order to generate an estimate about average growth per annum for the twentieth century. The final column in Table 4, 'Adjusted Growth' estimates what GDP per capita would be if it included the gains in QALE that are in the preceding columns. Once this has been achieved it is possible to consider the relative value of health gains versus GDP gains. The results in Table 6 bolster claims about the need to consider both mortality and morbidity when measuring health due to the magnitude of the average annual growth of mortality and morbidity gains. Despite the increase in prevalence of morbidity, the quality of life implications in tandem with the value of the decline in infectious diseases means that there is a positive morbidity contribution to 'Adjusted Growth', even though it is never more than 0.5 percent.

Table 6 also reinforces the need to measure health in some form of extended GDP or 'utility national income'. At the lowest bound estimate (provided by C & K) the QALE gain is nearly as valuable as twentieth century GDP gains: growth of GDP was 1.4 percent per annum versus QALE gain growth of 1.3 percent per annum. Put another way, if conventional measures of economic growth included health output, then the value of GDP increases would have been nearly double.

Finally, Table 6 also highlights the importance of making these types of quantitative considerations, given the magnitude and nature of twentieth century QALE gains and, even though the QALE gain methodology can only generate approximations, it still provides the most thorough attempt at measuring historical levels of health in a quantitative index. In doing so, the results of the QALE indicate important historical details that have, to date, not been estimated. In its entirety, the QALE also provides a detailed justification for EuroQol referencing of historical morbidity, which was necessary to determine a quantitative index from extensive qualitative literature²⁴. The QALE methodology considers mortality and morbidity, from the perspective of quality of life associated with ill health.

The methodology makes no consideration for co-morbidity, and this represents a refinement that ought to be considered. However, given the versatile nature of the QALE methodology, it is possible to re-work the numbers with alternative data and QALY estimates, for co-morbidity. Hence, one of the most important features of the QALE is that the most contentious components of the methodology (VSL, QALY, and VSHLY) can be substituted with alternatives. The numbers used here are what the author deems most accurate.

The findings of this paper are also important because of the developments it has made towards a more rounded and accurate health measure, which provides results that have not necessarily been predicted and would have been

²³ See Maddison (2001) for GDP figures

²⁴ Hickson (2006)

unidentifiable without this type of QALE methodology. Most noteworthy is the point that: although the prevalence of certain disease groups has increase (namely, chronic, degenerative diseases) and there are more unhealthy life years associated with these illness, the quality of life gains for these illnesses have outweighed some of the increase in prevalence. (This is least true for disabilities, especially blindness). Conclusions of this nature highlight the need to measure more rounded notions of health, such as the QALE.

Despite these attributes of the QALE there are some shortcomings associated with the QALE, which are largely as result of the historical nature of measurement. Deriving the QALY is an intricate and lengthy process, which yields a QALY result that is open to criticism. Following on from this the VSHLY, which is comprised of the QALY and the VSL, is even more contentious, because of the problems associated with identifying a historical QALY combined with the disagreement about what the VSL value should be. Additionally, the VSHLY represents a rather crude health valuing tool. Currently there are no better alternatives, although the QALE methodology has been designed so that it is straightforward to utilise preferable VSL, QALY, VSHLY values when they materialise.

The QALE also suffers from generic historical health measurement problems: the changes in disease classification make it virtually impossible to precisely define and value of health improvements: in 1901 ICD1 contained 192 categories and in the year 2000 ICD9 contained 5,292 categories. Additionally, because of the time taken to value the QALY it would be nearly insurmountable to value every single morbidity type over history. This means that the QALE methodology can only yield approximations about the value of all historical health gains.

4. Conclusion

Through developing a new methodology that utilises existing data in a new way and generates new data about the quality of life during historical eras the paper provides original quantitative results about the value of long run changes in Quality Adjusted Life Expectancy (QALE).

The findings of this paper seem sensible, since mortality and morbidity improvements in twentieth century England have been substantial and health gains are valuable to individuals (which is highlighted by the magnitude of the VSL and VSHLY). The calculation of such valuable developments, from a conservative standpoint, provides considerable weight to claims for measuring health. The findings that, at a lower bound estimate, the value of twentieth century health improvements of 8 billion (1990 international \$), which translates into a near doubling of GDP if measured on a 'utility national income' basis (compound average growth of GDP: 1.4 percent versus QALE gain: 1.3 percent) contribute to claims that improvements in health (both mortality and morbidity) have been a major contributor to economic welfare in twentieth century England and have provided considerable additions to the growth of national income defined on a utility basis. Moreover, the positive contribution from aggregate morbidity gains, although small – 0.5 percent per annum at best – still indicate important features, which highlights the need to consider morbidity as well as mortality.

Although it is impossible to determine a precisely accurate figure, it is possible to conclude that improvements in health have been extensive and valuable. These results are so significant that they ought to be included in some form of 'utility national income', in order to more accurately assess economic development and how this it has impacted upon the populations' standards of living. And the QALE methodology ought to be used to consider the contribution of the NHS and answer many debates about its efficiency and benefits versus costs.

Lexicon

Term	Abbreviation	Definition
Mortality		Death (as measured by the death rate)
Morbidity		Illness (as measured by the burden of diseases and disabilities)
Health: in the context of the paper		Mortality AND Morbidity
Epidemiological Transition		Omran (1971) depicted an 'epidemiological transition', consisting of a passage from a regime in which there was a conversion of the pattern of mortality from one dominated by infectious diseases to one dominated chronic degenerative diseases; this also entails a decline in the death rates accompanied by a seemingly paradoxical increase in morbidity rates. This concept provides the best framework from which to select illnesses for consideration in the thesis.
Willingness to Pay	WTP	This methodology essentially considers the value of improved mortality by asking (or observing, through revealed preferences surveys) the amount of consumption an individual would be willing to pay to trade off consumption for health.
Willingness to Pay (Mortality)	WTPMT	
Willingness to Pay (Morbidity)	WTPMB	
Value of a Statistical Life	VSL	This considers the aggregate (population) value of a death averted. This concept is defined as the aggregate amount that a population is willing to pay to reduce its death toll by one (anonymous/hypothetical) individual.
Value of a Statistical Healthy Life Year	VSHLY	VSL notions will be developed in order to identify the (population) value of averting one unhealthy life year. It is also likely that varying degrees of unhealthy life years will be considered.
Quality Adjusted Life Year	QALY	Economists have designed a series of econometric scaling techniques in an attempt to assign a numerical value to health status. These are known as utility ratings, of which the most famous is the QALY.
Disability Adjusted Life Year	DALY	Essentially the DALY gauges exactly the same features as the QALY, although the DALY is measured as the inverse of a QALY
Quality Adjusted Life Expectancy	QALE	This is the central model of the paper, which can be distinguished through its ability to simultaneously value improvements in mortality and morbidity and hence provide an overall health measure
EuroQol	EQ-5D	EuroQol is an instrument to describe and value health. This is achieved through a series of health attribute characteristics and a corresponding series of ranks, which provides a standardized device for measuring the burden of quality of life of different diseases over different eras
International Classification of Disease	ICD	This represents the universal classification of all causes of death and is compiled by the World Health Organisation (WHO). Over the twentieth century this classification system has been developed, such that in 1900 ICD1 was used and in 2000 ICD9
National Health Service	NHS	The NHS is the publically funded health care service that covers all citizens of England and Wales. Virtually all services are free at the point of delivery. The NHS came into effect in 1949, and since then has provided the majority of all health care in England and Wales, although there has been growth in private sector health care, especially during the final decades of the twentieth century

References

- Cameron, T. & DeShazo, J.** (2004) "An Empirical Model of Demand for Future Health States when Valuing Risk-Mitigating Programs", University of Oregon, Economics Department Working Papers 2005-7: University of Oregon
- Costa, D. & Kahn, M.** (2003) "Changes in the Value of a Statistical Life, 1940-1980", NBER Working Paper: 9396
- Crafts, N.** (2005) "The Contribution of Increased Life Expectancy to Growth of Living Standards in the UK, 1870-1998". Retrieved 17 June 2005, from: www.york.ac.uk/res/wpeg/documents/crafts.pdf
- Cutler, D. & Richardson, E.** (1999) "Your Money or Your Life: The Value of Health and what Affects It", NBER Working Papers: 6895
- Hickson, K.** (2002) "The Contribution of Increased Life Expectancy to Standards of Living in Twentieth Century Japan" MSc Thesis: London School of Economics and Political Science
- Hickson, K.** (2006) "The Contribution of Improved Health to Standards of Living in Twentieth Century England and Wales" PhD: London School of Economics and Political Science
- Maddison, A.** (2001) "The World Economy: A Millennial Perspective", Organization for Economic Co-operation and Development: Paris
- Miller, T.** (2000) "Variations between Countries in Values of Statistical Life", Journal of Transport Economics and Policy 34: 169-188
- Murray, C. & Lopez, A.** (1996) "The Global Burden of Disease", Harvard University Press: Massachusetts
- Nordhaus, W.** (1999) "The Health of Nations: The Contribution of Improved Health to Living Standards", Yale University: USA
- Office of National Statistics** (2003) "Twentieth Century Mortality: 100 Years of Mortality Data in England and Wales by Age, Sex, Year and Underlying Cause", CD-ROM
- Office of National Statistics / Government Actuaries Department** (2006) "England and Wales Mortality Database", CD-ROM
- Omran, A.** (1971) "The Epidemiological Transition: A Theory of the Epidemiology of Population Change", Milbank Memorial Fund Quarterly 49: 509-538
- Usher, C.** (1980) "The Measure of Economic Growth". Blackwell: Oxford
- Viscusi, K & Aldy, J.** (2003) "The Valuation of a Statistical Life: A Critical Review of Market Estimates Throughout the World", NBER Working Paper: 9487