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Letter title:
The impact of NHS expenditure on health outcomes in England:
alternative approaches to identification in all-cause and disease specific models of mortality.

Keywords: health outcomes, mortality, expenditure, cost per QALY, English NHS.

Abstract

Several recent studies have estimated the responsiveness of mortality to English NHS spending. Although broadly similar, the studies differ in how they identify the outcome equation. One approach uses conventional socio-economic variables as instruments for endogenous health care expenditure while the other exploits exogenous elements in the resource allocation formula for local budgets. The former approach has usually been applied to specific disease areas (for example, for cancer and circulatory disease) while the other has only been applied to all-cause mortality. In this letter we compare the two approaches by using them to estimate the direct all-cause elasticity as well as disease-specific elasticities. We also calculate the implied all-cause elasticity associated with the disease-specific results. We find that the 'funding rule' approach to identification can be successfully replicated and applied to disease area models. This is important because disease area models reduce the danger of aggregation bias present in all-cause analysis, and they offer the opportunity to link estimated mortality effects to more complete measures of health outcome that reflect what is currently known about the survival and morbidity disease burden in different programmes.

1. Introduction

Work by Claxton et al (2015, 2017) uses English data on disease-specific expenditure and mortality to estimate the health opportunity cost of NHS spending. Using a conventional instrumental variable approach, this work estimates (own programme) outcome and expenditure elasticities for each disease area. The study combines these elasticities with information about the burden of disease to obtain a cost per QALY of just under £13,000 for NHS expenditure in 2008 (Claxton et al, 2015 and 2017). The disease-specific elasticities are also used to calculate an implied all-cause elasticity of mortality with respect to health expenditure, and the value of this elasticity is -0.795 for 2008 (Claxton et al, 2017).

Andrews et al (2017) use a very similar dataset but a rather different estimation approach. Rather than estimate disease-specific elasticities, Andrews et al (2017) directly estimate the all-cause elasticity of mortality with respect to total health expenditure. The estimation of this (all programme) outcome elasticity is complicated by the fact that expenditure (both in total and for individual programmes) is likely to be endogenous and, therefore, should be instrumented. Claxton et al (2015, 2017) use various socio-economic variables as instruments and their approach has met with some criticism (for example, Barnsley et al (2013) question the reliability of expenditure data for individual programme budget categories).[1] Andrews et al note that the per capita budget assigned to each health authority is the product the national per capita budget and four adjustments reflecting local circumstances (eg the age index reflects the demographic profile of the local population). Andrews et al argue that three of these four adjustment factors are uncorrelated with mortality and,

[1] Barnsley et al (2013) also criticise how the elasticities estimated by Claxton et al (2015) were linked to more complete measures of health outcomes (QALYs), and whether the assumptions necessary for such calculations were optimistic or pessimistic with respect to health outcomes.

therefore, can be used as instruments for total expenditure. Using these so-called 'funding rule' instruments, Andrews et al report an all-cause elasticity of mortality with respect to NHS expenditure of -0.705 for 2005.

This letter reports the findings from an exploratory study that uses the Andrews et al funding rule instruments to estimate disease-specific outcome elasticities. This approach builds on the strengths of the studies mentioned above. First, the use of disease-specific expenditure and mortality data facilitates the use of burden of disease information to convert the cost per life year results into more useful cost per QALY estimates. Second, the use of the Andrews et al funding rule instruments permits an examination of what impact this alternative approach to identification has on the estimated outcome elasticity and implied cost per QALY of NHS expenditure.

2. Methods

The English National Health Service (NHS) is a centrally planned and publicly funded health care system. Its revenue derives almost entirely from national taxation, and access to the system is generally free to the patient. Primary care is an important element of the system, and general practitioners act as gatekeepers to secondary care and pharmaceuticals. The system is organized geographically, with responsibility for the local administration of the NHS devolved to local health authorities. Until April 2013 these authorities were known as Primary Care Trusts (PCTs). PCTs were allocated fixed annual budgets by the national ministry, within which they were expected to meet expenditure on most aspects of health care, including inpatient, outpatient and community care, primary care and pharmaceutical prescriptions (Claxton et al, 2015).

The share of the national budget allocated to each PCT was determined by the Department of Health's funding rule. This rule reflected each PCT's expenditure needs and this, in turn, reflected their population size, age profile, local input prices, and other need factors. Periodically, the Department revised its funding rule and this generated a new target allocation for each PCT. For some PCTs, the new funding rule might result in a large change in its target allocation and, to avoid sudden large reductions in actual allocations (budgets), such changes were usually phased in over a number of years.

Andrews et al (2017, p31) note that each PCT's annual allocation of health expenditure could be expressed as:

Health Expenditure per person= (National Budget per person) * (Age Index) *

(Additional Needs Index) * (Input Price Index) * (DFT Index) (1)

where: (a) the age index reflects the demographic profile of the local population; (b) the additional needs index reflects local deprivation and other factors likely to influence the need for health care; (c) the input price index reflects prices in the local health economy; and (d) the distance from target (DFT) index reflects how far each PCT's actual allocation is from its target allocation. The four index adjustments all take a mean value of one (Andrews et al, 2017, p31).

The health outcome equation estimated by both Claxton et al (2015, 2017) and Andrews et al (2017) is of the form:

$$\ln(\text{mortality rate}) = \ln(\text{health expenditure per person}) + \text{controls} + e \quad (2)$$

where expenditure is likely to be endogenous, the controls reflect the need for health care expenditure, and e reflects everything not included elsewhere in the specification. As controls, Claxton et al use a small number census based indicators of deprivation (eg the proportion of lone parent households) while Andrews et al use measures of education deprivation and income deprivation in older people. The use of different controls by the two research teams is considered to be of relatively little importance.

However, there is considerably more debate about the appropriate approach to identification. In their disease-specific work, Claxton et al use various socio-economic variables (such as the proportion of the population providing unpaid care) as instruments for expenditure. For their all-cause specification, Andrews et al argue that there is no need to use these variables as instruments because three of the four adjustment factors in (1) are unlikely to be correlated with mortality and therefore are appropriate instruments for total expenditure. The only exception is the additional needs index which is potentially endogenous because it contains historical mortality (reverse causation). Using three of these so-called 'funding rule' variables as instruments, Andrews et al report an all-cause elasticity of mortality with respect to NHS expenditure of -0.705 for 2005.

With only an all-cause elasticity and no disease-specific detail, it is very difficult to convert the Andrews et al elasticity to a cost per QALY basis. To overcome this problem, we re-estimate equation (2) for the four largest (in terms of mortality) disease categories: for cancer, circulatory disease, respiratory disease, and gastro-intestinal problems. As our starting point we use the funding rule variables identified by Andrews et al as instruments. Theory

provides little guidance as to the appropriate controls so, following Claxton et al, we identify a dozen socio-economic variables such as the proportion of lone pensioner households, the proportion of the population providing unpaid care, and the proportion of owner-occupied households (Claxton et al, 2015).

For each disease area, we start by estimating (2) with all socio-economic variables included as controls. The least significant regressor is removed from the specification and the equation is re-estimated. This process – of dropping the least significant regressor and re-estimating -- continues until there are only significant controls remaining. This specification becomes our preferred result if it also passes the appropriate statistical tests (eg the instruments are valid, and the instruments are strong) but, if this is not the case, the specification is adjusted (eg an invalid instrument is removed) and the equation re-estimated.

3. Data

Andrews et al use mortality and programme budgeting expenditure data for 152 PCTs for 2005/06 and, for comparability purposes, we adopt the same study year in this exploratory analysis. Expenditure and DFT data by PCT and disease area are available from the Department of Health's website [see https://www.england.nhs.uk/resources/resources-for-ccgs/prog-budgeting/] and historical mortality data is available on request from NHS Digital. The latest release of mortality data (for 2012-14) is available via the NHS Digital Indicator portal [see https://indicators.hscic.gov.uk/webview/]. We use the age/gender standardised rate of years of life lost (SYLLR) as the measure of mortality (Claxton, 2015).

The Department of Health's resource allocation books for 2003/4, 2004/5 and 2005/6 can be used to extract the relevant age and MFF indices for Hospital and Community Health

Services (HCHS) [see http://webarchive.nationalarchives.gov.uk/20090120134027/http://dh.gov.uk/en/Managingyourorganisation/Financeandplanning/Allocations/DH_4000344]. These allocations were for the 303 PCTs in existence in April 2003. In October 2006 there was a major re-organisation of PCTs and their number was reduced from 303 to 152. The mortality data for 2005-07 was constructed after this re-organisation and therefore relates to 152 PCTs. As we do not have an appropriate mapper to convert the age and MFF indices for the 303 PCTs to 152, we consulted later (post-reorganisation) resource allocation books for proxies for these variables. The resource allocation book for 2009/10 contains a MFF for HCHS but the age index for HCHS is combined with the additional need index for this year. As we want a pure age index, we use the age index for prescribing services from the allocation book for this year [see http://webarchive.nationalarchives.gov.uk/+/www.dh.gov.uk/en/Managingyourorganisation/Financeandplanning/Allocations/DH_091850]. The socio-economic variables are constructed using 2001 population census data.

4. Results

Table 1 shows our preferred specifications for the all-cause and the four disease-specific models. In all five cases the test statistics show that expenditure is endogenous, that the instruments are valid, and that they can be considered to be strong instruments (F statistic value about ten or better).

Column (1) reveals that the outcome elasticity for the all-cause model is -1.089. As all variables are measured as logarithms, this implies that 1% increase in expenditure per person is associated with a 1.089% reduction in mortality. This specification excludes the 'distance

from target' variable as an instrument because the Hansen-Sargan test statistic suggests that this is not a valid instrument.

The outcome elasticity for expenditure on cancer is -0.272 (see column (2)). This result includes all three funding rule variables as instruments. Column (3) reveals a significant outcome elasticity (=-2.450) for expenditure on circulatory disease and again this result includes all three funding rule variables as instruments.

Column (4) shows that the outcome elasticity for expenditure on respiratory disease is -2.194 and that this figure is statistically significant at the 5% level. This result only incorporates a single instrument (the input price index) although a very similar result is obtainable (with a coefficient of -2.355) if the MFF index is added to the specification. However, the addition of this extra instrument generates a slightly weaker set of instruments (Kleibergen-Paap F statistic=7.070) so we favour the single instrument specification (Angrist and Pischke, 2009).

Finally, the outcome elasticity for expenditure on gastro-intestinal problems is -2.888 (see column (5)) and this estimate is statistically significant at the 1% level. This result also omits one of the funding rule variables (the distance from target index) as the Hansen-Sargan test suggests that this is not a valid instrument.

5. Discussion

The results presented above can be compared with previous estimates. First, the all-cause outcome elasticity (=-1.089) is slightly larger (absolutely) than that (=-0.705) reported by Andrews et al (2017) for the same year (2005) but both values are within the 95% confidence interval of each other. There are various reasons why the two estimates might differ: first,

Andrews et al use different controls (education deprivation and income deprivation in older people) to those employed here; second, Andrews et al use a directly age-standardised mortality rate as their outcome variable but we use a directly age-standardised years of life lost rate; third, Andrews et al use the HCHS age index (for 2005/6 allocations) as an instrument but we use the prescribing age index (for 2009/10 allocations); and fourth, we weight observations by PCT population size when estimating the regressions (because PCTs differ greatly in size) but Andrews et al appear to give the same weight to each PCT.

The all-cause elasticity reported in Table 1 (=-1.089) can also be compared with the implied all-cause elasticity obtained from disease-specific work. Claxton et al (2017) use data on mortality and expenditure to estimate disease-specific outcome elasticities for 2005. These elasticities can be used to calculate an implied all-cause elasticity (=-1.372) and its associated 95% confidence interval (-1.905, -0.890). The directly estimated all-cause elasticity might be smaller (absolutely) than the implied all-cause value from the disease-specific results due to the presence of aggregation bias in the directly estimated all-cause specification.

The disease-specific (all programme) outcome elasticities reported in Table 1 and summarised in column 1 of Table 2 can be compared with disease-specific (own programme) outcome elasticities obtained with the use of a different set of (non-funding rule) instruments. Claxton et al (2017) use various socio-economic indicators as instruments and the outcome elasticities associated with a change in own programme expenditure are shown in the second column of Table 2. These elasticities are associated with a small change in own programme expenditure so they cannot be directly compared with the elasticities shown in column 1 because the latter reflect a small change in the total (not own programme) budget. Fortunately, however, Claxton et al (2017) also report expenditure elasticities; these show the

change in own programme expenditure that is associated with a change in total budget (see column 3 of Table 2). If we form the product of the elasticities shown in columns 2 and 3 of Table 2, we obtain the elasticities shown in column 4 and, as these reflect the responsiveness of mortality to a small change in total budget, they can be directly compared with the outcome elasticities shown in Table 1 and reproduced in column 1 of Table 2. This comparison reveals that the choice of instruments has virtually no impact on the elasticities for both cancer and circulatory disease. The funding rule outcome elasticity for respiratory disease is slightly smaller than that obtained with the use of socio-economic instruments, and the funding rule outcome elasticity for gastro-intestinal problems is larger than that obtained with the use of socio-economic instruments.

One advantage of the funding rule approach over that of Claxton (2015, 2017) is that, by using total expenditure rather than individual programme expenditure, it is less susceptible to questions about the reliability of individual programme budget data. Moreover, the study of the impact of own programme expenditure on PBC outcome means that the resulting elasticity is unable to reflect the impact of other programme expenditure on own programme mortality. Similarly, own programme expenditure might be contributing to other programme mortality. If co-morbidities are important, we would expect the (all budget) outcome elasticities to be larger (absolutely) than the own programme outcome elasticities because the former will reflect the impact of spending in all programmes on programme-specific mortality, whereas the own programme outcome elasticities will only reflect spending in the specific programme.

6. Conclusion

Although these results are only for one year and only for four programmes, they provide no evidence to suggest that an entirely different approach to identification generates materially different results. These findings also suggest that the 'funding rule' approach to identification can be successfully replicated and applied to disease area models. This is important because disease area models reduce the danger of aggregation bias present in all-cause analysis, and they offer the opportunity to link estimated mortality effects to more complete measures of health outcome that reflect what is currently known about the survival and morbidity disease burden in different programmes.

The 'funding rule' approach to instrumentation combined with its application at disease area level is likely to provide a secure foundation for re-estimating health opportunity costs as data on expenditure and outcomes by programme evolve in the UK. This approach also points to fruitful ways to investigate health opportunity costs in other health care systems where there are exogenous elements in resource allocation mechanisms.

References

Martyn Andrews, Obbey Elamin, Alastair R. Hall, Kostas Kyriakoulis and Matthew Sutton (2017). Inference in the presence of redundant moment conditions and the impact of government health expenditure on health outcomes in England, Econometric Reviews, 36:1-3, 23-41, DOI: 10.1080/07474938.2016.1114205

Angrist J and Pischke J S (2009). A Note on Bias in Just Identified IV with WeakInstruments. Mimeo, available at http://econ.lse.ac.uk/staff/spischke/mhe/josh/solon_justid_April14.pdf.

Paul Barnsley, Adrian Towse, Sarah Karlsberg Schaffer and Jon Sussex (2013). Critique of CHE Research Paper 81: Methods for the Estimation of the NICE Cost Effectiveness Threshold. OHE Occasional Paper 13/01.

Claxton K, Martin S, Soares M, et al. Methods for the estimation of the National Institute for Health and Care Excellence cost-effectiveness threshold. Southampton (UK): NIHR Journals Library; 2015 February (Health Technology Assessment, No. 19.14.) Available from: https://www.ncbi.nlm.nih.gov/books/NBK274315/ doi: 10.3310/hta19140.

Claxton K, et al (2017). Re-estimating health opportunity costs in the NHS. Available at: https://www.york.ac.uk/che/research/teehta/health-opportunity-costs/re-estimating-health-opportunity-costs/#tab-2.

Table 1 Preferred outcome specifications for all-cause mortality and four disease-specific causes of mortality

VARIABLES	(1) PBC All 2005/06 spend SYLLR 2005/06/07 all cause outcome	(2) PBC 02 2005/06 spend SYLLR 2005/06/07 cancer outcome	(3) PBC 10 2005/06 spend SYLLR 2005/06/07 circulatory outcome	(4) PBC 11 2005/06 spend SYLLR 2005/06/07 respiratory outcome	(5) PBC 13 2005/06 spend SYLLR 2005/06/07 gastro outcome
Expenditure per person	-1.089***	-0.272	-2.450***	-2.194**	-2.888***
	[0.359]	[0.175]	[0.539]	[1.013]	[0.995]
Controls					
Proportion of residents born outside the EU		-0.052***			
		[0.009]			
Proportion of population aged 16-74 without qualifications		0.094**			
		[0.039]			
Proportion of one parent households	0.296***	0.337***		0.446***	
	[0.048]	[0.047]		[0.154]	
Proportion of owner occupier households	-0.541***	-0.225**	-0.419**	-0.956**	
	[0.162]	[0.102]	[0.186]	[0.420]	
Proportion of households without a car			1.029***		2.400***
			[0.142]		[0.851]
Proportion of those aged 16-74 in professional occupations			-0.331***		
			[0.089]		
Proportion of those aged 16-74 in employment in agriculture				-0.119***	
				[0.038]	
Proportion of population aged 16-74 with a limiting long-term illness	0.651***			1.195***	4.452**
	[0.104]			[0.319]	[2.137]
Constant	8.437***	5.903***	6.011***	6.546***	12.335***
	[0.271]	[0.119]	[0.342]	[0.539]	[2.428]
Observations (PCTs)	152	152	152	152	152
Endogeneity test statistic	19.361	3.452	28.750	7.541	9.677
Endogeneity p-value	0.000	0.063	0.000	0.006	0.002
Hansen-Sargan test statistic	0.842	3.586	0.396		0.063
Hansen-Sargan p-value	0.359	0.166	0.820		0.801
Kleibergen-Paap LM test statistic	14.302	20.794	21.890	8.896	15.111
Kleibergen-Paap p-value	0.001	0.000	0.000	0.003	0.001
Kleibergen-Paap F statistic	9.411	12.305	11.641	9.618	10.066
Pesaran-Taylor reset statistic	0.004	1.375	0.007	0.043	0.396
Pesaran-Taylor p-value	0.951	0.241	0.931	0.835	0.529

Notes: (i) Robust standard errors in brackets; ***p<0.01, **p<0.05, *p<0.01.
(ii) The gastro-intestinal specification also includes two squared controls (households with no car and population with a limiting long-term illness).

Table 2 Comparing outcome elasticities using different approaches to identification

	Using funding rule variables as instruments	Using socio-economic variables as instruments		
	Outcome elasticity associated with a 1% increase in total budget	Outcome elasticity associated with a 1% increase in own programme expenditure	Expenditure elasticity associated with a 1% increase in total budget	Implied outcome elasticity associated with a 1% increase in total budget
Disease area	(1)	(2)	(3)	(4)
Cancer	-0.272	-0.159	1.592	-0.253
Circulatory disease	-2.450	-1.637	1.477	-2.418
Respiratory disease	-2.194	-2.217	1.225	-2.716
Gastro-intestinal problems	-2.888	-1.014	1.076	-1.091