Working Paper No: 5/2007 January 2007 LSE Health

Alistair McGuire and Maria Raikou

Inferring the Value of Medical Research to the UK

THE LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE

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Alistair McGuire* and Maria Raikou*

*LSE Health
London School of Economics and Political Science

Working Paper No. 5/2007

First published in January 2007 by:
LSE Health
The London School of Economics and Political Science
Houghton Street
London WC2A 2AE

British Library Cataloguing in Publication Data
A catalogue record for this publication is available from the British Library
ISBN [07530 1975 2]

Abstract

The aim of this paper is to estimate the return to the UK from health sector R&D drawing on the value of life methodology and the work by Murphy and Topel (2003). While acknowledging the caveats arising in making such calculations, not least the lack of consideration given to spillover effects from R&D undertaken elsewhere, this method is useful in at least attempting to initiate a quantification of the returns to medical R&D. Using life cycle consumption information, value of life estimates for the UK and changes in survival probabilities, the value of improved longevity in the UK over the years 1970-2000 is estimated at approximately £2.84 trillion, or £2.58 trillion after netting out health care expenditure. This is approximately double the current yearly GDP of the UK. The estimated gains are greatest for the period 1980-1990. Given that the UK spends less than 0.5% of its GDP per annum (approximating £0.2 trillion over the 30-year period) on medical R&D, while clearly not all the gains in longevity can be attributed solely to medical R&D, the inference is that the returns to such investments are substantial. While such gains might be considered an upper estimate, given that the approach attributes all gains in life expectancy as a return to medical R&D over the period, gains in morbidity attributable to improved health delivery arising from medical R&D are not included in the estimate thus imparting a downward bias on the estimates as well as highlighting an obvious extension to this research.

Contact details: Alistair McGuire, LSE Health, Cowdray House J405, Houghton Street, London, WC2A 2AE. Tel: +44(0)20 7955 6375. E-mail: a.j.mcguire@lse.ac.uk

Acknowledgements: We would like to thank David Armstrong, Walter Holland and Caroline Rudisill for their comments on earlier versions of this paper. This work was funded in part by an educational grant provided by Pfizer Inc. UK.

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1. Introduction

Continuing research and development is an important contributory factor to economic growth in any country. In 2001 the UK spent approximately 1.8% of GDP (£17.5 billion) on research. In 2004, as part of the UK government's plans to increase the country's productivity, the government announced a 10-year strategy committing an increase in R&D funding to 2.5% of GDP by 2014 with an average increase over the next 3-years of 5.8%. Medical research remains a major contributor to general UK R&D and, in particular is a major public sector activity in the UK. The absolute levels of medical research in the UK are considerable. Table 1 gives a breakdown of UK R&D medical research expenditure by different funding board category from the year 1997/98 up to 2002/03 for the public sector (including non-profit making, charitable foundations). UK medical research by public bodies approached £2.5 billion in 2002/03. This public funding was approximately matched by UK pharmaceutical company R&D expenditure of £2.9 billion, of which approximately £250m is channelled through university research, to give a total annual investment of research funds in the UK health care sector of approximately £5.3 billion.[1] Internationally, this makes the UK one of the largest contributors to medical research across the world.

With the government committed to increasing R&D expenditure, health sector R&D is also set to grow. Therefore, it is not surprising that increasing attention is being focused on the returns from such funding. At least three levels of returns to medical R&D can be distinguished: returns specified in terms of scientific knowledge; returns specified in terms of health benefits; and returns specified in terms of wider economic returns. The aim of this paper is to outline monetary estimates of the economic value of changes in UK life expectancy over the period 1970 to 2000, by drawing on a methodology proposed by Murphy and Topel (2003). In doing so this represents a first stage in attempting to attribute gains in longevity as a return to medical R&D. It is a first step for

a number of reasons: first, attributing all gains in longevity to R&D is not just heroic, it is obviously wrong. It is bound to overestimate a dimension of the gain. That said,

[1] The US scientific base of billion is used to represent 10^9 and trillion is used to represent 10^{12}. Traditional British use would denote 10^{12} as a billion. Harold Wilson, the Prime Minister of the UK, announced in 1974 that government statistics would conform to US standard usage with the term billion taken to mean 10^9 , and 10^{12} taken to be a trillion. It would appear he therefore devalued more than the pound sterling.

gains in terms of morbidity are not considered at all and the attribution of return to medical R&D will be tempered in this respect. One justification for pursuing the approach is that it indicates the potential size of the return to medical R&D in a quantifiable manner. That said no precise value of the return is highlighted for a number of reasons, both conceptual and practical.

Table 1. Total Health Research and Development Expenditure (excluding profit making sector). £ Millions

	1998/99	1999/00	2000/01	2001/02	2002/03
Higer Education Funding COuncils					
HEFCE	219.4	238.3	243.7	249.9	255.5
SHEFC	26.7	27.1	27.5	28.6	34
HEFCW	8.1	8.7	9	10.6	9.2
DEL/NI	1.8	1.9	2.1	2.3	3.2
Research Councils					
BBSRC	89.4	94.1	98.7	93.1	103.4
MRC	310	339.5	362.9	423.5	434.5
Civil Departments					
NHS/DOH	420	434	448	475	506
DFID	47.6	81.2	123.7	99.3	168.3
Private Non-Profit					
AMRC	418	544	632	594	660
WELLCOME	173	279	348	273	345
TOTAL	**1,714.0**	**2,047.8**	**2,295.6**	**2,249.3**	**2,519.1**

As an economic commodity R&D has a number of characteristics that may result in general underinvestment. In particular, uncertainty and the public good nature of the commodity, where once knowledge has been released it becomes consumable by all, make the return to R&D high risk. Notwithstanding the inherently risky nature of R&D it has long been recognised that it is notoriously difficult to estimate the return to R&D (Arrow, 1962). As with most service-based industries, the problem of estimating returns to R&D is intensified as specific returns to medical care research are difficult to capture.

Many innovations come in the form of changes in process or techniques that can not be patented, making it difficult to for the private investor to capture the return. This return to R&D should be set in terms of increases to economic welfare. The difficulty becomes how to measure this increase in economic welfare. R&D expenditure, even if

the area of concern is limited to the health care sector, is heterogeneous. By definition there is both research and development; moreover research may be classified as basic or applied. Various types of spending on the diverse characteristics of R&D will result in different types of additions to economic welfare. In the area of health care the social benefit is especially difficult to quantify.

As well as conceptual problems there are practical concerns. Stoneman (2001) identifies at least three. First, the issue of counterfactual evidence ought to be addressed. The measurement of R&D policy requires evidence on what would have occurred if the policy had not been undertaken. In the case of R&D in the health care sector the obvious question is, given the impact of lifestyle and environment on health, what gains would have been achieved even without technical advances in medical care? Second, how should spillover effects, either the medical advances achieved elsewhere the gains from which are realised in the UK or the returns achieved in other settings from UK R&D, be accounted for? The public good nature of research, essentially through the dissemination of knowledge, makes it most susceptible to these external effects. There are also direct spillover effects gained from medicines developed and imported from abroad. While trade balances in pharmaceuticals do not map the spillover gains they do give an indication of potential importance of such effects; the UK for example exported £12.3 billion in pharmaceutical trade and imported £8.6 billion in 2004. Third, the time span over which the effects should be measured also presents an issue. For example, health benefits may have an effect over generations.

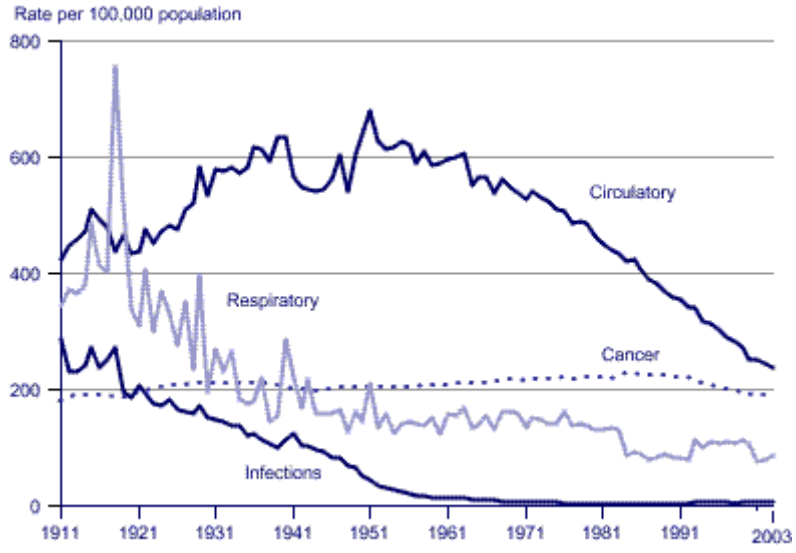
Despite the acknowledgement of such conceptual and practical issues, a recent paper by Murphy and Topel (2001) attempted to indicate the value of medical R&D to society through considering the impact that medical research has had on health, specifically

mortality rates by age and sex, by estimating the monetary value that society places on the health gains achieved through increased longevity. The Murphy and Topel (op. cite.) paper was based on US data and thus estimates returns to US medical research. This paper draws on the methodology used by Murphy and Topel to give broad estimates of the magnitude of the return to UK medical research over the period 1970

to 2000 as based on the value of longevity achieved over this period. To do so assumptions similar to those in the Murphy and Topel study are made but UK data are used to indicate UK specific values of the return to medical R&D.

One practical issue, as noted above, is the choice of timeframe. The health of the UK population has been improving markedly for a long period. Crude mortality rates for various diseases exhibit marked declines as shown by Figure 1 with consequent improvement in life expectancy. The most remarkable decline has been with respect to circulatory diseases, even though this remains the most common cause of death. Cancers are now the second most common cause of death in England and Wales, but even here there has been a slight decline in mortality rates over the last 10-years. It is undoubtedly true, for example that major pharmacological and surgical innovations, including the introduction of beta-blockers, ACE inhibitors, statins and diuretics as well as the introduction of angioplasty and stenting have had a marked impact on morbidity and mortality arising from circulatory diseases, but so too has the change in smoking habits. While undoubtedly arbitrary, 1970 is taken as the starting point for the analysis as it was during this decade that the first major treatment improvements with respect to heart disease were introduced.

Figure 1. Common causes of death in England and Wales. Mortality rates 1911-2003



Source: ONS

The paper is structured as follows. The next section discusses the methodological approach used to value changes in life expectancy in some detail. This is then followed by the basic results gained from the UK calculation. A discussion of limitations and potential improvements on the approach then follow.

2. Methods

The basic approach adopted by Murphy and Topel draws on an established literature suggesting that estimates of individuals' willingness-to-pay (WTP) for reductions in mortality risks can be converted into an estimate of the value of a statistical life (Viscusi and Aldy, 2003). The fundamental idea is to assume that individuals would be willing to pay a monetary sum to reduce the risk of mortality. Estimates of the values attached to reductions in these risk levels extrapolate to an estimate of the value of a (statistical) life. This literature has a long history (Mishan, 1971).

The formulation of the WTP for changes in the risk of dying is premised on the utility gained from wealth under different mortality risks. The concept of the value of a statistical life has been traditionally formulated in this manner with much empirical work, based largely in the USA, deriving values of the WTP for changes in the risk of death from observed differences in the income levels associated with risky(in terms of risk of death) and low risk occupations (Viscusi and Aldy, 2003). The associated empirical literature produces a range of estimates that involve implicit tradeoffs between mortality risk and wealth, essentially calculating the average marginal rate of substitution of wealth for risk, in a number of different circumstances. Most of these estimates have been based on the so-called compensating variation required by individuals to undertake risky tasks in the labour market. The extension to calibration with wealth is obvious. The formulation can however be changed to calibrate WTP for changes in mortality risk with utility levels, (i.e. measures of individual welfare), derived from consumption and leisure activities with the basic idea being that individuals derive utility not from wealth per se but from the use of wealth in consumption and leisure activities. Again this calibration can be performed for different ages and across different time periods. The approach adopted below extends this empirical literature through an adaptation based on Murphy and Topel (2003), utilising the calibration of WTP for reduced mortality risk with the utility derived from lifetime consumption and leisure.

Such WTP estimates were used as an essential component of the Murphy and Topel calculation. It is well recognised however that there are limitations to this approach. The most obvious drawback is that such estimates are based on implied trade-offs gained from individuals of working age. It is also accepted that future life expectancy will affect the value of a statistical life. Age obviously affects the duration of life at risk but may also be correlated with other factors, including changes in preferences, especially about exposing oneself to and taking risks, which will affect an individuals' WTP to for changes in survival probability. Moreover, non-pecuniary aspects of work will be omitted from such labour market based calculations. Injury risk may also be correlated with mortality risk and the implied estimated gained from labour market studies may be biased because of the lack of inclusion of this injury risk. Indeed even individual characteristics, such as clumsiness, may affect the estimates gained from implicit trade-offs based on labour market studies. Moreover, given the expected positive income elasticity with respect to the value of risks to an individual's life, it might be predicted that estimates gained from studies conducted in the USA would have a tendency to be higher than in other countries, given the higher average earnings of workers in the USA compared to other countries. Indeed a recent review of the literature on the value of a statistical life found that UK studies estimate compensating differentials which are "implausibly large" and of the order of 10 percent of wage income compared to the 1 to 2 percent of wages found for the USA (Viscusi and Aldy, 2003).

Given these implausible values and the fact that the UK literature on the WTP for reduction in mortality risk literature has been dominated by a related but different methodology, an altered approach to WTP forms the basis of the analysis presented here. UK measures of the WTP for changes in mortality risk, and subsequent valuation of a statistical life, have been based upon contingent valuation studies that use direct questionnaire based methods to elicit explicit trade-offs between wealth and safety. The resultant monetary values of individuals' WTP to reduce the risk of fatalities, accidents and morbidity are used by UK governmental departments to assist in the calculation of the costs and benefits of various public sector funded projects. Thus, as reported by Chilton et al (2002) the value of the prevention of a statistical fatality used by the UK Department of Environment, Transport and Regions (DETR)

in evaluating public sector road projects has been based on questionnaire based preference elicitation techniques to calculate the value individuals place on safety which is then used to estimate the marginal value of a change in the probability of survival. The current value of a statistical life used by the DETR as based on preference elicitation techniques is £1.14 million (2000 prices).[2]

Recent attempts to re-estimate these values in the UK have focused on relative valuations of the WTP for reduction in mortality risk in different settings (Chilton et al, 2002). This recent work recognises that various aspects of individual decisions may affect the preference based valuations of risk of death when these risks are assessed in different contexts. Thus issues of control over the circumstance, past experience, knowledge, fear, dread and expectation could also affect the elicited valuation.[3] That said, most empirical work suggests that individual estimates of the value of a statistical life do not significantly vary across different settings (Chilton et al, 2002). The relative valuation approach also recognises that small absolute risk values, as used in calculations where circumstances were such that low absolute risk values formed the basis of the calculation as death was rare in the examples used, may lead to error in the direct estimation of willingness-to-pay (WTP) values for changes in survival probability. Typically such estimates of WTP are calculated by dividing mean reported WTP estimates for a given reduction by the risk reduction itself. Where this is the case, even small miscalculation of the WTP response by respondents will lead to over-estimation of the WTP. The relative value approach uses an estimated relative value ratio of, for example, risk of death from road and rail travel in conjunction with the (relatively high) absolute risk of death from road travel to overcome this. This approach is similar to the "person trade-off" methodology adopted by Nord (1992) and suggested as a means of estimating the relative values of specific health care interventions.

Using as a base the estimated value of a statistical life set at £1.14 million as used by the UK Department of Environment, Transport and Regions, the analysis continues by

[2] eftec (2004), in a review for the UK Department of Environment, Food and Rural Affairs, states that the value of life estimates are largely invariant to context and a consensus figure of £1 to £1.2 million emerges from a review of stated preference studies. One area where there is considerable variation arises when individuals are asked questions relating to death from specific disease, most notable cancer, where the returned estimates are approximately double this figure.

[3] See footnote 2 above for discussion.

assuming that medical research leads to further improvement in individual survival probabilities that may be given a monetarised value based on this estimated value of a statistical life.[4] The basic approach sees an individual trying to maximise their own welfare through enjoying consumption and non-market activities over a healthy lifetime; individuals derive utility from consumption and leisure the benefits from which may be estimated over their lifetime in terms of a discounted monetary equivalent sum. The estimation of the value of a gain in survival time is calculated by ignoring non-healthy time; that is by assuming that a gain in life expectancy is of value regardless of how healthy the individual is with improved life expectancy. To the extent that an individual will pay more for improved health as well as life expectancy the estimated value of a gain in survival time is therefore conservative. Any WTP for a gain in survival time must then be equal to the utility gains enjoyed from improved life expectancy; the marginal costs defined in terms of WTP must equal the marginal benefits defined in terms of utility gain. Thus an estimated WTP for a stated reduction in annual mortality risk, taken from the UK literature based on the normalised value of a statistical life, is set equal to full lifetime consumption, amended for any surplus gained from any preference for consumption at given points in an individual's life cycle, further weighted by changes in life expectancy. That is, the marginal cost in terms of WTP for additional survival is equal to the marginal benefit in terms of additional utility gained from additional life expectancy controlling for consumption and saving preferences over an individual's lifetime.

A standard individual lifetime utility maximising model is then the starting point for the Murphy and Topel model. This can be represented, using their notation, as:

$$V = \int_0^{\infty} e^{-pt} H(t) u(c(t), l(t)) S(t) dt \qquad [1]$$

Where V is the expected lifetime utility of an individual and is given as the discounted gains (with the discounting factor given as e^{-pt}) derived from consumption $c(t)$ and non-market $l(t)$ activities enjoyed over healthy $H(t)$ survival time $S(t)$. Ignoring

[4] The value of a statistical life is normally gained from contingent valuation questions which relate to questions based on risks in mortality around 1/10,000 or 1/100,000 (Jones-Lee et al, 1995). So the value of a statistical life can be re-based into a change in a small risk. In our case a change in mortality risk of 1/10,000 is used.

the health status aspects of changes in life expectancy and assuming that life cycle preferences can be modelled as a given surplus of present consumption over lifetime consumption then the WTP for improved longevity may be expressed as:

$$\frac{dV}{\mu} = \int_0^{\infty} e^{-rt}\theta C_F(t)\Delta S(t)dt \qquad [2]$$

where $\frac{dV}{\mu}$ is the WTP for improved longevity which is equal to the discounted (at a constant rate r) value of the additional survival gains $\Delta S(t)$ valued in terms of the life time consumption of market and non-market activities (the monetary value of consumption and leisure activities ($C_F(t)$)) weighted by the value of life cycle preferences to the individual (θ). This general equation can be evaluated at different ages and set equal to a pre-defined WTP for a given reduction in the probability of death ($W(a)\lambda$) to give the WTP for improved longevity at age a ($\frac{dV(a)}{\mu(a)}$) as:

$$\frac{dV(a)}{\mu(a)} = \lambda\int_a^{\infty} e^{-r(t-a)}\theta C_F(t)\frac{S(t)}{S(a)}dt = \lambda W(a) \qquad [3]$$

where all terms are as before with the exception that the additional survival gain is from age a and the change in longevity is defined as $\frac{S(t)}{S(a)}dt$ and λ is the pre-specified magnitude of the reduction in the risk of death as defined previously.

Assuming that the improvement in longevity is attributable to both improvements in medical knowledge and health care itself then the gain to an individual who has survived to age a from improvements in medical knowledge through medical research, can be given as:

$$V_R(a,R) = \int_a^{\infty} e^{-r(t-a)}S_R(a,t,R,Z)\theta C_F(t)dt \qquad [4]$$

where $V_R(a,R)$ is the value of the gain in medical research R to an individual aged a, $S_R(a,t,R,Z)$ is the gain in longevity for an individual aged a attributable to medical research R and health care Z, and all other terms are as before. A discrete version of (4) amenable to empirical investigation is given as:

$$V_2 - V_1 = \int_a^{\infty} e^{-r(t-a)} \theta C_F(t) [S_2(t) - S_1(t)] dt \qquad [5]$$

where $S_1(t)$ and $S_2(t)$ are two survival functions which individuals can switch across and assuming $S_2(t) > S_1(t)$ encompasses the gains in longevity.

Finally this value of increased longevity can be aggregated from the individual level to the population level across all age groups such that the population gains are given as:

$$V_R(t) = \sum_{a=0}^{T} N(a,t) V_R(a,R) \qquad [6]$$

where $N(a,t)$ is the number of individuals of age a at a given time t, and V_R is given by equation [4] .

This basic methodological framework draws heavily on and replicates the Murphy and Topel (2003) approach to allow an indication of the possible value of medical research to any given population calculated through the WTP for a reduction in mortality risk and the utility benefits gained from increased longevity.

Of course a number of assumptions have been made to make this method amenable to empirical investigation. First, a time period has to be specified. This paper considers the period 1970 to 2000. This period is arbitrary but coincides with large mortality declines in the UK population from various diseases, most notably coronary heart disease. Second, gains in health from medical research are calculated having taken account only any contemporaneous gains attributable to health care. Any health gains from lagged health care effects, changes in individual behaviour or changes in

environmental conditions are not estimated with the possible inference that there is over-estimation of the benefits from medical research. On the other hand, in compensation, any health gains attributable to medical research resulting in changes in morbidity and quality of life are not included in the calculation/estimate thereby underestimating the return to medical research.

3. Empirical Results

The estimates of the WTP are derived for 3 sub-periods, (1970-1980; 1980-1990; 1990-2000), and then aggregated for the full period 1970-2000. To gain empirical estimates the investigation proceeds as follows. First, a value of the WTP for a given reduction in the probability of death is specified which to enable estimation of the parameter θ from equation [3] given above and repeated below

$$\frac{dV(a)}{\mu(a)} = \lambda \int_{a}^{\infty} e^{-r(t-a)} \theta C_F(t) \frac{S(t)}{S(a)} dt = \lambda W(a)$$

As Murphy and Topel note, $W(a)$ is commonly referred to as the "value of a statistical life" when λ is set equal to 1. However empirical estimates of the WTP for changes in survival probability are normally gained when λ is set to a value less than 1 or when individuals are requested to provide information on WTP for values of λ less than 1. The current value of a statistical life used by the UK Department of Transport as based on preference elicitation techniques £1.14 million (2000 prices) and this forms the basic input into the equation above.

The calculation also requires information on life cycle consumption, $C_F(t)$. This is gained, as in the Murphy and Topel study, through a proxy based on male lifetime earnings. This was taken from an ONS/DTI study on individual income (ONS, 2004) which reported the median income by age band for men and women in 2003/04. The relevant figures, based on net median weekly income for men, are reported in Table 2 and taken as a proxy for lifetime consumption[5]. Finally a discount rate of 3.5% is used as recommended by the UK Treasury for the discounting of health benefits.

[5] This follows the same assumption as Murphy and Topel that full income is proportional to male lifetime income profile and is captured by a representative earnings profile. The earnings profile is extended to those younger than 16 by assuming their median "income" is the same as for the 16-19 year olds.

Table 2

Age	Annual Median Income, Males 2003
16-19	£5,096
20-24	£10,712
25-30	£17,160
30-34	£20,540
35-39	£21,996
40-44	£21,944
45-49	£21,840
50-54	£19,188
55-59	£17,784
60-64	£13,104
65-69	£11,128
70-74	£10,296
75-79	£9,308
80-84	£8,632
85+	£8,736

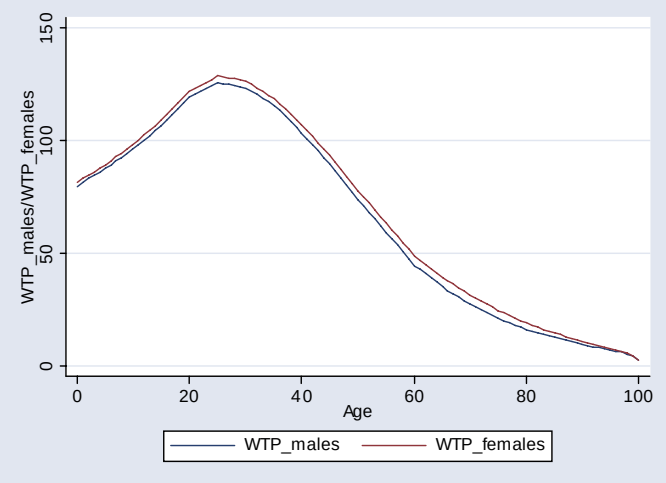
Substitution of the relevant values into equation [3] and solving for θ, the weight allocated by individuals to life-cycle consumption relative to current consumption, results in an estimate of 2.89 for this parameter.[6] Figure 2 reports the resultant life cycle profile for an individual's WTP for a 1/10,000 reduction in contemporaneous mortality risk for men and women based on the value of a statistical life set at £1.14 million (the y-axis measures WTP in £s; the x-axis measures age). This life cycle estimate of full income allows calculation of the monetary value of further reductions in mortality risk attributable to R&D.

This calculation of the WTP for changes in survival probability at the individual level can be used to consider the value associated with changes in life expectancy attributable to medical research across all age groups. Following Murphy and Topel the increased value in life expectancy is estimated through the following equation, with the definitions as given above by equation [5] reproduced below

$$V_2 - V_1 = \int_a^{\infty} e^{-r(t-a)} \theta C_F(t) \left[S_2(t) - S_1(t) \right] dt$$

[6] This is remarkably similar to Murphy and Topel's estimate of 2.9 in their calculations.

Figure 2 Value of a reduction of a 1/10,000 risk of mortality by age (£2000 prices)



The value of increased longevity can be aggregated to the population level such that the population gains are given as:

$$V_R(t) = \sum_{a=0}^{T} N(a,t) V_R(a,R) \qquad [7]$$

To implement these calculations the value of θ is equal to 2.89 as estimated previously and the two survivor functions $S_1(t)$ and $S_2(t)$ relate to the years 1970 and 1980, 1980 and 1990, and 1990 and 2000 in respective calculations. For all calculations the base year population is taken from the year 2000 and the discount rate is 3.5% per year.

Figures 3 and 4 show the results in terms of the estimated per capita gains in monetary terms that are associated with improved UK survival functions for the periods 1970-1980; 1980-1990; 1990-2000. The graphs cumulate the per capita gains in each period so that the total height of the graph reports the total per capita gains in reduced mortality over the whole period 1970-2000. The monetary measurement of the gains in individual survival over the period are substantial. Improvements in life expectancy over the total period peak for men around the age of 60 at approximately £90,000, while for women they peak at around £60,000 at 65 years of age.

Figure 3 Value of monetary gains from increased survival probability: males

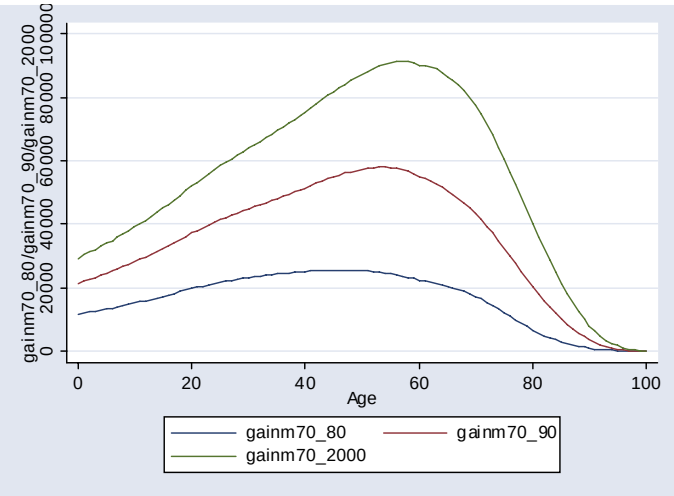


Figure 4. Value of monetary gains from increased survival probability: females

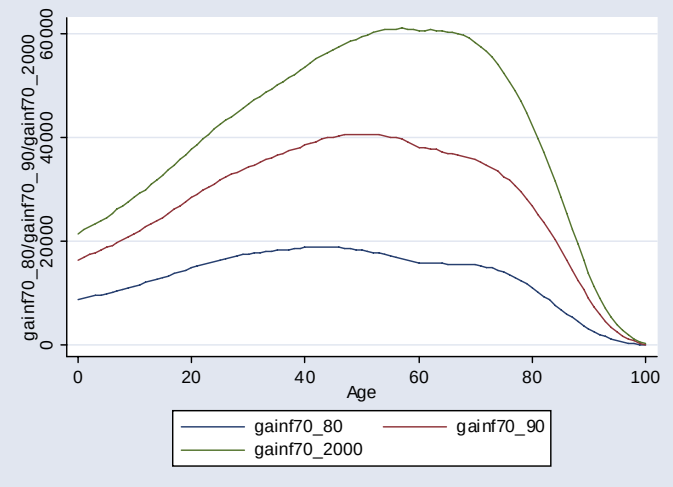


Table 3 reports the gains in economic welfare from improved survival for the periods 1970-1980; 1980-1990; 1990-2000 and over the whole period 1970-2000 and forms the basic results. The Table shows the gains by age group for the various sub-periods for males and females. The table also shows the aggregate gains. Over the whole period the gains are substantial at approximately £2.84 trillion. This is approximately double the current yearly GDP of the UK. The gains are greatest for the period 1980-1990.

Table 3 Economic gains from reduction in mortality by age

Table 3a

Males **Aggregate Gains (£, 2000 prices)**

Agegroup	**1970-1980**	**1980-1990**	**1990-2000**
Birth	£3,610,000,000	£3,010,000,000	£2,480,000,000
1-4	£16,300,000,000	£13,700,000,000	£11,300,000,000
5-9	£24,200,000,000	£20,600,000,000	£17,200,000,000
10-14	£27,800,000,000	£23,900,000,000	£20,300,000,000
15-19	£29,500,000,000	£25,700,000,000	£22,000,000,000
20-24	£31,200,000,000	£27,600,000,000	£23,800,000,000
25-29	£39,000,000,000	£35,400,000,000	£30,900,000,000
30-34	£46,900,000,000	£44,400,000,000	£39,300,000,000
35-39	£49,500,000,000	£49,900,000,000	£44,700,000,000
40-44	£45,100,000,000	£49,000,000,000	£44,500,000,000
45-49	£41,800,000,000	£49,600,000,000	£45,800,000,000
50-54	£44,400,000,000	£58,000,000,000	£55,500,000,000
55-59	£33,800,000,000	£47,600,000,000	£48,700,000,000
60-64	£27,400,000,000	£39,900,000,000	£45,000,000,000
65-69	£21,400,000,000	£31,300,000,000	£39,200,000,000
70-74	£14,400,000,000	£22,400,000,000	£30,100,000,000
75-79	£7,310,000,000	£13,100,000,000	£18,500,000,000
80-84	£2,060,000,000	£4,440,000,000	£6,690,000,000
85-90	£431,000,000	£1,050,000,000	£1,690,000,000
90+	£27,800,000	£59,900,000	£111,000,000
Total	£506,138,800,000	£560,659,900,000	£547,771,000,000

Table 3b

Females **Aggregate Gains (£, 2000 prices)**

Agegroup	**1970-1980**	**1980-1990**	**1990-2000**
Birth	£2,580,000,000	£2,230,000,000	£1,500,000,000
1-4	£11,700,000,000	£10,100,000,000	£6,820,000,000
5-9	£17,300,000,000	£15,200,000,000	£10,300,000,000
10-14	£19,900,000,000	£17,700,000,000	£12,200,000,000
15-19	£21,400,000,000	£19,300,000,000	£13,300,000,000
20-24	£23,900,000,000	£21,800,000,000	£15,200,000,000
25-29	£30,600,000,000	£28,700,000,000	£20,400,000,000
30-34	£36,400,000,000	£35,600,000,000	£25,900,000,000
35-39	£37,900,000,000	£38,800,000,000	£29,000,000,000
40-44	£34,000,000,000	£36,700,000,000	£28,500,000,000
45-49	£31,100,000,000	£36,100,000,000	£29,200,000,000
50-54	£32,200,000,000	£40,800,000,000	£35,200,000,000
55-59	£24,300,000,000	£33,100,000,000	£31,100,000,000
60-64	£20,700,000,000	£28,600,000,000	£29,700,000,000
65-69	£18,700,000,000	£25,000,000,000	£27,800,000,000
70-74	£17,000,000,000	£22,200,000,000	£24,500,000,000
75-79	£13,600,000,000	£18,400,000,000	£19,100,000,000
80-84	£6,680,000,000	£9,970,000,000	£9,540,000,000
85-90	£2,530,000,000	£4,360,000,000	£3,790,000,000
90+	£317,000,000	£552,000,000	£460,000,000
Total	£402,807,000,000	£445,212,000,000	£373,510,000,000

Table 3c **Aggregate Gains (£, 2000 prices)**

Total gains (males)	**£1.61 trillion**
Total gains (females)	**£1.22 trillion**
TOTAL	**£2.84 trillion**

The economic return arising from improved survival presented above has been calculated without consideration of health care expenditure. Of course over the time period under consideration there have been improvements in the delivery of health care and increased funding of health care delivery throughout the UK. Following the approach by Murphy and Topel, the net return associated with improved survival over the period is calculated by removing/adjusting for the impact of health care expenditure over the same period as

$$\Delta V^{N}(a) = \int_{a}^{\infty} e^{-r(s-a)}[S_2(s) - S_1(s)]\theta C_F(s)ds - \int_{a}^{\infty} e^{-r(s-a)} S^{*}(s)\Delta X(s)ds \qquad [8]$$

Where all the terms are defined as above with the exception of $S^{*}(s)$ which denotes the survival function fixed at year 2000 levels and $\Delta X(s)$ which is the increase in real expenditures over a given period . The estimate for $\Delta X(s)$, given in 2000 prices, is based on the real per capita health care expenditures for the relevant years. These per capita figures were given an age profile by adjusting by the age breakdown of per capita health care expenditures in 2004 for the age groups 0-4, 5-14, 15-44, 45-64, 65-74, 75-84 and over 85. Table 4 reports the results and shows that the overall total economic gain remains substantial, at £2.58 trillion even after netting out the growth in health care expenditures over the period 1970-2000.

Table 4 Gains from reduction in mortality by age attributed to increased survival net of health care expenditure growth

Table 4a

Males **Aggregate Gains (£, 2000 prices)**

Agegroup	**1970-1980**	**1980-1990**	**1990-2000**
Birth	£2,760,000,000	£2,110,000,000	£824,000,000
1-4	£12,800,000,000	£9,900,000,000	£4,410,000,000
5-9	£22,800,000,000	£19,000,000,000	£14,400,000,000
10-14	£26,400,000,000	£22,400,000,000	£17,500,000,000
15-19	£27,700,000,000	£23,700,000,000	£18,300,000,000
20-24	£29,500,000,000	£25,800,000,000	£20,500,000,000
25-29	£37,100,000,000	£33,400,000,000	£27,300,000,000
30-34	£44,800,000,000	£42,200,000,000	£35,300,000,000
35-39	£47,500,000,000	£47,800,000,000	£40,900,000,000
40-44	£43,500,000,000	£47,300,000,000	£41,300,000,000
45-49	£39,600,000,000	£47,300,000,000	£41,500,000,000
50-54	£42,300,000,000	£55,700,000,000	£51,400,000,000
55-59	£32,300,000,000	£46,100,000,000	£45,800,000,000
60-64	£26,300,000,000	£38,700,000,000	£42,800,000,000
65-69	£19,500,000,000	£29,300,000,000	£35,500,000,000
70-74	£13,300,000,000	£21,200,000,000	£27,800,000,000
75-79	£6,300,000,000	£12,000,000,000	£16,500,000,000
80-84	£1,760,000,000	£4,120,000,000	£6,110,000,000
85-90	£322,000,000	£931,000,000	£1,470,000,000
90+	£21,700,000	£53,400,000	£99,400,000
Total	£476,563,700,000	£529,014,400,000	£489,713,400,000

Table 4b

Females **Aggregate Gains (£, 2000 prices)**

Agegroup	1970-1980	1980-1990	1990-2000
Birth	£1,760,000,000	£1,350,000,000	-£107,000,000
1-4	£8,230,000,000	£6,470,000,000	£128,000,000
5-9	£15,900,000,000	£13,700,000,000	£7,600,000,000
10-14	£18,500,000,000	£16,300,000,000	£9,460,000,000
15-19	£19,500,000,000	£17,300,000,000	£9,680,000,000
20-24	£22,100,000,000	£19,900,000,000	£11,700,000,000
25-29	£28,500,000,000	£26,500,000,000	£16,400,000,000
30-34	£34,200,000,000	£33,200,000,000	£21,500,000,000
35-39	£35,700,000,000	£36,500,000,000	£24,900,000,000
40-44	£32,200,000,000	£34,900,000,000	£25,000,000,000
45-49	£28,600,000,000	£33,500,000,000	£24,500,000,000
50-54	£29,700,000,000	£38,200,000,000	£30,500,000,000
55-59	£22,500,000,000	£31,200,000,000	£27,700,000,000
60-64	£19,300,000,000	£27,100,000,000	£27,100,000,000
65-69	£16,100,000,000	£22,300,000,000	£22,700,000,000
70-74	£15,100,000,000	£20,200,000,000	£20,800,000,000
75-79	£11,500,000,000	£16,100,000,000	£15,000,000,000
80-84	£5,810,000,000	£9,050,000,000	£7,850,000,000
85-90	£2,030,000,000	£3,830,000,000	£2,820,000,000
90+	£266,000,000	£497,000,000	£360,000,000
Total	£367,496,000,000	£408,097,000,000	£305,591,000,000

Table 4c **Aggregate Gains (£, 2000 prices)**

Total gains (males)	**£1.5 trillion**
Total gains (females)	**£1.08trillion**
TOTAL	**£2.58trillion**

Following Murphy and Topel's methodology, estimates of the monetarised gains that would be established if R&D in medical care gave rise to a further 1%, 10% and 100% fall in the probability of death from major diseases were obtained. Use of the basic approach given in equation [5] and application to the range of diseases defined in the tables resulted in the estimates shown in Tables 5, 6 and 7. For a 1% decrease in the probability of death from the defined diseases a total of £3,000 million in economic welfare would be achieved from such a reduction, with the largest gains being achieved through improving life expectancy associated with heart disease and cancer. These results are replicated for a 10% decrease and a 100% decrease in the relevant probabilities. Focusing on the calculations of a 10% fall in the probability of death from major diseases, table 6 shows that the total gain would be £37,000 million with heart disease and diseases relating to malignant neoplasms again being the largest contributors towards gains. The prospective gain in mortality from heart disease being reduced by 10% would be close to £8,000 million. Of course while such gains assume no diminishing returns to health investments in these areas, they are nevertheless impressive.

Table 5. Prospective gains from a permanent 1% reduction in death rates by major cause of death

	Males	Females	Total
All causes	**£2,030,877,524**	**£1,672,899,141**	**£3,703,776,665**
Infectious and parasitic diseases	£11,750,601	£10,029,363	£21,779,964
Diabetes mellitus	£12,777,009	£12,388,204	£25,165,213
Pneumonia & influenza	£89,442,215	£108,440,513	£197,882,728
Chronic liver disease and cirrhosis	£22,699,221	£13,737,527	£36,436,747
Chronic obstructive pulmonary disease and allied conditions	£62,268,067	£49,121,157	£111,389,224
Malignant neoplasms	£348,751,319	£319,532,484	£668,283,802
Malignant neoplasm of digestive organs and peritoneum digestive organs	£103,699,269	£74,552,906	£178,252,174
Malignant neoplasm of trachea, bronchus and lung respiratory	£90,341,273	£54,689,359	£145,030,632
Malignant neoplasm of female breast	Not applicable	£64,211,175	£64,211,175
Malignant neoplasm of genitourinary organs	£56,743,386	£48,800,857	£105,544,243
Major cardiovascular disease	£559,535,860	£439,464,320	£999,000,180
Diseases of the heart	£469,229,898	£319,233,242	£788,463,140
Cerebrovascular disease	£82,972,850	£113,666,039	£196,638,889
Accidents and adverse effects	£55,450,025	£24,359,230	£79,809,255
Motor vehicle traffic accidents	£24,146,419	£7,448,706	£31,595,125
Homicide and injury purposely inflicted by other persons	£2,054,339	£1,118,714	£3,173,053
Suicides and injury undetermined whether accidentally or purposely inflicted	£39,015,775	£12,105,345	£51,121,120

Note: Sub-categories are not exclusive and therefore do not total to the figures given in major categories

Table 6. Prospective gains from a permanent 10% reduction in death rates by major cause of death

	Males	Females	Total
All causes	**£20,313,861,359**	**£16,732,088,925**	**£37,045,950,285**
Infectious and parasitic diseases	£115,716,366	£99,084,256	£214,800,622
Diabetes mellitus	£130,030,063	£124,821,863	£254,851,926
Pneumonia & influenza	£896,555,281	£1,085,704,943	£1,982,260,224
Chronic liver disease and cirrhosis	£228,956,475	£136,257,429	£365,213,904
Chronic obstructive pulmonary disease and allied conditions	£624,002,538	£492,985,476	£1,116,988,014
Malignant neoplasms	£3,489,167,761	£3,194,545,748	£6,683,713,508
Malignant neoplasm of digestive organs and peritoneum digestive organs	£1,035,944,984	£746,734,911	£1,782,679,895
Malignant neoplasm of trachea, bronchus and lung respiratory	£903,510,859	£547,508,496	£1,451,019,356
Malignant neoplasm of female breast	not applicable	£644,106,359	£644,106,359
Malignant neoplasm of genitourinary organs	£568,762,040	£487,621,167	£1,056,383,207
Major cardiovascular disease	£5,595,604,968	£4,396,739,344	£9,992,344,312
Diseases of the heart	£4,691,439,374	£3,191,307,798	£7,882,747,172
Cerebrovascular disease	£828,305,582	£1,135,153,553	£1,963,459,135
Accidents and adverse effects	£553,175,198	£244,911,322	£798,086,520
Motor vehicle traffic accidents	£241,718,343	£72,890,129	£314,608,472
Homicide and injury purposely inflicted by other persons	£22,442,942	£11,189,616	£33,632,558
Suicides and injury undetermined whether accidentally or purposely inflicted	£388,528,585	£120,526,517	£509,055,102

Note: Sub-categories are not exclusive and therefore do not total to the figures given in major categories

Table 7. Prospective gains from a permanent 100% reduction in death rates by major cause of death

	Males	Females	Total
All causes	**£203,140,372,839**	**£167,330,471,615**	**£370,470,844,454**
Infectious and parasitic diseases	£1,156,885,862	£991,046,009	£2,147,931,871
Diabetes mellitus	£1,299,705,279	£1,247,622,327	£2,547,327,606
Pneumonia & influenza	£8,967,261,281	£10,860,054,742	£19,827,316,023
Chronic liver disease and cirrhosis	£2,287,054,105	£1,363,442,507	£3,650,496,612
Chronic obstructive pulmonary disease and allied conditions	£6,239,521,972	£4,927,746,179	£11,167,268,151
Malignant neoplasms	£34,892,465,117	£31,944,737,630	£66,837,202,747
Malignant neoplasm of digestive organs and peritoneum digestive organs	£10,357,803,479	£7,468,435,528	£17,826,239,007
Malignant neoplasm of trachea, bronchus and lung respiratory	£9,033,157,317	£5,476,734,767	£14,509,892,084
Malignant neoplasm of female breast	not applicable	£6,441,039,590	£6,441,039,590
Malignant neoplasm of genitourinary organs	£5,690,157,730	£4,878,605,276	£10,568,763,006
Major cardiovascular disease	£55,957,300,000	£43,971,252,817	£99,928,552,817
Diseases of the heart	£46,914,208,701	£31,912,430,292	£78,826,638,993
Cerebrovascular disease	£8,282,121,199	£11,353,267,008	£19,635,388,207
Accidents and adverse effects	£5,530,400,000	£2,446,200,000	£7,976,600,000
Motor vehicle traffic accidents	£2,419,853,662	£729,772,682	£3,149,626,344
Homicide and injury purposely inflicted by other persons	£224,949,449	£112,142,201	£337,091,650
Suicides and injury undetermined whether accidentally or purposely inflicted	£3,887,527,687	£1,205,942,060	£5,093,469,747

Note: Sub-categories are not exclusive and therefore do not total to the figures given in major categories

4. Sensitivity analysis

The general results are of course dependent on to the assumptions made. The basic calculation rests on the value of the discount rate, the change in survival probabilities seen across the various decades analysed, the value of θ assumed, which is in turn dependent on the value of life assumed and the value of lifetime consumption, which itself depends on the proxy values for life cycle earnings. It seems reasonable to maintain a discount rate of 3.5% as this is historically low and reflects current anticipation of the public sector riskless return. The change in survival probabilities cannot reasonably be changed. It is reasonable to assume the value of lifetime consumption is not subject to alteration. The value of life however varies markedly across different studies even if only UK studies are considered (Viscusi and Alby, 2003). However, before noting the sensitivity to changes in the value of life, a comparison of the UK and US findings as calculated by Murphy and Topel (op.cite.) is undertaken to set the context.

Assuming the US population to be approximately 3.5 times as large as the UK population, an exchange rate of £1 to $0.54 and that average wages are comparable, the crude conversion of the UK findings to US figures suggests a figure of approximately $20 trillion as the measure of gain from medical R&D in the UK over the period 1970-2000. This is substantially below the Murphy and Topel estimate of $46 trillion. It might be argued that demographic structure accounts for some of the difference but in fact the UK has a slightly higher proportion of the elderly and lower proportion of the young in its population than the USA. In other words the higher gains in the US do not reflect substantially different demographics which translate into higher improvements in survival probabilities. Nevertheless there is some evidence to suggest that the US population may be less healthy than the UK population and therefore may have more to gain from R&D investment (Banks, 2006). In all likelihood however it is the estimate of the value of life used in the present study (£1.14 million; approximately $0.6 million) compared to the $5 million used by Murphy and Topel which explains the difference across the calculations. The value of life provides data necessary to calculate the parameter θ from equation [3] and used in subsequent calculations. In fact when the UK value of life is set at £1.14 million the value of θ is 2.84, as compared to a value of θ of 2.9 calculated by

Murphy and Topel when using a value of life set at $5 million. As noted in the introduction, the estimates of the value of life gained from the UK vary widely and the estimates based on compensating differentials are "implausibly large" (Viscusi and Abby, 2003). This notwithstanding if the UK value of life is increased to £2.7 million (approximately $5 million), which is at the higher end of the UK valuations, θ becomes 6.73 and the calculated gain from medical R&D becomes £6.4 trillion ($12.8 trillion), which when multiplied up to the US population scale gives a close approximation to the Murphy and Topel estimate ($44.8 trillion). This increase in the value of life is roughly in line with the upper end of UK value of life estimates which are gained when individuals are asked about risk of death in direct relation to specific diseases, most notably heart disease and cancer (Jones-Lee et al, 1985; Andrews and McCrea, 1999). The main point is therefore that amongst other factors the results are extremely sensitive to the value of life adopted. The £1.14 million adopted in this study reflects the value currently adopted by UK government. Figures 5 and 6 indicate the spread of these gains across the UK population from 1970 – 2000 for males and females respectively.

Figure 5. Calculated monetary return to increased survival using a value of life of £2.7 million. Males

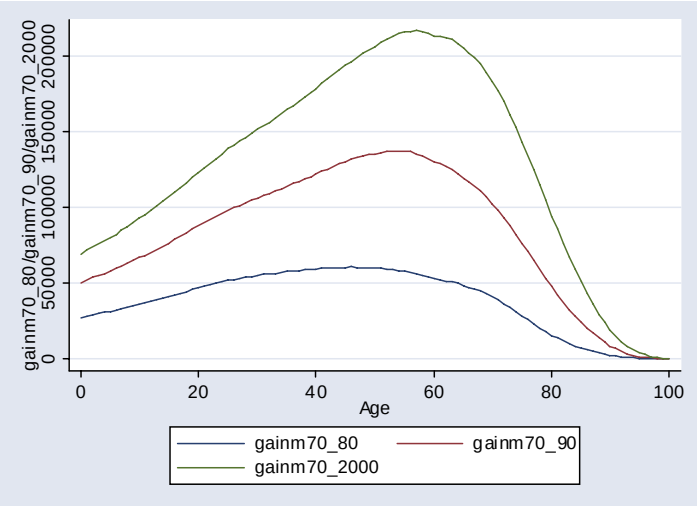
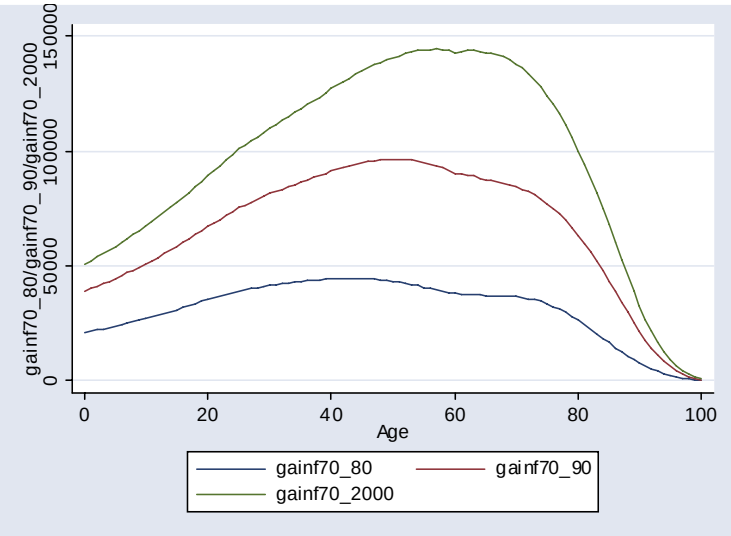


Figure 6. Calculated monetary return to increased survival using a value of life of £2.7 million. Females



Of course one must be careful in drawing inferences with respect to the monetarised gains of reductions in mortality and relating these to the rate of return from medical R&D. First all of the caveats concerning the calculations should be borne in mind: in particular the inferred gain rests on a number of assumptions relating to the value of life, lifecycle consumption and the conversion of R&D into reductions in survival probability regardless of gains achieved through changes in life style and environment. It is simply incorrect to attribute the full return of improved UK survival rates (probability) merely to UK medical R&D given the significant effect of life style changes, environmental changes and any spillover benefits gained from R&D conducted abroad although the fact that improvements in quality of life have not been considered in the analysis is expected to mitigate the bias.

Obviously the annual investment in the UK medical sector is small compared to the estimated net gain of £2.58 trillion, albeit that this gain accrued over a 30-year period. The investment is less than 1% of the total monetarised gains estimated above. Moreover this assumes investments have been at this historically high level, which is not the case.

5. Conclusions

This paper has replicated the work of Murphy and Topel in the UK context at a time when there has been increased interest in the return to health sector R&D (UK Evaluation Forum, 2006). The results show that even when, in comparison to this earlier work, the value of a statistical life is lower in absolute terms and health expenditure growth is netted out of the calculations the return to UK medical R&D is (can be) inferred to be substantial. This conclusion is reached with fairly rudimentary calculations of the monetary return to improved life expectancy. Of course such an inference neglects any impact of lifestyle and environment on life expectancy during the timeframe considered, but this omission is balanced by focus on mortality to the neglect of monetary estimates of the improvements in quality of life attributable to medical research over the period.

This paper represents a first attempt to apply the value of life approach with the aim to at least provide an indication of the order of magnitude the gains to medical research within the UK might be over the period 1970-2000. Buxton et al (2004) attempt to calculate the return within the UK context in a different manner which does not easily lend itself to aggregation of benefits. This notwithstanding many conceptual issues remain unresolved with the present methodology such as the appropriateness of the time period considered, how to deal with the issue of externalities, suitable elicitation of value of life and not least how to truly net out the impact of R&D alone on improvements in life expectancy let alone gains in quality of life. The results suggest, with all the caveats above, that the monetarised gains in longeviety equate to approximately two years of GDP growth. Such conclusions are preliminary of course and much refinement is required before a more precise figure can be put on the actual return to medical R&D in the UK.

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For further information on this or any of the Health publications contact:

Champa Heidbrink
Managing Editor
LSE Health
The London School of Economics and Political Science
Houghton Street
London WC2A 2AE

Tel: + 44 (0)20 7955 6840
Fax: + 44 (0)20 7955 6090
Email: c.heidbrink@lse.ac.uk
Website: www.lse.ac.uk/collections/LSEHealth/