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The Standard of Living Gains Generated by the Elimination of Tuberculosis in Twentieth Century England and Wales

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Abstract

The article presents quantitative estimates about the value of the elimination and amelioration of tuberculosis from a health and welfare standards of living perspective, in twentieth century England and Wales. By applying an original methodology, qualitative tuberculosis data has been transformed into a quantitative index in order to calculate the (monetary) value of the decline in the burden of tuberculosis. While it is not possible to determine a precise value, at a lower bound approximate the elimination and amelioration of tuberculosis in twentieth century England and Wales is estimated to be in excess of £30 billion. Such significant results have important implications for our understanding about the achievements associated with combating tuberculosis and the wider optimism this adds to stories about living standards in twentieth century England and Wales.

I

'As a fundamental destructive social force tuberculosis was rivalled among illnesses only by venereal disease and insanity at the dawn of the twentieth century'¹. The decline and virtual elimination of tuberculosis in England and Wales represents one of the most important and valuable health gains during the twentieth century. In 1901 tuberculosis was regarded as a 'comprehensive sentence of death'² or an 'anti longevity force'³. When tuberculosis was not resolved in death ex-patients were often 'stigmatised and ostracised for the rest of their lives'⁴. By the close of the twentieth century tuberculosis sufferers' lives 'were altered very little'⁵. Although this story about twentieth century tuberculosis has been well documented in the qualitative literature there is a dearth of quantitative estimates about the value of the virtual elimination of tuberculosis over the twentieth century in England and Wales. The analysis presented here will provide an original effort to fill this void.

This more rigorous evaluation of the tuberculosis decline is facilitated by applying a new quantitative methodology, which is able to summarise and evolve qualitative information into a series of quantitative indices that are utilised to account for historical improvements in health and welfare related quality of life. This will then be combined with existing quantitative data about the prevalence and death rate of tuberculosis in order to provide detailed results about the (monetary) value of the health gains generated by the virtual elimination and amelioration of tuberculosis in England and Wales between 1901 and 2000.

The relevance of this study is accentuated by the general shortage of quantitative health and welfare estimates for historical eras, which is largely a result of the difficulty in trying to gauge genuine levels of health, whereby 'the concept of morbidity and its measurement are plagued by conceptual and methodological difficulties'⁶. Additionally, throughout the twentieth century illness prevalence statistics have come to gauge more than just prevalence, some of which is exogenous to health. For example, Johansson highlights the 'social inflation of morbidity', which is more a function of lower ceilings for being ill as a country becomes more affluent and

¹ Smith, *The retreat of tuberculosis*, p.1.

² Macnalty, A report on tuberculosis, p. 1.

³ Dublin & Whitney, On the costs of tuberculosis, p. 443.

⁴ Bryder, *Below the magic mountain*, p. 5.

⁵ Citron *et al*, Tuberculosis today.

⁶ See Murray & Chen, Understanding morbidity change, for a detailed outline of morbidity definition and measurement problems.

developed, than prevalence per se⁷. Moreover, prevalence rates do not provide information about the burden or severity of tuberculosis for the sufferer. Although inferences can be drawn (e.g. low prevalence of an illness implies that it is less virulent) it is not possible to make meaningful conclusions about standards of living associated with any illness.

When health is considered over a long run retrospective period these problems are exacerbated to an extent where nearly all existing quantitative twentieth century health measures use mortality as a proxy for health. Mortality or the death rate or life expectancy is not a sufficient measure about the health or morbidity of the population and certainly not the health and welfare related burden of illness experienced by disease sufferers⁸. The analysis below will indicate how misleading this is, given the magnitude of morbidity improvements.

The contribution of the results are for the estimates they provide about the value of the virtual elimination and amelioration of tuberculosis in twentieth century England and Wales in terms of: (i) the overall value of twentieth century gains in health associated with tuberculosis, (ii) the declining probability of death from tuberculosis, as valued by the fall in the tuberculosis death rate, and (iii) the health and welfare related quality of life gains associated with a reduced burden of tuberculosis when suffering from this disease. This represents the most innovative aspect of the paper and will provide a value for the changing nature of tuberculosis as an illness, due to twentieth century health and welfare advances.

In Section II the qualitative tuberculosis literature will be summarised. Section III will provide a detailed outline about the development of quantitative indices from the qualitative literature. Section IV will present the quantitative tuberculosis data and generate results about the value of the twentieth century decline in tuberculosis. Section V will consider the implications of the results and the value that they add to the qualitative story. Section VI concludes.

II

By 1901 the controversy associated with Koch's announcement in April 1882, that tuberculosis was a communicable disease, had mostly subsided and the mainstream opinion had come into alignment with Koch. This was reflected in the government's approach to combating tuberculosis (prior to this discovery it was generally thought that tuberculosis was a

⁷ Johansson, The health transition: the cultural inflation of morbidity.

⁸ Riley, The risk of being sick, p. 405.

hereditary disease)⁹. The seeds of government legislation for tuberculosis were planted in the nineteenth century (under the 1896 Public Health Act) with policy that focused on containing the spread of tuberculosis, and continued with similar objectives into the early years of the twentieth century. For example under the 1908 Public Health Act it was the duty of the medical officer of a Poor Law Institution: 'to within 48 hours of his first recognition of the symptoms of pulmonary tuberculosis in the case of an inmate of the institution, report to the medical officer of health of the sanitary district'¹⁰. This approach was enhanced as the twentieth century unfolded. The special methods that the government felt necessary culminated in the 1912 Notification of Infectious Diseases Act, when further regulations were made extending the compulsory reporting system to cases occurring among the in-patients or out-patients of hospitals or other similar institutions for the treatment of the sick. Notwithstanding the strength of the desires of the government to control tuberculosis and the feeling that compulsory notification was an 'indispensable preliminary to its [tuberculosis] effective administration', these policies were not overly successful¹¹. In certain towns compulsory notification had been well established and in others the approach was haphazard and incomplete. For example, between 1915 and 1918 in England and Wales, 19 percent of deaths certified as resulting from tuberculosis had not been notified¹².

It was not until 1911 (Finance Act) and 1912 (Health Insurance Act) that any genuine government aid was provided for tuberculosis sufferers. Even though Coltart *et al* heralded the 1912 Health Insurance Act, 'one of the greatest social measures of the century', it was not until 1929 that state policies embraced welfare orientated objectives, and even after 1948 tuberculosis legislation was by no means comprehensive¹³. The 1929 Local Government Act provided the first decisive step towards the unification of tuberculosis treatment centres and an improvement in tuberculosis treatment, particularly for sufferers who were uninsured. These developments were extended in 1948 under the National Health Service Act, when responsibility for the entire health service was placed upon the Minister of Health and treatment was administered without insurance. Under Section 28 arrangements were legislated for the comprehensive care of tuberculosis sufferers: from prevention to medical care for sufferers, including after-care. The 1948 National Assistance Act provided sickness

⁹ Latham & Garland, *The conquest of consumption*, p. 19.

¹⁰ The National Archives: MH55(521).

¹¹ *Ibid.*

¹² Smith, *The retreat of tuberculosis*, p. 69.

¹³ Coltart *et al*, *Social work in tuberculosis*, p. 123.

benefits for the sizable population who contributed to the insurance, which is especially pertinent given the aetiology of tuberculosis. Although these rates provided a significant gain compared to what they succeeded, in the pre antibiotic era the only way to combat tuberculosis was through a strong immune system (and this was the rationale underlying sanatoria treatment), which required a nourishing diet, warm clothing and good living conditions (including adequate fuel supply), and it was felt that these elements were not afforded by the National Assistance. For example, 'when the sufferer was the breadwinner, it was thought that his family could get by on only National Assistance payouts for about a year'¹⁴.

During the second half of the twentieth century the only tuberculosis legislation that was passed regarded the management of the contagiousness of this disease, through strengthening existing notification and segregation policies, under the 1969 Public Health (Infectious Diseases) Regulations and the 1984 Public Health (Control of Disease) Act. Additionally, between 1950 and 1960 there were considerations about strengthening regulations on immigration policy, although there was never any legislation passed on this issue¹⁵.

Therefore, government legislation was not very far reaching towards improving the quality of life of tuberculosis sufferers. Despite the lack of commitment shown by the government towards improving the standards of living of tuberculosis sufferers, there were other areas that made considerable efforts towards boosting the welfare related quality of life of tuberculosis patients, most notably the medical profession and during the middle of the twentieth century charities played a noteworthy role.

The main role of charities was to provide financial aid to help support tuberculosis sufferers and their families, especially during the early years of the twentieth century, when less government help was available. The growth of sanatoria before 1911 was mainly a result of voluntary efforts¹⁶. These charities, for example, the British Red Cross Society and the Chest Clinic Samaritan Funds, provided assistance for tuberculosis sufferers' treatment and

¹⁴ Coltart *et al*, *Social work in tuberculosis*, p. 139.

¹⁵ The National Archives: MH 55(2277).

¹⁶ Bryder, *Below the magic mountain*, p. 36.

household income¹⁷. Charity services had practical importance for the sufferer because they provided nursing equipment, food and better living conditions, which were all essential to the restoration of a patient's physical health. Additionally, numerous charities existed to try and help the patient with mental and social problems. E.g. voluntary organisations provided psychiatric help on matrimonial problems and emotional problems brought about by the onset of tuberculosis¹⁸. Despite the contribution of charities there were some shortcomings, which were largely related to resource allocation. Gerard suggests that resources were not evenly distributed towards those who needed them most, whereby the rich and less needy tended to receive more than their fair share¹⁹. Additional resource allocation problems may have been generated by the number of small tuberculosis charities, whereby greater cooperation and coordination could have generated economies of scale benefits and possibly more impact when campaigning for improved government commitment to helping tuberculosis sufferers.

The efforts of committees (both governmental and charitable) played an important (largely indirect) role in boosting the quality of life of tuberculosis sufferers. The Joint Tuberculosis Council and medical associations (especially the British Medical Association) served to campaign for improved welfare treatment of tuberculosis sufferers. For example, the Tuberculosis Council took issue with the level of funds payable to patients for undergoing treatment and pushed for increases and the British Medical Association consistently drew attention towards the flaws in the government's approach to tuberculosis treatment. Even in 1950, the BMA's National Health Service Report stated that 'the inadequacy of present provision for the diagnosis, treatment and after-care of tuberculosis in this country is a national scandal which can no longer be viewed with complacency'²⁰. There were also organisations that consistently monitored the progress of contemporary tuberculosis issues. Most noteworthy was the Tuberculosis Advisory Committee, which focused much attention towards the re-housing of tuberculosis sufferers during the late 1950s²¹, and the Joint Tuberculosis Council, which considered tangential concerns, e.g. the nutrition and treatment of tuberculosis sufferers²².

¹⁷ Coltart *et al*, *Social work in tuberculosis*, pp. 109, 112.

¹⁸ *Ibid*.

¹⁹ Gerard, *Charities in Britain: conservatism or change?*, p. 21.

²⁰ The National Archives: MH 55(1163).

²¹ The National Archives: MH 55(2280).

²² The National Archives: MH 57(429).

Although there were some important contribution from the government, government committees and charities, improvements in the quality of life associated with tuberculosis did not really originate with the work and policies of charities and government legislation, instead these improvements were primarily yielded from medical developments.

Iseman heralded that 'one of the most important achievements of modern medicine has been the development of therapy for tuberculosis'²³. By 1947 streptomycin was being distributed in small quantities in the UK. This discovery marked the beginning of a new era in the combat of tuberculosis as it drastically reduced the epidemiological consequences of tubercle bacillus. Moreover, within a few years of the streptomycin revolution, the impetus for further developments in the treatment of tuberculosis had yielded positive results. Part of this impetus was a result of the shortcomings of streptomycin. Fortunately, from the perspective of sufferers' quality of life, two additional medications were discovered shortly after streptomycin. Para-amino-salicylic acid (1948) and isoniazid (1952) provided the necessary partners to streptomycin, such that when patients were treated with therapy combining all three antibiotics, not only were they cured of the disease but there was no (initial) emergence of resistance.

Despite the significant attributes of these discoveries, when this therapy was first devised, in the early 1950s, its implementation was problematic, due to the uncertainty with the ideal course of therapy: courses were short (four to six weeks), dosages were small (partly because supplies were short) and some initial results were ambiguous and some physicians only viewed this chemotherapy as '*supplemental*'²⁴. A further drawback of this therapy regime is the continued side effects. Most noteworthy is the potential for hepatitis from the isoniazid component.

With the introduction and broad base of tuberculosis combined therapy, the development of drug resistance and failure of cure became very rare. This achievement was enhanced by the affordable, coordinated and rapid mainstream utilisation of this therapy²⁵. As a result of the National Health Service access to the cure for tuberculosis was facilitated to all tuberculosis sufferers, for which the government ought to be commended. Furthermore, because of the

²³ Iseman, *Evolution of drug resistance tuberculosis*, p. 2428.

²⁴ Smith, *The retreat of tuberculosis*, p. 247.

²⁵ Although drug resistance issues developed over time, the introduction in the 1960s and 1970s of novel new agents (e.g. rifampicin and ephambutol) helped to overcome problems of resistance.

inexpensive and largely straightforward nature of tuberculosis therapy the scope for problems was reduced and subsequently tuberculosis treatment was largely successful. This was achieved soon after the initial introduction of a tuberculosis therapy regime, by the late 1950s there was very little evidence of drug cost, administration or availability issues²⁶. Bryder claims that 'this success can be measured in the surplus of hospital beds that was evident by 1955 and the closure of many former tuberculosis treatment centres, and although drug treatment still required hospitalisation the treatment time had been significantly reduced'²⁷. The only exception to the above success story was salvage therapy which was considerably more expensive than standard therapy, albeit available if needed.

As a result of these health developments the prevalence of tuberculosis declined markedly during the second half of the twentieth century. On an aggregate level this has meant that the threat of tuberculosis no longer triggers anxiety and pandemonium, as it had at the beginning of the twentieth century. In the pre-antibiotic era the contraction of the tuberculosis disease almost certainly meant hardship, suffering (physically, economically, and often emotionally) and often death. After the mainstream utilisation of chemotherapy tuberculosis no longer had such severe implications. 'Before the introduction of chemotherapy in the treatment of tuberculosis, treatment spread over long periods, patients were kept in sanatoria beds, allowed to do very little for themselves and ceased to be productive members of the community, sometimes for years; furthermore, although they were able to return to work and a full life few of them could be said to have been cured from the disease which was to dominate the rest of their lives'²⁸.

Other important medical advances associated with improving the quality of life associated with tuberculosis are prevention (BCG²⁹) and screening (radiography). The benefit of BCG vaccination was in the preventative effects it had upon tuberculosis, which ultimately contributed to reducing the infectiousness of this disease and therefore provided an (indirect) positive contribution to aggregate (population) health related quality of life. BCG was not administered widely in England until the 1950s. For example, it was not until 1953 that BCG was recommended for all school children by the Ministry of Health³⁰. Despite the vaccination

²⁶This point is indicated by Ross, *Modern drug treatment in tuberculosis*.

²⁷Bryder, *Below the magic mountain*, p. 262.

²⁸The National Archives: MH 154(53).

²⁹Named after the inventors: Bacille, Calmette, and Guerin.

³⁰Citron *et al*, *Tuberculosis today*, p. 4.

being discovered thirty years earlier plus the necessary proof of its efficacy, the scepticism among British medical practitioners retarded introduction of BCG. However, by the 1970s it had provided a great boost in the prevention of tuberculosis in England. Evidence suggested that by the 1970s BCG vaccination was providing a protection level of about 75 percent, and the vaccine was thought to be so effective that there were some who claimed the school BCG programme should be stopped as a result of a falling incidence of tuberculosis in the UK, during the 1970s³¹. This marks a stark contrast with the situation twenty years earlier when it was claimed, by the government, that ‘there is no scientific evidence of its true value’³².

A final area of improved medical technology, which was able to provide a positive contribution to the quality of life associated with tuberculosis, was radiography. Although this invention provided a significantly lower contribution than the other ‘health developments’ sub variables, the aid radiography provided in the detection of tuberculosis ought to be noted. Mass Miniature Radiography was introduced in 1943, under the recommendations of the Medical Research Council established by the Minister of Health. Since its introduction mass miniature radiography made great strides in the examination of large groups of apparently healthy individuals³³. As a result, mass miniature radiography, was able to detect cases of tuberculosis by chance, i.e. those cases which had revealed no obvious symptoms. By the mass radiography schemes introduced in the 1940s an active case rate of 1 per 1,000 was discovered among those previously unsuspected of having tuberculosis³⁴. It should be noted that the key contribution here would be related to the prevention of further cases being created. By the end of 1953 there were about 70 units in operation, more than double the number when the NHS was introduced, and examined about two million people a year, particularly those in industrial employment³⁵.

Finally, there is evidence that environmental factors played some role in the decline in tuberculosis, which began in the mid nineteenth century, before the provision of any kind of medical advances and in conjunction with significant improvements in public health reforms which provided cleaner water, more effective waste disposal, safer food handling and improved housing conditions. When considering environmental factors and their relation to

³¹ Bannon, BCG and tuberculosis, p. 81.

³² The National Archives: MH 55(993).

³³ Ibid.

³⁴ Bryder, *Below the magic mountain*, p. 5.

³⁵ Ibid.

tuberculosis it is possible to differentiate these features into two broad categories: environmental developments that reduce exposure to tuberculosis and those which increase resistance to tuberculosis (the latter represents a McKeown type argument)³⁶. It should be noted that there is strong evidence of interaction between these two broad explanations.

In all aspects of tuberculosis it is thought that the wealthier fared better, both before and after the introduction of chemotherapy in the 1950s. This provides one of the strongest indications that better nutrition, superior housing with less crowding and better ventilation, the ability to afford warm clothing and the necessary fuel were important in the reduction of tuberculosis. A final environmental facet which played a role in the early declines in tuberculosis, although to a lesser extent than the features analysed above, is the awareness of tuberculosis and understanding about how to prevent tuberculosis. For example 'a potent reason³⁶ for why so many cases of consumption escape detection at the early stage among working class is the fact that working classes have not yet been educated to the point of grasping the importance of an early diagnosis'³⁷.

Therefore, both environmental and health developments provided valuable contributions to the combat of tuberculosis. The decline in tuberculosis was well under way before the introduction of medical developments, although tuberculosis would not have been eliminated and ameliorated without medical developments. Government initiatives and help and the recognition and awareness generated by the work of charities provided for some gains in the quality of life associated with tuberculosis, although medical developments represented the prominent force for the magnitude of standards of living gains, which is outlined below. However, the government was an important enabler (of these health development gains), through the role of master of the NHS and the provision of medical care free at the point of delivery for the entire population.

III

The next stage in the methodology is to quantitatively summarise the health and welfare developments associated with tuberculosis, which have been outlined above. The most pertinent health and welfare variables for tuberculosis quality of life (government initiatives and help, recognition and awareness, health developments, pain and discomfort, ability to

³⁶ McKeown, *The modern rise of population*.

³⁷ Latham & Garland, *The conquest of consumption*, p. 35.

lead a normal life) need to be gauged for their improvement over the twentieth century, which is achieved through generating 'Quality Adjusted Life Year' (QALY) weights for these five variables in 1901 and 2000. Moreover, through delineating the five health and welfare variables it is possible to highlight the most prominent areas for improving tuberculosis sufferers' quality of life.

A QALY is a common tool in health economics and is frequently utilised across a variety of studies about the burden of illnesses³⁸. The QALY used here represents a summary measure (between 0 and 1, where 0 is equal to death and 1 is equal to a year lived in perfect health) of progress regarding five fundamental aspects of health and welfare quality of life (government initiatives and help, recognition and awareness, health developments, pain and discomfort, and ability to lead a normal life), referred to as quality of life variables for twentieth century tuberculosis.

The QALY results, presented in Table 1, have been generated through conducting a detailed survey of a wide range of literature (government documents, charity and physician reports, British Medical Association comments, reports from tuberculosis sufferers, minutes of committees and expert consultations, and secondary literature), which has been very briefly summarised above in Section II. This literature review was utilised to create a detailed profile about the health and welfare circumstances facing a typical tuberculosis sufferer in 1901 and 2000, from the perspective of the five quality of life variables. Once an initial QALY estimate had been generated from the qualitative literature review it was substantiated through a series of revealed preference exercises in order to ensure consistency and consensus between the original QALY estimate for the five quality of life variables and the QALY estimates that were derived through the 'visual analogue scale', 'time trade off' and 'standard gamble' revealed preference exercises. This method of substantiating QALY estimates has been used by numerous studies³⁹. The 'visual analogue scale' was used to rank (between death [0] and perfect health [100]) the quality of life of tuberculosis sufferers (e.g. in 1901 tuberculosis ranked at 33 out of 100 or 0.333 out of 1). The consistency of the tuberculosis QALY burden was further tested by the 'time trade off' process, which considers the number of tuberculosis

³⁸ For example, see Chiange, An index of health: mathematical models, and, Fanshek & Bush, A health status index and its application to health service outcome, for the original work on developing the concept of QALYs, see Culyer, *Health indicators*, and Bowling, *Measuring health: A review of quality of life and measurement scales*, for a general explanation about the mainstream use of QALYs in health measurement.

³⁹ For example, see Murray & Lopez, *The global burden of disease*, and Stouthard *et al*, Disability weights for diseases.

life years that would be traded off for healthy life years (e.g. in 1901 three full healthy life years were estimated to be equivalent to 10 tuberculosis life years). Lastly, 'standard gamble' was utilised to further validate the QALY through considering the level of death risk that was acceptable in return for a hypothetical tuberculosis cure (e.g. in 1901 a 70 percent chance of immediate death was acceptable for a 30 percent chance of complete recovery from tuberculosis). The QALY results from these four – initial literature review, visual analogue scale, time trade off, standard gamble – sources were then reconsidered until consensus was achieved and a single QALY value elicited.

Out of all the quality of life variables, 'government initiatives and help' received the lowest QALY appraisal (0.6 or 'fair' quality of life in the year 2000). Despite the lack of commitment shown by the government towards improving the standards of living of tuberculosis sufferers, there were other areas that made considerable efforts towards a significant boost to the welfare related quality of life of tuberculosis patients, most notably the medical profession and during the middle of the twentieth century charities played a noteworthy role.

By the 1950s the performance of charities towards raising the profile and standards of living associated with tuberculosis had fostered 'good' quality of life levels associated with 'recognition/awareness' (or a QALY of 0.8), but by the year 2000 their work was less important (given medical developments, which are outlined below) and it could also be argued that tuberculosis charities and committees were slow to respond to new demands at the end of the twentieth century (manifest in the unconventional tuberculosis charity needs of infected AIDS sufferers, poor immigrants and homeless who were largely responsible for the resurgence of tuberculosis in England and Wales), and therefore, in 2000 'recognition/awareness' achieved 'fair' quality of life (QALY = 0.6).

The culmination of 'health developments' provides the most important twentieth century quality of life gains and as such the most substantial QALY gains, from 0.3 in 1901 to 0.8 in 2000, or from 'poor' to 'good' quality of life over the twentieth century. Moreover, the 'cure' quality of life sub variables of 'health developments', improved from 0.1 ('no' quality of life) to 1 ('complete' quality of life), which is a remarkable achievement relative to other tuberculosis quality of life variables and most other morbidity in twentieth century England and Wales.

The 'pain and discomfort' associated with this tuberculosis was significant and in 1901 there was relatively little that could be done to abate the symptoms. Because of the method of treatment this physical pain was also likely to have been matched by emotional and mental distress as a result of the segregation that many experienced as a course of their treatment. The QALY for 'pain and discomfort' in 1901 represents this 'poor' quality of life (QALY = 0.3). As medical technology advanced over the twentieth century this variable improved, such that by the year 2000, the advent of modern medicine, less aggressive therapy regimes and substantially reduced treatment time enabled quality of life to reach 'good' levels, i.e. a QALY of 0.8.

The financial burden that was placed upon a family, particularly if the sufferer was the breadwinner followed a similar pattern to 'pain and discomfort'. In 1901 when sufferers not only had to cease work and fund their treatment, the financial burden of tuberculosis was significant and created 'poor' quality of life conditions (QALY = 0.3). By the close of the twentieth century, when comprehensive tuberculosis treatment was provided by the NHS and required a much shorter absence from employment, which was supported by further government aid, the quality of life associated with 'financial burden' improved to 'complete' (QALY = 1).

The 'anxiety' associated with the contraction of a disease that was so strongly associated with no cure and 'social difficulties' meant that there was 'poor' quality of life associated with this sub variable in 1901. By 2000, with the advent of efficacious therapy and a virtual elimination of tuberculosis there was minimal 'anxiety/depression' and 'good' quality of life (QALY = 0.8), which was also the case for 'social difficulties'. This burden of financial problems, social difficulties and anxiety is represented by the 'poor' quality of life associated with tuberculosis sufferers' 'ability to lead a normal life', shown as QALY = 0.3 in 1901, which marks a contrast with the 'complete' quality of life associated with 'ability to lead a normal life' in 2000 (QALY = 1).

Therefore, in 1901 tuberculosis represented a poorly understood and treated illness with numerous adverse quality of life implications, due to the lack of cure, the social stigma, and very little government aid to alleviate the quality of life problems of tuberculosis. By the close of the twentieth century all tuberculosis quality of life variables had experienced substantial

gains to reach an overall 'good' quality of life, this is especially pronounced for the health related variables, which provided the largest standards of living gains associated with tuberculosis. The conclusion of this progress can be considered through comparing the aggregate average QALY in 1901 and 2000. This is calculated as an average summary QALY rank based on the QALYs that were achieved for the five quality of life variables (government initiatives and help, recognition and awareness, health developments, pain and discomfort, ability to lead a normal life) in Table 1. As such the QALY weights presented in Table 1 represent the summary health and welfare quality of life index for tuberculosis in 1901 and 2000.

Table 1: Tuberculosis: aggregate average QALY value (as a proportion of 1 healthy life year), 1901-2000

Year	Aggregate average tuberculosis QALY value
1901	0.3
2000	0.8

The verbal translation of the QALY values: 0.333 represents 'poor' quality of life and 0.833 represents 'good' quality of life

Table 1 highlights that during the twentieth century the implications of having tuberculosis improved substantially: in 1901 tuberculosis sufferers experienced 'poor' quality of life versus 2000 when the quality of life associated with tuberculosis was 'good'. Table 1 highlights that the tuberculosis QALY improved from 0.3 of a healthy life year to 0.8 of a healthy life year. Hence, in 1901 the collection of health and welfare standards of living meant that tuberculosis sufferers only enjoyed about 30 percent of a healthy life year. By 2000, improvements largely in health but also welfare enabled the standards of living associated with tuberculosis to increase to a level that represents about 80 percent of a full healthy life year and in doing so provided one of the most significant contributions to standards of living for the twentieth century England and Wales population.

IV

The importance of these gains in the quality of life associated with tuberculosis is accentuated by the prominence of tuberculosis mortality and morbidity. Table 2 highlights the significant twentieth century decline in tuberculosis mortality. This decline began in the late nineteenth century and gathered pace throughout the twentieth century, such that by 1980 tuberculosis

mortality had virtually been eliminated, when the tuberculosis death rate per 10,000 population was less than 0.1.

Table 2: Number of tuberculosis deaths and tuberculosis deaths rate per 10,000 population in England and Wales, 1901-2000⁴⁰

Year	Number of tuberculosis deaths	Tuberculosis deaths rate per 10,000 population
1901	58930	18.1
1920	36342	9.8
1940	27814	7.0
1950	15969	3.6
1960	3435	0.8
1980	605	0.1
2000	370	0.07

Further gains in the standards of living associated with tuberculosis mortality are manifest in the age profile, which changed considerably over the twentieth century. In 1901 the majority (nearly 50 percent) of tuberculosis deaths occurred in ages 25-54 and ages 0-4 accounted for nearly 20 percent of tuberculosis mortality⁴¹. The age distribution continually improved such that by 2000 nearly 75 percent of deaths occurred at ages 65+⁴².

Tuberculosis prevalence – as defined by notifications to the medical officer – also experienced important declines over the twentieth century. This data needs to be analysed with much caution due to the strong prospect of under and uneven reporting. Although this distortion is more pronounced in earlier years it should be regarded as applicable to the entire twentieth century, as despite repeated efforts to improve reporting, e.g. through the 1948 National Health Service Act, numerous [Infectious Disease] reporting regulations, and compulsory notification of all smear positive patients in 1973, there were still likely to be many undetected and unreported cases. Although problematic, notifications under reporting is not thought to be significant enough to affect the overall trend of the tuberculosis decline in twentieth century England and Wales, which is reported in Table 3.

⁴⁰ Calculated from Office for National Statistics, Twentieth century mortality.

⁴¹ Ibid.

⁴² Ibid.

Table 3: Number of tuberculosis notifications and tuberculosis notifications per 10,000 population in England and Wales, 1901-2000⁴³

Year	Number of tuberculosis notifications	Tuberculosis notifications rate per 10,000 population
1901	70000	21.5
1920	60500	16.2
1940	35000	8.8
1950	42000	9.6
1960	21000	4.6
1980	6000	1.2
2000	6087	1.2

Table 3 highlights the decline in tuberculosis morbidity during the twentieth century. The tuberculosis notification rate or morbidity rate declined markedly between 1901 and 1980, by which time tuberculosis morbidity had been virtually eliminated. However, between 1940 and 1950 the tuberculosis notification increased, which is a likely result of NHS initiatives at more comprehensive reporting, rather than a genuine worsening in the prevalence of tuberculosis.

The culmination of these developments, where the mortality and morbidity rate have been reduced to negligible levels has meant that the adversities associated with tuberculosis had largely subsided by the close of the twentieth century. The above analysis has highlighted the extensiveness of the mortality and morbidity decline of tuberculosis, in terms of the fall in the death rate (Table 2) and notification rate (Table 3) and the gains associated with quality of life (QALY) when suffering from tuberculosis (Table 1). These developments can be better highlighted through considering the aggregate number of additional life years that have been generated as a result of the falling tuberculosis death and notification rate, and the improved quality of life (QALY) associated with tuberculosis as the twentieth century unfolded. Table 4 presents this calculation, which considers the fall in the number of tuberculosis deaths and notifications and the gain in the QALY associated with tuberculosis between 1901 and 2000.

⁴³ Notifications: 1915-1980: Citron *et al*, Tuberculosis today; 1990: Watson *et al*, Notifications of tuberculosis; 2000: Joint Tuberculosis Committee of the British Thoracic Society, Control and prevention of tuberculosis. Deaths: Office for National Statistics, Twentieth century mortality.

Table 4: Calculation of life years gained due to the amelioration and elimination of tuberculosis in England and Wales, 1901-2000

Year	Number of lost life years from mortality	Number of notifications (prevalence)	Proportion of a healthy life year lost (1 – QALY)	Number of lost life years from morbidity	Number of life years lost from mortality and morbidity	Number of life years gained 1901-2000
1901	58930	70000	(1 - 0.3) = 0.7	49000	107930	
2000	370	6087	(1 - 0.8) = 0.2	1217	1587	
Number of life years gained (1901 life years lost – 2000 life years lost)						106343

Table 4 considers the loss of life years in 1901 for mortality and morbidity. The mortality component is calculated as the number of deaths in 1901 and 2000, and the morbidity comprises the number of notifications or prevalence (i.e. the number of people documented as suffering from tuberculosis in 1901 and 2000) adjusted for the severity of tuberculosis, which is calculated as the portion of a health life year lost due to tuberculosis (i.e. the inverse QALY)⁴⁴. These two calculations are then summed to calculate the number of healthy life years lost from mortality and morbidity. For example, in 1901 there were 58,930 tuberculosis deaths (or lost life years) and 70,000 people reported as suffering from tuberculosis, and in 1901 tuberculosis sufferers only experienced 0.3 (instead of 1) healthy life year (and as such lost 0.7 of a healthy life year and in aggregate $70,000 * 0.7 = 49,000$). Therefore life years lost as a result of tuberculosis mortality and morbidity = $58,930 + 49,000 = 107,930$. In order to identify the number of additional healthy life years that have been generated by the amelioration and virtual elimination of tuberculosis the difference between the number of healthy life years lost in 1901 and 2000 needs to be considered, which is calculated to be 106,343 (= $107,930 - 1,587$) additional health life years by the close of the twentieth century. Hence, as a result of mortality, morbidity and the QALY gains 106,343 healthy life years were spared of tuberculosis between 1901 and 2000.

In order to add greater significance to the results presented in Table 4 the number of additional healthy life years that have been gained can be valued. This will generate an

⁴⁴ The QALYs presented in Table 1 represent the proportion of a healthy life year lived when suffering from tuberculosis. In order to consider the proportion of a healthy life year lost when suffering from tuberculosis, the inverse QALY or 1 - QALY needs to be calculated.

approximate estimate about the monetary value associated with the amelioration and elimination of tuberculosis. This is achieved through identifying the 'value of a statistical life' (VSL) or the value of one healthy life year gained through averting death and sickness, which is utilised to estimate the value of the 106, 343 additional healthy life years that have been gained between 1901 and 2000 in England and Wales. The term 'value of a statistical life' is used widely in economics and regulation literature to denote the value placed on the policies that can reduce the statistically expected number or risk of death by one, and does not represent the value placed on a particular life or healthy life year⁴⁵.

There is a growing body of empirical evidence concerning premiums individuals are willing to pay to reduce the risk of death by small amounts. These estimates can be derived through revealed preference in consumption (e.g. individual behaviour to eliminate risk through purchasing safety in terms of smoke alarms, replacing tyres, etc), revealed preference in the labour market (such as a compensating wage premium accepted for a risky occupation) and contingent valuation (i.e. asking individuals what they would be willing to pay to hypothetically reduce fatality risk). To date estimates of the 'value of a statistical life' range widely: from about £300,000 to several million and even the most reliable VSL studies lack precision in consensus. In order to add validity to the results a lower bound VSL (worth £300,000, instead of several million) will be used. Hence, although it is not possible to calculate a precise estimate, it is possible to calculate an exaggerated lower value, which generates a likely underestimate of true contribution of the additional healthy life years associated with tuberculosis elimination in twentieth century England and Wales. This lower bound VSL is applied to the number of health life years gained, which is also a lower bound estimate due to problems of underreporting prevalence and the inherent assumption in the calculations that the average tuberculosis prevalence was only one year, which is an underestimate for most of the twentieth century.

⁴⁵ Laxminarayan *et al*, Economic benefit of tuberculosis control, p. 10.

Table 5: Calculation of the value of healthy life years gained due to the elimination and amelioration of tuberculosis in England and Wales (million £⁴⁶), 1901-2000

Number of life years gained from mortality and morbidity	'Value of a statistical life year' (million £)	Value of life years gained from mortality and morbidity (million £)
106343	0.30	31903

The result in Table 5 is calculated by valuing the number of healthy life years gained by a 'value of a statistical life' function ($106343 * 0.30 = 31903$). This yields results about the value of the additional life years generated by the elimination of tuberculosis, which is estimated to be in excess of £30 billion at a lower bound estimate. The gain in the number and value of healthy life years can also be considered as the value of the improved prognosis associated with tuberculosis in terms of mortality and morbidity, or the quality adjusted life expectancy. Hence, the value of the gain in the quality adjusted life expectancy associated with tuberculosis in England and Wales over the twentieth century has been calculated to be in excess of £30 billion, at a lower bound estimate.

When considering the tuberculosis quality adjusted life expectancy gain results it is important to recognise precisely what this approximation pertains to. The results presented in Table 5 represent the monetary value of the decline in the mortality and morbidity burdens. The estimates do not include an adjustment for the contribution to the wider population (as a result of the decline of tuberculosis in the environment and therefore a quality of life gain as the risk of catching tuberculosis declined). As well as being tenuous, making this type of calculation would increase the value of the tuberculosis quality adjusted life expectancy gains identified above. Hence, not including this consideration does not upwardly bias the results and as such reinforces the lower bound nature of the results presented above.

V

During the twentieth century England and Wales experienced a significant decline in tuberculosis: in 1901 tuberculosis represented about 11 percent of all deaths versus the year 2000, when tuberculosis represented less than 0.1 percent of all deaths⁴⁷. Citron *et al* highlight that 'people suffering from tuberculosis today are not easily recognised by the general public as the pattern of their lives is altered very little by modern treatment... at the

⁴⁶ Current prices.

⁴⁷ Calculated from Office for National Statistics, Twentieth century mortality.

beginning of the twentieth century the situation was quite different; the impact of the disease on the population was considerable and associated with fear and despondency⁴⁸. Moreover, Bryder has highlighted that 'in the first half of the twentieth century tuberculosis was not only a major killer it also became a social problem'⁴⁹. The veracity of the tuberculosis decline is widely accepted and reported in the literature and the benefit to individuals and society in general has also been postulated. However, to date there is a shortage of quantitative estimates about the value of the decline in tuberculosis.

It could be argued that the most pronounced contrast between the qualitative literature and the quantitative results presented here is that the tuberculosis gains generated by the quantitative methodology seem more valuable than those that currently exist in the literature. For example, although the literature indicates the significance of the elimination of tuberculosis it does not indicate that the value of twentieth century health improvements associated with tuberculosis is worth in excess of £30 billion.

The estimates provided here represent an important initial quantitative approximation about the value of the virtual elimination of tuberculosis in twentieth century England and Wales, in terms of health and welfare related quality of life generated by a falling death rate, prevalence rate and QALY burden. The changing twentieth century profile of tuberculosis has been gauged by the development of a methodology that is able to summarise and evolve qualitative literature into a series of quantitative indices. This has helped to identify improvements in the health and welfare quality of life for eras and variables where there is no existing quantitative data. The drawback of this approach is that the results can only ever be approximates even though this is somewhat substantiated through the consistent lower bound considerations. Furthermore, even though it is impossible to determine a precise figure about the quality of life value of the virtual elimination of tuberculosis, it is possible to conclude that these improvements have been extensive and valuable.

Another valuable refinement that has been made here is the consideration of tuberculosis improvements for mortality and morbidity. Both of these estimates yield pertinent results, although this is particularly true for morbidity, due to the more original nature of this feature. In 1901 more than sixty percent of tuberculosis morbidity was resolved in death, versus only six

⁴⁸ Citron et al, *Tuberculosis today*, p. 6.

⁴⁹ Bryder, *Below the magic mountain*, p. 6.

percent in the year 2000⁵⁰. Between 1901 and 2000 the burden of tuberculosis (as defined by the QALY) experienced significant improvements from 'poor' quality of life to 'good' quality of life. The number of tuberculosis notification in 2000 was less than one tenth of the number in 1901. Moreover, the prevalence decline was even more marked given the decline in the average duration of tuberculosis over the twentieth century: 'standard treatment for tuberculosis in the 1960s was administered for 18 months to two years'⁵¹, chemotherapy was further refined over the next three decades, 'until it was possible to effect cures in only 6 months'⁵² with regimens that entailed fewer antibiotics. The transformations identified for tuberculosis mortality and morbidity, and the subsequent value of the quality adjusted life expectancy gain highlight the value of improvements in the standards of living associated with tuberculosis mortality and morbidity over the twentieth century.

VI

Through developing a new methodology that utilises existing data in a new way and generates new (quantitative) information about the health and welfare quality of life associated with tuberculosis morbidity and mortality during historical eras (for which the necessary QALY data does not exist), the paper provides original quantitative results about the value of eliminating and ameliorating tuberculosis in twentieth century England and Wales.

The most important contributions of this paper are the estimates about the value of the decline in tuberculosis mortality and morbidity for the standards of living of the twentieth century England and Wales population, particularly those who were disease sufferers. The lower bound estimate about the value of improvements in the death rate, prevalence rate and QALY burden associated with tuberculosis was estimated to be worth in excess of £30 billion. In addition to providing original quantitative results about the value of the virtual elimination of tuberculosis, these results also corroborate a more sanguine conclusion about the value and contribution (to standards of living) of the tuberculosis decline in twentieth century England and Wales.

⁵⁰ Notifications: 1915-1980: Citron *et al*, Tuberculosis today; 1990: Watson *et al*, Notifications of tuberculosis; 2000: Joint Tuberculosis Committee of the British Thoracic Society, Control and prevention of tuberculosis. Deaths: Office for National Statistics, Twentieth century mortality.

⁵¹ Wellcome Trust Centre for the History of Medicine, Short course chemotherapy for tuberculosis, p. 19.

⁵² Iseman, *Tempus fugit*, p. 1.

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