

## ESTIMATING EXPECTED HEALTH OPPORTUNITY COSTS IN THE NHS

### (Analysis of 2012/13 Expenditure Data)

#### YORK TEAM

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## Summary

This document comprises of two appendices:

### Summary of Appendix 1: Outline of data update, estimation strategy, and results for outcome and expenditure models for 2012/13

#### Starting point: the 2011/12 specification

1. Identify the preferred specification for the outcome and expenditure equation for each programme budget category (PBC) for 2011/12. The outcome and expenditure elasticities generated by these specifications are shown in Table 1.

#### Re-estimate the 2011/12 specifications using updated data

2. The 2011/12 specifications have been derived using a combination PCT-level data mapped to LA-level and direct LA-level data. Update PCT-level data to 2012/13 and put updated PCT-level data through the appropriate mapper to obtain LA-level data. This will include updating and mapping:

- the PB expenditure data from 2011/12 to 2012/13
- the raw population, unified weighted population, and MFF estimates used and implied from the 2012/13 DH resource allocation exposition book
- PB specific indices of need (eg infectious diseases, mental health, maternity) from the DH resource allocation exposition book (where possible).

The PB specific disease prevalence rates as extracted from the HSCIC's QOF database are reported for 2012/13 at CCG-level and not PCT-level. Therefore we use values for the previous year (2011/12); these were reported at PCT-level.

3. Obtain LA-level statistics for those variables that are reported at this unit of analysis. This will involve updating LA-level data for 2011/12 to 2012/13. This will include updating:

- mortality data for 2011/12/13 with data for 2012/13/14.

Ideally, we should like to update the Census-based variables for 2011 to 2012, but values for the latter year are not available. Here we use values for 2011 (i.e., values obtained by the Census for that year). This approach (i.e., using the most recent census value) is identical to the one adopted in previous work where we did not have two Census values (eg for 2001 and 2011) to interpolate between.

#### Estimation strategy for 2012/13: same as for 2011/12

4. Having updated all data (where possible), use the preferred specification for 2011/12 to re-estimate each outcome and expenditure equation for 2012/13.

5. If this re-estimation produces a result which (a) passes the appropriate statistical tests and (b) generates coefficients in line with theoretical priors, use this result as our preferred result for 2012/13. This rule is applied to cases where the preferred specification for 2011/12 is either IV or OLS. If this re-estimation produces an acceptable result, the resulting elasticity shown in Table 1 has a '--' in the next column.

6. If the re-estimation produces a result which does not pass tests/have coefficients in line with priors, re-estimate the equation having adjusted the specification as suggested by the initial result. So, for example, if the initial estimation implies the presence of weak instruments and one of the instruments is insignificant in the first-stage regression, try re-estimating the equation without the insignificant instrument. And if, for example, one of the regressors in the second-stage regression is insignificant, try re-estimating without it. If this re-estimation produces an acceptable result, the resulting elasticity shown in Table 1 has an 'A' in the next column.
7. If a relatively minor adjustment to the 2011/12 specification does not generate a statistically and theoretically acceptable result, re-derive the IV equation to be estimated (again, this applies to cases where the preferred specification for 2011/12 is either IV or OLS). That is, use OLS with backward stepwise regression to identify relevant covariates to be included in the second-stage regression having forced in the relevant variables throughout. For the outcome equation we force in own programme expenditure, and for the expenditure equation the other programme need variable and the total budget term are forced in throughout the stepwise procedure.
8. Having identified relevant covariates for the second-stage regression, again use stepwise backward regression to identify relevant instruments for the first-stage conditioning on the covariates for the second-stage identified above. In other words, these second-stage covariates are forced in throughout stepwise procedure to identify relevant instruments.
9. Having identified covariates for the second-stage (in 7 above) and instruments for the first-stage (in 8 above), re-estimate the IV specification equation using these two sets of variables. If the endogeneity test suggests that a variable (eg own programme expenditure in the outcome equation) is clearly not endogenous then re-estimate using OLS. If this re-estimation produces an acceptable result, the resulting elasticity shown in Table 1 has a 'B' in the next column.
10. If the above re-estimation approach produces a result which does not pass tests/have coefficients in line with priors, re-estimate the equation having adjusted the specification as suggested by the initial result (for example, if the result fails the misspecification test try adding the squared value of one of the regressors to the specification). If this re-estimation produces an acceptable result, the resulting elasticity shown in Table 1 has a 'C' in the next column.
11. If all of the above approaches fail to produce an acceptable result, consider excluding PCTs with extreme values of expenditure per person. Only explore this option for programmes with small amounts of expenditure and/or mortality. If this re-estimation approach produces an acceptable result, the resulting elasticity shown in Table 1 has a 'D' in the next column.
12. The estimation strategy outlined above generated the outcome and expenditure elasticities for 2012/13 shown in Table 1.
13. The full result [IV (second-stage) or OLS] associated with each elasticity reported in Table 1 can be found in Table A3 (for the outcome equations) and Table A4 (for the expenditure equations) in the appendix.
14. The full estimation path for each result (starting with the re-estimation of the 2011/12 specification with updated data) can be found in Table A5 (for the outcome equations) and Table A6 (for the expenditure equations) in the appendix.

Table 1 Outcome and expenditure elasticities for 2008/09, 2009/10, 2010/11, 2011/12 and 2012/13

PBC #	PBC description	for 2008/09				for 2009/10				for 2010/11				for 2011/12				for 2012/13			
		Outcome elasticity	Re-est. n/a	Spend elasticity	Re-est. OLS	Outcome elasticity	Re-est. A	Spend elasticity	Re-est. A	Outcome elasticity	Re-est. A	Spend elasticity	Re-est. B	Outcome elasticity	Re-est. B	Spend elasticity	Re-est. A	Outcome elasticity	Re-est. B	Spend elasticity	Re-est. A
1	Infectious diseases	-0.466**	IV	1471**	OLS	-0.310*	A	0.968***	-	-0.256	A	1006***	-	-0.305***	B	0.841**	-	-0.362***	-	0.749***	-
2	Cancers and tumours	-0.287***	IV	0.518*	IV	-0.345***	-	0.502**	A	-0.220***	-	0.438	-	-0.430***	A	0.961**	-	-0.361**	-	1027***	-
3	Diseases of the blood	n/a		1071**	OLS	n/a		1060***	B	n/a		0.332	B	n/a		0.876***	-	n/a		1119***	-
4	Endocrine, nutritional, metabolic	-0.746*	IV	0.367	IV	-1075**	A	0.708***	-	-0.174	B	0.696***	C	-0.199	-	1116***	A	-0.499	B	0.951**	A
5	Mental health disorders	n/a		0.995***	OLS	n/a		0.899***	-	n/a		0.973***	-	n/a		1194***	-	n/a		1023***	-
6	Learning disability	n/a		0.037	IV	n/a		0.647**	B	n/a		1208**	C	n/a		0.741†	D	n/a		0.000	B
7	Neurological problems	-0.304	IV	0.897***	IV	-1357	C	0.850***	-	-0.374	C	0.557***	A	-1415	C	0.703***	A	-0.009	B	0.856***	-
8	Vision problems	n/a		0.503	IV	n/a		0.934***	A	n/a		0.997***	-	n/a		1279***	-	n/a		1411**	-
9	Hearing problems	n/a		1223	OLS	n/a		1273***	C	n/a		0.808*	-	n/a		1231**	C	n/a		1523***	-
10	Circulatory problems	-1384***	IV	0.614	IV	-1842***	-	0.494*	-	-1692***	-	1013***	B	-1611**	-	1491**	-	-1464***	-	1285***	A
11	Respiratory problems	-1940***	IV	0.752**	IV	-2103***	B	0.576***	-	-2006**	A	1192***	A	-1743***	-	1360***	A	-1704***	A	0.928***	-
12	Dental problems	n/a		0.404**	OLS	n/a		0.765***	B	n/a		0.229	B	n/a		0.843***	C	n/a		0.855***	B
13	Gastro-intestinal problems	-1553**	IV	0.520*	IV	-1989*	A	0.387*	-	-1425**	A	1040***	A	-2000**	A	1033***	A	-1904**	A	0.997***	-
14	Skin problems	n/a		0.677**	IV	n/a		0.890***	D	n/a		0.422*	B	n/a		0.681**	A	n/a		1158***	A
15	Musculo-skeletal problems	n/a		0.413	IV	n/a		0.295	B	n/a		0.489**	C	n/a		0.456**	C	n/a		0.725***	-
16	Trauma and injuries	0	n/a	1344***	OLS	0	B	1090***	-	-0.064	-	0.589**	A	0	B	1024***	A	0	n/a	1058***	-
17	Genito-urinary problems	-0.346	IV	0.733***	OLS	-2997	B	0.878***	-	-2.83	B	0.631**	A	-0.494	A	0.598***	-	-0.160	C	0.855***	-
18	Maternity and reproductive health	0.043	IV	0.963***	IV	-0.166*	B	0.653***	-	-0.04	B	0.342	-	-0.136	A	0.481**	A	-0.106	-	0.833***	-
19	Neonates																				
20	Poisoning and adverse events	n/a		0.674*	IV	n/a		0.658**	-	n/a		1078**	A	n/a		0.631**	-	n/a		1124***	-
21	Healthy individuals	n/a		0.952	OLS	n/a		1246**	-	n/a		1359**	A	n/a		1748***	-	n/a		1172***	A
22	Social care needs	n/a		0.830	OLS	n/a		0.844	B	n/a		1592**	-	n/a		1859***	-	n/a		1613***	A
23	Other (includes GM S/PMS)	n/a		0.494***	OLS	n/a		0.564***	B	n/a		0.520***	-	n/a		0.518***	A	n/a		0.585***	-

Notes: (i) see pp1-2 of text for the meaning of the symbols in 're-estimation' columns;  
(ii) there are no 're-estimation' columns for 2008/09 because these results were obtained by re-estimating preferred PCT-level specifications using LA-level data for this year (i.e., there were no changes to model specification).

## **Summary of Appendix 2: Expected health opportunity costs in the NHS (2012/13 results)**

### **Overview**

15. In the second appendix results are presented that reflect the available data for 2012/13 expenditure (this forms Appendix 2.1). In Appendix 2.2, the results are also analysed in terms of how sensitive the results are to two key inputs: i) each of the estimated elasticities and ii) assumptions made in order to overcome data limitations for each PBC (only have mortality outcome data and for only a portion of PBCs). Finally, Appendix 2.3 briefly considers an update regarding data from ONS used to inform burden of disease.

### **Results**

16. Results are presented in two ways as the point estimate of the cost per QALY of marginal activity in the NHS, or alternatively expressed as the expected QALY health opportunity cost for £10,000,000 expenditure.

Table 2 results for 2012/13 expenditure compared to previously generated results

2008/09 (re-applied PCT model)	Point estimate (deterministic)	Point estimate (probabilistic)	5th percentile	95th percentile
Cost per QALY	£12,311	£12,570	£7,820	£32,666
Health opportunity costs of £10mn (QALYs)	812	796	306	1,279

2009/10	Point estimate (deterministic)	Point estimate (probabilistic)	5th percentile	95th percentile
Cost per QALY	£9,887	£9,920	£6,802	£17,296
Health opportunity costs of £10mn (QALYs)	1,011	1,008	578	1,470

2010/11	Point estimate (deterministic)	Point estimate (probabilistic)	5th percentile	95th percentile
Cost per QALY	£10,225	£10,214	£7,073	£17,153
Health opportunity costs of £10mn (QALYs)	978	979	583	1,414

2011/12	Point estimate (deterministic)	Point estimate (probabilistic)	5th percentile	95th percentile
Cost per QALY	£8,997	£8,985	£6,520	£13,945
Health opportunity costs of £10mn (QALYs)	1,112	1,113	717	1,534

2012/13	Point estimate (deterministic)	Point estimate (probabilistic)	5th percentile	95th percentile
Cost per QALY	£14,410	£14,411	£11,182	£19,861
Health opportunity costs of £10mn (QALYs)	694	694	504	894

It can be seen from Table 2 that the expected health opportunity costs of a change in expenditure have decreased slightly between 2011/12 and 2012/13 and so the cost per QALY ratio has risen. The health opportunity costs of £10mn are greater than those estimated using 2008/9 data with the re-applied specifications from the PCT model. In this table, the uncertainty associated with these estimates is shown and it can be judged to what extent any changes in the point estimate between years should be interpreted as a signal of any trend. From Table 2 it is hard to conclude that there is a significant change in the health opportunity costs of £10mn expenditure, since there is a great deal of overlap between the 90% confidence intervals of the years shown.

Figure 1 Results illustrating uncertainty for 2012/13 and previously generated results – cost per QALY

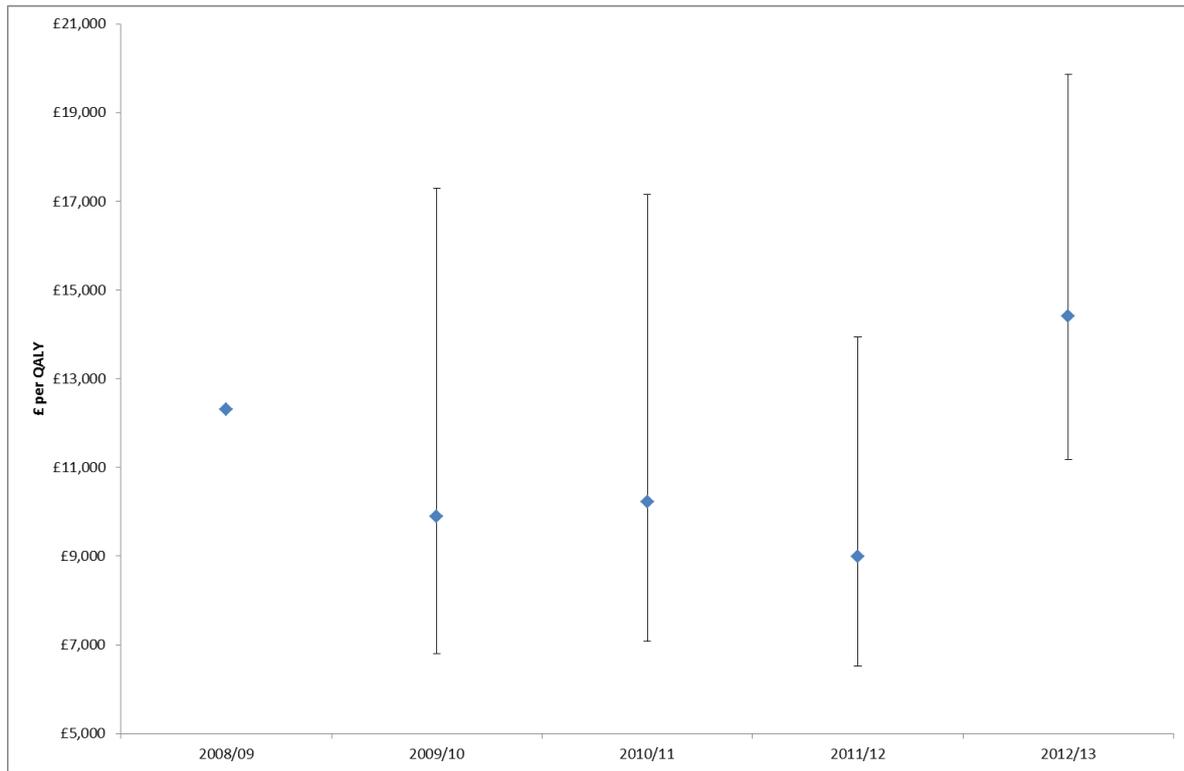
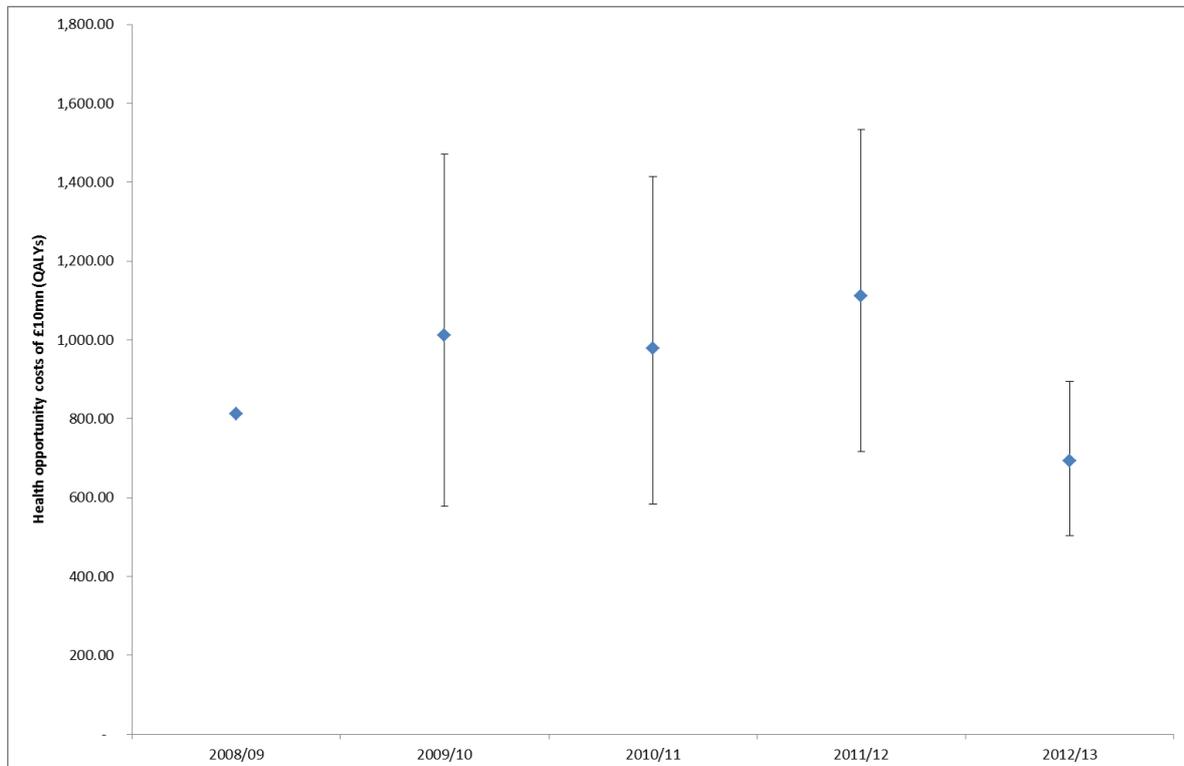


Figure 2 Results illustrating uncertainty for 2012/13 and previously generated results – Health opportunity costs of £10mn (QALYs)



17. The results contained within Table 2 are also represented graphically in Figures 1 and 2. The confidence intervals are presented for results pertaining to 2009/10 elasticities, 2010/11 elasticities, 2011/12 elasticities and 2012/13 elasticities, but not for 2008/9 elasticities. The reason for this is that the specifications used for 2009/10, 2010/11, 2011/12 and 2012/13 equations were adjusted if a re-application of the previous year's specifications resulted in poor statistical performance (see Appendix 1). The specification of the 2008/9 models, however, were directly taken from Claxton et al. (2015) where there were two key differences: analysis was at PCT and not LA level and census variables used 2001 values not 2008 values (calculated by interpolation between 2001 and 2011 census data). As such, the specification in the 2008/9 models may not have passed all statistical performance tests once moved to LA level and the instruments were updated to 2008 values (e.g. 2008/9 specification may possess weak instruments that lead to imprecise coefficient estimation).

18. It can also be seen from Figures 1 and 2 that while the confidence interval is far from symmetrically distributed around the point estimate of the cost per QALY ratio in Figure 1 (where uncertainty is reflected in the denominator), when expressed as health opportunity costs per £10mn then the distribution of uncertainty is much more symmetric in Figure 2 (uncertainty is reflected in the numerator).

### **Sensitivity analysis**

19. Appendix 2.2 details three sensitivity analyses that were performed. The first two concerned the elasticities that were econometrically estimated for each of the PBCs. In the first case each of the estimated PBC outcome elasticities are varied by +/- 1 standard error. Then, the difference between the two resulting opportunity costs is presented. When this is larger, this implies that the overall resulting estimate of health opportunity costs is more sensitive to the outcome elasticity under consideration. The same procedure is then carried out for each of the PBC expenditure elasticities. The results of these sensitivity analyses are reported in Tables 3 and 4, with analysis and interpretation found in Appendix 2.2.

Table 3 Sensitivity of results to estimated outcome elasticities

	Change in spend	Change in QALY death + QALY alive	Implied PBC cost per QALY (£)	Difference in health opportunity costs between +1 SE and -1 SE in PBC outcome elasticity	% difference in health opportunity costs between +1 SE and -1 SE in PBC outcome elasticity	Importance of PBC (rank)	Importance of PBC (rank) 2011/12	Importance of PBC (rank) 2010/11	Importance of PBC (rank) 2009/10
2 Cancer	£ 662,897.55	42	£ 15,898.57	52	7.48%	5	5	7	7
10 Circulatory	£ 1,007,028.41	138	£ 7,274.40	88	12.71%	3	3	3	3
11 Respiratory	£ 494,916.09	205	£ 2,411.65	134	19.31%	1	2	1	2
13 Gastro-intestinal	£ 539,720.67	84	£ 6,432.45	96	13.85%	2	4	4	4
1 Infectious diseases	£ 131,518.91	3	£ 40,830.94	2	0.27%	8	8	8	8
4 Endocrine	£ 330,707.15	31	£ 10,523.80	46	6.59%	6	6	6	5
7 Neurological	£ 431,954.90	2	£ 256,923.73	73	10.54%	4	1	2	1
17 Genito-urinary	£ 463,947.64	1	£ 707,660.45	11	1.57%	7	7	5	6
16 Trauma & injuries*	£ 447,083.30	0	N/A	-	-	-	-	-	-
18+19 Maternity & neonates*	£ 424,516.42	0	£ 4,731,851.32	0	0.03%	9	9	9	9
3 Disorders of Blood	£ 146,330.91	20	£ 7,189.07	-	-	-	-	-	-
5 Mental Health	£ 1,311,251.36	92	£ 14,289.44	-	-	-	-	-	-
6 Learning Disability	£ -	0	N/A	-	-	-	-	-	-
8 Problems of Vision	£ 369,173.21	9	£ 41,341.39	-	-	-	-	-	-
9 Problems of Hearing	£ 78,811.30	17	£ 4,510.01	-	-	-	-	-	-
12 Dental problems	£ 348,207.85	11	£ 31,506.40	-	-	-	-	-	-
14 Skin	£ 276,255.90	3	£ 84,740.12	-	-	-	-	-	-
15 Musculo skeletal	£ 440,252.82	33	£ 13,545.60	-	-	-	-	-	-
20 Poisoning and AE	£ 125,330.07	2	£ 78,625.37	-	-	-	-	-	-
21 Healthy Individuals	£ 242,347.45	1	£ 346,536.63	-	-	-	-	-	-
22 Social Care Needs	£ 612,797.70	0	N/A	-	-	-	-	-	-
23 Other	£ 1,114,950.40	0	N/A	-	-	-	-	-	-

Total: 694

Table 4 Sensitivity of overall results to estimated spend elasticities

	Change in spend	Change in QALY death + QALY alive	Implied PBC cost per QALY (£)	Difference in health opportunity costs between +1 SE and -1 SE in PBC spend elasticity	% difference in health opportunity costs between +1 SE and -1 SE in PBC spend elasticity	Importance of PBC (rank)	Importance of PBC (rank) 2011/12	Importance of PBC (rank) 2010/11	Importance of PBC (rank) 2009/10
2 Cancer	£ 662,897.55	42	£ 15,898.57	8	1.22%	12	9	3	12
10 Circulatory	£ 1,007,028.41	138	£ 7,274.40	33	4.79%	2	5	2	2
11 Respiratory	£ 494,916.09	205	£ 2,411.65	69	9.90%	1	2	1	1
13 Gastro-intestinal	£ 539,720.67	84	£ 6,432.45	15	2.18%	9	15	20	10
1 Infectious diseases	£ 131,518.91	3	£ 40,830.94	7	1.00%	14	12	12	15
4 Endocrine	£ 330,707.15	31	£ 10,523.80	1	0.11%	21	13	11	14
7 Neurological	£ 431,954.90	2	£ 256,923.73	18	2.53%	6	1	21	3
17 Genito-urinary	£ 463,947.64	1	£ 707,660.45	14	1.95%	10	10	10	11
16 Trauma & injuries*	£ 447,083.30	0	N/A	16	2.24%	8	7	7	5
18+19 Maternity & neonates*	£ 424,516.42	0	£ 4,731,851.32	17	2.50%	7	6	6	4
3 Disorders of Blood	£ 146,330.91	20	£ 7,189.07	5	0.66%	18	21	18	22
5 Mental Health	£ 1,311,251.36	92	£ 14,289.44	0	0.05%	22	18	22	13
6 Learning Disability	£ -	0	N/A	8	1.19%	13	11	8	9
8 Problems of Vision	£ 369,173.21	9	£ 41,341.39	6	0.80%	16	16	17	17
9 Problems of Hearing	£ 78,811.30	17	£ 4,510.01	6	0.81%	15	19	13	20
12 Dental problems	£ 348,207.85	11	£ 31,506.40	5	0.70%	17	17	15	16
14 Skin	£ 276,255.90	3	£ 84,740.12	9	1.28%	11	14	14	18
15 Musculo skeletal	£ 440,252.82	33	£ 13,545.60	1	0.14%	20	22	19	21
20 Poisoning and AE	£ 125,330.07	2	£ 78,625.37	3	0.46%	19	20	16	19
21 Healthy Individuals	£ 242,347.45	1	£ 346,536.63	18	2.56%	5	8	9	8
22 Social Care Needs	£ 612,797.70	0	N/A	23	3.27%	4	4	5	6
23 Other	£ 1,114,950.40	0	N/A	25	3.62%	3	3	4	7

Total: 694

20. Following these two sensitivity analyses, a third is performed with a different emphasis, which analyses the sensitivity of the overall health opportunity cost estimate to two key assumptions:

*Surrogacy*- we are required to make an assumption about how the effect on mortality for PBCs with a mortality indicator can be used as a *surrogate* for the effect that expenditure has on morbidity (or health-related quality of life) in those PBCs.

*Extrapolation*- We are required to make an assumption about how the estimated effects on mortality found for PBCs with a mortality indicator can be *extrapolated* to the effect that expenditure has on mortality for those PBCs that do not have a mortality indicator.

In order to assess the impact of these assumptions on the overall results for the NHS, we evaluate the health effects of £10mn spending at the margin in the NHS when either:

- a) For PBCs with a mortality indicator: no surrogacy assumption, therefore expenditure has no effect on morbidity
- b) For PBCs without a mortality indicator: assume no health effects at all, neither on mortality (extrapolation assumption) nor morbidity (surrogacy assumption)

The results are found here in Table 5. Interpretation and analysis is found in Appendix 2.2.

Table 5 Sensitivity of overall results to surrogacy and extrapolation assumptions

	Change in spend	Change in QALY death	Change in QALY alive	Health opportunity costs sensitivity to mortality/morbidity assumption (%)	Importance of PBC (rank)	Importance of PBC (rank) 2011/12	Importance of PBC (rank) 2010/11	Importance of PBC (rank) 2009/10
2 Cancer	£ 662,897.55	39	3	-0.43%	12	12	18	16
10 Circulatory	£ 1,007,028.41	97	42	-6.00%	4	5	4	5
11 Respiratory	£ 494,916.09	11	194	-27.93%	1	1	1	2
13 Gastro-intestinal	£ 539,720.67	32	52	-7.51%	3	4	3	6
1 Infectious diseases	£ 131,518.91	1	2	-0.36%	13	15	14	13
4 Endocrine	£ 330,707.15	2	30	-4.26%	6	10	11	4
7 Neurological	£ 431,954.90	0	2	-0.24%	14	2	5	1
17 Genito-urinary	£ 463,947.64	0	1	-0.07%	17	18	10	10
16 Trauma & injuries*	£ 447,083.30	0	0	0.00%	-	-	-	-
18+19 Maternity & neonates*	£ 424,516.42	0	0	0.00%	18	19	19	19
3 Disorders of Blood	£ 146,330.91	1	19	-2.93%	7	7	9	7
5 Mental Health	£ 1,311,251.36	8	84	-13.22%	2	3	2	3
6 Learning Disability	£ -	0	0	0.00%	19	13	12	15
8 Problems of Vision	£ 369,173.21	0	9	-1.29%	10	11	8	12
9 Problems of Hearing	£ 78,811.30	0	17	-2.52%	8	8	7	8
12 Dental problems	£ 348,207.85	0	11	-1.59%	9	9	13	11
14 Skin	£ 276,255.90	1	2	-0.47%	11	14	16	14
15 Musculo skeletal	£ 440,252.82	2	31	-4.68%	5	6	6	9
20 Poisoning and AE	£ 125,330.07	0	1	-0.23%	15	17	15	17
21 Healthy Individuals	£ 242,347.45	0	1	-0.10%	16	16	17	18
22 Social Care Needs	£ 612,797.70	0	0	0.00%	-	-	-	-
23 Other	£ 1,114,950.40	0	0	0.00%	-	-	-	-
Total:		194	500					
Total change in QALY death + QALY alive			694					

## **Appendix 1: Outline of data update, estimation strategy, and results for outcome and expenditure models for 2012/13**

### **Starting point: the 2011/12 specification**

21. Identify the preferred specification for the outcome and expenditure equation for each programme budget category (PBC) for 2011/12. The outcome and expenditure elasticities generated by these specifications are shown in Table A1.

### **Re-estimate the 2011/12 specifications using updated data**

22. The 2011/12 specifications have been derived using a combination PCT-level data mapped to LA-level and direct LA-level data. Update PCT-level data to 2012/13 and put updated PCT-level data through the appropriate mapper to obtain LA-level data. This will include updating and mapping:

- the PB expenditure data from 2011/12 to 2012/13
- the raw population, unified weighted population, and MFF estimates used and implied from the 2012/13 DH resource allocation exposition book
- PB specific indices of need (eg infectious diseases, mental health, maternity) from the DH resource allocation exposition book (where possible).

The PB specific disease prevalence rates as extracted from the HSCIC's QOF database are reported for 2012/13 at CCG-level and not PCT-level. Therefore we use values for the previous year (2011/12); these were reported at PCT-level.

23. Obtain LA-level statistics for those variables that are reported at this unit of analysis. This will involve updating LA-level data for 2011/12 to 2012/13. This will include updating:

- mortality data for 2011/12/13 with data for 2012/13/14.

Ideally, we should like to update the Census-based variables for 2011 to 2012, but values for the latter year are not available. Here we use values for 2011 (i.e., values obtained by the Census for that year). This approach (i.e., using the most recent census value) is identical to the one adopted in previous work where we did not have two Census values (eg for 2001 and 2011) to interpolate between.

### **Estimation strategy for 2012/13: same as for 2011/12**

24. Having updated all data (where possible), use the preferred specification for 2011/12 to re-estimate each outcome and expenditure equation for 2012/13.

25. If this re-estimation produces a result which (a) passes the appropriate statistical tests and (b) generates coefficients in line with theoretical priors, use this result as our preferred result for 2012/13. This rule is applied to cases where the preferred specification for 2011/12 is either IV or OLS. If this re-estimation produces an acceptable result, the resulting elasticity shown in Table A1 has a '--' in the next column.

26. If the re-estimation produces a result which does not pass tests/have coefficients in line with priors, re-estimate the equation having adjusted the specification as suggested by the initial result.

So, for example, if the initial estimation implies the presence of weak instruments and one of the instruments is insignificant in the first-stage regression, try re-estimating the equation without the insignificant instrument. And if, for example, one of the regressors in the second-stage regression is insignificant, try re-estimating without it. If this re-estimation produces an acceptable result, the resulting elasticity shown in Table A1 has an 'A' in the next column.

27. If a relatively minor adjustment to the 2011/12 specification does not generate a statistically and theoretically acceptable result, re-derive the IV equation to be estimated (again, this applies to cases where the preferred specification for 2011/12 is either IV or OLS). That is, use OLS with backward stepwise regression to identify relevant covariates to be included in the second-stage regression having forced in the relevant variables throughout. For the outcome equation we force in own programme expenditure, and for the expenditure equation the other programme need variable and the total budget term are forced in throughout the stepwise procedure.

28. Having identified relevant covariates for the second-stage regression, again use stepwise backward regression to identify relevant instruments for the first-stage conditioning on the covariates for the second-stage identified above. In other words, these second-stage covariates are forced in throughout stepwise procedure to identify relevant instruments.

29. Having identified covariates for the second-stage (in 27 above) and instruments for the first-stage (in 28 above), re-estimate the IV specification equation using these two sets of variables. If the endogeneity test suggests that a variable (eg own programme expenditure in the outcome equation) is clearly not endogenous then re-estimate using OLS. If this re-estimation produces an acceptable result, the resulting elasticity shown in Table A1 has a 'B' in the next column.

30. If the above re-estimation approach produces a result which does not pass tests/have coefficients in line with priors, re-estimate the equation having adjusted the specification as suggested by the initial result (for example, if the result fails the misspecification test try adding the squared value of one of the regressors to the specification). If this re-estimation produces an acceptable result, the resulting elasticity shown in Table A1 has a 'C' in the next column.

31. If all of the above approaches fail to produce an acceptable result, consider excluding PCTs with extreme values of expenditure per person. Only explore this option for programmes with small amounts of expenditure and/or mortality. If this re-estimation approach produces an acceptable result, the resulting elasticity shown in Table A1 has a 'D' in the next column.

32. The estimation strategy outlined above generated the outcome and expenditure elasticities for 2012/13 shown in Table A1.

33. The full result [IV (second-stage) or OLS] associated with each elasticity reported in Table A1 can be found in Table A4 (for the outcome equations) and Table A5 (for the expenditure equations) in the appendix.

34. The full estimation path for each result (starting with the re-estimation of the 2011/12 specification with updated data) can be found in Table A6 (for the outcome equations) and Table A7 (for the expenditure equations) in the appendix.

Table A1 Outcome and expenditure elasticities for 2008/09, 2009/10, 2010/11, 2011/12 and 2012/13

PBC #	PBC description	for 2008/09				for 2009/10				for 2010/11				for 2011/12				for 2012/13			
		Outcome elasticity	Re-est. n/a	Spend elasticity	Re-est. OLS	Outcome elasticity	Re-est. A	Spend elasticity	Re-est. -	Outcome elasticity	Re-est. -	Spend elasticity	Re-est. B	Outcome elasticity	Re-est. B	Spend elasticity	Re-est. -	Outcome elasticity	Re-est. -	Spend elasticity	Re-est. -
1	Infectious diseases	-0.466**	IV	1471**	OLS	-0.310*	A	0.968***	-	-0.256	A	1006***	-	-0.305***	B	0.841**	-	-0.362***	-	0.749***	-
2	Cancers and tumours	-0.287***	IV	0.518*	IV	-0.345***	-	0.502**	A	-0.220***	-	0.438	-	-0.430***	A	0.961**	-	-0.361**	-	1027***	-
3	Diseases of the blood	n/a		1071**	OLS	n/a		1060***	B	n/a		0.332	B	n/a		0.876***	-	n/a		1119***	-
4	Endocrine, nutritional, metabolic	-0.746*	IV	0.367	IV	-1075**	A	0.708***	-	-0.174	B	0.696***	C	-0.199	-	1116***	A	-0.499	B	0.951**	A
5	Mental health disorders	n/a		0.995***	OLS	n/a		0.899***	-	n/a		0.973***	-	n/a		1194***	-	n/a		1023***	-
6	Learning disability	n/a		0.037	IV	n/a		0.647**	B	n/a		1208**	C	n/a		0.741†	D	n/a		0.000	B
7	Neurological problems	-0.304	IV	0.897***	IV	-1357	C	0.850***	-	-0.374	C	0.557***	A	-1415	C	0.703***	A	-0.009	B	0.856***	-
8	Vision problems	n/a		0.503	IV	n/a		0.934***	A	n/a		0.997***	-	n/a		1279***	-	n/a		1411**	-
9	Hearing problems	n/a		1223	OLS	n/a		1273***	C	n/a		0.808*	-	n/a		1231**	C	n/a		1523***	-
10	Circulatory problems	-1384***	IV	0.614	IV	-1842***	-	0.494*	-	-1692***	-	1013***	B	-1611**	-	1491**	-	-1464***	-	1285***	A
11	Respiratory problems	-1940***	IV	0.752**	IV	-2103***	B	0.576***	-	-2006**	A	1192***	A	-1743***	-	1360***	A	-1704***	A	0.928***	-
12	Dental problems	n/a		0.404**	OLS	n/a		0.765***	B	n/a		0.229	B	n/a		0.843***	C	n/a		0.855***	B
13	Gastro-intestinal problems	-1553**	IV	0.520*	IV	-1989*	A	0.387*	-	-1425**	A	1040***	A	-2000**	A	1033***	A	-1904**	A	0.997***	-
14	Skin problems	n/a		0.677**	IV	n/a		0.890***	D	n/a		0.422*	B	n/a		0.681**	A	n/a		1158***	A
15	Musculo-skeletal problems	n/a		0.413	IV	n/a		0.295	B	n/a		0.489**	C	n/a		0.456**	C	n/a		0.725***	-
16	Trauma and injuries	0	n/a	1344***	OLS	0	B	1090***	-	-0.064	-	0.589**	A	0	B	1024***	A	0	n/a	1058***	-
17	Genito-urinary problems	-0.346	IV	0.733***	OLS	-2997	B	0.878***	-	-2.83	B	0.631**	A	-0.494	A	0.598***	-	-0.160	C	0.855***	-
18	Maternity and reproductive health	0.043	IV	0.963***	IV	-0.166*	B	0.653***	-	-0.04	B	0.342	-	-0.136	A	0.481**	A	-0.106	-	0.833***	-
19	Neonates																				
20	Poisoning and adverse events	n/a		0.674*	IV	n/a		0.658**	-	n/a		1078**	A	n/a		0.631**	-	n/a		1124***	-
21	Healthy individuals	n/a		0.952	OLS	n/a		1246**	-	n/a		1359**	A	n/a		1748***	-	n/a		1172***	A
22	Social care needs	n/a		0.830	OLS	n/a		0.844	B	n/a		1592**	-	n/a		1859***	-	n/a		1613***	A
23	Other (includes GM S/PMS)	n/a		0.494***	OLS	n/a		0.564***	B	n/a		0.520***	-	n/a		0.518***	A	n/a		0.585***	-

Notes: (i) see pp1-2 of text for the meaning of the symbols in 're-estimation' columns;  
(ii) there are no 're-estimation' columns for 2008/09 because these results were obtained by re-estimating preferred PCT-level specifications using LA-level data for this year (i.e., there were no changes to model specification).

## **Overview of results by PBC**

### **Infectious diseases**

35. Outcome: Re-estimation of the 2011/12 specification using updated data generates an acceptable result, both statistically and in line with priors (see Table A4 and Table A6).

36. Expenditure: Re-estimation of the 2011/12 specification reveals some evidence of mis-specification (see Table A7). Using our pool of census-based variables, we tried adding an additional regressor and re-estimating. We did this for each potential additional regressor and selected the result that 'passed' the usual tests and which generated the most significant additional regressor (see Table A5 and Table A7).

### **Cancer and tumours**

37. Outcome: Re-estimation of the 2011/12 specification using updated data generates an acceptable result, both statistically and in line with priors (see Table A4 and Table A6).

38. Expenditure: Re-estimation of the 2011/12 specification using updated data generates an acceptable result (see Table A5 and Table A7).

### **Blood disorders**

39. Expenditure: Re-estimation of the 2011/12 specification using updated data generates an acceptable result (see Table A5 and Table A7).

### **Endocrine, nutritional and metabolic**

40. Outcome: Re-estimation of the 2011/12 specification using updated data reveals some evidence of mis-specification (see Table A6). Re-derivation of the specification generates a reasonable result but the relevant statistical test suggests that expenditure is not endogenous. However, the OLS equivalent of the IV specification 'fails' the reset test so we persevere with the IV result (Table A4 and Table A6).

41. Expenditure: Re-estimation of the 2011/12 specification using updated data reveals some evidence of mis-specification (see Table A7). We tried adding an additional regressor and re-estimating but this was not successful. However, the removal of one of the instruments from the 2011/12 specification resolved the issue (see Table A5 and Table A7).

### **Mental health disorders**

42. Expenditure: The 2011/12 specification generates an acceptable result (Table A5 and Table A7).

### **Learning disability**

43. Expenditure: The 2011/12 specification generates a poor result with only one significant variable (Table A7). Re-derivation of the IV specification for 2012/13 generates an acceptable result but the endogeneity test suggests that OLS can be used (Table A7). Re-estimation using OLS generates an acceptable result (Table A5 and Table A7). [Outliers beyond the 5%tiles and 95%tiles are excluded.]

### **Neurological problems**

44. Outcome: Re-estimation of the 2011/12 specification using updated data generates a poor result (Table A6). Re-derivation generates an acceptable result (Table A6) but expenditure is not endogenous. OLS re-estimation generates the result shown in Table A4 and Table A6.

45. Expenditure: Re-estimation of the 2011/12 specification using updated data generates a reasonable result (Table A5 and Table A7).

#### **Problems of vision**

46. Expenditure: Re-estimation of the 2011/12 specification using updated data generates an acceptable result (Table A5 and Table A7).

#### **Problems of hearing**

47. Expenditure: Re-estimation of the 2011/12 specification using updated data generates a reasonable result (Table A5 and Table A7).

#### **Circulatory problems**

48. Outcome: The 2011/12 specification generates an acceptable result (Table A4 and Table A6).

49. Expenditure: Re-estimation of the 2011/12 specification using updated data reveals some evidence of mis-specification (Table A7). We tried adding an additional regressor and re-estimating. This approach was successful with the addition of either the proportion of the population born outside the EU or the proportion of the population in the white ethnic group.

We selected the specification with the 'white ethnic group' variable because this variable was the more significant of the two (Table A5 and Table A7).

#### **Respiratory problems**

50. Outcome: The 2011/12 specification has weak instruments (Table A6) so we tried adding an additional instrument and re-estimating. The addition of the 'unpaid carers' variable passed all of our tests and generated the best (the most significant) weak instrument test result (see Table A4 and Table A6).

51. Expenditure: The 2011/12 specification generates an acceptable result (Table A5 and Table A7).

#### **Dental problems**

52. Expenditure: The 2011/12 specification generates a poor result (eg instruments are not valid; see Table A7). Re-derivation of an IV specification generates a more acceptable result (see Table A5 and Table A7).

### **Gastro-intestinal problems**

53. Outcome: The 2011/12 specification is OK but it reveals that the current instrument (households without a car) is a slightly weak one (see Table A6). Using the relevant F-statistic to judge strength, we selected the instrument that generates the most significant coefficient on spend subject to the instrument being a strong one (i.e., with an F-statistic ideally at least 10). This instrument (lone pensioner households) resolves the weak instrument problem (see Table A4 and Table A6).

54. Expenditure: The 2011/12 specification generates an acceptable result (Table A5 and Table A7).

### **Skin problems**

55. Expenditure: The 2011/12 specification fails the instrument validity test (Table A7). However, the addition of one of the instruments (population in professional occupations) to the set of second-stage regressors generates a significant coefficient on this regressor and this specification passes all tests and all other regressors are significant (see Table A5 and Table A7). The addition of the other instrument to the set of second-stage regressors was much less successful.

### **Musculo-Skeletal system**

56. Expenditure: The 2011/12 specification generates an acceptable result (Table A5 and Table A7).

### **Trauma and injuries**

57. Outcome: No updated outcome measure for 2012/13/14 is available (HSCIC).

58. Expenditure: The 2011/12 specification generates an acceptable result (Table A5 and Table A7).

### **Genito-urinary system**

59. Outcome: The 2011/12 specification generates a poor result (positive coefficient on expenditure; see Table A6). Re-derivation proves unsuccessful (significant positive coefficient on expenditure) so we returned to the OLS specification associated with the re-derivation and re-estimated the second-stage using OLS, each time adding a single additional regressor. The only result in line with our priors was the specification with the CARAN need variable and this result is shown in Table A4 and Table A6.

60. Expenditure: The 2011/12 specification generates a plausible result (Table A5 and Table A7).

### **Maternity/Neonates**

61. Outcome: The 2011/12 specification generates an acceptable result (see Table A4 and Table A6).

62. Expenditure: The 2011/12 specification generates an acceptable result (see Table A5 and Table A7).

### **Poisoning**

63. Expenditure: The 2011/12 specification generates an acceptable result (Table A5 and Table A7).

### **Healthy Individuals**

64. Expenditure: The 2011/12 specification generates an OK result but the 'no qualifications' variable is insignificant. We tried re-estimating the specification, replacing the 'no qualifications' variable with each of the other available needs indicators. Only one specification generated a result in line with our priors and this replaced the 'no qualifications' variable with the 'percentage long-term unemployed' variable (Table A5 and Table A7).

### **Social Care**

65. Expenditure: The 2011/12 specification fails the reset test (Table A7) so we tried adding one regressor to the specification from the available pool of needs indicators and re-estimating. We did this for each available regressor, and our preferred specification generates three significant regressors, passes the reset test, and has the largest R-squared (see Table A7 and Table A5). Note that the sample restriction to LAs with expenditure per head between the 5<sup>th</sup> and 95<sup>th</sup> percentiles is necessary to exclude 'outliers' eg PCTs that are Care Trusts.

### **GMS/PMS**

66. Expenditure: The 2011/12 specification generates a reasonable result (see Table A5 and Table A7).

### **All PBCs: Comparing specifications for 2011/12 and 2012/13**

67. Table A2 summarises whether the preferred specification for each equation is the same as for the previous year (indicated by a blank cell) or, if not, why the previous year's specification is not suitable. For example, this might be because the previous specification does not 'pass' the appropriate statistical tests when estimated on updated data (indicated by "Tests"). It could also be because the estimated coefficients are incompatible with our prior beliefs about their sign and significance. For example, one of our priors is that, for the outcome equation, health care expenditure should not have a negative marginal effect on mortality and another is that ("Prior"), in the expenditure equation, budget should have a positive marginal effect on PBC expenditure ("Prior (A)"). In a small number of cases, the previous specification might 'fail' on both statistical tests and on priors.

68. Finally, Table A3 reports the number times where the preferred specification for 2012/13 is OLS and this is the same/similar specification as was preferred for the previous year (i.e., we do not re-derive the specification).

### **Note**

69. 2012/13 was the third year the mortality data used the new European Standard Population.

Table A2 Whether the preferred specification for each equation is the same as for the previous year

PBC #	PBC Title	2009/10 Outcome	2009/10 Expenditure	2010/11 Outcome	2010/11 Expenditure	2011/12 Outcome	2011/12 Expenditure	2012/13 Outcome	2012/13 Expenditure
1	Infectious diseases	Tests		Tests		Tests			Tests
2	Cancers and tumours		Prior (A)			Tests			
3	Diseases of the blood	n/a	Prior (A)	n/a	Prior (A)	n/a		n/a	
4	Endocrine, nutritional, metabolic	Tests		Tests	Prior (B)		Tests	Tests	Tests
5	Mental health disorders	n/a		n/a		n/a		n/a	
6	Learning disability	n/a	Tests	n/a	Priors (A, C)	n/a	Tests, prior (C)	n/a	Prior (C)
7	Neurological problems	Prior		Tests	Priors (A, B)	Tests, prior	Prior (C)	Tests, prior	
8	Vision problems	n/a	Priors (A, C)	n/a		n/a		n/a	
9	Hearing problems	n/a	Priors (A, C)	n/a		n/a	Prior (B)	n/a	
10	Circulatory problems				Prior (A)				Tests
11	Respiratory problems	Tests		Tests	Prior (A)		Tests	Tests	
12	Dental problems	n/a	Tests	n/a	Tests, priors (B, C)	n/a	Tests, priors (A, C)	n/a	Tests, prior (C)
13	Gastro-intestinal problems	Tests		Tests	Prior (A)	Tests	Tests	Tests	
14	Skin problems	n/a	Tests	n/a	Prior (C)	n/a	Tests	n/a	Tests, prior (C)
15	Musculo-skeletal problems	n/a	Prior (A)	n/a	Prior (A)	n/a	Prior (B)	n/a	
16	Trauma and injuries	n/a*		n/a*	Tests	Prior	Prior (C)	n/a*	
17	Genito-urinary problems	Prior		Tests, prior	Prior (C)	Tests		Prior	
18	Maternity and reproductive health						Tests		
19	Neonates	Tests		Prior					
20	Poisoning and adverse events	n/a		n/a	Tests, prior (A)	n/a		n/a	
21	Healthy individuals	n/a		n/a	Prior (C)	n/a		n/a	Prior (C)
22	Social care needs	n/a	Prior (C)	n/a		n/a		n/a	Tests
23	Other (includes GMS/PMS)	n/a	Priors (B, C)	n/a		n/a	Tests	n/a	
	*no preferred specification from previous year								
Totals	Pass (= blank cell)	n=2	n=12	n=2	n=8	n=4	n=10	n=4	n=14
	Tests	n=5	n=3	n=5	n=1	n=4	n=6	n=3	n=4
	Prior (negative coefficient on expenditure)	n=2		n=1		n=1		n=1	
	Tests and priors	n=0	n=0	n=1	n=2	n=1	n=2	n=1	n=2
	Prior (A: 'significant', +ve coefficient on budget)		n=3		n=5		n=0		n=0
	Prior (B: no significant +ve coefficient on o/need)		n=0		n=1		n=2		n=0
	Prior (C: other coefficients significant)		n=1		n=3		n=2		n=2
	Priors (A, B)		n=0		n=1				
	Priors (A, C)		n=2		n=1				
	Priors (B, C)		n=1						

Table A3 OLS specification for previous year and current year

Number of times preferred specification is OLS and the same/similar OLS specification as in the previous year		2009/10	2010/11	2011/12	2012/13
Outcome equation	(maximum n=10)	n=0	n=0	n=2	n=2
Expenditure equation	(maximum n=22)	n=5	n=7	n=9	n=11

In this section, Tables A4 and A5 provide details of our preferred specification for each outcome and expenditure model by PBC for 2012/13.

Table A4 Preferred outcome specifications for 2012/13

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	PBC 1	PBC 2	PBC 4	PBC 7	PBC 10	PBC 11	PBC 13	PBC 17	PBC 1819
	infectious	cancer	endocrine etc	neurological etc	circulatory	respiratory	gastro-intestinal	renal	mat/neonates
	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend
	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	infant m/rate 2012/13/14
	spend model	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model
	instrument n/a	instrument spend	instrument spend	instrument n/a	instrument spend	instrument spend	instrument spend	instrument n/a	spend exogenous
	weighted	weighted	weighted	weighted	weighted	weighted	weighted	weighted	weighted
	OLS	IV second stage	IV second stage	OLS	IV second stage	IV second stage	IV second stage	OLS	OLS
	LA-level	GMM2S	GMM2S	LA-level	GMM2S	GMM2S	GMM2S	LA-level	LA-level
	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality
	actual census 11	actual census11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11
VARIABLES	11/12 version	11/12 version	Re-derived	Re-derived, OLS	11/12 version	11/12 revised	11/12 revised	Re-derived+	11/12 version
ILAg1_1213pheadOHP	-0.362*** [0.089]								
ILAhivneedph	0.276*** [0.045]								
ILAIMD2010	0.649*** [0.064]		0.579*** [0.116]	0.289*** [0.088]					
LLONEPENH11	-0.177 [0.183]								
ILAg2_1213pheadOHP		-0.361** [0.149]							
ILACARANneed1213		1.023*** [0.134]			2.304*** [0.234]		3.878*** [0.832]	2.141* [1.253]	1.926*** [0.378]
ILAg4_1213pheadOHP			-0.499 [0.349]						
LPROFOCCU11			-0.409** [0.165]					3.875*** [1.283]	
ILAg7_1213pheadOHP				-0.009 [0.188]					
LBORNEXEU11				-0.169*** [0.050]					0.247*** [0.064]
ILAg10_1213pheadOHP					-1.464*** [0.268]				
ILAg11_1213pheadOHP						-1.704*** [0.459]			
LPERMSICK11						6.265*** [1.189]			
LPERMSICK11SQ						0.742*** [0.166]			

ILAg13_1213pheadOHP								-1.904**		
								[0.897]		
ILACARANneed1213SQ								3.735***		
								[1.352]		
ILAg17_1213pheadOHP									-0.160	
									[0.753]	
LNQUAL17411									3.888***	
									[1.146]	
LWHITEEG11									-3.045***	
									[0.558]	
ILAg1819_1213phOHP										-0.106
										[0.129]
LHHNOCAR11										-0.365***
										[0.102]
Constant	0.698	6.744***	1.118	-0.032	11.541***	23.203***	11.547***	9.081*	1.529**	
	[0.437]	[0.691]	[1.164]	[0.782]	[1.302]	[3.903]	[4.024]	[4.938]	[0.671]	
Observations	147	149	149	149	149	149	149	149	148	
R-squared	0.582			0.107				0.233	0.229	
Ramsey reset F statistic	1.139			1.414				2.110	1.064	
Probability > F	0.336			0.241				0.102	0.366	
Endogeneity test statistic		8.481	0.064		30.621	20.193	8.574			
Endogeneity p-value		0.004	0.801		0.000	0.000	0.003			
Kleibergen-Paap LM test statistic		10.435	27.631		24.067	19.742	10.507			
Kleibergen-Paap p-value		0.001	0.000		0.000	0.000	0.001			
Kleibergen-Paap F statistic		11.262	24.515		19.517	16.644	10.363			
Pesaran-Taylor reset statistic		0.408	1.563		0.086	0.096	0.039			
Pesaran-Taylor p-value		0.523	0.211		0.769	0.757	0.843			
Hansen-Sargan test statistic			1.428		0.810	2.227				
Hansen-Sargan p-value			0.490		0.368	0.136				

Robust standard errors in brackets

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table A5 Preferred expenditure specifications for 2012/13

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	PBC 1	PBC 2	PBC 3	PBC 4	PBC 5	PBC 6	PBC 7	PBC 8	PBC 9
	infectious	cancer	blood disorders	diabetes	mental health	LDisability	epilepsy	vision	hearing issues
	2011/12 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend
	SYLLR 2011/12/13	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	all cause SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14
	spend model	spend model	spend model	spend model	spend model	spend model	spend model	spend model	spend model
	instrument n/a	instrument o/ need	instrument n/a	instrum o/need	instrument n/a	instrument n/a	instrum o/need	instrum o/need	instrument n/a
	weighted	weighted	weighted	weighted	weighted	weighted	weighted	weighted	weighted
	OLS	IV second stage	OLS	IV second stage	OLS	OLS	IV second stage	IV second stage	OLS
		GMM2S		GMM2S			GMM2S	GMM2S	
	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level
	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality
	actual census 11	actual census11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11
VARIABLES	11/12 revised	11/12 version	11/12 version	11/12 revised	11/12 version	Re-derived, OLS	11/12 version	11/12 version	11/12 version
lAgall_1213pheadOHP	0.749*** [0.252]	1.027** [0.522]	1.119*** [0.253]	0.951*** [0.128]	1.023*** [0.221]	0.000 [0.451]	0.856*** [0.168]	1.411*** [0.234]	1.523*** [0.357]
lAhivneedph	0.342*** [0.028]								
lacsyllrexIP1214	0.160 [0.193]								
lAhivneedphSQ	0.087*** [0.019]								
LWHITEEG11	-0.303** [0.122]			-0.243*** [0.038]					
lacsyllrexcancer1214		-1.565*** [0.326]							
lACARANneed1213		1.472** [0.599]							
LPROFOCCU11		-0.472*** [0.173]							-0.060 [0.267]
lacmSYLLR1214			-0.321* [0.192]		0.043 [0.116]	0.245 [0.331]		-1.047*** [0.236]	0.419 [0.367]
LBORNEXEU11			0.189*** [0.030]			-0.162*** [0.051]			
lacsyllrexDIAB1214				-0.440*** [0.138]					
LNQUAL17411				0.359*** [0.062]				0.607*** [0.081]	
lAmhneedindexpp					0.334** [0.146]				
LPOPPUCAR11					-0.408*** [0.116]				
lacsyllrexEPI1214							-0.326** [0.157]		
lLAepiprev1213							0.489***		

							[0.090]		
LOWNOCC11									0.587***
Constant	-3.303**	5.169	-2.932**	0.056	-3.512*	1.414	2.362**	0.395	-11.656***
	[1.322]	[3.768]	[1.213]	[0.737]	[1.994]	[2.473]	[1.205]	[0.930]	[2.388]
Observations	147	149	149	149	149	135	149	149	149
R-squared	0.788		0.301		0.715	0.081			0.329
Ramsey reset F statistic	2.104		0.196		1.023	0.388			1.093
Probability > F	0.103		0.899		0.384	0.762			0.354
Endogeneity test statistic		28.098		8.114			13.076	9.351	
Endogeneity p-value		0.000		0.004			0.000	0.002	
Hansen-Sargan test statistic		0.008		2.726			0.918	1.707	
Hansen-Sargan p-value		0.929		0.099			0.338	0.191	
Kleibergen-Paap LM test statistic		18.904		28.095			33.802	24.062	
Kleibergen-Paap p-value		0.000		0.000			0.000	0.000	
Kleibergen-Paap F statistic		18.752		43.928			130.353	23.271	
Pesaran-Taylor reset statistic		2.365		1.162			0.643	0.736	
Pesaran-Taylor p-value		0.124		0.281			0.422	0.391	

Robust standard errors in brackets

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table A5 continued Preferred expenditure specifications for 2012/13

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	PBC 10	PBC 11	PBC 12	PBC 13	PBC 14	PBC 15	PBC 16	PBC 17	PBC 1819
	circulatory	respiratory	dental problems	gastro problems	skin problems	musculo-skeletal	trauma/injuries	renal	maternity/neonates
	2012/13 spend	2011/12 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend
	SYLLR 2012/13/14	SYLLR 2011/12/13	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14
	spend model	spend model	spend model	spend model	spend model	spend model	spend model	spend model	spend model
	instrument o/need	instrument o/need	instrument o/need	instrument o/need	instrument o/need	instrument n/a	instrument n/a	instrument n/a	instrument n/a
	weighted	weighted	weighted	weighted	weighted	weighted	weighted	weighted	weighted
	IV second stage	IV second stage	IV second stage	IV second stage	IV second stage	OLS	OLS	OLS	OLS
	GMM2S	GMM2S	GMM2S	GMM2S	GMM2S				
	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level
	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality
	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11
VARIABLES	11/12 revised	11/12 version	Re-derived	11/12 version	11/12 revised	11/12 version	11/12 version	11/12 version	11/12 version
lacsyllrexcirc1214	-0.908*** [0.159]								
ILAgall_1213pheadOHP	1.285*** [0.161]	0.928*** [0.163]	0.855*** [0.158]	0.997*** [0.171]	1.158*** [0.322]	0.725*** [0.184]	1.058*** [0.171]	0.855*** [0.119]	0.833*** [0.159]
LNQUAL17411	0.382*** [0.078]	0.408*** [0.071]		0.357*** [0.076]		0.173* [0.094]			
LWHITEEG11	0.191*** [0.050]				0.225* [0.115]			-0.147*** [0.038]	
lacsyllrexp1214		-0.370* [0.193]							
ILACARANneed1213SQ		1.945*** [0.395]		0.622 [0.475]					
lacmSYLLR1214			-0.276* [0.158]		-0.976* [0.559]	0.210 [0.137]	-0.270** [0.117]		-0.472*** [0.126]
LBORNEXEU11			-0.062*** [0.017]						
LLONEPARH11			0.344*** [0.083]						
lacsyllrexp1214				-0.570*** [0.218]					
LPC74LTUN11					0.277* [0.158]	-0.378*** [0.076]			
LPROFOCCU11					-0.308* [0.175]				
LOWNOCC11						0.384*** [0.103]			
ILAIMD2010						0.136 [0.107]			
LHHNOCAR11							-0.129*** [0.038]		
lacsyllrexrenal1214								-0.093 [0.078]	

ILAmatneedindexpp										
Constant	1.110 [0.993]	0.296 [0.744]	0.237 [1.060]	0.942 [0.872]	1.704 [2.538]	-3.635** [1.403]	-2.230** [0.961]	-1.375** [0.623]	1.129*** [0.083]	1.035 [0.783]
Observations	149	149	149	149	147	149	149	149	149	149
R-squared						0.594	0.240	0.505		0.676
Endogeneity test statistic	12.964	6.507	2.711	7.495	4.994					
Endogeneity p-value	0.000	0.011	0.100	0.006	0.025					
Hansen-Sargan test statistic	2.162	0.000	2.463							
Hansen-Sargan p-value	0.141	0.985	0.482							
Kleibergen-Paap LM test statistic	31.331	23.711	43.690	29.937	15.054					
Kleibergen-Paap p-value	0.000	0.000	0.000	0.000	0.000					
Kleibergen-Paap F statistic	65.251	23.538	50.773	122.358	20.121					
Pesaran-Taylor reset statistic	0.807	0.484	0.354	0.023	0.002					
Pesaran-Taylor p-value	0.369	0.487	0.552	0.878	0.964					
Ramsey reset F statistic						0.257	1.071	0.879		0.323
Probability > F						0.856	0.363	0.454		0.809

Robust standard errors in brackets

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table A5 continued Preferred expenditure specifications for 2012/13

	(1)	(2)	(3)	(4)
	PBC 20	PBC 21	PBC 22	PBC 23a
	poisoning	HI	social care	GMS
	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend
	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14
	spend model	spend model	spend model	spend model
	instrument o/need	instrument n/a	instrument n/a	instrument n/a
	weighted	weighted	weighted	weighted
	IV second stage	OLS	OLS	OLS
	GMM2S			
	LA-level	LA-level	LA-level	LA-level
	actual mortality	actual mortality	actual mortality	actual mortality
	actual census 11	actual census 11	actual census 11	actual census 11
VARIABLES	11/12 version	11/12 revised	11/12 revised	11/12 version
lacmSYLLR1214	-0.601*** [0.229]	-0.455 [0.488]	-0.852** [0.408]	-0.113 [0.088]
ILAgall_1213pheadOHP	1.124*** [0.252]	1.172* [0.645]	1.613*** [0.430]	0.585*** [0.095]
LNQUAL17411	0.142 [0.111]			
LPC74LTUN11		0.902*** [0.312]		
LPROFOCCU11			-0.886*** [0.246]	-0.182*** [0.063]
Constant	-1.673 [1.280]	1.059 [5.485]	-3.927 [2.680]	1.115* [0.654]
Observations	149	149	133	149
R-squared		0.234	0.210	0.474
Endogeneity test statistic	8.286			
Endogeneity p-value	0.004			
Hansen-Sargan test statistic	0.008			
Hansen-Sargan p-value	0.930			
Kleibergen-Paap LM test statistic	24.062			
Kleibergen-Paap p-value	0.000			
Kleibergen-Paap F statistic	23.271			
Pesaran-Taylor reset statistic	1.578			
Pesaran-Taylor p-value	0.209			
Ramsey reset F statistic		0.056	2.080	1.333
Probability > F		0.983	0.106	0.266

Robust standard errors in brackets

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

In this section, Tables A6 and A7 provide details of the estimation path to our preferred specifications for each outcome and expenditure model by PBC for 2012/13. For each PBC, we first estimate the model for 2012/13 using our preferred specification for 2011/12. If this specification fails to meet either the necessary statistical tests or our prior beliefs about the sign/size/significance of coefficients, then the specification is adjusted in line with our estimation strategy outlined on pp14-15 and the model is re-estimated. This process continues until we identify a specification that meets our priors and passes the relevant statistical tests. The final, preferred specification for each PBC for 2012/13 is also shown here, along with the results associated with the estimation of selected intermediate specifications.

Table A6 Estimation path to preferred outcome specifications for 2012/13

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	PBC 1	PBC 2	PBC 4	PBC 4	PBC 07	PBC 07	PBC 7
	infectious	cancer	endocrine etc	endocrine etc	neurological etc	neurological etc	neurological etc
	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend
	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14
	spend model	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model
	instrument n/a	instrument spend	instrument n/a	instrument spend	instrument spend	instrument spend	instrument n/a
	weighted	weighted	weighted	weighted	weighted	weighted	weighted
	OLS	IV second stage	OLS	IV second stage	IV second stage	IV second stage	OLS
	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level
	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality
	actual census 11	actual census11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11
VARIABLES	11/12 version	11/12 version	11/12 version	Re-derived	11/12 version	Re-derived	Re-derived, OLS
lLAg1_1213pheadOHP	-0.362*** [0.089]						
lLAhivneedph	0.276*** [0.045]						
lLAIMD2010	0.649*** [0.064]			0.579*** [0.116]	0.264** [0.129]	0.351** [0.178]	0.289*** [0.088]
lLONEPENH11	-0.177 [0.183]						
lLAg2_1213pheadOHP		-0.361** [0.149]					
lLACARANneed1213		1.023*** [0.134]					
lLAg4_1213pheadOHP			-0.150 [0.190]	-0.499 [0.349]			
lPROFOCCU11			-1.009*** [0.150]	-0.409** [0.165]			
lLOWNOCC11			-0.668*** [0.119]				

ILAg7_1213pheadOHP					0.331	-0.342	-0.009
					[0.801]	[0.760]	[0.188]
LWORKAGRI11					0.068*		
					[0.036]		
ILAepiprev1213					0.170		
					[0.544]		
LBORNEXEU11						-0.209*	-0.169***
						[0.111]	[0.050]
Constant	0.698	6.744***	0.422	1.118	0.175	1.152	-0.032
	[0.437]	[0.691]	[0.740]	[1.164]	[5.845]	[2.646]	[0.782]
Observations	147	149	149	149	149	149	149
R-squared	0.582		0.343				0.107
Ramsey reset F statistic	1.139		6.613				1.414
Probability > F	0.336		0.000				0.241
Endogeneity test statistic		8.481		0.064	0.151	0.204	
Endogeneity p-value		0.004		0.801	0.697	0.651	
Kleibergen-Paap LM test statistic		10.435		27.631	10.384	8.491	
Kleibergen-Paap p-value		0.001		0.000	0.001	0.004	
Kleibergen-Paap F statistic		11.262		24.515	10.999	9.536	
Pesaran-Taylor reset statistic		0.408		1.563	0.463	0.029	
Pesaran-Taylor p-value		0.523		0.211	0.496	0.865	
Hansen-Sargan test statistic				1.428			
Hansen-Sargan p-value				0.490			

Robust standard errors in brackets

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table A6 continued Estimation path to preferred outcome specifications for 2012/13

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	PBC 10	PBC 11	PBC 11	PBC 13	PBC 13	PBC 17	PBC 17	PBC 1819
	circulatory	respiratory	respiratory	gastro-intestinal	gastro-intestinal	renal	renal	mat/neonates
	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend
	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	infant mort rate 2012/13/14
	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model
	instrument spend	instrument spend	instrument spend	instrument spend	instrument spend	instrument n/a	instrument n/a	spend exogenous
	weighted	weighted	weighted	weighted	weighted	weighted	weighted	weighted
	IV second stage	IV second stage	IV second stage	IV second stage	IV second stage	OLS	OLS	OLS
	GMM2S	GMM2S	GMM2S	GMM2S	GMM2S			
	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level
	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality
	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11
VARIABLES	11/12 version	11/12 version	11/12 revised	11/12 version	11/12 revised	11/12 version	Re-derived+	11/12 version
ILAg11_1213pheadOHP		-2.908** [1.408]	-1.704*** [0.459]					
LPERMSICK11		8.747*** [3.029]	6.265*** [1.189]					
LPERMSICK11SQ		1.062*** [0.400]	0.742*** [0.166]					
ILAg10_1213pheadOHP	-1.464*** [0.268]							
ILACARANneed1213	2.304*** [0.234]			4.368*** [1.086]	3.878*** [0.832]		2.141* [1.253]	1.926*** [0.378]
ILAg13_1213pheadOHP				-2.463** [1.220]	-1.904** [0.897]			
ILACARANneed1213SQ				3.855*** [1.497]	3.735*** [1.352]			
LWHITEEG11						-1.713*** [0.349]	-3.045*** [0.558]	
LNQUAL17411						1.150** [0.481]	3.888*** [1.146]	
ILAg17_1213pheadOHP						0.749 [0.663]	-0.160 [0.753]	
LPROFOCCU11							3.875*** [1.283]	
ILAg1819_1213phOHP								-0.106 [0.129]
LBORNEXEU11								0.247*** [0.064]
LHHNOCAR11								-0.365*** [0.102]
Constant	11.541*** [1.302]	33.235*** [11.712]	23.203*** [3.903]	14.059** [5.482]	11.547*** [4.024]	-3.230 [3.281]	9.081* [4.938]	1.529** [0.671]

Observations	149	149	149	149	149	149	149	148
R-squared						0.165	0.233	0.229
Endogeneity test statistic	30.621	18.635	20.193	11.065	8.574			
Endogeneity p-value	0.000	0.000	0.000	0.001	0.003			
Hansen-Sargan test statistic	0.810		2.227					
Hansen-Sargan p-value	0.368		0.136					
Kleibergen-Paap LM test statistic	24.067	5.686	19.742	6.427	10.507			
Kleibergen-Paap p-value	0.000	0.017	0.000	0.011	0.001			
Kleibergen-Paap F statistic	19.517	6.613	16.644	8.139	10.363			
Pesaran-Taylor reset statistic	0.086	3.575	0.096	0.000	0.039			
Pesaran-Taylor p-value	0.769	0.059	0.757	0.989	0.843			
Ramsey reset F statistic						1.838	2.110	1.064
Probability > F						0.143	0.102	0.366

Robust standard errors in brackets

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table A7 Estimation path to preferred expenditure specifications for 2012/13

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	PBC 1	PBC 1	PBC 2	PBC 3	PBC 4	PBC 4	PBC 5	PBC 6	PBC 6	PBC 6
	infectious	infectious	cancer	Blood disorders	diabetes	diabetes	Mental health	LDisability	LDisability	LDisability
	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend
	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14
	spend model	spend model	spend model	spend model	spend model	spend model	spend model	spend model	spend model	spend model
	instrument n/a	instrument n/a	instrument	instrument n/a	instrument	instrument	instrument n/a	instrument n/a	instrument	instrument n/a
	weighted	weighted	o/need	weighted	o/need	o/need	weighted	weighted	o/need	weighted
	OLS	OLS	IV second stage	OLS	IV second stage	IV second stage	OLS	OLS	IV second stage	OLS
	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level
	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality
	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11
VARIABLES	11/12 version	11/12 revised	11/12 version	11/12 version	11/12 version	11/12 revised	11/12 version	11/12 version	Re-derived	Re-derived, OLS
lAgall_1213phea										
dOHP	0.750*** [0.261]	0.749*** [0.252]	1.027** [0.522]	1.119*** [0.253]	0.930*** [0.119]	0.951*** [0.128]	1.023*** [0.221]	0.421 [0.436]	0.142 [0.508]	0.000 [0.451]
lAhivneedph	0.400*** [0.017]	0.342*** [0.028]								
lacsyllrexIP1214	0.175 [0.197]	0.160 [0.193]								
lAhivneedphSQ	0.091*** [0.021]	0.087*** [0.019]								
LWHITEEG11		-0.303** [0.122]			-0.240*** [0.036]	-0.243*** [0.038]				
lacsyllrexcancer12 14			-1.565*** [0.326]							
lACARANneed12 13			1.472** [0.599]							
LPROFOCCU11			-0.472*** [0.173]					-0.289 [0.333]		
lacmSYLLR1214				-0.321* [0.192]			0.043 [0.116]	0.542 [0.557]	0.172 [0.442]	0.245 [0.331]
LBORNEXEU11				0.189*** [0.030]					-0.153*** [0.048]	-0.162*** [0.051]
lacsyllrexDIAB121 4					-0.410*** [0.114]	-0.440*** [0.138]				
LNQUAL17411					0.347*** [0.052]	0.359*** [0.062]				
lAmhneedindexp p							0.334** [0.146]			
LPOPPUCAR11							-0.408***			

							[0.116]			
LPC74LTUN11								-0.587**		
Constant	-3.327**	-3.303**	5.169	-2.932**	0.009	0.056	-3.512*	[0.225]	0.810	1.414
	[1.381]	[1.322]	[3.768]	[1.213]	[0.718]	[0.737]	[1.994]	[3.928]	[2.336]	[2.473]
Observations	147	147	149	149	149	149	149	135	135	135
R-squared	0.778	0.788		0.301			0.715	0.078		0.081
Ramsey reset F statistic	3.058	2.104		0.196			1.023	0.930		0.388
Probability > F	0.030	0.103		0.899			0.384	0.428		0.762
Endogeneity test statistic			28.098		10.957	8.114			0.059	
Endogeneity p-value			0.000		0.001	0.004			0.808	
Hansen-Sargan test statistic			0.008		2.887	2.726			0.768	
Hansen-Sargan p-value			0.929		0.236	0.099			0.681	
Kleibergen-Paap LM test statistic			18.904		31.972	28.095			40.711	
Kleibergen-Paap p-value			0.000		0.000	0.000			0.000	
Kleibergen-Paap F statistic			18.752		58.510	43.928			83.564	
Pesaran-Taylor reset statistic			2.365		4.485	1.162			0.035	
Pesaran-Taylor p-value			0.124		0.034	0.281			0.853	
<hr/>										
Robust standard errors in brackets										
*** p<0.01, ** p<0.05, * p<0.1										

Table A7 continued Estimation path to preferred expenditure specifications for 2012/13

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	PBC 7	PBC 8	PBC 9	PBC 10	PBC 10	PBC 11	PBC 12	PBC 12
	epilepsy	Vision	hearing problems	circulatory	circulatory	respiratory	dental problems	dental problems
	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend
	all cause SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14
	spend model	spend model	spend model	spend model	spend model	spend model	spend model	spend model
	instrument o/need	instrument o/need	instrument n/a	instrument o/need	instrument o/need	instrument o/need	instrument o/need	instrument o/need
	weighted	weighted	weighted	weighted	weighted	weighted	weighted	weighted
	IV second stage	IV second stage	OLS	IV second stage	IV second stage	IV second stage	IV second stage	IV second stage
	GMM2S	GMM2S		GMM2S	GMM2S	GMM2S	GMM2S	GMM2S
	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level
	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality
	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11
VARIABLES	11/12 version	11/12 version	11/12 version	11/12 version	11/12 revised	11/12 version	11/12 version	Re-derived
lacsyllrexEPI1214	-0.326** [0.157]							
lAgall_1213pheadOHP	0.856*** [0.168]	1.411*** [0.234]	1.523*** [0.357]	1.589*** [0.257]	1.285*** [0.161]	0.928*** [0.163]	0.906*** [0.174]	0.855*** [0.158]
lAepiprev1213	0.489*** [0.090]							
lacmSYLLR1214		-1.047*** [0.236]	0.419 [0.367]				-0.087 [0.323]	-0.276* [0.158]
LNQUAL17411		0.607*** [0.081]		0.614*** [0.097]	0.382*** [0.078]	0.408*** [0.071]		
LOWNOCC11			0.587*** [0.204]					
LPROFOCCU11			-0.060 [0.267]				-0.181 [0.128]	
lacsyllrexcirc1214				-1.480*** [0.279]	-0.908*** [0.159]			
LWHITEEG11					0.191*** [0.050]			
lacsyllrexresp1214						-0.370* [0.193]		
lLACARANneed1213SQ						1.945*** [0.395]	-0.574 [0.637]	
lLAIMD2010							-0.006 [0.083]	
LBORNEXEU11								-0.062*** [0.017]
LLONEPARH11								0.344*** [0.083]
Constant	2.362** [1.205]	0.395 [0.930]	-11.656*** [2.388]	2.473** [1.161]	1.110 [0.993]	0.296 [0.744]	-2.230 [1.475]	0.237 [1.060]

Observations	149	149	149	149	149	149	149	149
Endogeneity test statistic	13.076	9.351		22.226	12.964	6.507	1.057	2.711
Endogeneity p-value	0.000	0.002		0.000	0.000	0.011	0.304	0.100
Hansen-Sargan test statistic	0.918	1.707		0.942	2.162	0.000	4.431	2.463
Hansen-Sargan p-value	0.338	0.191		0.332	0.141	0.985	0.035	0.482
Kleibergen-Paap LM test statistic	33.802	24.062		22.189	31.331	23.711	19.538	43.690
Kleibergen-Paap p-value	0.000	0.000		0.000	0.000	0.000	0.000	0.000
Kleibergen-Paap F statistic	130.353	23.271		25.011	65.251	23.538	31.815	50.773
Pesaran-Taylor reset statistic	0.643	0.736		3.080	0.807	0.484	0.618	0.354
Pesaran-Taylor p-value	0.422	0.391		0.079	0.369	0.487	0.432	0.552
R-squared			0.329					
Ramsey reset F statistic			1.093					
Probability > F			0.354					

Robust standard errors in brackets

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table A7 continued Estimation path to preferred expenditure specifications for 2012/13

	(1)	(2)	(3)	(4)	(5)
	PBC 13	PBC 14	PBC 14	PBC 15	PBC 16
	gastro problems	skin problems	skin problems	musculo-skeletal	trauma/injuries
	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend
	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14
	spend model	spend model	spend model	spend model	spend model
	instrument o/need	instrument o/need	instrument o/need	instrument n/a	instrument n/a
	weighted	weighted	weighted	weighted	weighted
	IV second stage	IV second stage	IV second stage	OLS	OLS
	GMM2S	GMM2S	GMM2S		
	LA-level	LA-level	LA-level	LA-level	LA-level
	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality
	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11
VARIABLES	11/12 version	11/12 version	11/12 revised	11/12 version	11/12 version
lacsyllrexgast1214	-0.570*** [0.218]				
ILAgall_1213pheadOHP	0.997*** [0.171]	0.831*** [0.241]	1.158*** [0.322]	0.725*** [0.184]	1.058*** [0.171]
LNQUAL17411	0.357*** [0.076]			0.173* [0.094]	
ILACARANneed1213SQ	0.622 [0.475]				
lacmSYLLR1214		-0.214 [0.299]	-0.976* [0.559]	0.210 [0.137]	-0.270** [0.117]
LPC74LTUN11		0.143 [0.126]	0.277* [0.158]	-0.378*** [0.076]	
LWHITEEG11		0.145 [0.091]	0.225* [0.115]		
LPROFOCCU11			-0.308* [0.175]		
LOWNOCC11				0.384*** [0.103]	
ILAIMD2010				0.136 [0.107]	
LHHNOCAR11					-0.129*** [0.038]
Constant	0.942 [0.872]	-0.655 [1.953]	1.704 [2.538]	-3.635** [1.403]	-2.230** [0.961]
Observations	149	147	147	149	149
R-squared				0.594	0.240
Endogeneity test statistic	7.495	1.747	4.994		
Endogeneity p-value	0.006	0.186	0.025		
Kleibergen-Paap LM test statistic	29.937	26.054	15.054		
Kleibergen-Paap p-value	0.000	0.000	0.000		

Kleibergen-Paap F statistic	122.358	37.718	20.121		
Pesaran-Taylor reset statistic	0.023	0.035	0.002		
Pesaran-Taylor p-value	0.878	0.852	0.964		
Hansen-Sargan test statistic		3.167			
Hansen-Sargan p-value		0.075			
Ramsey reset F statistic				0.257	1.071
Probability > F				0.856	0.363

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Robust standard errors in brackets

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table A7 continued Estimation path to preferred expenditure specifications for 2012/13

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	PBC 17	PBC 1819	PBC 20	PBC 21	PBC 21	PBC 22	PBC 22	PBC 23a
	renal	maternity/neonates	poisoning	HI	HI	social care	social care	GMS
	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend	2012/13 spend
	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14	SYLLR 2012/13/14
	spend model	spend model	spend model	spend model	spend model	spend model	spend model	spend model
	instrument n/a	instrument n/a	instrument o/need	instrument n/a	instrument n/a	instrument n/a	instrument n/a	instrument n/a
	weighted	weighted	weighted	weighted	weighted	weighted	weighted	weighted
	OLS	OLS	IV second stage	OLS	OLS	OLS	OLS	OLS
	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level	LA-level
	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality	actual mortality
	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11	actual census 11
VARIABLES	11/12 version	11/12 version	11/12 version	11/12 version	11/12 revised	11/12 version	11/12 revised	11/12 version
LWHITEEG11	-0.147*** [0.038]							
lacsyllrexrenal1214	-0.093 [0.078]							
lAgall_1213pheadOHP	0.855*** [0.119]	0.833*** [0.159]	1.124*** [0.252]	1.524** [0.647]	1.172* [0.645]	1.570*** [0.446]	1.613*** [0.430]	0.585*** [0.095]
lAmatneedindexpp		1.129*** [0.083]						
lacmSYLLR1214		-0.472*** [0.126]	-0.601*** [0.229]	0.762 [0.539]	-0.455 [0.488]	0.014 [0.321]	-0.852** [0.408]	-0.113 [0.088]
LNQUAL17411			0.142 [0.111]	-0.221 [0.274]				
LPC74LTUN11					0.902*** [0.312]			
LPROFOCCU11							-0.886*** [0.246]	-0.182*** [0.063]
Constant	-1.375** [0.623]	1.035 [0.783]	-1.673 [1.280]	-12.967*** [3.939]	1.059 [5.485]	-7.797*** [2.688]	-3.927 [2.680]	1.115* [0.654]
Observations	149	149	149	149	149	133	133	149
R-squared	0.505	0.676		0.163	0.234	0.156	0.210	0.474
Ramsey reset F statistic	0.879	0.323		0.282	0.056	2.962	2.080	1.333
Probability > F	0.454	0.809		0.838	0.983	0.035	0.106	0.266
Endogeneity test statistic			8.286					
Endogeneity p-value			0.004					
Hansen-Sargan test statistic			0.008					
Hansen-Sargan p-value			0.930					
Kleibergen-Paap LM test statistic			24.062					
Kleibergen-Paap p-value			0.000					
Kleibergen-Paap F statistic			23.271					
Pesaran-Taylor reset statistic			1.578					

Pesaran-Taylor p-value

0.209

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Robust standard errors in brackets

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

## Appendix 2: Expected health opportunity costs in the NHS (2012/13 results)

### Overview

70. In the second appendix results are presented that reflect the available data for 2012/13 expenditure (this forms Appendix 2.1). In Appendix 2.2, the results are also analysed in terms of how sensitive the results are to two key inputs: i) each of the estimated elasticities and ii) assumptions made in order to overcome data limitations for each PBC (only have mortality outcome data and for only a portion of PBCs). Finally, Appendix 2.3 briefly considers an update regarding data from ONS used to inform burden of disease.

### Appendix 2.1 Results

71. Results are presented in two ways as the point estimate of the cost per QALY of marginal activity in the NHS, or alternatively expressed as the expected QALY health opportunity cost for £10,000,000 expenditure.

Table A8 Results for 2012/13 compared to previously generated results

Year	2008/09*	2009/10	2010/11	2011/12	2012/13
Cost per QALY	£12,311	£9,887	£10,225	£8,997	£14,410
Health opportunity costs of £10mn (QALYs)	812	1,011	978	1,112	694

\*re-applied PCT model

72. It can be seen from Table A8 that the expected health opportunity costs of a given level of expenditure have decreased between 2011/12 and 2012/13 and so the cost per QALY ratio has increased. The associated uncertainty with each of these results is presented in Table A9 and figures A1 and A2 below.

Table A9 results for 2012/13 expenditure compared to previously generated results

2008/09 (re-applied PCT model)	Point estimate (deterministic)	Point estimate (probabilistic)	5th percentile	95th percentile
Cost per QALY	£12,311	£12,570	£7,820	£32,666
Health opportunity costs of £10mn (QALYs)	812	796	306	1,279

2009/10	Point estimate (deterministic)	Point estimate (probabilistic)	5th percentile	95th percentile
Cost per QALY	£9,887	£9,920	£6,802	£17,296
Health opportunity costs of £10mn (QALYs)	1,011	1,008	578	1,470

2010/11	Point estimate (deterministic)	Point estimate (probabilistic)	5th percentile	95th percentile
Cost per QALY	£10,225	£10,214	£7,073	£17,153
Health opportunity costs of £10mn (QALYs)	978	979	583	1,414

2011/12	Point estimate (deterministic)	Point estimate (probabilistic)	5th percentile	95th percentile
Cost per QALY	£8,997	£8,985	£6,520	£13,945
Health opportunity costs of £10mn (QALYs)	1,112	1,113	717	1,534

2012/13	Point estimate (deterministic)	Point estimate (probabilistic)	5th percentile	95th percentile
Cost per QALY	£14,410	£14,411	£11,182	£19,861
Health opportunity costs of £10mn (QALYs)	694	694	504	894

It can be seen from Table A9 that the expected health opportunity costs of a change in expenditure have decreased between 2011/12 and 2012/13 and so the cost per QALY ratio has risen. The health opportunity costs of £10mn are smaller than those estimated using 2008/9 data with the re-applied specifications from the PCT model. In this table, the uncertainty associated with these estimates is shown and it can be judged to what extent any changes in the point estimate between years should be interpreted as a signal of any trend. From Table A9 it is hard to conclude that there is a significant change in the health opportunity costs of £10mn expenditure, since there is a great deal of overlap between the 90% confidence intervals of the years shown.

Figure A1 Results illustrating uncertainty for 2012/13 and previously generated results – cost per QALY

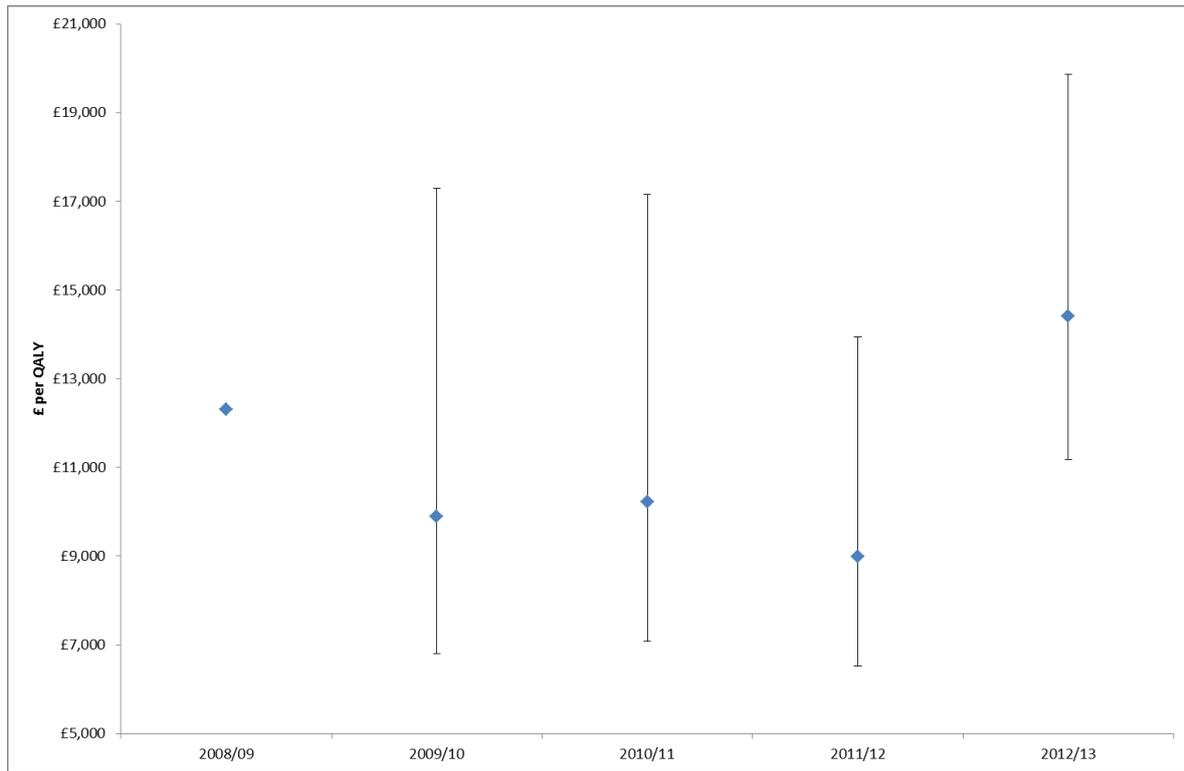
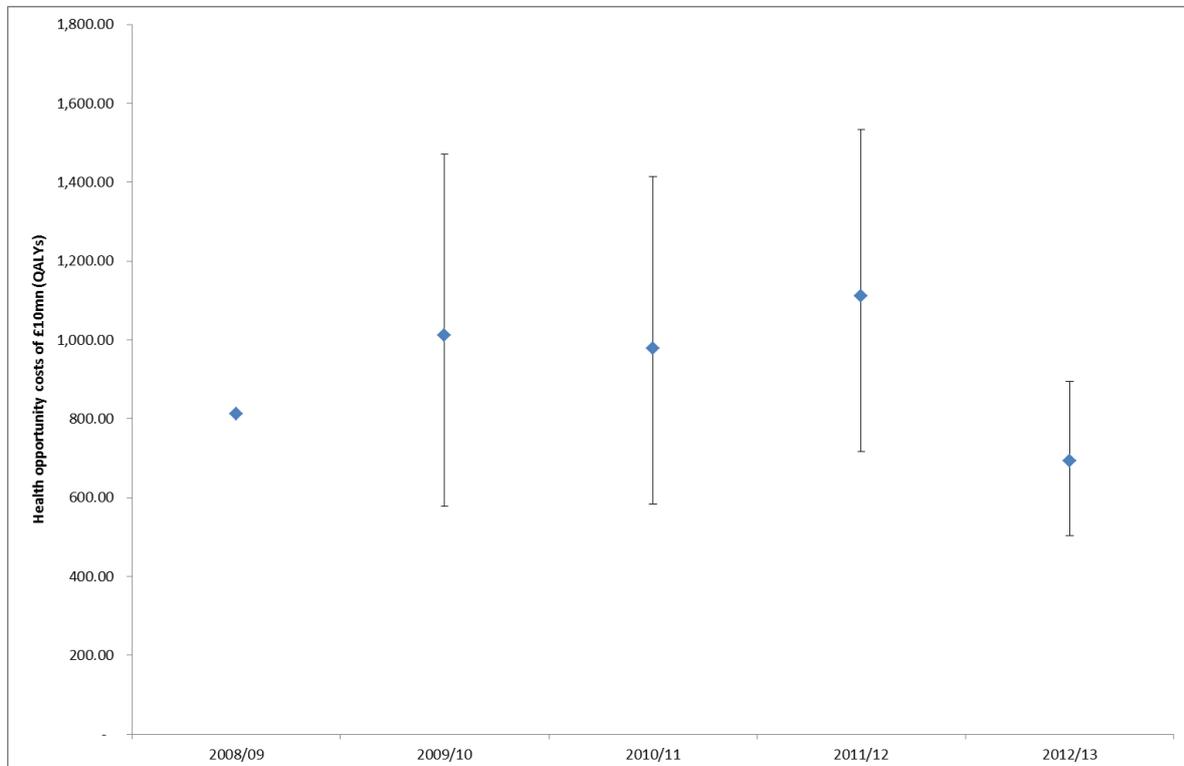


Figure A2 Results illustrating uncertainty for 2012/13 and previously generated results – Health opportunity costs of £10mn (QALYs)



73. The results contained within Table A9 are also represented graphically in Figures A1 and A2. The confidence intervals are presented for results pertaining to 2009/10 elasticities, 2010/11 elasticities, 2011/12 elasticities and 2012/13 elasticities, but not for 2008/9 elasticities. The reason for this is that the specifications used for 2009/10, 2010/11, 2010/11 and 2012/13 equations were adjusted if a re-application of the previous year's specifications resulted in poor statistical performance (see Appendix 1). The specification of the 2008/9 models, however, were directly taken from Claxton et al. (2015) where there were two key differences: analysis was at PCT and not LA level and census variables used 2001 values not 2008 values (calculated by interpolation between 2001 and 2011 census data). As such, the specification in the 2008/9 models may not have passed all statistical performance tests once moved to LA level and the instruments were updated to 2008 values (e.g 2008/9 specification may possess weak instruments that lead to imprecise coefficient estimation).

74. It can also be seen from Figures A1 and A2 that while the confidence interval is far from symmetrically distributed around the point estimate of the cost per QALY ratio in Figure A1 (where uncertainty is reflected in the denominator), when expressed as health opportunity costs per £10mn then the distribution of uncertainty is much more symmetric in Figure A2 (uncertainty is reflected in the numerator).

75. There are three potential causes for the variations between years: baseline values (burden and expenditure by PBCs), estimated outcome elasticities and estimated expenditure elasticities. In Table A10 and Figure A3 below we attempt to decompose the contribution of each of these different sources onto the overall estimate of health opportunity costs of £10mn. We do this by beginning with the model for 2011/12 and then sequentially partially inputting 2012/13 values until we arrive at the 2012/13 model. This allows us to 'step-through' the process of generating results for a new year of analysis. The sequence is as follows:

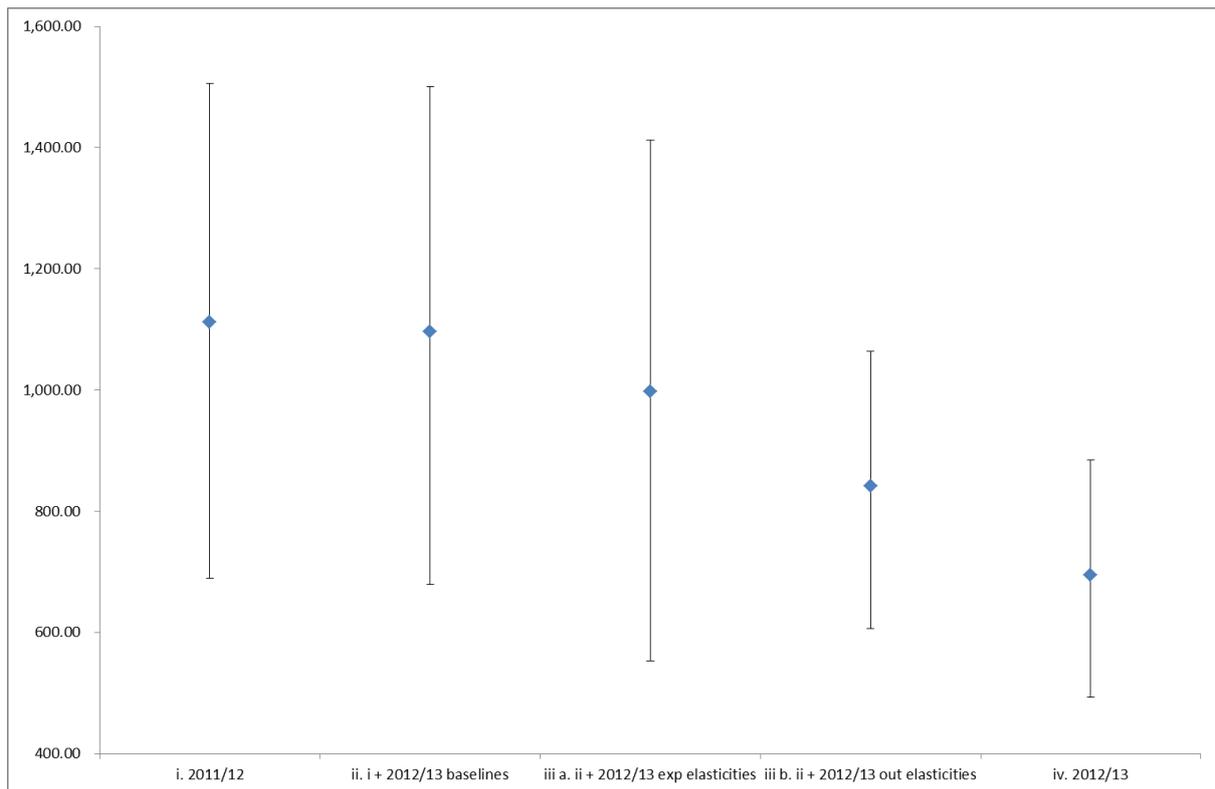
- i. 2011/12 model
- ii. 2011/12 model with 2012/13 baseline values
- iii.
  - a. 2011/12 model with 2012/13 baseline values and expenditure elasticities
  - b. 2011/12 model with 2012/13 baseline values and outcome elasticities
- iv. 2012/13 model

For each of ii, iii and iv the probabilistic analysis was performed on 5,000 iterations as opposed to the normal 20,000 iterations used in i and iv.

Table A10 Decomposing change in overall health opportunity costs of £10mn estimate between 2011/12 and 2012/13

Health opportunity costs of £10mn (QALYs)	Point estimate (deterministic)	Point estimate (probabilistic)	5th percentile	95th percentile
<b>i. 2011/12</b>	1,112	1,113	717	1,534
<b>ii. i + 2012/13 baselines</b>	1,096	1,092	691	1,513
<b>iii a. ii + 2012/13 exp elasticities</b>	997	994	582	1,441
<b>iii b. ii + 2012/13 out elasticities</b>	842	842	620	1,078
<b>iv. 2012/13</b>	694	694	504	894

Figure A3 Decomposing change in overall health opportunity costs of £10mn estimate between 2011/12 and 2012/13



76. From these results it is clear that the changes between 2011/12 and 2012/13 overall estimates result from a combination of the differences in estimated expenditure elasticities and estimated outcome elasticities. In addition, there is some interaction between these two that affects the overall result, since the difference between i and iv is greater than the difference between i and iii a

and i and iii b combined. Further, it can be seen that there is a clear reduction in uncertainty when 2012/13 outcome elasticities are inputted compared to the 2011/12 outcome elasticities.

77. It is also possible to generate implied cost per QALY ratio results for each individual PBC. If taken at face values then these results would have important policy implications, for example to divest from one PBC, perhaps maternity and neonates (PBCs 18 and 19), and to invest in another, for example respiratory (PBC 11). There are good reasons why this should not happen, namely potential ‘spillovers’ between PBCs and the assumption of proportionality between the effect of changes in expenditure on the QALY burden disease and the estimated proportionate effect on the mortality burden, which may be more appropriate for some PBCs than others. In Table A11, we consider how cost per QALY ratios for specific PBCs vary over time.

Table A11 Implied PBC cost per QALY ratios over time

	Implied PBC cost per QALY (£) 2009/10	Implied PBC cost per QALY (£) 2010/11	Implied PBC cost per QALY (£) 2011/12	Implied PBC cost per QALY (£) 2012/13
2 Cancer	£ 16,523.87	£ 25,406.48	£ 12,952.38	£ 15,898.57
10 Circulatory	£ 5,544.45	£ 6,108.68	£ 6,582.53	£ 7,274.40
11 Respiratory	£ 1,889.33	£ 1,912.83	£ 2,210.58	£ 2,411.65
13 Gastro-intestinal	£ 5,583.95	£ 7,724.82	£ 5,851.88	£ 6,432.45
1 Infectious diseases	£ 41,541.64	£ 51,622.80	£ 46,086.46	£ 40,830.94
4 Endocrine	£ 4,056.79	£ 28,337.44	£ 26,211.12	£ 10,523.80
7 Neurological	£ 1,866.46	£ 6,585.53	£ 1,710.05	£ 256,923.73
17 Genito-urinary	£ 28,904.12	£ 33,577.90	£ 215,941.87	£ 707,660.45
16 Trauma & injuries*	N/A	N/A	N/A	N/A
18+19 Maternity & neonates*	£ 2,765,793.49	£ 11,427,595.27	£ 3,722,944.22	£ 4,731,851.32
3 Disorders of Blood	£ 7,331.55	£ 5,221.93	£ 5,360.81	£ 7,189.07
5 Mental Health	£ 13,301.48	£ 10,161.35	£ 10,577.65	£ 14,289.44
6 Learning Disability	£ 103,050.77	£ 71,730.28	£ 41,727.46	N/A
8 Problems of Vision	£ 35,141.24	£ 29,389.20	£ 30,301.58	£ 41,341.39
9 Problems of Hearing	£ 4,875.99	£ 3,237.62	£ 3,439.82	£ 4,510.01
12 Dental problems	£ 30,249.72	£ 22,655.89	£ 22,467.03	£ 31,506.40
14 Skin	£ 78,047.29	£ 59,906.77	£ 62,989.94	£ 84,740.12
15 Musculo skeletal	£ 11,569.64	£ 9,323.76	£ 9,787.69	£ 13,545.60
20 Poisoning and AE	£ 83,574.76	£ 55,355.67	£ 58,373.17	£ 78,625.37
21 Healthy Individuals	£ 378,806.71	£ 287,282.84	£ 286,931.70	£ 346,536.63
22 Social Care Needs	N/A	N/A	N/A	N/A
23 Other	N/A	N/A	N/A	N/A

78. The results in Table A11 for each PBC are largely driven by two key variables: each PBC's estimated outcome elasticity and the changing burden of disease for PBCs. Expenditure elasticities only affect PBCs without a mortality signal through the mortality elasticity used for extrapolation, which depends upon expenditure elasticities. As a result, the variations observed in Table A11 reflect variations that can be seen in the elasticities found in Table A1. Take for instance PBC 7 – neurological – the highest (lowest) implied cost per QALY ratio is observed in 2012/13 (2011/12), which is the year with the smallest (largest) magnitude of outcome elasticity.

### **Appendix 2.2 Sensitivity analysis**

79. Appendix 2.2 details three sensitivity analyses that were performed. The first two concerned the elasticities that were econometrically estimated for each of the PBCs. In the first case each of the estimated PBC outcome elasticities are varied by +/- 1 standard error. Then, the difference between the two resulting opportunity costs is presented. When this is larger, this implies that the overall resulting estimate of health opportunity costs is more sensitive to the outcome elasticity under consideration. The same procedure is then carried out for each of the PBC expenditure elasticities. The results of these sensitivity analyses are reported in Tables A12 and A13.

Table A12 Sensitivity of results to estimated outcome elasticities

	Change in spend	Change in QALY death + QALY alive	Implied PBC cost per QALY (£)	Difference in health opportunity costs between +1 SE and -1 SE in PBC outcome elasticity	% difference in health opportunity costs between +1 SE and -1 SE in PBC outcome elasticity	Importance of PBC (rank)	Importance of PBC (rank) 2011/12	Importance of PBC (rank) 2010/11	Importance of PBC (rank) 2009/10
2 Cancer	£ 662,897.55	42	£ 15,898.57	52	7.48%	5	5	7	7
10 Circulatory	£ 1,007,028.41	138	£ 7,274.40	88	12.71%	3	3	3	3
11 Respiratory	£ 494,916.09	205	£ 2,411.65	134	19.31%	1	2	1	2
13 Gastro-intestinal	£ 539,720.67	84	£ 6,432.45	96	13.85%	2	4	4	4
1 Infectious diseases	£ 131,518.91	3	£ 40,830.94	2	0.27%	8	8	8	8
4 Endocrine	£ 330,707.15	31	£ 10,523.80	46	6.59%	6	6	6	5
7 Neurological	£ 431,954.90	2	£ 256,923.73	73	10.54%	4	1	2	1
17 Genito-urinary	£ 463,947.64	1	£ 707,660.45	11	1.57%	7	7	5	6
16 Trauma & injuries*	£ 447,083.30	0	N/A	-	-	-	-	-	-
18+19 Maternity & neonates*	£ 424,516.42	0	£ 4,731,851.32	0	0.03%	9	9	9	9
3 Disorders of Blood	£ 146,330.91	20	£ 7,189.07	-	-	-	-	-	-
5 Mental Health	£ 1,311,251.36	92	£ 14,289.44	-	-	-	-	-	-
6 Learning Disability	£ -	0	N/A	-	-	-	-	-	-
8 Problems of Vision	£ 369,173.21	9	£ 41,341.39	-	-	-	-	-	-
9 Problems of Hearing	£ 78,811.30	17	£ 4,510.01	-	-	-	-	-	-
12 Dental problems	£ 348,207.85	11	£ 31,506.40	-	-	-	-	-	-
14 Skin	£ 276,255.90	3	£ 84,740.12	-	-	-	-	-	-
15 Musculo skeletal	£ 440,252.82	33	£ 13,545.60	-	-	-	-	-	-
20 Poisoning and AE	£ 125,330.07	2	£ 78,625.37	-	-	-	-	-	-
21 Healthy Individuals	£ 242,347.45	1	£ 346,536.63	-	-	-	-	-	-
22 Social Care Needs	£ 612,797.70	0	N/A	-	-	-	-	-	-
23 Other	£ 1,114,950.40	0	N/A	-	-	-	-	-	-

Total: 694

Table A13 Sensitivity of overall results to estimated spend elasticities

	Change in spend	Change in QALY death + QALY alive	Implied PBC cost per QALY (£)	Difference in health opportunity costs between +1 SE and -1 SE in PBC spend elasticity	% difference in health opportunity costs between +1 SE and -1 SE in PBC spend elasticity	Importance of PBC (rank)	Importance of PBC (rank) 2011/12	Importance of PBC (rank) 2010/11	Importance of PBC (rank) 2009/10
2 Cancer	£ 662,897.55	42	£ 15,898.57	8	1.22%	12	9	3	12
10 Circulatory	£ 1,007,028.41	138	£ 7,274.40	33	4.79%	2	5	2	2
11 Respiratory	£ 494,916.09	205	£ 2,411.65	69	9.90%	1	2	1	1
13 Gastro-intestinal	£ 539,720.67	84	£ 6,432.45	15	2.18%	9	15	20	10
1 Infectious diseases	£ 131,518.91	3	£ 40,830.94	7	1.00%	14	12	12	15
4 Endocrine	£ 330,707.15	31	£ 10,523.80	1	0.11%	21	13	11	14
7 Neurological	£ 431,954.90	2	£ 256,923.73	18	2.53%	6	1	21	3
17 Genito-urinary	£ 463,947.64	1	£ 707,660.45	14	1.95%	10	10	10	11
16 Trauma & injuries*	£ 447,083.30	0	N/A	16	2.24%	8	7	7	5
18+19 Maternity & neonates*	£ 424,516.42	0	£ 4,731,851.32	17	2.50%	7	6	6	4
3 Disorders of Blood	£ 146,330.91	20	£ 7,189.07	5	0.66%	18	21	18	22
5 Mental Health	£ 1,311,251.36	92	£ 14,289.44	0	0.05%	22	18	22	13
6 Learning Disability	£ -	0	N/A	8	1.19%	13	11	8	9
8 Problems of Vision	£ 369,173.21	9	£ 41,341.39	6	0.80%	16	16	17	17
9 Problems of Hearing	£ 78,811.30	17	£ 4,510.01	6	0.81%	15	19	13	20
12 Dental problems	£ 348,207.85	11	£ 31,506.40	5	0.70%	17	17	15	16
14 Skin	£ 276,255.90	3	£ 84,740.12	9	1.28%	11	14	14	18
15 Musculo skeletal	£ 440,252.82	33	£ 13,545.60	1	0.14%	20	22	19	21
20 Poisoning and AE	£ 125,330.07	2	£ 78,625.37	3	0.46%	19	20	16	19
21 Healthy Individuals	£ 242,347.45	1	£ 346,536.63	18	2.56%	5	8	9	8
22 Social Care Needs	£ 612,797.70	0	N/A	23	3.27%	4	4	5	6
23 Other	£ 1,114,950.40	0	N/A	25	3.62%	3	3	4	7

Total: 694

80. The first thing that is striking is that PBC 6 (learning disability) is associated with no change in spend. This results from the zero point estimate of its spend elasticity. Generally, the results display varying degrees of sensitivity to estimated elasticities depending upon the PBC under consideration. In general, but not always, the results are more sensitive to specific PBC outcome elasticities than to specific PBC spend elasticities. Looking first at Table A13, for many PBCs, the difference between the overall health opportunity cost when the spend elasticity is increased by one standard error compared to the result when the standard error is reduced by one standard error represents less than 1% of the overall point estimate of health opportunity costs (PBCs 1, 4, 3, 8, 9, 12, 15 and 20). This difference is only greater than 10% for PBC 11 (respiratory). A significant change from the results for 2011/12 concerns PBC 7: neurological, the most important PBC in terms of spend elasticity in 2011/12, but only 7<sup>th</sup> most important in 2012/13. This can be explained by the considerably higher implied PBC cost per QALY for PBC 7 in 2012/13 compared to 2011/12. Switching to look at Table A12 it can be seen that the most important PBC in terms of outcome elasticity sensitivity is PBC 11: respiratory, as it is when spend elasticity is considered. The overall estimated health opportunity cost is also sensitive to PBC 13 (gastro-intestinal) and to a lesser extent PBCs 7 and 10 (neurological and circulatory).

81. Following these two sensitivity analyses, a third is performed with a different emphasis, which analyses the sensitivity of the overall health opportunity cost estimate to two key assumptions:

*Surrogacy*- we are required to make an assumption about how the effect on mortality for PBCs with a mortality indicator can be used as a *surrogate* for the effect that expenditure has on morbidity (or health-related quality of life) in those PBCs.

*Extrapolation*- We are required to make an assumption about how the estimated effects on mortality found for PBCs with a mortality indicator can be *extrapolated* to the effect that expenditure has on mortality for those PBCs that do not have a mortality indicator.

In order to assess the impact of these assumptions on the overall results for the NHS, we evaluate the health effects of £10mn spending at the margin in the NHS when either:

- a) For PBCs with a mortality indicator: no surrogacy assumption, therefore expenditure has no effect on morbidity
- b) For PBCs without a mortality indicator: assume no health effects at all, neither on mortality (extrapolation assumption) nor morbidity (surrogacy assumption)

The results are found here in Table A14.

Table A14 Sensitivity of overall results to surrogacy and extrapolation assumptions

	Change in spend	Change in QALY death	Change in QALY alive	Health opportunity costs sensitivity to mortality/morbidity assumption (%)	Importance of PBC (rank)	Importance of PBC (rank) 2011/12	Importance of PBC (rank) 2010/11	Importance of PBC (rank) 2009/10
2 Cancer	£ 662,897.55	39	3	-0.43%	12	12	18	16
10 Circulatory	£ 1,007,028.41	97	42	-6.00%	4	5	4	5
11 Respiratory	£ 494,916.09	11	194	-27.93%	1	1	1	2
13 Gastro-intestinal	£ 539,720.67	32	52	-7.51%	3	4	3	6
1 Infectious diseases	£ 131,518.91	1	2	-0.36%	13	15	14	13
4 Endocrine	£ 330,707.15	2	30	-4.26%	6	10	11	4
7 Neurological	£ 431,954.90	0	2	-0.24%	14	2	5	1
17 Genito-urinary	£ 463,947.64	0	1	-0.07%	17	18	10	10
16 Trauma & injuries*	£ 447,083.30	0	0	0.00%	-	-	-	-
18+19 Maternity & neonates*	£ 424,516.42	0	0	0.00%	18	19	19	19
3 Disorders of Blood	£ 146,330.91	1	19	-2.93%	7	7	9	7
5 Mental Health	£ 1,311,251.36	8	84	-13.22%	2	3	2	3
6 Learning Disability	£ -	0	0	0.00%	19	13	12	15
8 Problems of Vision	£ 369,173.21	0	9	-1.29%	10	11	8	12
9 Problems of Hearing	£ 78,811.30	0	17	-2.52%	8	8	7	8
12 Dental problems	£ 348,207.85	0	11	-1.59%	9	9	13	11
14 Skin	£ 276,255.90	1	2	-0.47%	11	14	16	14
15 Musculo skeletal	£ 440,252.82	2	31	-4.68%	5	6	6	9
20 Poisoning and AE	£ 125,330.07	0	1	-0.23%	15	17	15	17
21 Healthy Individuals	£ 242,347.45	0	1	-0.10%	16	16	17	18
22 Social Care Needs	£ 612,797.70	0	0	0.00%	-	-	-	-
23 Other	£ 1,114,950.40	0	0	0.00%	-	-	-	-
Total:		194	500					
Total change in QALY death + QALY alive			694					

82. It can be seen that the surrogacy assumption is especially impactful for PBC 11 (respiratory) while the assumption is only of negligible (<1%) importance for PBCs 1, 2, 7, 17 and 18+19 (infectious diseases, cancer, neurological, genito-urinary and maternity & neonates). PBC 7 is less important in terms of sensitivity in 2012/13 because of the much smaller estimated outcome elasticity in 2011/12 compared to 2010/11. Extrapolation and surrogacy is particularly important for PBC 5 (mental health) and only negligibly important for PBCs 6, 8, 14, 20 and 21 (learning disability, problems of vision, skin, poisoning and AE and healthy individuals).

### Appendix 2.3 Outline of ONS data update for 2012/13

83. The calculation of net YLL by PBC relies on two crucial inputs. The first is data on deaths within each PBC and the age of death, which is then compared to the benchmark of the second input, PBC life expectancy. Each death can then be translated into a number of years of life lost (YLL) if death occurred before the life expectancy and years of life gained (YLG) when the death occurred after the life expectancy. The difference between YLL and YLG gives net YLL, which is an input into the calculation of results. PBC life expectancy itself has to be calculated and relies on data provided by national life tables.

Table A15 Net YLL for 2008-2010, 2009-2011, 2010-2012, 2011-2013 and 2012-2014 using LE for each PBC

#### 2008-2010

PBC	GP LE (M)	GP LE (F)	PBC LE (M)	PBC LE (F)	All deaths	Net YLL
1	80.1	84.0	80.1	84.0	5,262	39,656
2	83.4	85.1	83.4	85.1	131,945	1,369,741
4	81.4	85.1	81.4	85.1	6,763	51,348
7	80.1	83.7	80.1	83.7	16,771	93,096
10	83.4	86.8	83.4	86.8	151,443	778,237
11	80.7	84.4	80.7	84.4	64,449	85,785
13	81.0	84.9	81.0	84.9	23,898	230,841
17	83.9	85.9	83.9	85.9	11,345	15,635
18+19	79.3	83.5	79.3	83.5	265	19,907

**2009-2011**

<b>PBC</b>	<b>GP LE (M)</b>	<b>GP LE (F)</b>	<b>PBC LE (M)</b>	<b>PBC LE (F)</b>	<b>All deaths</b>	<b>Net YLL</b>
<b>1</b>	80.5	84.3	80.5	84.3	4,907	38,814
<b>2</b>	83.7	85.4	83.7	85.4	132,656	1,395,819
<b>4</b>	81.7	85.4	81.7	85.4	6,477	51,079
<b>7</b>	80.5	84.0	80.5	84.0	17,113	93,164
<b>10</b>	83.6	87.1	83.6	87.1	142,567	768,320
<b>11</b>	81.1	84.7	81.1	84.7	63,088	101,927
<b>13</b>	81.4	85.2	81.4	85.2	23,499	235,041
<b>17</b>	84.1	86.2	84.1	86.2	10,600	16,230
<b>18+19</b>	79.7	83.8	79.7	83.8	252	18,895

**2010-2012**

<b>PBC</b>	<b>GP LE (M)</b>	<b>GP LE (F)</b>	<b>PBC LE (M)</b>	<b>PBC LE (F)</b>	<b>All deaths</b>	<b>Net YLL</b>
<b>1</b>	80.7	84.5	80.7	84.5	4,721	36,662
<b>2</b>	83.8	85.5	83.8	85.5	134,236	1,405,256
<b>4</b>	81.9	85.5	81.9	85.5	6,348	50,182
<b>7</b>	80.7	84.1	80.7	84.1	18,312	91,923
<b>10</b>	83.8	87.2	83.8	87.2	136,790	741,406
<b>11</b>	81.3	84.8	81.3	84.8	64,034	99,150
<b>13</b>	81.6	85.3	81.6	85.3	23,325	232,162
<b>17</b>	84.3	86.3	84.3	86.3	9,876	15,325
<b>18+19</b>	80.0	83.9	80.0	83.9	234	17,773

**2011-2013**

<b>PBC</b>	<b>GP LE (M)</b>	<b>GP LE (F)</b>	<b>PBC LE (M)</b>	<b>PBC LE (F)</b>	<b>All deaths</b>	<b>Net YLL</b>
<b>1</b>	80.9	84.6	80.9	84.6	4,836	36,190
<b>2</b>	83.9	85.5	83.9	85.5	135,439	1,411,055
<b>4</b>	82.1	85.6	82.1	85.6	6,227	51,216
<b>7</b>	80.9	84.2	80.9	84.2	19,603	89,638
<b>10</b>	83.9	87.2	83.9	87.2	131,189	717,461
<b>11</b>	81.5	84.9	81.5	84.9	66,138	96,351
<b>13</b>	81.8	85.3	81.8	85.3	22,922	228,849
<b>17</b>	84.4	86.3	84.4	86.3	8,983	14,710
<b>18+19</b>	80.1	84.0	80.1	84.0	219	16,478

**2012-2014**

<b>PBC</b>	<b>GP LE (M)</b>	<b>GP LE (F)</b>	<b>PBC LE (M)</b>	<b>PBC LE (F)</b>	<b>All deaths</b>	<b>Net YLL</b>
<b>1</b>	81.0	84.6	81.0	84.6	4,797	35,741
<b>2</b>	84.0	85.6	84.0	85.6	136,592	1,413,327
<b>4</b>	82.2	85.7	82.2	85.7	6,440	53,424
<b>7</b>	81.0	84.3	81.0	84.3	21,451	86,067
<b>10</b>	84.0	87.3	84.0	87.3	130,040	712,590
<b>11</b>	81.6	85.0	81.6	85.0	65,766	101,468
<b>13</b>	81.9	85.4	81.9	85.4	22,807	224,613
<b>17</b>	84.5	86.4	84.5	86.4	8,744	14,334
<b>18+19</b>	80.3	84.1	80.3	84.1	220	16,530

## Appendix 2.4 Calculation of elasticity for extrapolation and overall NHS mortality elasticities

84. Whilst we have estimated outcome elasticities for PBCs 2, 10, 11, 13, 1, 4, 7, 17 and 18+19, we need to use these to generate an overall elasticity for two purposes. The first is that we wish to extrapolate an estimated outcome elasticity to those PBCs without outcome indicators. The second is that there is a vast body of literature that estimates the elasticity of all-cause mortality with respect to health care expenditure, but this is not easily compared with disease-specific mortality elasticities.

85. For the purposes of extrapolation, a weighted average of outcome elasticities was employed by Claxton et al. (2015), where the weight was determined by the change in spend in each of the PBCs with outcome indicators (including PBC 16). However, this does not result in an overall elasticity as such, i.e. it does not reflect the % change in mortality across these PBCs for a % increase in expenditure for these PBCs. In order to obtain an elasticity like this, it is necessary to simulate the changes in expenditure and mortality that would result from a % increase in overall budget and then calculate the resulting % changes in expenditure and mortality to calculate the elasticity.

86. We also want to construct an estimate of overall mortality elasticity that can be used to compare with other studies that have estimated an all-cause mortality model. To do this, a similar procedure to that explained above (in 85.) is implemented, only the increase in mortality is expressed as a % of all mortality, rather than as a % of the mortality just from those PBCs with outcome indicators.

87. The effect of changing the way in which extrapolated elasticity is calculated has an ambiguous effect on the extrapolated elasticity and consequently the overall health opportunity costs estimate. Practically, we find that it has a modest effect, generally from extrapolated elasticity increases (all years except 2009/10) as shown in Table A16 where we give the results for 2009/10, 2011/12, 2012/13 and re-applied 2008/09 using both methods of elasticity extrapolation. We also provide overall mortality elasticity estimates for these years for comparison with all-cause model mortality elasticities.

Table A16 Estimated overall elasticities and implications for results

		<i>Year</i>				
<i>Year</i>		<i>*re-applied PCT model</i>				
		<i>2008/09*</i>	<i>2009/10</i>	<i>2010/11</i>	<i>2011/12</i>	<i>2012/13</i>
<b>Claxton et al. (2015) extrapolated elasticity</b>	<b>Cost per QALY</b>	£13,095	£9,662	£10,750	£9,643	£15,714
	<b>Health opportunity costs of £10mn (QALYs)</b>	764	1,035	930	1037	636
	<b>Elasticity for extrapolation</b>	0.66	1.25	1.25	1.07	0.79
<b>New extrapolated elasticity</b>	<b>Cost per QALY</b>	£12,311	£9,887	£10,225	£8,997	£14,410
	<b>Health opportunity costs of £10mn (QALYs)</b>	812	1,011	978	1,112	694
	<b>Elasticity for extrapolation</b>	0.88	1.13	1.55	1.53	1.15
	<b>Elasticity comparable to all-cause model results</b>	0.85	0.94	1.33	1.39	1.03

88. The methods compared in Table A16 are expressed in algebraic terms in the following paragraphs, for purposes of simplifying algebraic notation, PBC number re-assigned as below, with new number on the left and old number on the right:

1	2	Cancer
2	10	Circulatory problems
3	11	Respiratory problems
4	13	Gastro-intestinal problems
5	1	Infectious diseases
6	4	Endocrine problems
7	7	Neurological problems
8	17	Genito-urinary problems
9	16	Trauma & injuries*
10	18+19	Maternity & neonates*
11	3	Disorders of Blood
12	5	Mental Health Disorders
13	6	Problems of Learning Disability
14	8	Problems of Vision
15	9	Problems of Hearing
16	12	Dental problems
17	14	Problems of the Skin
18	15	Problems of the Musculo skeletal system
19	20	Poisoning and adverse effects
20	21	Healthy Individuals
21	22	Social Care Needs
22	23	Other

89. A list of the variables and label are provided below:

$\epsilon_{PBC}^{Exp}$	adjusted* PBC expenditure elasticity
$\dot{\epsilon}_{PBC}^{Exp}$	adjusted* PBC expenditure elasticity
$\epsilon_{PBC}^{Out}$	adjusted PBC outcome elasticity
$Exp_{PBC}$	PBC expenditure
$M_{PBC}$	PBC mortality (source: ONS)
$M_{ONS}$	All-cause mortality (source: ONS)
$\Delta Exp_{PBC}$	PBC change in expenditure
$\Delta M_{PBC}$	PBC change in mortality

\* Consider a change in overall budget of 1%

$\dot{\epsilon}_{PBC}^{Exp}$  represents adjusted elasticity so that 1% increase in budget is equal to the increases in PBC expenditures added together, i.e.  $\dot{\epsilon}_{PBC}^{Exp} = k * \epsilon_{PBC}^{Exp}$  where k is such that:

$$\sum_{PBC=1}^{22} \Delta Exp_{PBC} = \sum_{PBC=1}^{22} 0.01 * \dot{\epsilon}_{PBC}^{Exp} * Exp_{PBC} = 0.01 * \sum_{PBC=1}^{22} Exp_{PBC}$$

89. Claxton et al. (2015) approach  $\bar{\epsilon}$

Weighted average of the outcome elasticity by the change in expenditure for each PBC following a 1% increase in overall budget:

$$\bar{\epsilon} = \frac{\sum_{PBC=1}^{10} 0.01 * \dot{\epsilon}_{PBC}^{Exp} * Exp_{PBC} * \epsilon_{PBC}^{Out}}{\sum_{PBC=1}^{10} 0.01 * \dot{\epsilon}_{PBC}^{Exp} * Exp_{PBC}}$$

90. Alternative approaches – general equation:

$$Mortality\ elasticity = \frac{\Delta M / M}{\Delta Exp / Exp}$$

91. Calculating  $\check{\epsilon}$  (elasticity for extrapolation):

$$\Delta Exp = \sum_{PBC=1}^{10} \Delta Exp_{PBC} = \sum_{PBC=1}^{10} 0.01 * \dot{\epsilon}_{PBC}^{Exp} * Exp_{PBC}$$

$$Exp = \sum_{PBC=1}^{10} Exp_{PBC}$$

$$\Delta M = \sum_{PBC=1}^{10} \Delta M_{PBC} = \sum_{PBC=1}^{10} 0.01 * \dot{\epsilon}_{PBC}^{Exp} * \epsilon_{PBC}^{Out} * M_{PBC}$$

$$M = \sum_{PBC=1}^{10} M_{PBC}$$

$$\check{\epsilon} = \frac{\sum_{PBC=1}^{10} 0.01 * \dot{\epsilon}_{PBC}^{Exp} * \epsilon_{PBC}^{Out} * M_{PBC} / \sum_{PBC=1}^{10} M_{PBC}}{\sum_{PBC=1}^{10} 0.01 * \dot{\epsilon}_{PBC}^{Exp} * Exp_{PBC} / \sum_{PBC=1}^{10} Exp_{PBC}}$$

92. Calculating  $\hat{\epsilon}$  (overall elasticity to compare with all-cause mortality models):

$$\Delta Exp / Exp = 0.01$$

(%change in expenditure relevant here is % overall change in budget)

$$\Delta M = \sum_{PBC=1}^{10} \Delta M_{PBC} = \sum_{PBC=1}^{10} 0.01 * \dot{\epsilon}_{PBC}^{Exp} * \epsilon_{PBC}^{Out} * M_{PBC}$$

Effectively assume that no mortality effects in any of the other PBCs beside 10 with mortality indicator

$$\hat{\epsilon} = \frac{\sum_{PBC=1}^{10} 0.01 * \dot{\epsilon}_{PBC}^{Exp} * \epsilon_{PBC}^{Out} * M_{PBC} / M_{ONS}}{0.01}$$