A Cost-benefit Analysis of Cataract Surgery based on the English Longitudinal Survey of Ageing*

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17th March 2011

Abstract

This paper uses the English Longitudinal Survey of Ageing to explore the self-reported effect of cataract operations on eye-sight. A non-parametric analysis shows clearly that cataract patients report improved eye-sight after surgery and a parametric analysis provides further information: it shows that the beneficial effect is larger the worse was self-reported eye-sight preceding surgery. For the 5.6% of patients with excellent eye-sight ahead of surgery it is, however, found that surgery is not associated with improved eye-sight in the short term. Nevertheless, the long-run effect is suggested to be beneficial. Calibrating the results to existing studies of the effect of imperfect eye-sight on quality of life, the impact of cataract operations on quality-adjusted life-years is found to be similar to that established in previous studies and well above the costs of cataract operations in most circumstances.

Keywords: QALY, Cataract Surgery, English Longitudinal Survey of Ageing
JEL Codes: D19, I12

*Financial support under the INDICSER project funded by the European Commission is gratefully acknowledged. An earlier version of this paper was presented at the Conference on the Measurement of Government Activity Conference held in Cardiff in November 2009. I am very grateful for comments received from Aileen Simkins, Tony Harrison, Robert Weale, from participants at the conference, and from three anonymous referees.

1 Introduction

This paper uses the English Longitudinal Survey of Ageing (Marmot et al. 2009) (ELSA) to determine the expected gain in Quality Adjusted Life Years (QALYs) resulting from cataract surgery. It then compares the costs and benefits of such surgery. The study of cataract surgery is of particular interest because it is so widespread. The number of operations has risen 3.7 times since 1989 (Black et al. 2009) and by 50% since 1999 to reach over 300,000 today (*Hospital Episode Statistics* 2009-10).

A comparison of the benefits with the costs of any medical intervention is at the core of an analysis of whether the money used to finance such an intervention is well-spent. Studies which explore the benefits of intervention may focus on the question whether the intervention has achieved its intended effect, or they may attempt to establish how far patients feel that their welfare has been improved as a result of the intervention. Plainly these approaches can both be informative; it is possible that an intervention would achieve its medical purpose without having much influence on welfare. On the other hand it would be questionable to justify an expensive intervention if no medical benefits could objectively be identified.

Benefits of medical interventions are usually measured in QALYs[1]; the information required to assess the gain in QALYs resulting from an intervention is normally collected by means of a specific survey instrument even if the structure of the instrument can be generic (Devlin et al. 2009), perhaps in the form proposed by EQ5-D (Greiner et al. 2003). Such studies have typically examined groups of patients in a particular locality at a particular time. Thus Kobelt et al. (2002) used a subsample of a group of patients participating in a continuing study (the Swedish Cataract Register) of patients before and after surgery. Detailed information was collected from these patients on their eye-sight measured both objectively and as perceived subjectively, their general perceptions of their health state and welfare and their demographic characteristics. Using these data it was possible to explore both how much eye-sight improved as a result of surgery, and how far patients felt their well-being had improved. McGwin et al. (2003) by contrast set up an *ad hoc* study which measured the eye-sight of patients and assessed their visual capacity using the Activities of Daily Vision Scale. This was done before surgery, a year after surgery and also over the same period for patients in whom cataracts

[1] Although the use of QALYs is not without controversy (Dolan et al. 2005). Murphy & Topel (2006) suggest a measure based more directly on utility but its implementation requires parametisation of a utility function.

had been diagnosed but who declined surgery. Rasanen et al. (2006) carried out a similar study, but focused on health related quality of life and visual acuity, rather than on activities of daily vision. More recently, and again using the Swedish Cataract Register, Lundstrom & Pesudovs (2009) compared the answers to a questionnaire on vision (the Catquest questionnaire), and assessed the responses of both a summary measured of the questionnaire findings and visual acuity to cataract surgery. Of course, adverse consequences may follow from poor eye-sight; Sach et al. (2007) investigated the relationship between the need for cataract surgery and the risk of patients falling over. But the general point is that these studies show the effects of cataract surgery on visual acuity and that some of them offer a basis for linking visual acuity to welfare, and thus a means by which the benefits of cataract surgery can be assessed in QALY terms. In these calculations other studies, such as Brown et al. (2003), linking visual acuity to welfare, can be useful even though they do not explicitly consider the effects of cataracts and their removal.

However, the use of specific surveys faces two drawbacks. First of all, they and particularly those which collect a wide range of self-reported and medical data, may be expensive, and secondly, the surveys are typically one-off exercises (Black et al. 2009, Kobelt et al. 2002, Rasanen et al. 2006, McGwin et al. 2003) conducted soon after intervention[2]; it is not generally possible to form any view about the long-run effects of any intervention from most one-off studies. This means it is not possible to assess the life-time gain to patients from intervention except by making very simple assumptions, such as that the effect identified in the survey is permanent, and that the eye-sight of patients would not have changed in the absence of surgery. General-purpose panel surveys, by contrast, offer a means of collecting information from patients before and after intervention and also following them up in the long-term. They also provide information, both on people who have not been told that they have cataracts developing, and on those who have had them diagnosed but have not yet had cataract surgery. Thus, should the data provided by such surveys prove to be satisfactory, they offer a useful additional source of information about the benefits of medical interventions.

A methodology for the use of a survey, such as ELSA, to estimate the benefits of cataract surgery is set out here, and the paper suggests that, at least in the context of procedures such as cataract surgery which are widespread, such surveys can be a useful means of measuring the benefits flowing from medical interventions. Thus use of ELSA

[2] Moenstam & Lundqvist (2005) do examine patients five years after intervention, but focus specifically on ability to drive.

can form a valuable complement to specific instruments such as the Patient Reported Outcome Measures (PROMs), developed by the Department of Health to explore the benefits of common medical procedures[3]. As the number of waves of ELSA rises, its value as a means of identifying the benefits of interventions will increase. It may, for example, also be possible to use it to establish the benefits of hip replacement, since there are around 90,000 of these each year. On the other hand with only just over 20,000 coronary bypass operations annually, it is unlikely that enough will be found in the sample to estimate the benefits of such a procedure.

The paper proceeds to a more detailed summary of the findings of studies of the effects of cataract surgery. This is followed by presentation of the data from ELSA, showing how the self-reported eye-sight of people aged sixty and over changes over time. Respondents who have cataract surgery between waves of the survey are distinguished from those who do not. This non-parametric analysis is followed by a parametric one which identifies more precisely the effects of untreated cataracts and cataract surgery on respondents who report them. However, in order to interpret the results in terms of their effects on welfare it is necessary to calibrate them against existing studies of i) the connection between self-reported eye-sight and quantified measures of eye-sight, and ii) the link between eye-sight and welfare. A section is devoted to this, followed by one which balances an evaluation of the financial benefits against the costs of cataract surgery. Finally conclusions are presented.

2 Existing Research on Cataract Progression and the Effects of Cataract Surgery

Here we bring together the work described in the studies on cataract surgery discussed above. We show in table 1 that there is quite a range of values both for average eye-sight before surgery and for the improvement which results from surgery. These differences may well arise from different practices in the different countries (Finland, Sweden and the United States) to which the studies relate. Cataract surgery seems to be offered to people with better eye-sight in the United States than in Finland and Sweden.

The results here are presented in LogMAR units, while those of other studies we draw on later use the more familiar Snellen fraction[4]. We quote results in the original

[3]PROMs are to be compiled for hernia repair, hip and knee replacement and treatment for varicose veins. It was originally planned to collect information on cataract surgery in addition, but substantial doubts arose about the validity of the data which were being collected (Devlin et al. 2009).

[4]The Snellen fraction is drawn from the alphabetic charts familiar from sight tests conducted by

Study	Country	Eye-sight before Surgery (First Eye)	Eye-sight after Surgery
		LogMAR units	
Kobelt et al. (2002)[5]	Sweden	0.70	0.0
McGwin et al. (2003)	USA	0.52	0.20
Lundstrom & Pesudovs (2009)	Sweden	0.59	0.15

Table 1: Effects of Cataract Surgery shown in Specific Studies

Study	Country	Eye-sight at First Assessment (Worse Eye)	Eye-sight after One Year
		LogMAR units	
Leinonen & Laatikainen (1999)	Finland	0.68	0.96 (13.2 months average)
McGwin et al. (2003)	USA	0.34	0.38 (12 months average)

Table 2: The Deteriorartion of the Eye-sight of Patients with Untreated Cataracts thought in Need of Surgery

form in which they were presented and, where necessary, we convert from Snellen to logMAR as logMAR value=$\log_{10}$(Snellen fraction).

In assessing the benefits of cataract surgery one needs to take into account not only the improvement to eye-sight achieved by the operation, but also the fact that, without surgery, eye-sight would continue to deteriorate. Fewer studies of this were found, but the differences shown in table 2 are nevertheless striking. No progression is found on average in the untreated American patients, while substantial and statistically significant progression is found with the Finnish patients. Nevertheless, Leinonen & Laatikainen (1999) record that over the period of one year, half the patients showed no deterioration in their eye-sight.

One further study, also carried out in the United States, should be mentioned Gloor & Farrell (1989) suggested that a patient typically moves up the Snellen Chart at 1.5 lines per annum, approximately equivalent to just under 0.25 logMar units per annum and thus a little slower than the average deterioration shown by Leinonen & Laatikainen (1999).

opticians. It compares what can be read at 6m with the distance that the same text could be read by someone with normal vision. Thus a Snellen fraction of 6/9 means that someone can read at 6m what could be seen with normal eyesight a 9m. The logMAR scale uses a chart where, unlike with the Snellen chart, the spacing of the letters is proporational to their size. The score is the log (base 10) of the reciprocal of the Snellen score. Thus logMAR of 1 means that the patient can read at 6m what could with normal eyesight be seen at 60m. This relationship is used to convert the Snellen to logMAR scale and *vice versa* even though the differences between the charts means that the conversion is not exact.

We draw two conclusions from these studies. First, those in table 1 show a marked improvement in eye-sight after cataract surgery, which we should therefore expect to find in ELSA. Secondly, evidence on the progression of cataracts in untreated patients is more divided, and it is an open question whether we should expect to find, on average, much evidence of progression in ELSA.

3 Eye-sight and Cataract Surgery in the English Longitudinal Survey of Ageing (ELSA)

ELSA is a study of people aged fifty and over and their younger partners living in England. The sample was drawn from previous respondents to the Health Survey of England in 1998, 1999 or 2001. Respondents are interviewed every two years with wave one carried out between March 2002 and March 2003, wave two between July 2004 and August 2005, and wave three between May 2006 and August 2007. The survey asks a range of questions about health status, and respondents also provide blood samples and anthropometric data. These are combined with wide-ranging socio-economic data.

The Survey, although not its precursor, has asked respondents a number of questions about their eye-sight and cataract operations. They are asked to grade their eye-sight, using normal glasses on a five-point Likert scale ranging from excellent to poor. Respondents are also asked whether they have ever been told they have cataracts developing, and whether they have had cataract operations. The survey does not distinguish first and second operations, but these normally follow within a few weeks so that it is unlikely that more than ten per cent of respondents will have participated in ELSA between operations. A general survey such as ELSA obviously does not focus attention on people immediately before and after operations, but it has the merit that it also includes people who have not had cataract operations and, indeed, who do not have cataracts. It also (unlike PROMs) will eventually allow us to study people's experiences long after their cataract operations.

There were 4308 people who provided complete records of their experience with cataracts in all three waves, together with records on their self-assessed eye-sight. Tables 3 and 4 summarise the data for these people, showing their eye-sight as a function of that two years earlier. It is clear that self-reported eye-sight can improve as well as worsen with the passage of time, perhaps because some respondents have their eyes tested and prescriptions updated between survey waves. But there may also be a random element which affects the responses to successive surveys.

Turning now to cataracts, 142 people reported having had cataract operations in 2004, but not when interviewed in 2002, while 179 reported them in 2006, having not had them in 2004, giving a total of 321 cataract patients. This lies well within the range of a number of *ad hoc* studies.

For those ELSA patients who reported cataract operations between the surveys, we can replicate the tables showing their self-reported eye-sight. Tables 5 and 6 show that, in 2002, 32.4% of patients had reported fair or poor eye-sight ahead of their operation while 37.6% reported this in 2004. For comparison Sach et al. (2007) found 25% of subjects had eye-sight worse than 6/12 before surgery[6]. A cataract operation did not guarantee markedly improved eye-sight; substantial proportions of those whose eye-sight was fair or poor before surgery found it still fair or poor after surgery. This is perhaps surprising, in that past practice has been not to operating on patients whose eye-sight would be unlikely to be improved, because they also suffer from other conditions such as macular degeneration. But the sharp increase in the number of operations since the 1990s suggests either that there were then patients who would have benefited considerably but who did not receive surgery, or, on the other hand that, because surgery has become more available, it is now offered to patients for whom the chance of benefit may seem low.

[6] This is approximately the threshold for driving.

		Eye-sight in 2002: Number of Respondents					
		Excellent	Very Good	Good	Fair	Poor	Total
	Excellent	210	188	117	14	2	531
Eye-sight	Very Good	253	595	468	65	6	1387
in	Good	142	475	859	210	21	1707
2004	Fair	19	66	216	170	46	517
	Poor	5	15	41	52	53	166
	Total	629	1339	1701	511	128	4308
		As Percentage of Category in 2002					Total
	Excellent	33.4%	14%	6.9%	2.7%	1.6%	12.3%
Eye-sight	Very Good	40.2%	44.4%	27.5%	12.7%	4.7%	32.2%
in	Good	22.6%	35.5%	50.5%	41.1%	16.4%	39.6%
2004	Fair	3%	4.9%	12.7%	33.3%	35.9%	12.0%
	Poor	0.8%	1.1%	2.4%	10.2%	41.4%	3.9%
	Total	100%	100%	100%	100%	100%	100%

Table 3: Self-reported Eye-sight in 2002 and 2004: People aged 60 or older in 2002

		Eye-sight in 2004: Number of Respondents					
		Excellent	Very Good	Good	Fair	Poor	Total
	Excellent	193	167	74	13	0	447
Eye-sight	Very Good	200	618	419	41	12	1290
in	Good	122	505	913	192	32	1764
2006	Fair	15	79	268	199	49	610
	Poor	1	18	33	72	73	197
	Total	531	1387	1707	517	166	4308
		As Percentage of Category in 2004					Total
	Excellent	26.3%	12.3%	4.3%	2.5%	0%	10.4%
Eye-sight	Very Good	37.7%	44.6%	24.6%	7.9%	7.2%	29.9%
in	Good	23.0%	36.4%	53.5%	37.1%	19.3%	40.9%
2006	Fair	2.8%	5.7%	15.7%	38.5%	29.5%	14.2%
	Poor	0.2%	1.3%	1.9%	13.9%	44.0%	4.6%
	Total	100%	100%	100%	100%	100%	100%

Table 4: Self-reported Eye-sight in 2004 and 2006: People aged 60 or older in 2002

		Eye-sight in 2002: Number of Respondents					
		Excellent	Very Good	Good	Fair	Poor	Total
	Excellent	2	5	5	2	2	16
Eye-sight	Very Good	2	6	14	7	2	31
in	Good	1	5	25	13	5	49
2004	Fair	2	2	11	8	4	27
	Poor	0	1	2	8	8	19
	Total	7	19	57	38	21	142
		As Percentage of Category in 2002					Total
	Excellent	28.6%	26.3%	8.8%	5.3%	9.5%	11.3%
Eye-sight	Very Good	28.6%	31.6%	24.6%	18.4%	9.5%	21.8%
in	Good	14.3%	26.3%	43.9%	34.2%	23.8%	34.5%
2004	Fair	28.6%	10.5%	19.3%	21.1%	19.0%	19.0%
	Poor	0%	5.3%	3.5%	21.1%	38.1%	13.4%
	Total	100%	100%	100%	100%	100%	100%

Table 5: Self-reported Eye-sight of People Age 60 or older with Cataracts in 2002 who were treated by 2004

		Eye-sight in 2004: Number of Respondents					
		Excellent	Very Good	Good	Fair	Poor	Total
	Excellent	1	4	3	1	0	9
Eye-sight	Very Good	2	10	8	3	1	24
in	Good	2	21	39	14	1	77
2006	Fair	6	8	15	10	2	41
	Poor	0	6	7	8	7	28
	Total	11	49	72	36	11	179
		As Percentage of Category in 2004					Total
	Excellent	9.1%	8.2%	4.2%	2.8%	0%	5%
Eye-sight	Very Good	18.2%	20.4%	11.1%	8.3%	9.1%	13.4%
in	Good	18.2%	44.9%	54.2%	38.9%	9.1%	43.0%
2006	Fair	54.5%	16.3%	20.8%	27.8%	18.2%	23.0%
	Poor	0%	12.2%	9.7%	22.2%	63.6%	14.6%
	Total	100%	100%	100%	100%	100%	100%

Table 6: Self-reported Eye-sight of People aged 60 or older in 2002 who reported Cataracts in 2004 and were treated by 2006

We identify the numbers of people reporting improved, unchanged or deteriorated eye-sight, both for those who have had cataract operations and for the population as a whole. The general pattern observed is coherent with the results presented by McGwin et al. (2003). They found, looking at self-reported visual difficulties rather than self-reported eye-sight, that, after surgery, cataract patients faced less difficulty with visual tasks. Returning to our own data, using Pearson's χ^2 test, we find that the distribution of outcomes is significantly different for the population which has had cataract surgery (χ_2^2 = 16.8 for 2002-4 and χ_2^2 =35.7 for 2004-6), and that this is the consequence of a higher proportion reporting improved eye-sight in the population who experience surgery than in that who do not. Nevertheless, it is surprising that such a high proportion of people operated on for cataract report a deterioration of their vision and it would be desirable to form some understanding of this; this can be done only by combining self assessment with professional examination of eye-sight one or two years after cataract surgery.

	Whole Sample				Respondents Treated for Cataract			
	2002-4		2004-6		2002-4		2004-6	
	Number	%	Number	%	Number	%	Number	%
Deterioration	1284	29.8	1313	30.5	34	23.9	37	20.7
No Change	1887	43.8	1996	46.3	49	34.5	67	37.4
Improvement	1137	26.4	999	23.2	59	41.6	75	41.9

Table 7: Summary of Changes to Self-reported Eye-sight: People aged 60 or older in 2002

4 Parametric Analysis

This non-parametric analysis does not, however, provide any detailed framework for estimating the benefits of cataract surgery. We explore this by means of ordered probit models specified in terms of Age, the age of the respondent in period $t-2$, Sex, a variable which takes a value 0 for a man and 1 for a woman, and number of other dummy variables. Thus D_{jt-2} takes a value 1 if the respondent reports eye-sight in period $t-2$ to be in category C_j and 0 otherwise. E_{1t-2} takes a value 1 if the respondent reports neither a developing cataract nor having had cataract surgery when interviewed in period $t-2$, with E_{1t} the corresponding variable for period t, E_{2t-2} takes a value 1 if the respondent reports an untreated cataract in period $t-2$ and 0 otherwise. Finally E_{3t} takes a value 1 if the respondent reports cataract surgery between the interview in

$t-2$ and the interview in t. Thus the model allows for the effect of cataract surgery to be a consequence of eye-sight reported at the interview before the surgery.. We assume that there is an unobserved latent variable, y_{it}, which measures eye-sight for respondent i in year t; we refer to the values of y_{it} as units of visual acuity. What we observe in fact are not the values of this but whether it lies in one of the five categories shown in tables 3 and 4. Denoting these by C_1 to C_5 we assume that respondent i reports category C_j if $y^*_{j-1,t} < y_{it} < y^*_{jt}$ with $y^*_{0t} = -\infty$ and $y^*_{5t} = \infty$. Note that one lag category. D_{jt-2}, has to be omitted from the equation since otherwise the cut points, y^*_{1t} to y^*_{4t} cannot be uniquely determined. Their values, but not the intervals between them, depend on which lag category is omitted. Here we have omitted the lag for people reporting poor eye-sight in the previous survey ($j = 5$).

We assume that y_{it} is determined as follows

$$\begin{aligned} y_{it} = \alpha_1 Age_{it-2} + \alpha_2 Sex_i + \textstyle\sum_{j=1}^{5} \beta_{jt} D_{jt-2} + \gamma_1 E_{1t-2} + \gamma_2 E_{2t-2} \\ + \gamma_3 E_{1t} + \textstyle\sum_{j=1}^{5} \delta_{jt} E_{3t} D_{jt-2} + \varepsilon_{it}; \qquad \varepsilon_{it} \sim N(0,1) \end{aligned} \tag{1}$$

We show the estimated coefficients and standard errors for the model fitted to the two separate data sets and also for the pooled data. In order to save space we present P-values only for the last of these.

The χ^2_{14} statistics allow us to test whether pooling is valid. The total value of χ^2 taken from the two separate regressions adds to $\chi^2_{28} = 2817.96$. Restricting the parameters to be equal in both regressions reduces the number of degrees of freedom to 14 and the χ^2 statistic to $\chi^2_{14} = 2797.18$. The restriction can be tested from the difference of the two χ^2 with 14 degrees of freedom, $\chi^2_{14} = 20.68$, P=0.11. Thus using a conventional significance test we accept the hypothesis that the same underlying process drives the observations in both pairs of years, and work from the results for the pooled data-set.

We noted in section 3 that there may a random element affecting people's responses to the survey. However, the fact that we find some structure to the data, as reflected in the statistical significance of the model coefficients, suggests that this random element is not so substantial as to obscure any signal present in the data.

In the interpretation of these results we first discuss the influence of the variables which influence the latent variable. We then move on to a discussion of the interpretation of the latent variable itself. The lower the value of y_{it}, the better is eye-sight. First we can see that eye-sight clearly declines with age and that it is lower for women than for men. Secondly, it is clear that there is considerable persistence in visual acuity. Someone whose eye-sight was excellent in one survey has, in the next survey, on average, eye-sight

Variable	Para-meter	2002/2004 Coef.	2002/2004 S.E.	2004/2006 Coef.	2004/2006 S. E.	Pooled Coef	Pooled S. E.	Pooled P
Age	α_1	0.01	0.00	0.01	0.00	0.01	0.00	0.0%
Prev eye-sight Excel	β_1	-2.66	0.12	-2.88	0.11	-2.76	0.08	0.0%
Prev eye-sight V.G.	β_2	-2.19	0.12	-2.26	0.11	-2.21	0.08	0.0%
Prev eye-sight Good	β_3	-1.69	0.11	-1.67	0.10	-1.68	0.08	0.0%
Prev eye-sight Fair	β_4	-1.03	0.12	-0.80	0.11	-0.92	0.08	0.0%
No Prev Cat	γ_1	0.42	0.08	0.23	0.07	0.31	0.05	0.0%
Prev Untreated Cat	γ_2	0.33	0.08	0.14	0.07	0.23	0.05	0.0%
Cat Op×Excel	δ_1	0.11	0.41	0.40	0.36	0.26	0.17	33.5%
Cat Op×V.G	δ_2	-0.42	0.25	0.01	0.22	-0.18	0.16	28.5%
Cat Op×Good	δ_3	-0.34	0.15	-0.24	0.13	-0.28	0.10	0.5%
Cat Op×Fair	δ_4	-0.37	0.18	-1.17	0.18	-0.77	0.13	0.0%
Cat Op×Poor	δ_5	-1.03	0.26	-1.05	0.23	-1.04	0.17	0.0%
No Curr. Cat	γ_3	-0.49	0.06	-0.35	0.05	-0.40	0.04	0.0%
Sex	α_2	0.05	0.03	0.06	0.03	0.06	0.02	1.3%
Thresholds								
Excellent	y^*_{1t}	-2.21	0.23	-2.48	0.23	-2.34	0.16	
V. Good	y^*_{2t}	-1.05	0.23	-1.28	0.23	-1.17	0.16	
Good	y^*_{3t}	0.31	0.23	0.12	0.23	0.21	0.16	
Fair	y^*_{4t}	1.28	0.23	1.17	0.23	1.21	0.16	
χ^2_{14}			1266.11		1551.85		2797.18	

Table 8: Parameters of the Ordered Probit Model explaining changes to Self-reported Eye-sight Health

2.76 units better than someone whose eye-sight was poor in the first survey. This is important because, in any subjective measurement exercise one might be concerned that people change the way they describe eye-sight which, measured objectively, would be unchanging. It suggests that, while such effects may be present, they do not dominate the data. There are nevertheless questions like whether the way in which people report their eye-sight depends on their activities. People who are keen readers may be more likely to report a given level of resolution as poor than are people who do not use close-up vision very much.

Some care is needed in the interpretation of the various terms relating to cataracts. Someone who had not had a cataract (either treated or untreated) in adjacent surveys benefits from a decline of 0.09 units, $\gamma_1 + \gamma_3$, in y_{it} since the dummy variable E_1 takes a value 1 in both 2002 and 2004, this effect being measured relative to someone who has already had cataract operations by the first survey and for whom $E_{1t-2} = E_{1t} = 0$. Someone who has an untreated cataract in the first survey, and who has not had an operation by the second, suffers by the 0.23 units shown by γ_2, the coefficient on E_{2t-2}. The impact of cataract operations depends on visual acuity before the operation. Someone, who reported an untreated cataract in the first survey, with poor eye-sight, and who was treated by the second, benefits by 1.04 units of acuity, while someone with good eye-sight ahead of surgery, would suffer by 0.3 units of visual acuity. This last term is not statistically significant; one can accept the hypothesis that, both for such patients and for those whose previous eye-sight was very good, the surgery has no short-term effect. The estimated values of $y^*_{1...}y^*_4$ indicate the range of values of y_{it} which results in any particular qualitative response with a value of y_{it} below y^*_1.This allows us to establish whether that qualitative response would be "excellent" etc.

The model is open to the criticism that some of the explanatory variables may be endogenous. Whether people are identified as having a cataract is obviously intimately related to their eye-sight and may be driven by a common underlying and unobserved factor. Similarly, for any given previous level of eye-sight, whether people have cataract operations or not, may depend on what has happened to their eye-sight since their previous interview.

We can examine whether the parameters of the model are significantly affected by endogeneity by estimating probit equations for i) whether someone has a cataract operation as function of their age, sex and initial eye-sight, and ii) whether they have an identified untreated cataract as a function of the same variables. For these two probit equations we calculate generalised residuals (Gourieroux et al. 1987). If, using a conventional χ^2test, these residuals are found to play no significant role when inserted as additional explanatory variables in equation (1), we can use the results of table 8 and do not need to make any corrections for endogeneity (Smith & Blundell 1986). There are six additional explanatory variables, namely the residuals from the cataract equation multiplied by each of the five dummy variables, and the residuals from the equation explaining whether people have developed untreated cataracts since the previous survey. We find that we can accept the hypothesis that all these terms have zero coefficients, $\chi^2_6 = 9.53$, P=0.15, so there is no need to make adjustments for exogeneity.

This model implies that eye-sight depends on previously reported eye-sight and also on whether the subject has untreated or treated cataracts. It also identifies the effect of cataract surgery between two interviews. But it does not address the possibility that beyond the shift terms, γ_1 and γ_2, the dynamics of eye-sight may depend on whether someone lacks evidence of a cataract or, alternatively, has had an earlier cataract operation. We can examine this by fitting the ordered probit equation

$$y_{it} = \alpha_1 Age_{it-2} + a_2 Sex_i + \sum_{j=1}^5 \beta_{jt} D_{jt-2} + \gamma_3 E_{1t} + \sum_{j=1}^5 \delta_{jt} E_{3t} D_{jt-2} + \sum_{j=1}^5 \zeta_{jt} E_{1t-2} D_{jt-2} + \sum_{j=1}^5 \theta_{jt} E_{2t-2} D_{jt-2} + \varepsilon_{it}; \qquad \varepsilon_{it} \sim N(0,1) \tag{2}$$

Here the shift terms associated with no evidence of cataract, $E_{1t-2} = 1$, or untreated cataract, $E_{2t-2} = 1$ are replaced by interactive terms in which each of these is multiplied by the dummy variables which indicate previously reported eye-sight. Thus ζ_{1t} shows the effect of both D_{1t-2} =1 and $E_{1t-2} = 1$, in other words someone has no evidence of cataract and reports excellent eye-sight. Similarly ζ_{5t} shows the effect when D_{5t-2} =1 and $E_{1t-2} = 1$; i.e. someone with no evidence of cataract has reported poor eye-sight in the previous survey. The terms in θ_{jt} show similar effects for people who had untreated cataracts in the previous survey. Since the D_{jt-2} terms cover all respondents, everybody with evidence of cataract falls into one of these five groups, and the term $\gamma_1 E_{1t-2}$ is therefore redundant. The term $\gamma_2 E_{2t-2}$ disappears for the same reason.

This extended model reduces to the earlier one if we can accept the joint hypothesis that $\zeta_{1t} = \zeta_{2t} = \zeta_{3t} = \zeta_{4t} = \zeta_{5t}$ and $\theta_{1t} = \theta_{2t} = \theta_{3t} = \theta_{4t} = \theta_{5t}$. We show the results of the χ^2 test for each equation for each of the two sets of coefficients separately, and also for the joint hypothesis that both sets of coefficients meet the required restrictions. The results in table 9 suggest that the model of equation (1) is satisfactory and that, working at standard levels of significance, there is no substantial evidence pointing to the more complicated dynamic structure of equation (2). The implications of the dynamic structure are discussed further in section 5.

Restriction	Pooled Data	
ζ_{jt} all equal	χ_4^2 =5.51	P=0.24
θ_{jt} all equal	$\chi_4^2 = 8.34$	P=0.08
Both restrictions	$\chi_8^2 = 8.77$	P=0.36

Table 9: Tests to Examine the Pattern of Visual Dynamics

5 Calibration of Results: the Effects of Cataract Surgery on Eye-sight as implied in ELSA

To calibrate our results, in order to find the effects of cataract surgery on welfare, two steps are needed. First of all, we need to relate the various categories identified in ELSA to quantified measures of eye-sight. Secondly we need to relate those quantified measures of eye-sight to more general levels of welfare and thus to quality-adjusted life.

5.1 Calibration of the ELSA Responses to Quantified Measures of Eye-sight

Our parametric analysis of the effects of cataract surgery identified the benefits of this in terms of the latent variable, y_{it}, which is assumed to drive the responses to the question on eye-sight. We therefore need, first of all, to know the average value of this latent variable, conditional on each of the five categorical responses, and before identifying the effects of any particular visual defect or intervention. Since the y_{it} are not observed this needs to be done by simulation. We estimate the unconditional ordered probit equation

$$y_{it} = \alpha_1 Age_{it-2} + a_2 Sex_i + \sum_{j=1}^{4} \beta_{jt} D_{jt-2} + \varepsilon_{it}; \quad \varepsilon_{it} \sim N(0,1)$$

The coefficients are shown in table 10.

In each case the spread of the thresholds, as identified by the difference between the first cut and the fourth cut is almost exactly the same in the conditional cases of table 8 and the unconditional case shown in table 10. Thus we need have no concern about using the unconditional model as a means of calibrating results derived from the conditional model. However, we need to relate these thresholds to measures of visual acuity. We do this by comparing the classification of people in ELSA with the results of studies which measure the visual acuity of the population. Here the ELSA data are weighted

		2004		2006		Pooled		
		Coef.	S.E.	Coef.	S.E.	Coef	S.E.	P-value
Age	α_1	0.02	0	0.01	0	0.02	0	0.0%
Prev. Eye-sight. Excel	β_1	-2.56	0.11	-2.72	0.1	-2.63	0.08	0.0%
Prev Eye-sight V. G.	β_2	-2.08	0.11	-2.1	0.09	-2.09	0.07	0.0%
Prev Eye-sight Good	β_3	-1.57	0.1	-1.52	0.09	-1.54	0.07	0.0%
Prev Eye-sight Fair	β_4	-0.9	0.11	-0.71	0.1	-0.80	0.07	0.0%
Sex	α_2	0.08	0.03	0.07	0.03	0.07	0.02	0.1%
Threshold								
Excellent	y^*_{1t}	-1.79	0.21	-2.07	0.21	-1.95	0.14	
Very Good	y^*_{2t}	-0.63	0.21	-0.88	0.2	-0.78	0.14	
Good	y^*_{3t}	0.71	0.21	0.49	0.2	0.57	0.14	
Fair	y^*_{4t}	1.66	0.21	1.52	0.21	1.56	0.14	
χ^2_6		1174.37		1447.63		2621.29		

Table 10: Parameters of the Unconditional Ordered Probit Model

for non-response which explains the difference between these and the summaries shown in table 4 The data from ELSA are compared in table 11 with data from three studies, namely Wormald et al. (1992), van der Pols et al. (2000) and Evans et al. (2002).

We can see in table 11 that there are more people who suffer from sight 6/18 (logMAR 0.48) or worse than there are those who classify their eye-sight as poor. The position on the relationship between 6/12 eye-sight (LogMAR 0.30) and those who classify their eye-sight as fair or poor is less clear-cut. Looking at the full population of people aged 65 and over, Wormald et al. (1992) find more people in this position than with sight 6/12 or worse. So, too, do Evans et al. (2002) . However, van der Pols et al. (2000) find more people with eye-sight 6/12 or worse than with sight classified as fair or poor.

One further source of information is available. 0.77% of the population aged 65-74 and 5.6% of the population aged 75+ were registered as blind or partially sighted, corresponding to eye-sight worse than 6/60 (logMAR 1). People who are registered as blind or partially sighted are particularly likely to live in care institutions, rather than households, and thus do not feature in ELSA. But this makes it clear that the people on the threshold of fair and poor vision have eye-sight appreciably better than 6/60. While these observations do not allow a precise calibration of each of the thresholds shown in table 10, they do suggest that it would be reasonable to relate the fair/poor threshold, 1.52, to logMAR of 0.7 and the good/fair threshold, 0.49, to logMAR of 0.3. There are further points to bear in mind. An average healthy eye should have 6/4 vision (logMAR -0.18) and maximum acuity is thought to be 6/3 (logMAR -0.30). This suggests it

ELSA- Summary Tabulation					
Age	Excellent	Very Good	Good	Fair	Poor
60+	12.9%	29.7%	39.1%	13.6%	4.7%
65-74	13.7%	31.8%	39.6%	12.0%	2.9%
65+	11.7%	29.0%	39.1%	14.7%	5.4%
75+	9.2%	25.5%	38.6%	18.2%	8.5%
		6/12 or worse	6/18 or worse		
Wormald					
65-74		0.99%	0.99%		
65+		11.6%	7.7%		
75+		19.9%	12.4%		
van der Pols					
65-74		8.6%	2.5%		
65+		22.4%	9.9%		
75+		28.1%	13.2%		
Evans					
75+		19.9%	12.4%		

Table 11: The Distribution of Self-reported and Measured Eye-sight

Scale	**logMAR**
1.56	0.7
0.57	0.3
-0.45	0.1
-1.95	-0.25

Table 12: The relationship between the Eyesight Scale and Visual Acuity

might be reasonable to set the very good/excellent threshold at logMAR -0.25 (6/3.37) An American study (Haegerstrom-Portnoy et al. 1999) suggested that mean eye-sight of people aged 65 and older is considerably worse than logMAR 0. The median is likely to be appreciably closer to 0 because, there is a long tail of people with very poor sight. Interpolation of our subjective distribution between the thresholds of table 10 suggests that the median value on the scale implied by the threshold is -0.46. While, on the one hand Haegerstrom-Portnoy et al. (1999) note that visual acuity is not the only dimension of eye-sight and, on the other hand, that it would be desirable to have specific data to match self-reported eye-sight to measured visual acuity, we summarise these informed conjectures in table 12.

Although there are too few points to give it a statistical interpretation, fitting a regression line through the four points is nevertheless the best way of establishing the average slope that they imply. Such a regression line suggests that an improvement of 1 logMAR unit in visual acuity is associated on average with a reduction of 3.74 units along the eye-sight scale. This offers a basis for calibrating our findings on the influence of cataract surgery on eye-sight.

5.2 The Relationship between Eye-sight and Welfare

To complete our calibration we need to have some view of the relationship between eye-sight and surgery. Brown et al. (2003) explored the relationship between quality of life and visual loss. They interviewed five hundred people with differing levels of visual acuity, asking them first of all for how many more years they expected to live and secondly how many of those years they would be prepared to trade off in exchange for guaranteed permanent normal eye-sight. They stratified the subjects into four categories based on the best-corrected eye-sight in the better-seeing eye, as follows finding the average ratios of life-span with normal eye-sight to actual life-span denoted as utility ratios in table 13. The maximum possible ratio, with normal eye-sight for the rest of expected life is one, and the lower value reflects the risk that, even though people may currently have 6/6 eye-sight, they are not guaranteed that this would persist for the rest of their life. Brown et al. (2003) state that their estimated utility ratios are not significantly dependent on the ages of the respondents.

	Eye-sight (Snellen) Better-seeing Eye	Eye-sight (LogMAR)	Utility Ratio
Group 1	6/6 to 6/7.5	0.048	0.88
Group 2	6/9 to 6/15	0.287	0.81
Group 3	6/20 to 6/30	0.611	0.72
Group 4	6/60 or worse	1.125	0.61

Table 13: Visual Acuity and Utility Ratios

This valuation is probably broadly representative.Althin et al. (2002) constructed an indicator based on the frequency of performing visual activities the ease with which they could be performed rather than one constructed directly by asking people how much of their remaining life they might give up in exchange for 6/6 eye-sight. This indicator gave a score of 0.93 for someone with logMAR 0 vision in both eyes and 0.58 for someone with logMAR 1 vision in both eyes. Drummond (1987) suggested a rather lower QALY value associated with blindness, using 0.36 if the patient had not adapted and 0.48 if the patient had adapted. But Rein et al. (2007) produce figures broadly consistent with Brown et al. (2003), suggesting a ratio of 0.8 for 6/12 vision, 0.75 for 6/20 vision and 0.67 for 6/60 vision.

If we calculate the decrement in utility per unit decline in eye-sight measured by logMAR, we find, with the values shown in table 13, a ratio of 0.25 units of utility per logMAR. If we replace the figure for 6/60 or worse with the utility level of 0.67 mentioned for 6/60, then the ratio falls to 0.22 with a standard deviation of 0.03. These results can be compared with those provided by Kobelt et al. (2002), who finds that a decrement of eye-sight by 1 logMAR unit reduces utility by 0.16 units. It should be noted that Brown et al. (2003) relate their calculations to the better-seeing eye, while Kobelt et al. (2002) compute an overall visual acuity based on 75% of the logMAR score of the better-seeing eye, and 25% of that of the worse eye. On this basis a change of 1 logMAR unit in the better eye would change the overall score by only 0.75 units, and thus utility would change by only 0.12 units.

5.3 Linking ELSA Responses to Welfare

The results of the two preceding sections allow us to calibrate the relationship between the latent variable, which underpins responses to the question on eye-sight in ELSA, and utility. We denote the coefficient linking the change in the utility ratio to one unit of the ELSA scale as u. One logMAR unit is associated with a movement of 3.74 units along the scale identified in ELSA, and one logMAR unit is also associated with a change of 0.22 to the utility ratio. Thus, drawing on the results presented by Brown et al. (2003) $u = 0.22/3.74$=0.059 change to the utility ratio per unit of logMAR while Kobelt et al. (2002) imply a figure of $u = 0.012/3.74$ =0.032. We work with the mid-point of these, u =0.045 but also explore the effects of the implications of the results produced by a lower value so as to examine how far our results might be affected if the benefits of cataract surgery were markedly smaller than implied by our main assumption. The lower value of u cannot provide any basis for a formal confidence limit, but it does offer a subjective indication of the range of uncertainty faced in the calculations.

6 The Effects of Cataract Surgery on Welfare.

Having calibrated our model we are now in a position to identify the effect of cataract surgery on a patient who has a diagnosed cataract as a function of age, sex, and eye-sight reported in the interview before the operation. As with the calibration exercise, this is calculated by simulating the experiences of a large number of people, and comparing the simulated value of y_{it}, for someone who has had cataract surgery, with the value which would have been generated in its absence. In both cases, people are assumed to experience random shocks, but these are assumed to be the same with and without the cataract surgery. Once again, we use in our calculations the coefficients estimated from the pooled data. This simulation approach means that we measure the long-term benefits of cataract surgery relative to the normal deterioration of eye-sight which takes place with age. The impact of the latter is reflected by the *Age* term in the equation (1).

For a patient who is treated between two surveys after an untreated cataract was reported in the previous survey, variable E_1 takes the value 0, and E_2 takes a value 1. E_3 takes a value 1 only if a subject has reported cataract surgery in the interval since the previous interview. Thus the short-term impact of cataract surgery arises from the interaction between E_3 and eye-sight as reported in the previous period. This term enters in the first period of the simulation only. After this it retains some influence because, in the first period, and thus in subsequent periods, it influences the way in which people classify their eye-sight. But one would expect its influence eventually to die out, so that the only long-run influence arises from the fact that E_{1t-2} and E_{1t} for a patient with a treated cataract while they would take values of 1 for a respondent with no evidence of a cataract. This is independent of eye-sight as reported before the cataract operation. Thus a consequence of the finding that the extra interactive terms of equation (2) are not significant, and thus set to zero, is that the long-term influence of cataract surgery is modelled to be independent of self-perceived eye-sight before the surgery[7].

The impact of this for men is shown in figure 1 which identifies the difference in QALY units for people who receive surgery having reported each of the five possible eye-sight states ahead of surgery. It can be seen that, after fifteen years, on the assumption that the patient survives so long, most of the difference associated with pre-surgery health performance has disappeared.

FIGURE 1 HERE PLEASE

Figure 1: The Benefits of Cataract Surgery for Men aged between 60 and 62

The implication of the model that, after the passage of time, the effect of the operation is independent of visual performance immediately before the operation, cannot be tested. Nevertheless, it is entirely coherent with the idea that, on average, cataracts progress, so that, even if people are operated on soon after reported excellent eye-sight, the operation is, on average better described as premature than as unnecessary.

[7] As the longitudinal aspect of ELSA builds up it will be possible to address this question with increasing precision.

$u = 0.045$	Age 60-62		Age 80-82	
	Immediate	Life-time	Immediate	Life-time
Excellent	-0.012	0.21	-0.012	0.05
Very Good	0.008	0.26	0.008	0.10
Good	0.013	0.28	0.013	0.12
Fair	0.035	0.36	0.035	0.19
Poor	0.048	0.42	0.048	0.23
Average	0.020	0.31	0.020	0.14

Table 14: QALY Gain from Cataract Surgery: Men Aged 60-62 and 80-82

$u = 0.045$	Age 60-62		Age 80-82	
	Immediate	Life-time	Immediate	Life-time
Excellent	-0.012	0.24	-0.012	0.07
Very Good	0.008	0.30	0.008	0.12
Good	0.013	0.32	0.013	0.14
Fair	0.035	0.41	0.035	0.21
Poor	0.048	0.47	0.048	0.26
Average	0.020	0.35	0.020	0.16

Table 15: QALY Gain from Cataract Surgery: Women Aged 60-62 and 80-82

We can use the results above to calculate the expected gain in QALYs for someone who has had cataract surgery as a function of their age. In table 14 we show, with $u = 0.045$, both the gain immediately after surgery, and the expected life-time gain, for patients treated at ages 60-62 and 80-82. The equation provides biennial estimates. We interpolate to annual estimates using a cubic spline.

The short-term effects are independent of age and sex. The life-time benefits are calculated using the 2007 interim life tables for England to identify the survival probabilities for men and women. These estimates are calculated on the assumption that subjects have cataract operations just before their 62nd or 82nd birthdays, and that the benefits of the surgery then evolve in the manner implied by the curves shown in figure 1 or their equivalent as appropriate given age and sex. Future QALYs are discounted at $3\frac{1}{2}\%$ p.a., the rate recommended by H.M. Treasury (2003). The table also shows the average value calculated on the assumption that pre-surgery visual performance was distributed as found in the pooled data. The differences between men and women arise almost entirely because of the higher survival rates for women.

The average short-term gain of 0.020 QALYs is consistent with the figure of 0.028 identified by Kobelt et al. (2002) in their study of Swedish patients based on EQ-5D. On the other hand Rasanen et al. (2006) found QALY gains as low as 0.01 as a result of cataract surgery.

In order to calculate cost-benefit ratios these authors have had to assume that the benefits persist as initially recorded, while we are able to make use of the time profile shown in figure 1, or its equivalent, to assess the long-term benefits. The implication of the model is that even patients who derive relatively little short-term gain derive more substantial long-term gain from their surgery. Of course, these benefits of cataract surgery have to be offset against the costs. These are larger than simply those of the operation.

Sach et al. (2007) explored the full range of medical and care costs associated with both treated and untreated cataract patients. They itemised a cost of £672 for each cataract operation in 2004 together with out-patient costs of £1066 for first-eye surgery. Doubling these gives a total of £3476 for surgery to both eyes. Additionally, there is also higher expenditure on personal social services on cataract patients and a higher number of days in hospital than for those who are not treated. But it is not clear that these costs are associated with surgery itself rather than being a consequence of the other circumstances of the patients who happen to need surgery; in particular cataract surgery now is almost universally provided as day surgery. Furthermore, the out-patient costs include those of other hospital visits as well as those associated with cataracts, and the out-patient costs of second-eye surgery are unlikely to be as large as for first-eye surgery. Thus £3476 probably sets a reasonable upper limit to the cost of surgery although there may be other unidentified costs such as those of carers which might be higher for those who are operated on than those who are not. .

To balance these costs against the benefits, we need to value a QALY. The National Institute of Clinical Excellence[8] used a value of £30,000 in 2008, while Mason et al. (2009) present a range of calculations in 2005 prices which suggest values of between £30,000 and £70,000. Since there is little point in pretending that a precise calculation is possible, we assess the benefits on the assumption that, in 2004 prices, a QALY is valued at £40,000.

Table 14 then implies that surgery is worthwhile for both men and women aged 60-62. Even a man who reports his excellent vision should expect a life-time benefit of £8,400 as compared with the cost of £3,476. For patients aged 80-82 the benefit exceeds

[8] The National Institute of Clinical Excellence states,

"there should be increasingly strong reasons for accepting as cost effective interventions with an incremental cost-effectiveness ratio of over £30,000 per QALY" (National Institute of Clinical Excellence 2008, Chapter 8, p. 54)

£4,000, unless these patients previously report their sight as excellent. As patients age, the case for treating those who report reasonable vision diminishes. But for people who report their eye-sight as fair or poor which we translate as logMAR 0.3, Snellen 6/12, or worse (see section 5.1) the expected benefits of cataract surgery outweigh the costs for anyone who has a life expectancy of about two and a half years or more. The 2006-2008 life tables point to the operation being worthwhile for men up to the age of ninety-six and women up to the age of ninety-seven. These calculations assume, of course, that all the benefits accrue as a result of the increased welfare derived from improved eye-sight. To the extent that there are other benefits, such as the reduced risk of falling identified by Sach et al. (2007), the calculations may understate the true benefit.

Inevitably these results are sensitive to the value of u. A value of u of 0.032, derived from Kobelt et al. (2002), rather than 0.045, implies that the benefits fall by just under 30%. This raises the required life expectancy for surgery to be worthwhile, for those with fair or poor eye-sight, to about four years, i.e. for men aged ninety and women aged ninety-one.

However, there are two other reasons for thinking that these figures may be on the cautious side. First of all patients may benefit in ways which the QALY-based measure does not recognise. For example Sach et al. (2007) found that patients operated on for cataract were less likely to fall than were those in a control group who did not receive surgery. Secondly, despite our inability to find significant endogeneity influences as a result of selection for cataract surgery, it is quite possible that the patients treated between the surveys are those in most need of surgery, and therefore those whose sight has deteriorated most between the previous survey and their operations. Nevertheless, as was noted earlier, even among patients selected for surgery Leinonen & Laatikainen (1999) found that 48% of patients experienced no or minimal deterioration in an average waiting time of thirteen months; it is therefore possible that some of the treated patients both gained little from their surgery and also would not have deteriorated further without surgery.

Finally, we have to note that, even though these figures point to surgery, as it is carried out, being well worth while on average, any means of identifying in advance the patients who are not going report improved eye-sight after surgery would offer a means of improving the benefit-cost ratio. To the extent that surgery is premature, identification of such patients would also lead to an improvement. Such analysis is beyond the scope of the survey; while 5.6% of the patients reported their eye-sight as excellent ahead of surgery, a survey of this type obviously does not reveal any particular circumstances which might explain why they were nevertheless operated on when they were. One obviously possibility is that their eye-sight had deteriorated fairly rapidly between responding to ELSA and the date of their operations.

7 Conclusions

The key contribution of this paper is to show that data on self-reported health status, in this case with respect to eye-sight, collected in a general-purpose panel survey, can be used to examine the benefits of medical interventions, so as to work out the expected gain in welfare resulting from such interventions. Obviously surveys of this type can be used only for procedures which are widespread, since the sample has to contain enough cases for meaningful statistical analysis to be possible. But for an intervention as common as cataract surgery, the short-term benefits identified are coherent with what has been found in specific studies conducted using quite different approaches to data collection. As the ELSA panel develops, it will be possible to explore in more detail whether, following cataract surgery, the eye-sight of patients evolves in a manner similar to, or different from, that of people who have not suffered from cataract. It may also be possible to use ELSA to explore other medical interventions.

The results point to cataract surgery being generally good value in terms of benefits net of costs except for very elderly patients whose eye-sight is good or better than good at the time of their operations. Overall it seems unlikely that there is considerable over-use of cataract surgery. There may, nevertheless, be other areas of the National Health Service where the excess of benefits above costs of treatment would be higher and that might justify some reduction the number of operations.

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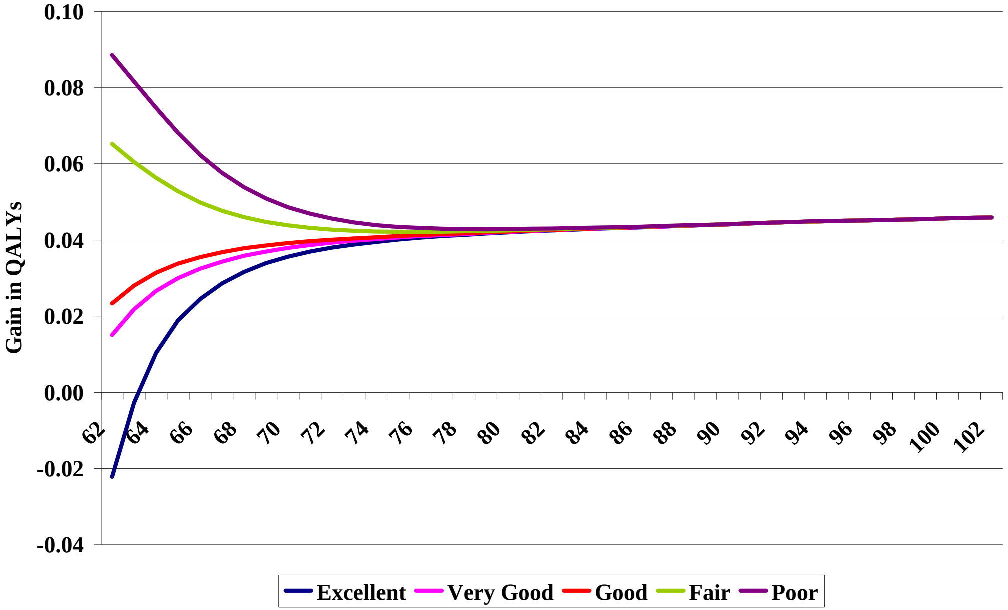

Figure 1: The Benefits of Cataract Surgery for Men aged between 60 and 62