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Causal impact of social care, public health and healthcare expenditure on mortality in England: cross-sectional evidence for 2013/2014

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ABSTRACT

Objectives The first objective is to estimate the joint impact of social care, public health and healthcare expenditure on mortality in England. The second objective is to use these results to estimate the impact of spending constraints in 2010/2011–2014/2015 on total mortality.

Methods The impact of social care, healthcare and public health expenditure on mortality is analysed by applying the two-stage least squares method to local authority data for 2013/2014. Next, we compare the growth in healthcare and social care expenditure pre-2010 and post-2010. We use the difference between these growth rates and the responsiveness of mortality to changes in expenditure taken from the 2013/2014 cross-sectional analysis to estimate the additional mortality generated by post-2010 spending constraints.

Results Our most conservative results suggest that (1) a 1% increase in healthcare expenditure reduces mortality by 0.532%; (2) a 1% increase in social care expenditure reduces mortality by 0.336%; and (3) a 1% increase in local public health spending reduces mortality by 0.019%. Using the first two of these elasticities and data on the change in spending growth between 2001/2002–2009/2010 and 2010/2011–2014/2015, we find that there were 57 550 (CI 3075 to 111 955) more deaths in the latter period than would have been observed had spending growth during this period matched that in 2001/2002–2009/2010.

Conclusions All three forms of public healthcare-related expenditure save lives and there is evidence that additional social care expenditure is more than twice as productive as additional healthcare expenditure. Our results are consistent with the hypothesis that the slowdown in the rate of improvement in life expectancy in England and Wales since 2010 is attributable to spending constraints in the healthcare and social care sectors.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ Cross-sectional analysis of the causal impact of social care, healthcare and public health expenditure on mortality.
- ⇒ Two-stage least squares regression allows for the endogenous nature of all three types of expenditure.
- ⇒ Controls for the need for healthcare-related expenditure are also included.
- ⇒ We compare the growth in healthcare and social care expenditure pre-2010 and post-2010. We find that there were 57 550 more deaths in the latter period than would have been observed had spending growth during this period matched that in the earlier period.
- ⇒ The responsiveness of mortality to changes in health-related expenditure in 2013/2014 may not hold in other years and there may be other factors affecting mortality beyond those included in this study.

INTRODUCTION

The rate of improvement in life expectancy in England and Wales has slowed markedly since 2010.[1–3] This decline has been most marked for women aged over 85 years and these people tend to be the most physically frail and/or disadvantaged.[4] It has also been noted that the very elderly tend to be the most dependent on a well-functioning publicly funded health and social care system.[5] As the slowdown in life expectancy growth has coincided with the imposition of government spending constraints, it has been hypothesised that these constraints are the major cause of the stalled improvement in life expectancy.[6 7]

A recent study assembled annual data on healthcare and social care spending for England from 2001 to 2014 to estimate the impact of the UK government's spending constraints on mortality.[8] Time trend analysis was used to compare the actual mortality rate between 2011 and 2014 with the expected counterfactual rate based on the trend before the imposition of budgetary restrictions in 2010. The study found that spending constraints between 2010 and 2014 were associated with an estimated 45 000 more deaths than would have been expected based on pre-2010 trends.[8]

This finding has generated considerable controversy and merits further investigation.

We approach the same issue but from a very different perspective. Instead of extrapolating historic trends at the national level, we use two-stage least squares (instrumental variable) regression to estimate the causal relationship between spending and mortality across local authorities (LAs) at a single point in time (2013/2014). Like the time trend study, we consider the impact of both healthcare and social care expenditure on mortality, but we also control for the impact of public health expenditure.

There are few English studies of the impact of healthcare on mortality, and even fewer of the joint impact of healthcare and public health expenditure on mortality.[9 10] The social care literature has concentrated on the impact of expenditure on the quality of life rather than on mortality.[11] Other studies focus on the relationship between the public social care and healthcare sectors. They find a substitution effect between social care and healthcare services so that an increase in social care services may improve hospital outcomes, for example, by reducing delayed discharges.[12–15] However, we are not aware of any English studies of the joint impact of social care, healthcare and public health expenditure on mortality, and hence this study presents the first such estimates. We combine these estimates with information about the size of the post-2010 spending constraints to provide an alternative estimate of how many lives such constraints cost between 2011 and 2014.

A recent American study looked at the association between healthcare/social service expenditure and health outcomes across the states for the period 2000–2009.[16] This concluded that debates about how much should be invested in healthcare should also consider how much is invested in social services. We build on this work in two ways so that we are able to provide more precise guidance for English policy makers. First, the American study defined social service expenditure as comprising public expenditure on all services (such as education, transportation and public safety) that address the social determinants of health. Instead, we focus on definitions of healthcare and adult social care expenditure as they reflect the different budgets allocated by central government to different public bodies in England. Second, by adopting this approach we are also able to estimate the size of the causal impact of this and other types of healthcare-related expenditure on mortality rather than examining observed associations. Such causal estimates can start to inform a range of decisions about the scale and allocation of public expenditure made by public bodies and central government.

The plan of this paper is as follows. The second section describes the institutional arrangements associated with the three types of health-related expenditure that are the focus of this study. The third section describes the health outcome equation to be estimated and how we address the issue of reverse causation (ie, that mortality may affect expenditure as well as vice versa). The fourth section describes our estimation approach and the fifth section presents brief details of the dataset. The sixth section presents our results and there is a discussion of them in the last section.

INSTITUTIONAL ARRANGEMENTS FOR HEALTH-RELATED EXPENDITURE IN ENGLAND IN 2013/2014

Social care

Adults with a physical disability, a learning disability, or a physical or mental illness often have difficulty with routine daily activities such as washing, dressing, cooking and shopping. Such individuals are usually supported in two main ways: either formally through services that they or their LA pay for; and/or informally by family, friends or neighbours.[17] In England, social care expenditure funds residential and nursing home placements, social care in the community to aid daily living, short-term care (eg, vision rehabilitation and other reablement services to improve independence), equipment and domestic adaptations, and information provision. Public spending on other services addressing the social determinants of health (such as housing, income support, sanitation, transport, etc) is not included in our measure of social care expenditure.

Funding for LAs comes from three major sources: the local council tax, central government grants and local business rates. The size of the central government grant will reflect the LA's relative need for expenditure and its income raising capability. LAs have extensive statutory responsibilities in the area of adult social care and they apply national criteria to assess whether people's needs are eligible for LA-funded social care. These national criteria were introduced by the Care Act (2014), and reduced the variation in the eligibility for LA-funded social care between local areas. Before the introduction of the Care Act, LAs were able to set their own thresholds for the need for social care based on the criteria set out in the Fair Access to Care Services framework.[18] Even if eligible for LA-funded social care, the provision of such funding is means tested so that, depending on a person's financial situation, they may be asked to contribute to some or all of their social care costs.[17]

Care needs are often multiple and interrelated with other needs. Adult social care is therefore part of a complex system of related public services and forms of support. Since 2010, spending constraints imposed by central government may have had some unfortunate effects on allied public services. For example, there is the long-standing argument that inadequate social care provision may be responsible for the delayed discharge of elderly patients from hospital, and that inadequate care in the community may contribute to the growth in emergency hospital admissions.[19 20] Moreover, inadequate social care provision may be associated with an increase in mortality. Although social care is primarily concerned with improving the quality of life, it is perfectly plausible that social care extends life and that those with care needs enjoy both a lower mortality rate and a better quality of life in those LAs with more generous social care provision.

Public health

Consideration of social care expenditure in isolation is slightly problematic because, since April 2013, LAs have also been responsible for local public health services. Each 'unitary' or upper tier LA receives a fixed annual budget, ring-fenced for public health activities.[21] For a few services there may be scope to use either the social care or the public health budget and so, when studying the impact of social care expenditure, it may be wise to control for expenditure on local public health services. And of course, public health expenditure will have a direct effect on mortality. Local public health activities accounted for over £2500 million of expenditure in 2013/2014 and included services related to substance misuse (roughly one-quarter of expenditure), sexual health (roughly one-third of expenditure), children's health (about 10%) and tobacco control (about 5%). Expenditure on national public health programmes is excluded from the analysis because no breakdown of this expenditure by locality is available.[22]

Healthcare in England

English National Health Service (NHS) healthcare expenditure was managed by 212 Clinical Commissioning Groups (CCGs) in 2013/2014.[23] These local health authorities were each allocated a fixed annual budget and this was determined centrally in a similar manner to how each LA was assigned its budget for local public health responsibilities. These budgets were used by CCGs to fund expenditure on various types of care including inpatient, outpatient and community care, and pharmaceutical prescriptions. It is worth noting that CCGs did not have responsibility for either primary care or specialised commissioning in the study year (2013/2014). These were administered centrally and expenditure on these items has been excluded from the study because data are not available by local area.

METHODS: THE ESTIMATING EQUATION AND THE SELECTION OF INSTRUMENTS FOR EXPENDITURE

The estimated health outcome equation

We adapt the usual health outcome equation to estimate the joint impact of social care, public health and healthcare expenditure on mortality across English LAs in 2013/2014.

We estimate

$$\text{morality rate}_i = f[\text{healthcare expenditure}_i,\ \text{public health expenditure}_i,\ \text{social care expenditure}_i] + \text{controls for need}_i + e_i \quad (1)$$

The control variables reflect the need for health-related expenditure in authority i, and e reflects everything not included elsewhere in the specification.[9] Quantifying the impact of these categories of expenditure on mortality is challenging for two reasons: first, there might be some reverse causation with historical outcomes (eg, mortality) influencing the current level of budget/expenditure; and second, there might be some unobserved factor that is driving both expenditure and mortality.

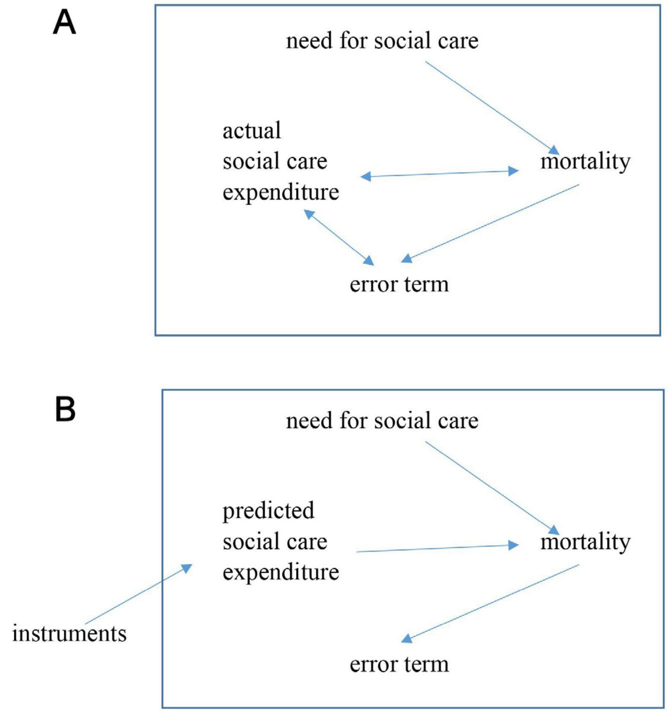

Figure 1 Illustration of the reverse causation issue and its resolution (created by the authors).

As an illustration of the reverse causation issue, consider figure 1. The box defines the structural model in which the mortality rate depends on social care expenditure and controls for need (we have omitted healthcare and public health expenditure from the figure for simplicity but the same illustration could also be used for these two other types of health-related expenditure). In figure 1A, social care expenditure both affects mortality and is affected by (historical) mortality. This reverse causation links expenditure and the error term, and this makes the ordinary least squares (OLS) estimator both biased and inconsistent.

The solution to this problem is to find variables (known as 'instruments') that are good predictors of expenditure but which have no direct impact on mortality and are unaffected by unobserved factors. These instruments lie outside the box in figure 1B because they do not belong in the structural model. They are used in a regression model to predict the level of expenditure that is not influenced by either historical mortality or unobserved factors (this is the first stage of the two-stage least squares approach). Having severed the link with unobserved factors and mortality, the predicted level of expenditure is then used in another regression model to examine the causal impact of (predicted) expenditure on mortality (this is the second stage of the two-stage least squares approach (2SLS)).

A recent study of the impact of healthcare expenditure suggested using components of the formulae used to distribute funding across health authorities as instruments for healthcare expenditure.[24] We apply this approach to identification here because the distribution of funding for all three types of health-related expenditure is informed by various centrally determined resource allocation formulae.

Instruments for social care expenditure

In the study year (2013/2014), each LA received a grant from central government that reflected its relative need for expenditure on a variety of services for which it was responsible. Each service area had its own relative needs formula (RNF) that contributed to its overall relative need, but LAs were free to decide how much to spend in each service area (subject to meeting their statutory obligations). Adult social care had two RNFs: one for people aged 18–64, and another for those aged over 65. The RNF for the older people's social care included a basic amount per client with top-ups for age, deprivation, low income, low population density (because this increases service delivery costs) and local input prices (in some areas, such as London, labour costs will be higher than elsewhere).[25] As any instrument should be well correlated with expenditure but not directly correlated with mortality, we use the sparsity and input price adjustment variables from the older person's RNF as instruments for (predictors of) social care expenditure.

A study of the impact of LA expenditure on home care services approached the instrument issue from a different perspective.[26] It claimed that social care expenditure will reflect the service eligibility policy employed by different LAs and that 'the innate culture and perspective of the council…will drive the generosity of policies more than small differences in the health of the population'. The researchers proposed the use of a set of four dummy variables reflecting the type of LA (Shire, Unitary, Metropolitan, London) as instruments on the assumption that 'similar' LAs will have 'similar' eligibility policies and expenditure levels.[26]

Finally, we note that LA-funded social care is means tested and, for example, owner occupiers who go into care homes are expected to sell their home to fund their care but that those in rented accommodation have their care costs paid for by the LA. This suggests that the proportion of households that are owner occupied in an area may serve as an instrument for LA social care expenditure (given appropriate controls for health-related need).

Together, the funding rule, the type of LA and the owner-occupied household variables provide seven potential instruments for social care expenditure.

Instruments for healthcare expenditure

For our study year (2013/2014), each local health authority (212 CCGs) was assigned a fixed share of the national budget (£65 billion) by the Department of Health within which they were supposed to meet expenditure on most types of healthcare except primary care, specialised commissioning and public health. With a little simplification, the budget available to each CCG can be expressed as

$$\begin{aligned}\text{local CCG budget per person} = \; & (\text{national budget per person}) \times \\ & (\text{local age index}) \times \\ & (\text{local additional needs index}) \times \\ & (\text{local input price index}) \times \\ & (\text{local DFT Index})\end{aligned} \quad (2)$$

where (1) the age index reflects the demographic profile of the local population; (2) the additional needs index reflects local deprivation and other factors likely to influence the need for healthcare and includes a measure of historical mortality; (3) the input price index (the market forces factor (MFF)) reflects prices in the local health economy; and (4) the distance from target (DFT) index reflects how far each health authority's actual budget allocation is from its target allocation.[24]

Because the additional needs index contains historical mortality, it is clear that reverse causality is an issue and that this (additional needs) index cannot constitute a plausible instrument for expenditure. However, the other indices provide suitable instruments for CCG expenditure. Further details about these instruments are in online supplemental appendix A1 but, in summary, these funding rule variables are as follows: (1) the DFT index for the total allocation; (2) the MFF for the Hospital and Community Health Services (HCHS) component of the total allocation; and (3) the age index from the cost of prescribing pharmaceuticals component of the total allocation.

Instruments for public health expenditure

We instrument the public health expenditure variable using a similar approach to both healthcare and social care expenditure. The resource allocation formula for the public health grant to LAs has a similar structure to the CCG grant (as outlined in equation (2)) and we use two of the four local adjustment factors for the public health grant (the MFF and the DFT) as instruments for public health expenditure. Further details about these instruments are in online supplemental appendix A2.

Are the selected instruments plausible and strong?

For 2SLS to generate consistent estimates of the impact of expenditure on mortality, certain assumptions have to be met. First, the instruments should be good predictors of the expenditure variable. The usual test for good ('strong') instruments is that the F statistic associated with the instrument(s) in the first-stage regression should be about 10 or better, and hence, we report the Sanderson-Windmeijer F test statistic for all first-stage estimations.[27] The second assumption is that any instrument for expenditure has no direct effect on mortality other than via its effect on expenditure, and that the instrument should be uncorrelated with unobserved determinants of expenditure and mortality (this is the validity assumption).

Studies that use instrumental variable regression usually contain a discussion about why the researchers believe that such instruments are likely to be valid. This discussion for the present study can be found in online supplemental appendix A3. In addition, the instrument validity assumption can be tested empirically and hence, where possible, we report the Hansen-Sargan test statistic of instrument validity for the second-stage equations.[28]

METHODS: ESTIMATION APPROACH

The estimation of equation (1) is complicated by the fact that theory provides little guidance as to the identity of the appropriate controls for need. Hence, following previous studies, we identify a dozen socioeconomic variable—such as the proportion of the population of working age employed in managerial/professional occupations—as potential controls for the need for healthcare/public health/social care expenditure.[9 10]

We also have a dozen instruments. There are four 'type of LA' dummy variables, two variables from the RNF for social care, and a measure of the local owner-occupation rate for social care expenditure. We also have two potential instruments for public health expenditure (the DFT index and the input price index) from its resource allocation formula. Finally, we have three potential instruments (the DFT index, the input price index and the age index) for healthcare expenditure from the resource allocation formula for healthcare budgets.

Ideally, we would like a more parsimonious set of controls (to reduce multicollinearity problems) and a more parsimonious set of instruments (to minimise problems with weak instruments). To achieve these goals, we first estimate a health outcome equation using OLS with all controls and all three types of expenditure included. The least significant control 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 (the expenditure variables are forced to be ever-present). Having identified potentially relevant covariates, these controls are then included in a two-stage least squares specification and a process similar to backward selection is used to eliminate problematic (invalid and/or weak) instruments.

As a sensitivity analysis, we repeat the above analysis but use forward rather than backward selection to identify a parsimonious set of controls.

When estimating regressions, the values for all variables are logged so that regression coefficients can be interpreted as elasticities (eg, the coefficient on an expenditure variable reflects the impact on mortality of a 1% change in the value of the expenditure variable). All observations are weighted by the size of LA's population. Estimation is undertaken using the *Stata ivreg2* program.[28] In addition to the weak instrument and instrument validity tests mentioned above, we also report a test for whether the expenditure variables are endogenous and a reset test (Pesaran-Taylor) for model mis-specification.[29]

Patient and public involvement

Neither patients nor the public were involved in the design, or conduct, or reporting or dissemination of our research.

DATA

We use the gross current expenditure on adult social services by each LA in 2013/2014 as our measure of social service expenditure.[22] This measure excludes capital charges and, to avoid any double counting issues, it also excludes income from joint commissioning arrangements and income from the NHS. However, it includes income from locally determined (and means tested) client contributions towards their LA care package. This expenditure figure is divided by the LA population size to generate a per capita expenditure figure. As table 1 shows, the average spend by LA is £307 per person, although there is considerable variation in expenditure across the country: for example, social service expenditure ranges from £209 per person in Barnsley to £404 in Camden and £660 in the City of London.

Healthcare expenditure data are available from each CCG's programme budgeting return.[30] These are converted to an LA basis using a mapping that translates population levels in mid-2012 from (parts of) CCGs to LAs. The average LA healthcare spend was £1152 per person in 2013/2014. Public health expenditure data are available from the LA revenue expenditure and financing document for 2013/2014.[22] The average public health spend for this year was £53 per person. Total healthcare expenditure (£65 billion) is about four times the size of social service expenditure (£17 billion), and the latter is six times the size of public health expenditure (£2.5 billion).

Descriptive statistics for all of the variables employed in the study are in table 1. The mortality indicator is the years of life lost per 100 000 people for deaths under age 75. The mean rate across all LAs is 443 years but this varies considerably, ranging from 268 years (in the City of London) to 776 years (in Blackpool). There is also considerable variation in the socioeconomic control variables (largely constructed using population census data for 2011). For example, on average, 84% of the population is in the white ethnic group but the average masks considerable variation, from 29% in Newham (London) to almost 99% in Cumbria, in Redcar and Cleveland, and in the Isles of Scilly.

Finally, descriptive statistics for the instruments for each type of expenditure are at the bottom of table 1. Some reveal considerable variation around the country (eg, the input price index for older people's social services) but others do not (eg, the impact of population sparsity on the measure of costs).

Table 1 Descriptive statistics for variables employed in study (created by the authors)

Variable description	Obs	Mean	SD	Min	Max
Mortality rate, population and expenditure variables					
Years of life lost rate, standardised, per 100 000 population, 2013/2014/2015 pooled	151	443.3	85	267.5	775.9
Local authority population, 2013/2014	151	369 361	271 897	2381	1 481 378
Social service spend per person, 2013/2014, £	151	306.6	46.58	209.08	660.42
NHS healthcare spend per person, 2013/2014, £	151	1152.13	75.81	1019.89	1479.11
Public health expenditure per person, 2013/2014, £	152	52.6	25.15	18.52	182.21
Controls					
Index of Multiple Deprivation 2010	152	23.0753	8.604	5.4466	43.4465
Young adult social service need per person	151	1.0000	0.2519	0.4341	1.7546
Older adult social service need per person	151	1.0000	0.2329	0.5714	1.9716
Proportion of all residents born outside the European Union	152	0.1281	0.1147	0.0144	0.5060
Proportion of population in white ethnic group	152	0.8364	0.1626	0.2897	0.9882
Proportion of population providing unpaid care	152	0.1008	0.0138	0.0651	0.1289
Proportion of population aged 16–74 with no qualifications	152	0.2469	0.0606	0.0720	0.3874
Proportion of households without a car	152	0.2862	0.1248	0.0899	0.6940
Proportion of households that are one pensioner households, 2011	152	0.1206	0.0208	0.0596	0.1667
Proportion of households that are lone parent households with dependent children	152	0.0745	0.0185	0.70208	0.1436
Proportion of population aged 16–74 that are permanently sick	152	0.0424	0.0149	0.0086	0.0879
Proportion of those aged 16–74 that are long-term unemployed	152	0.0183	0.0058	0.0043	0.0367
Proportion of those aged 16–74 in employment that are working agriculture	152	0.0064	0.0099	0.0003	0.0572
Proportion of those aged 16–74 in managerial and professional occupations	152	0.3114	0.0769	0.1835	0.6674
Instruments: for social service (GSS) expenditure					
Type of LA: county council	152	0.1776	0.3835	0.0000	1.0000
Type of LA: London borough	152	0.2171	0.4136	0.0000	1.0000
Type of LA: metropolitan district	152	0.2368	0.4266	0.0000	1.0000
Type of LA: unitary authority	152	0.3684	0.4840	0.0000	1.0000
Input price index for older people's social services	152	1.0426	0.0634	1.0000	1.3607
Population sparsity measure	151	1.0057	0.0079	1.0000	1.0345
Proportion of households that are owner occupied	152	0.6190	0.1152	0.2611	0.8086
Instruments: for public health (PH) expenditure					
Distance from target index, public health expenditure, 2013/2014	152	1.0667	0.5362	0.5362	6.6247
Input price index (MFF), public health expenditure, 2013/2014	152	1.0122	0.0790	0.9151	1.2076
Instruments: for NHS healthcare (PB) expenditure					
Distance from target index, NHS healthcare expenditure	152	1.0055	0.0515	0.9282	1.2250
Input price index (MFF), resource allocation HCHS formula	152	1.0063	0.0643	0.9319	1.1416
Age index, resource allocation prescribing formula	152	0.9776	0.1283	0.6422	1.3007

HCHS, Hospital and Community Health Services; LA, local authority; MFF, market forces factor; NHS, National Health Service.

RESULTS

Backward selection

We begin by estimating an OLS specification that includes all 14 controls for the need for health-related expenditure. Of the 14 controls, only 5 are significant at the 5% level and this result is in column 1 of table 2. Application of the backward selection process described above reveals a more parsimonious set of controls (column 2). If these are included in an IV specification with all 12 potential instruments, we obtain the result shown in column 3. The statistical tests reported at the foot of table 2 suggest that the instrument set associated with the column 3 result is both invalid (the Hansen-Sargan test statistic is significant) and weak (only one of the Sanderson-Windmeijer test statistics (for public health expenditure) is about 10 or better). The three first-stage equations used to predict healthcare, social care and public health expenditure are in columns

Table 2 Obtaining a preferred health outcome specification for social care, healthcare and public health expenditure, backward selection (second-stage results) (created by the authors)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	All causes	All causes	All causes	All causes	All causes	All causes	All causes
	2013/2014 PB/ GSS/PH spend	2013/2014 PB/ GSS/PH spend	2013/2014 PB/ PSS/PH spend	2013/2014 PB/PSS/ PH spend	2013/2014 PB/PSS/ PH spend	2013/2014 PB/PSS/ PH spend	2013/2014 PB/PSS/ PH spend
	SYLLR 2013/2014/2015	SYLLR 2013/2014/2015	SYLLR 2013/2014/2015	SYLLR 2013/2014/2015	SYLLR 2013/2014/2015	SYLLR 2013/2014/2015	SYLLR 2013/2014/2015
	Outcome model	Outcome model	Outcome model	Outcome model	Outcome model	Outcome model	Outcome model
			Instrument PB/ GSS/PH spend	Instrument PB/GSS/ PH spend	Instrument PB/GSS/ PH spend	Instrument PB/GSS/ PH spend	Instrument PB/GSS/ PH spend
	Weighted	Weighted	Weighted	Weighted	Weighted	Weighted	Weighted
	OLS	OLS	IV second stage	IV second stage	IV second stage	IV second stage	IV second stage
Variables	Full specification	Parsimonious specification	Parsimonious specification	Parsimonious_v2	Parsimonious_v3	Parsimonious_v4	Parsimonious_v5
Public health expenditure per person	0.037 (0.027)	0.029 (0.027)	0.017 (0.032)	0.010 (0.039)	0.017 (0.042)	−0.018 (0.041)	−0.019 (0.041)
CCG (PB) healthcare spend per person	−0.406*** (0.139)	−0.492*** (0.119)	−0.840*** (0.142)	−0.609** (0.251)	−0.514 (0.337)	−0.545** (0.243)	−0.532** (0.259)
Social service (GSS) spend per person	0.044 (0.055)	0.039 (0.053)	−0.078 (0.102)	−0.272** (0.124)	−0.326* (0.182)	−0.344** (0.134)	−0.336** (0.152)
Index of Multiple Deprivation 2010	0.219*** (0.074)	0.156** (0.066)	0.239*** (0.059)	0.243*** (0.068)	0.238*** (0.075)	−0.504* (0.260)	−0.505** (0.255)
Young adult social service need per person	0.096 (0.166)						
Older adult social service need per person	0.080 (0.073)						
% residents born outside the European Union	−0.038* (0.020)						
% population in white ethnic group	0.172*** (0.054)	0.227*** (0.036)	0.289*** (0.036)	0.309*** (0.038)	0.309*** (0.041)	0.321*** (0.041)	0.319*** (0.046)
% population providing unpaid care	−0.455*** (0.171)	−0.233*** (0.086)	−0.214** (0.087)	−0.251** (0.098)	−0.230** (0.108)	−0.188** (0.085)	−0.190** (0.085)
% population aged 16–74 with no qualifications	−0.043 (0.101)						
% households without a car	−0.201*** (0.074)						
% households that are one pensioner households	0.057 (0.073)						
% lone parent households with dependent children	0.025 (0.065)						
% population aged 16–74 that are permanently sick	0.162* (0.097)	0.217*** (0.069)	0.229*** (0.071)	0.262*** (0.087)	0.259*** (0.098)	0.271*** (0.080)	0.271*** (0.079)

Continued

Table 2 Continued

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	All causes	All causes	All causes	All causes	All causes	All causes	All causes
	2013/2014 PB/GSS/PH spend	2013/2014 PB/GSS/PH spend	2013/2014 PB/PSS/PH spend	2013/2014 PB/PSS/PH spend	2013/2014 PB/PSS/PH spend	2013/2014 PB/PSS/PH spend	2013/2014 PB/PSS/PH spend
	SYLLR 2013/2014/2015	SYLLR 2013/2014/2015	SYLLR 2013/2014/2015	SYLLR 2013/2014/2015	SYLLR 2013/2014/2015	SYLLR 2013/2014/2015	SYLLR 2013/2014/2015
	Outcome model	Outcome model	Outcome model	Outcome model	Outcome model	Outcome model	Outcome model
			Instrument PB/GSS/PH spend	Instrument PB/GSS/PH spend	Instrument PB/GSS/PH spend	Instrument PB/GSS/PH spend	Instrument PB/GSS/PH spend
	Weighted	Weighted	Weighted	Weighted	Weighted	Weighted	Weighted
	OLS	OLS	IV second stage	IV second stage	IV second stage	IV second stage	IV second stage
	Full specification	Parsimonious specification	Parsimonious specification	Parsimonious_v2	Parsimonious_v3	Parsimonious_v4	Parsimonious_v5
% aged 16–74 that are long-term unemployed	0.057 (0.057)						
% aged 16–74 in employment working agriculture	−0.013 (0.012)						
% aged 16–74 in managerial/professional occupations	−0.241*** (0.063)	−0.285*** (0.044)	−0.190*** (0.050)	−0.162*** (0.051)	−0.154** (0.060)	−0.098 (0.062)	−0.100 (0.065)
Index of Multiple Deprivation 2010 squared						0.130*** (0.043)	0.130*** (0.042)
Constant	7.319*** (1.040)	8.862*** (0.819)	11.187*** (1.021)	9.408*** (1.693)	8.710*** (2.295)	10.277*** (1.568)	10.199*** (1.662)
Observations	150	150	150	150	150	150	150
R-squared	0.919	0.908					
Ramsey reset F-statistic	5.096	6.448					
Probability >F	0.002	0.000					
Endogeneity test statistic			8.934	15.536	15.510	23.482	18.528
Endogeneity p value			0.030	0.001	0.001	0.000	0.000
Hansen-Sargan test statistic			21.671	10.327	2.506	0.265	0.257
Hansen-Sargan p value			0.006	0.066	0.286	0.876	0.612
Pesaran-Taylor reset statistic			0.187	2.892	3.540	0.008	0.285
Pesaran-Taylor p value			0.665	0.089	0.060	0.927	0.593
Sanderson-Windmeijer_PB F-statistic			8.390	8.966	13.333	14.352	15.818
Sanderson-Windmeijer _PB p value			0.000	0.000	0.000	0.000	0.000
Sanderson-Windmeijer _GSS F-statistic			4.437	4.875	6.720	9.063	11.567
Sanderson-Windmeijer _GSS p value			0.000	0.000	0.000	0.000	0.000
Sanderson-Windmeijer _PH F-statistic			28.259	37.927	56.035	56.146	59.408

Continued

Table 2 Continued

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	All causes	All causes	All causes	All causes	All causes	All causes	All causes
	2013/2014 PB/GSS/PH spend	2013/2014 PB/GSS/PH spend	2013/2014 PB/PSS/PH spend	2013/2014 PB/PSS/PH spend	2013/2014 PB/PSS/PH spend	2013/2014 PB/PSS/PH spend	2013/2014 PB/PSS/PH spend
	SYLLR 2013/2014/2015	SYLLR 2013/2014/2015	SYLLR 2013/2014/2015	SYLLR 2013/2014/2015	SYLLR 2013/2014/2015	SYLLR 2013/2014/2015	SYLLR 2013/2014/2015
	Outcome model	Outcome model	Outcome model	Outcome model	Outcome model	Outcome model	Outcome model
			Instrument PB/GSS/PH spend	Instrument PB/GSS/PH spend	Instrument PB/GSS/PH spend	Instrument PB/GSS/PH spend	Instrument PB/GSS/PH spend
	Weighted	Weighted	Weighted	Weighted	Weighted	Weighted	Weighted
	OLS	OLS	IV second stage	IV second stage	IV second stage	IV second stage	IV second stage
	Full specification	Parsimonious specification	Parsimonious specification	Parsimonious_v2	Parsimonious_v3	Parsimonious_v4	Parsimonious_v5
Sanderson-Windmeijer _PH p value			0.000	0.000	0.000	0.000	0.000

Robust SEs in parentheses.
***p<0.01, **p<0.05, *p<0.1.
CCG, Clinical Commissioning Group; IV, instrumental variable; OLS, ordinary least squares ; PB/GSS, programme budgeting/gross social service/public health; PH, public health; SYLLR, standardised years of life lost rate.

1–3, respectively, of table A1 in online supplemental appendix A4.

In an attempt to identify which of the instruments are invalid (and hence should not be used), we re-estimated the specification shown in column 3 of table 2, adding one instrument at a time to the set of second-stage controls. This process suggests that three instruments (the two MFF indices and the London LA dummy) are invalid and re-estimation without these yields the result shown in column 4 of table 2. As expected, the Hansen-Sargan test statistic has improved considerably but there is still a weak instrument issue for social service expenditure (the Sanderson-Windmeijer F-statistic is only 4.875). The equation used to predict social service expenditure is in column 5 of table A1 in online supplemental appendix A4 and this has three insignificant instruments (the unitary authority dummy, the area cost adjustment variable and the sparsity measure). If we re-estimate without these instruments, we obtain the second-stage result shown in column 5 of table 2. The Sanderson-Windmeijer test statistics improve but the Pesaran-Taylor reset test statistic suggests that there is some mis-specification. The addition of the squared value of the Index of Multiple Deprivation 2010 resolves reset test issue and generates the result shown in column 6.

Finally, the Sanderson-Windmeijer test statistic for the instruments for social care expenditure moves above the 'rule of thumb' critical value of 10 if the least significant instrument for this variable (the proportion of households that are owner occupied households) is deleted from the specification. This result is in column 7 of table 2 (the corresponding first-stage results are in columns 13–15 of table A1 in online supplemental appendix A4).

Forward selection

The use of forward selection to identify relevant control variables reveals a similar but slightly different set of control variables to those from the backward selection process. If this different set of controls is included in an IV specification with all potential instruments, then we obtain the result shown in column 1 of table 3 (the corresponding first-stage results are in columns 1–3 of table A2 in online supplemental appendix A4). This has three covariates all of which are statistically significant with negative coefficients on the three expenditure variables. The problem with this specification is that the instrument set is not valid, but if we drop the four most problematic instruments and re-estimate, we obtain the result in column 2 of table 3 (see columns 4–6 of table A2 in online supplemental appendix A4 for the first-stage results). Although the instruments are still invalid at the 5% level (Hansen-Sargan test statistic), there has been considerable improvement. However, the loss of these four instruments has not overcome the weakness issue associated with the instruments for healthcare and social service expenditure (the Sanderson-Windmeijer F-statistics are well below 10).

Table 3 Obtaining a joint preferred specification for social care, healthcare and public health expenditure by combining full specifications with forward selection (second-stage results) (created by the authors)

Variables	(1) All causes 2013/2014 PB/GSS/PH spend SYLLR 2013/2014/2015 Outcome model Instrument PB/GSS/PH spend Weighted IV second stage Parsimonious specification 11 instruments	(2) All causes 2013/2014 PB/GSS/PH spend SYLLR 2013/2014/2015 Outcome model Instrument PB/GSS/PH spend Weighted IV second stage Specification_2 7 instruments	(3) All causes 2013/2014 PB/GSS/PH spend SYLLR 2013/2014/2015 Outcome model Instrument PB/GSS/PH spend Weighted IV second stage Specification_3 5 instruments	(4) All causes 2013/2014 PB/GSS/PH spend SYLLR 2013/2014/2015 Outcome model Instrument PB/GSS/PH spend Weighted IV second stage Specification_4 4 instruments
Public health expenditure per person	−0.051 (0.039)	−0.043 (0.047)	−0.060 (0.044)	−0.099** (0.045)
CCG (PB) healthcare spend per person	−0.862*** (0.223)	−0.461 (0.313)	−0.637* (0.369)	−0.693** (0.333)
Social service (GSS) spend per person	−0.206 (0.133)	−0.469*** (0.161)	−0.370* (0.205)	−0.471** (0.237)
% population aged 16–74 that are permanently sick	0.649*** (0.046)	0.651*** (0.054)	0.672*** (0.052)	0.528*** (0.073)
% population providing unpaid care	−0.381*** (0.086)	−0.388*** (0.096)	−0.400*** (0.097)	−0.143 (0.118)
% population in white ethnic group	0.163*** (0.042)	0.195*** (0.043)	0.180*** (0.046)	0.299*** (0.078)
Older adult: social service need per person				0.416*** (0.143)
Constant	13.352*** (1.733)	10.204*** (2.389)	11.655*** (2.873)	12.245*** (2.546)
Observations	150	150	150	150
Endogeneity test statistic	10.644	17.686	21.100	23.214
Endogeneity p value	0.014	0.001	0.000	0.000
Hansen-Sargan test statistic	25.690	10.432	2.173	0.080
Hansen-Sargan p value	0.001	0.034	0.337	0.778
Pesaran-Taylor reset statistic	0.052	0.372	0.080	0.001
Pesaran-Taylor p value	0.820	0.542	0.777	0.972
SW_PB F-statistic	5.977	6.833	7.878	13.534
SW_PB p value	0.000	0.000	0.000	0.000
SW_GSS F-statistic	4.939	5.521	6.135	9.722
SW_GSS p value	0.000	0.000	0.001	0.000
SW_PH F-statistic	18.451	22.092	30.944	46.946
SW_PH p value	0.000	0.000	0.000	0.000

Robust SEs in parentheses.
***p<0.01, **p<0.05, *p<0.1.
CCG, Clinical Commissioning Group; PH, public health; SW, Sanderson-Windmeijer.

If we drop the two least significant instruments, we get the result in column 3 of table 3. The instrument set now shows no evidence of invalidity but there is still some evidence of weakness. We have no further instruments to add but, if we check to see whether any of the currently omitted covariates belong in the specification, we find that the addition of the measure of 'older person need for social service care' has a significant positive coefficient (result not shown). The inclusion of this variable generates an insignificant coefficient on the 'owner occupied' instrument for social service expenditure and, if we re-estimate without this, we obtain the result shown in column 4 of table 3. In this specification, the expenditure variables are endogenous, the instrument set is valid, and the

Table 4 Results summary (created by the authors)

Type of health-related expenditure	Health outcome elasticity: Backward selection	Health outcome elasticity: Forward selection	Spending gap per capita between 2001/2002–2009/2010 and 2010/2011–2014/2015	Deaths attributable to spending gap (=annual deaths*elasticity*gap): Backward selection	Deaths attributable to spending gap (=annual deaths*elasticity*gap): Forward selection	Deaths attributable to spending gap from time trend analysis[7]
	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Social care expenditure	−0.336	−0.471	15.08%	23 662	33 170	n/a
(95% CI)	(−0.031 to −0.640)	(0.003 to −0.945)		(2183 to 45 071)	(−211 to 66 550)	
Healthcare expenditure	−0.532	−0.693	13.64%	33 888	44 143	n/a
(95% CI)	(−0.014 to −1.050)	(−0.027 to −1.359)		(892 to 66 884)	(1720 to 86 567)	
Total social care and healthcare	n/a	n/a	n/a	57 550	77 313	45 368
(95% CI)				(3075 to 111 955)	(1509 to 153 117)	(34 530 to 56 206)

instruments for each expenditure variable demonstrate no evidence of weakness. There is also no evidence of mis-specification.

Application of estimated elasticities to spending constraints

In a recent paper annual data on healthcare and social care spending for England from 2001 to 2014 was used to estimate the impact of the UK government's austerity programme on mortality.[8] Time trend analysis was used to compare actual mortality rates in 2011–2014 with the counterfactual rates expected based on trends before the imposition of austerity. These authors found that spending constraints between 2010 and 2014 were associated with 45 368 more deaths than would have been expected based on pre-2010 trends.

We can use the outcome elasticities reported above to present some alternative but comparable estimates and these are summarised in table 4. The public health elasticities are not included in the excess deaths calculations because time series data for public health expenditure are not available before 2013/2014 and this is probably why the time trend analysis did not consider the impact of public health expenditure.[8] We have included this variable in the mortality outcome equations estimated here because our study year (2013/2014) is the first year for which public health expenditure data are reported and its omission may bias the estimated coefficients on the other two healthcare-related types of expenditure. Moreover, a recent paper suggests that public health expenditure has a significant effect on mortality.[10]

The outcome elasticities associated with healthcare and social care expenditure are in column 1 (backward selection) and column 2 (forward selection) of table 4. The time trend study reports that real social care spending per capita increased by 2.20% between 2001/2002 and 2009/2010 but decreased by 1.57% between 2010/2011 and 2014/2015. If this annual difference (3.77%) is applied to each of the latter 4 years, then the total spending gap is 15.08% (column 3). In 2012, there were 467 000 deaths in England. The more conservative of the two social care elasticity estimates suggests that a 1% increase in spend would save 1569 lives (=0.336% of 467 000). Hence, the 'loss' of 15.08% of social care expenditure over the period 2010/2011 to 2014/2015 is associated with 23 662 excess deaths.

A similar calculation can be undertaken for healthcare expenditure. The time trend study reports that real healthcare spending per capita increased by 3.82% between 2001/2002 and 2009/2010 but by 0.41% between 2010/2011 and 2014/2015. If this annual difference (3.41%) is applied to each of the latter 4 years, then the total spending gap attributable to austerity is 13.64%. Our healthcare elasticity suggests that a 1% increase in spend would save 2484 lives (=0.532% of 467 000). Hence, the 'loss' of 13.64% of healthcare expenditure over the period 2010/2011 to 2014/2015 is associated with 33 888 excess deaths.

The more conservative of our two sets of results suggest that the constraints on the growth of healthcare and social care expenditure during this period of 'austerity' have been associated with 57 550 (=23 662+33 888) more deaths than would have been observed had expenditure growth followed pre-2010 trends. The less conservative of our two sets of results suggests more deaths (see column 5 of table 4), and both estimates can be compared with the results from the time trend study (see column 6 of table 4).[8]

DISCUSSION

Although our study has adopted an entirely different approach to the time trend study, it reveals a broadly similar picture: that 'austerity'-related reductions in the growth of healthcare and social care expenditure have been associated with a much larger number of deaths than would have been expected had pre-austerity expenditure trends continued.

Both the healthcare and the social care expenditure variables have a significant negative effect on mortality in both the backward and the forward selection specifications, and the public health effect is also statistically significant in the latter specification. If we focus on the more conservative estimates (from the backward selection specification), we note that the coefficient on social care expenditure is −0.336. This suggests that a 1% increase in expenditure is associated with a 0.336% reduction in mortality. The coefficient on healthcare expenditure is larger (absolutely) at −0.532 but it should be noted that a 1% boost in the healthcare budget would cost about four times as much as a 1% boost in social care expenditure.

The coefficient on healthcare expenditure, −0.532 (backward selection) or −0.693 (forward selection), can be compared with that reported by a recent study that undertook a similar analysis of English data for 2013/2014 but which excluded social care expenditure from the estimating equation. In that study, the coefficient on healthcare expenditure was −0.672.[10] The difference between these estimates is relatively small. Several recent studies from Australia, England, Spain and Sweden have sought to establish how responsive mortality is to changes in healthcare expenditure.[31–34] These studies have typically omitted other types of health-related expenditure but our findings suggest that the addition of these other types of expenditure will have little impact on the responsiveness of mortality to healthcare expenditure.

As social care expenditure is designed primarily to improve recipients' quality of life, it is slightly surprising that the coefficient on social care is as large as −0.336, particularly when the elasticity associated with healthcare expenditure is −0.532 (both figures are backward selection estimates). To understand this relatively large mortality response to social care expenditure, we need to distinguish between the *direct* and *indirect* effects of healthcare and social care expenditure. Healthcare expenditure has a primarily *direct* effect on mortality; we would expect areas with better healthcare provision to have lower mortality rates because more expenditure will buy more medical staff and facilities, and these inputs are directly responsible for life-saving healthcare.

Social care, on the other hand, may generate both *direct* and *indirect* effects on mortality, and the relative size of each effect is unclear. There will be a direct effect via the prevention of life-threatening conditions (eg, better social care provision might mean that vulnerable people are less likely to have life-threatening falls), but there will also be an indirect effect where better social care facilitates access by others to healthcare services. For example, if a patient cannot be discharged from hospital due to a lack of social care provision (eg, due to a lack of care in the community or residential home beds), his/her hospital bed cannot be used by others who might benefit from it. In this way, the indirect effect of social care facilitates lower mortality, not for those receiving the social care, but for those who are able to access healthcare sooner than they would otherwise have done.

Study limitations

This study is constrained by the availability of mortality data and health-related expenditure data, and the implementation of central government funding formulae with exogenous elements for all three types of expenditure. Our study year (2013/2014) is the first year for which there were resource allocation formulae for both healthcare and public health expenditure, and an RNF informed the allocation of central government funding to LAs for social care. As a result, estimation of a panel data specification is not permitted by the data and the estimated elasticities for 2013/2014 may not hold in other years.

The estimated mortality equation contains no dynamics and implicitly assumes that all health benefits occur contemporaneously with expenditure. However, as our health outcome measure reflects mortality in both the same year as expenditure and also in the two subsequent years, we do capture some of the lagged effect. Nevertheless, we readily acknowledge that some health benefits associated with current expenditure may occur many years later. At the same time, however, we also acknowledge that current mortality may reflect health-related expenditure from many years ago. Our implicit assumption is that these two effects broadly cancel out each other so that, by relating current expenditure to current outcomes, we obtain a reasonable estimate of the total effect of expenditure on mortality.

We should also note that primary care and specialised commissioning are not included in the measure of healthcare expenditure used here. This is because responsibility for these types of expenditure returned to central administrators in April 2013 following the reforms associated with the Health and Social Care Act 2012. Therefore, if, for example, the centralisation of specialist commissioning led to the unequal provision of such services across the country, this could have an unaccounted-for effect on the relationship between local spending and mortality. Related to this, there is also the possibility that we have omitted a relevant confounder (eg, one that affects both mortality and expenditure) from our regression specifications and such an omission may affect the size of the mortality response to expenditure.

CONCLUDING REMARKS

Our results—using an entirely different estimation approach—have confirmed the results reported previously: that the restrictions on the growth in health and social care expenditure during 'austerity' have been associated with tens of thousands more deaths than would have been observed had pre-austerity expenditure growth been sustained.[8]

While previous studies have found that healthcare and public health expenditure have a significant negative effect on mortality, this study makes a major contribution by additionally estimating the effect of social care expenditure. There is evidence that all three types of health-related expenditure have a significant negative effect on mortality. There is also evidence that additional social care expenditure is more than twice as productive as additional healthcare expenditure, and that the addition of social care expenditure in the health outcome equation has little effect on the size of the mortality response to changes in healthcare expenditure.

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REFERENCES

1 Demakakos P. Austerity, socioeconomic inequalities and stalling life expectancy in the UK: two parallel stories or one? *Maturitas* 2019;123:89–90. doi:10.1016/j.maturitas.2018.12.007
2 Hiam L, Dorling D, McKee M. The cuts and poor health: when and how can we say that one thing causes another? *J R Soc Med* 2018;111:199–202. doi:10.1177/0141076818779237
3 Marmot M. Social causes of the slowdown in health improvement. *J Epidemiol Community Health* 2018;72:359–60. doi:10.1136/jech-2018-210580
4 Hiam L, Harrison D, McKee M, *et al*. Why is life expectancy in England and Wales 'stalling'? *J Epidemiol Community Health* 2018;72:404–8. doi:10.1136/jech-2017-210401
5 Faragher R. Is austerity really to blame for stalling life expectancy in England? *The Conversation* 2017 http://theconversation.com/is-austerity-really-to-blame-for-stalling-life-expectancy-in-england-81206
6 Loopstra R, McKee M, Katikireddi SV, *et al*. Austerity and old-age mortality in England: a longitudinal cross-local area analysis, 2007-2013. *J R Soc Med* 2016;109:109–16.
7 Dorling D. Austerity bites—falling life expectancy in the UK. *BMJ* 2019 https://blogs.bmj.com/bmj/2019/03/19/danny-dorling/
8 Watkins J, Wulaningsih W, Da Zhou C, *et al*. Effects of health and social care spending constraints on mortality in England: a time trend analysis. *BMJ Open* 2017;7:11.
9 Claxton K, Lomas J, Martin S. The impact of NHS expenditure on health outcomes in England: alternative approaches to identification in all-cause and disease specific models of mortality. *Health Econ* 2018;27:1017–23 https://onlinelibrary.wiley.com/doi/abs/doi:10.1002/hec.3650

10 Martin S, Lomas J, Claxton K. Is an ounce of prevention worth a pound of cure? A cross-sectional study of the impact of English public health grant on mortality and morbidity. *BMJ Open* 2020;10:e036411 https://bmjopen.bmj.com/content/10/10/e036411
11 Forder J, Vadean F, Rand S, *et al*. The impact of long-term care on quality of life. *Health Econ* 2018;27:58 doi:10.1002/hec.3612
12 Fernandez J-L, Forder J. Consequences of local variations in social care on the performance of the acute health care sector. *Applied Economics* 2008;40:1503–18 https://www.tandfonline.com/doi/full/10.1080/00036840600843939
13 Forder J. Long-term care and hospital utilisation by older people: an analysis of substitution rates. *Health Econ* 2009;18:1338 doi:10.1002/hec.1438
14 Gaughan J, Gravelle H, Siciliani L. Testing the bed-blocking hypothesis: does nursing and care home supply reduce delayed Hospital discharges? *Health Econ* 2015;24:44 doi:10.1002/hec.3150
15 Forder J, Gousia K, Saloniki E-C. The impact of long-term care on primary care doctor consultations for people over 75 years. *Eur J Health Econ* 2019;20:375–87 https://ideas.repec.org/a/spr/eujhec/v20y2019i3d10.1007_s10198-018-0999-6.html
16 Bradley EH, Canavan M, Rogan E, *et al*. Variation in health outcomes: the role of spending on social services, public health, and health care, 2000-09. *Health Aff* 2016;35:760–8. doi:10.1377/hlthaff.2015.0814
17 National Audit Office. Adult social care at a glance, 2018. Available: https://www.nao.org.uk/wp-content/uploads/2018/07/Adult-social-care-at-a-glance.pdf [Accessed 5 Sep 2020].
18 Department of Health. Fair access to care services guidance on eligibility criteria for adult social care, 2002. Available: https://webarchive.nationalarchives.gov.uk/20121205180615/http:/www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/documents/digitalasset/dh_4019641.pdf [Accessed 5 Sep 2020].
19 National Audit Office. Planning for the better care fund, 2014. Available: https://www.nao.org.uk/wp-content/uploads/2014/11/Planning-for-the-better-care-fund.pdf [Accessed 5 Sep 2020].
20 National Audit Office. Health and social care integration, 2017. Available: https://www.nao.org.uk/wp-content/uploads/2017/02/Health-and-social-care-integration.pdf [Accessed 5 Sep 2020].
21 Exposition book public health allocations 2013-14 and 2014-15: tchnical guide, 2012. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/213324/Public-Health-Weighted-Capitation-FormulaTechnical-Guide-v0.13.pdf [Accessed 5 Sep 2020].
22 MCHLG. Local authority revenue expenditure and financing England: 2013 to 2014 individual local authority data – outturn, 2015. Available: https://www.gov.uk/government/statistics/local-authority-revenue-expenditure-and-financing-england-2013-to-2014-individual-local-authority-data-outturn [Accessed 5 Sep 2020].
23 NHS England. Allocations for 2013/14, 2012. Available: https://www.england.nhs.uk/allocations/allocations-2013-14/ [Accessed 5 Sep 2020].
24 Andrews M, Elamin O, Hall AR, *et al*. Inference in the presence of redundant moment conditions and the impact of government health expenditure on health outcomes in England. *Econom Rev* 2017;36:23–41. doi:10.1080/07474938.2016.1114205
25 DCLG. Calculation of 2013/14 formula funding, 2013. Available: https://webarchive.nationalarchives.gov.uk/20140505105851/http://www.local.communities.gov.uk/finance/1314/CalcFFs.pdf
26 Forder J, Malley J, Towers A-M. Using cost-effectiveness estimates from survey data to guide commissioning: an application to home care. *Health Econ* 2014;23:979–92.
27 Sanderson E, Windmeijer F. A weak instrument [Formula: see text]-test in linear IV models with multiple endogenous variables. *J Econom* 2016;190:212–21.
28 Baum CF, Schaffer ME, Stillman S. ivreg2: Stata module for extended instrumental variables/2SLS, GMM and AC/HAC, LIML and k-class regression, 2010. Available: http://ideas.repec.org/c/boc/bocode/s425401.html [Accessed 5 Sep 2020].
29 Hashem Pesaran M, Taylor LW. Diagnostics for IV regressions. *Oxf Bull Econ Stat* 1999;61:255–81.
30 NHS England. 2013-14 CCG programme budgeting benchmarking tool, 2015. Available: https://www.england.nhs.uk/prog-budgeting/ [Accessed 5 Sep 2020].
31 Edney LC, Haji Ali Afzali H, Cheng TC, *et al*. Estimating the reference incremental cost-effectiveness ratio for the Australian health system. *Pharmacoeconomics* 2018;36:239–52. doi:10.1007/s40273-017-0585-2
32 Siverskog J, Henriksson M. Estimating the marginal cost of a life year in Sweden's public healthcare sector. *Eur J Health Econ* 2019;20:751–62. doi:10.1007/s10198-019-01039-0
33 Vallejo-Torres L, García-Lorenzo B, Serrano-Aguilar P. Estimating a cost-effectiveness threshold for the Spanish NHS. *Health Econ* 2018;27:746–61. doi:10.1002/hec.3633
34 Claxton K, Martin S, Soares M, *et al*. Methods for the estimation of the National Institute for health and care excellence cost-effectiveness threshold. *Health Technol Assess* 2015;19:504 doi:10.3310/hta19140