BMJ Open

The mortality effects of social care, public health and healthcare expenditure: cross-sectional evidence from England for 2013/14

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-046417
Article Type:	Original research
Date Submitted by the Author:	29-Oct-2020
Complete List of Authors:	Martin, Stephen; University of York Department of Economics and Related Studies, Longo, Francesco; University of York, Centre for Health Economics Lomas, James; University of York, Centre for Health Economics Claxton, Karl; University of York, Centre for Health Economics & Department of Economics
Keywords:	HEALTH ECONOMICS, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, STATISTICS & RESEARCH METHODS

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

The mortality effects of social care, public health and healthcare expenditure: cross-sectional evidence from England for 2013/14

Author/position/address
Dr Stephen Martin
Research Fellow, Department of Economics, University of York, York, YO10 5DD.

Dr Francesco Longo
Research Fellow, Centre for Health Economics, University of York, York, YO10 5DD.

Dr James Lomas
Research Fellow, Centre for Health Economics, University of York, York, YO10 5DD.

Dr Karl Claxton
Professor, Department of Economics & Centre for Health Economics, University of York, York, YO10 5DD.

Corresponding author and email address
Dr Stephen Martin Email: sdm1@york.ac.uk

Competing interest statement

All authors have completed the Unified Competing Interest form (available on request from the corresponding author) and declare: financial support from the National Institute for Health Research Policy Research Programme for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; and no other relationships or activities that could appear to have influenced the submitted work.

Contributors

All (SM, FL, JL and KC) authors contributed to the concept and design of this paper. SM led on the analysis and drafting, and the final paper was edited and approved by all four authors. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting these criteria have been omitted. SM is the paper's guarantor.

Transparency declaration

The lead author (the manuscript's guarantor) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Details of ethical approval

Ethical approval was not required because neither human participants nor animals were involved in the study.

Details of funding

This paper reports independent research funded by the National Institute for Health Research Policy Research Programme (NIHR PRP) through its Policy Research Unit in Economic Evaluation of Health & Care Interventions (EEPRU, grant reference PR-PRU-1217-20401).

Details of the role of the study sponsors

The views expressed in this publication are those of the authors and not necessarily those of the NHS, the National Institute for Health Research or the Department of Health and Social Care (DHSC).

Statement of independence of researchers from funders

Although funded by the funded by the National Institute for Health Research Policy Research Programme, neither the NIHR nor the DHSC had any influence on the study design, the way in which the research was undertaken, or the results.

Patient and public involvement statement

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

Acknowledgements

We should like to thank NHS Digital for supplying the mortality data. We should also like to acknowledge the assistance received from various individuals including Michael Chaplin at the Department of Health. In addition, we should like to acknowledge the comments received from various individuals at the Department of Health and Social Care and NHS England on an earlier version of this paper. Their suggestions have substantially improved the final version.

Data sharing statement

All of the raw data are in the public domain. The social care expenditure data is available from the publication 'Local authority revenue expenditure and financing England: 2013 to 2014 individual local authority data – outturn' at https://www.gov.uk/government/statistics/local-authority-revenue-expenditure-and-financing-england-2013-to-2014-individual-local-authority-data-outturn [accessed 05 September 2020]. The sparsity and input price adjustment variable from the older person's relative needs formula are available from the publication 'Calculation of 2013/14 Formula Funding' at https://webarchive.nationalarchives.gov.uk/20140505105851/http://www.local.communities.gov.uk/finance/1314/CalcFFs.pdf [accessed 05 September 2020]. The 'type of local authority' dummies are available from the data dictionary in the zip file at https://digital.nhs.uk/data-and-information/publications/statistical/adult-social-care-activity-and-finance-report/2017-18 [accessed 20 October 2020]. The healthcare expenditure data are available in the 2013-14 CCG Programme Budgeting Benchmarking Tool. This is available from https://www.england.nhs.uk/prog-budgeting/ [accessed 05 September 2020]. The socio-economic variables are constructed using the 2011 Population Census. Census data is available from the Office for National Statistics at https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/2011censuskeystatisticsforlocalauthoritiesinenglandandwales [accessed 05 September 2020]. The cells used to construct the socio-economic variables are listed in Table 92 of Claxton, K., Martin, S., Soares M, Rice N, Spackman E, Hinde S, Devlin N, Smith PC and Sculpher M. (2015). Methods for the estimation of the National Institute for Health and Care Excellence cost-effectiveness threshold. Health technology assessment, 19(14), pp.1-503. Available from https://www.ncbi.nlm.nih.gov/books/NBK274318/ [accessed 05 September 2020]. The public health expenditure data are available from 'Local authority revenue expenditure and financing England: 2013 to 2014 individual local authority data – outturn' which is available from https://www.gov.uk/government/statistics/local-authority-revenue-expenditure-and-financing-england-2013-to-2014-individual-local-authority-data-outturn [accessed 05 September 2020]'. The instruments for public health expenditure are available in 'Exposition Book Public Health Allocations 2013-14 and 2014-15: Technical Guide' and this is available from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/213324/Public-Health-Weighted-Capitation-FormulaTechnical-Guide-v0.13.pdf [accessed 05 September 2020]. The DFT variable for healthcare expenditure is available from the Department of Health's website at https://www.networks.nhs.uk/nhsnetworks/health-investment-network/news/2012-13-programme-budgeting-data-is-now-available [accessed 05 September 2020], and the MFF and prescribing cost age indices are available from the exposition books for the 2011/12 allocations at https://www.gov.uk/government/publications/exposition-book-2011-2012 [accessed 05 September 2020].

Word count

The text consists of 5,589 words. There are four tables in this document. There is one figure in a separate file.

The mortality effects of social care, public health and healthcare expenditure: cross-sectional evidence from England for 2013/14

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 2010/11 – 2014/15 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 2013/14. We compare the growth in healthcare and social care expenditure pre- and post-2010. We use the difference between these growth rates and the responsiveness of mortality to changes in expenditure to estimate the additional mortality generated by post-2010 spending constraints.

Results

Our most conservative results suggest that: (i) a 1% increase in healthcare expenditure reduces mortality by 0.532%; (ii) a 1% increase in social care expenditure reduces mortality by 0.336%; and (iii) 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 2001/02 - 2009/10 and 2010/11 – 2014/15, we find that there were 57,550 [CI: 3,075-111,955] more deaths in the latter period than would have been observed had spending growth during this period matched that in 2001/02 - 2009/10.

Conclusions

All three forms of public healthcare-related expenditure save lives. 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 impact of social care expenditure on mortality with controls for the level of healthcare and public health expenditure.
- 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- 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.
- There may be other factors affecting mortality beyond those included in this study.

The mortality effects of social care, public health and healthcare expenditure: cross-sectional evidence from England for 2013/14

1. Introduction

The rate of improvement in life expectancy in England and Wales has slowed markedly since 2010.[1 2 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]

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.[7] 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.[7]

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 at a single point in time (2013/14). Like the time trend study, we consider the impact of both healthcare and social care expenditure on mortality when estimating the size of this effect, 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.[8 9] The social care literature has concentrated on the impact of expenditure on the quality of life rather than on

mortality.[10] Other studies focus on the relationship between the public social care and healthcare sectors. They find a substitution effect between social and healthcare services so that an increase in social care services may improve hospital outcomes, for example, by reducing delayed discharges.[11 12 13 14] However, we are not aware of any English studies of the impact of social care on mortality and, by including healthcare and public health, we present what we believe are the first estimates of the joint impact of social care, healthcare, and public health expenditure on mortality. 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.

The plan of this paper is as follows. Section 2 describes the institutional arrangements associated with the three types of health-related expenditure that are the focus of this study. Section 3 describes the health outcome equation to be estimated and how we address the issue of reverse causation (i.e., that mortality may affect expenditure as well as vice versa). Section 4 describes our estimation approach and section 5 presents brief details of the dataset. Section 6 presents our results and there is a discussion of them in section 7.

2. Institutional arrangements for health-related expenditure in England in 2013/14

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 local authority pay for; and/or informally by family, friends, or neighbours.[15]

Funding for local authorities (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, local authorities 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.[16] 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.[15]

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.[17 18] 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 local authority receives a fixed annual budget, ring-fenced for public health activities.[19] 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 £2,500mn of expenditure in 2013/14 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.[20]

Healthcare in England

English National Health Service (NHS) healthcare expenditure was managed by 212 Clinical Commissioning Groups (CCGs) in 2013/14.[21] 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 (2013/14). These were administered centrally and expenditure on these items has been excluded from the study because data are not available by local area.

3. The estimating equation and the selection of instruments for expenditure

The estimated health outcome equation

We adapt the usual health outcome equation to consider the joint estimation of the impact of social care, public health and healthcare expenditure on mortality:

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

The control variables reflect the need for health-related expenditure, and e reflects everything not included elsewhere in the specification.[8] 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.

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). Figure 1a shows that 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 biased.

Insert Figure 1 near here

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 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 used in a regression model to examine the causal impact of expenditure on mortality (this is the second stage of the two-stage least squares approach).

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 expenditure.[22] We adopt this broad 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 (2013/14) 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 relative needs formulae: one for people aged 18-64, and another for those aged over 65. The relative needs formula for the older people's social care included a basic amount per client with top-ups for age, deprivation, low income, sparsity and local input prices.[23] 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 relative needs formula as instruments for social care expenditure.

A study of the impact of LA expenditure on home care services approached the instrument issue from a different perspective.[24] 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.[24]

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 (2013/14), each local health authority (212 CCGs) was assigned a fixed share of the national budget (£65bn) 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: (i) the age index reflects the demographic profile of the local population; (ii) the additional needs index reflects local deprivation and other factors likely to influence the need for health care and includes a measure of historical mortality; (iii) the input price index (the Market Forces Factor (MFF)) reflects prices in the local health economy; and (iv) the distance from target (DFT) index reflects how far each health authority's actual budget allocation is from its target allocation.[22]

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 appendix A1 but, in summary, these funding rule variables are: (i) the DFT index for the total allocation to CCGs; (ii) the Market Forces Factor for the Hospital and Community Health Services (HCHS) component of the total allocation; and (iii) the age index from the cost of prescribing pharmaceuticals component of the total allocation.

Instruments for public health expenditure

While not our primary focus within this paper, we also 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 local authorities 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 appendix A2.

Are the selected instruments plausible?

For all three types of health-related expenditure we use a local input price index (MFF) as an instrument. While there is no potential for reverse causality, this index might reflect characteristics of the local (health) economy that could be correlated with unmeasured determinants of mortality. The plausibility of this instrument therefore depends upon adequately controlling for need, for which we have over a dozen potential socio-economic controls in the baseline mortality equation. Further discussion about this instrument is in appendix A1.

The relevant DFT index is used as an instrument for both healthcare and public health expenditure. The DFT index reflects the fact that, periodically, the national ministry revises the funding formula and this, together with routine data updates, generates a new target budget allocation for each health authority. For some authorities, the new funding rule might generate a large change in its target allocation and, to avoid sudden large reductions in actual allocations (budgets), such changes are phased into actual budgets over a number of years in accordance with the Department of Health's 'pace of change' policy.[19] As a result, the DFT

index will reflect the resource allocation formula and 'pace of change' policy for each of these two types of expenditure. Any correlation between unmeasured determinants of mortality and the DFT index would be unexpected and so this instrument appears plausibly valid given there is unlikely to be an issue with reverse causality and given that controlling for need should avoid any unexpected confounding effect on mortality.

For healthcare expenditure we also use the age index from the prescribing cost component of the total allocation. As both this variable and the mortality rate are standardised for age so the prescribing cost age index is unlikely to be correlated with the error from equation (1).

Finally, the validity of all instruments is tested empirically using the Hansen-Sargan test.

4. 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 socio-economic variables -- 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.

We also have a dozen instruments. There are four 'type of LA' dummy variables, two variables from the relative need formula for social care, and a measure of the local owner-occupation rate. We also have two potential instruments for public health (the DFT index and the input price index) from the resource allocation formula. Finally, we have three potential instruments (the DFT, 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 multi-collinearity 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). 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 (for example, 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 local authority's population. Estimation is undertaken using the *Stata ivreg2* program.[25] Neither patients nor the public were involved in the design, or conduct, or reporting, or dissemination of our research.

5. Data

We use the gross current expenditure on adult social services by each local authority in 2013/14 as our measure of social service expenditure.[20] 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 £324 per person although there is considerable variation in expenditure across the country: for example, social service expenditure ranges from £244 per person in Barnsley to £432 in Camden and £764 in the City of London.

Healthcare expenditure data is available from each CCG's programme budgeting return.[26] These are converted to a local authority basis using a mapping that translates population levels in mid-2012 from (parts of) CCGs to LAs. The average LA healthcare spend was £1,152 per person in 2013/14. Public health expenditure data is available from the local authority revenue expenditure and financing document for 2013/14.[20] The average public health spend for this year was £53 per person. Total healthcare expenditure (£65bn) is about

four times the size of social service expenditure (£17bn), and the latter is six times the size of public health expenditure (£2.5bn).

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 socio-economic 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 & 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).

6. 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 six 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 ten or better). The three first-stage equations used to predict healthcare, social care and public health expenditure are in columns 1 to 3 respectively of Table A1 in appendix A3.

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 local authority 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 SW F-statistic is only 4.437). The equation used to predict social service expenditure is in column 5 of table A1 in appendix A3 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 IMD 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 ten 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 to 15 of table A1 in appendix A3).

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 appendix A3). 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 appendix A3 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 Sandersen-Windmeijer F-statistics are well below ten).

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

7. Discussion

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.[7] 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. The time trend analysis did not consider the impact of public health expenditure, probably because such expenditure was not specifically identified before 2013/14. We have included this variable in the mortality outcome equations estimated here because our study year (2013/14) is the first year for which public health expenditure data is 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.[9]

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 2001/02 and 2009/10 but decreased by 1.57% between 2010/11 and 2014/15. If this annual difference (3.77%) is applied to each of the latter four 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 1,569 lives (=0.336% of 467,000). Hence the 'loss' of 15.08% of social care expenditure over the period 2010/11 to 2014/15 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 2001/02 and 2009/10 but by 0.41% between 2010/11 and 2014/15. If this annual difference (3.41%) is applied to each of the latter four years then the total spending gap attributable to austerity is 13.64%. Our healthcare elasticity suggests that a 1% increase in spend would save 2,484 lives (=0.532% of 467,000). Hence the 'loss' of 13.64% of healthcare expenditure over the period 2010/11 to 2014/15 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 an even larger number 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).[7]

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 social care expenditure variables have a significant negative effect on mortality in both the backward and 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 2013/14 but which excluded social care expenditure from the estimating equation. In that study the coefficient on healthcare expenditure was -0.672.[9] 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 health care expenditure.[27 28 29 30] 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 (and better quality) 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 (for example, 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), their 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 (2013/14) is the first year for which there were resource allocation formulae for both health care and public health expenditure, and a relative needs formula 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.

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.

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.

8. 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.[7]

While previous studies have found significant negative effects on mortality of health care and public health expenditure, this study makes a major contribution in additionally estimating the effect on mortality of social care expenditure. There is evidence that all three types of health-related expenditure have a significant negative effect on mortality, and 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.

References

1. Demakakos, P. (2019). Austerity, socioeconomic inequalities and stalling life expectancy in the UK: Two parallel stories or one? Maturitas, 123, pp89-90. Available from https://doi.org/10.1016/j.maturitas.2018.12.007 [accessed 05 September 2020].

2. Hiam, L., Dorling, D. and McKee, M. (2018). The cuts and poor health: when and how can we say that one thing causes another? Journal of the Royal Society of Medicine, 111(6), 199–202. Available from https://doi.org/10.1177/0141076818779237 [accessed 05 September 2020].

3. Marmot M. J (2018). J Epidemiol Community Health, May, Vol 72 No 5, pp359-360. Available from https://jech.bmj.com/content/jech/72/5/359.full.pdf [accessed 05 September 2020].

4. Hiam L, Harrison D, McKee M and D Dorling (2018). Why is life expectancy in England and Wales 'stalling'? J Epidemiol Community Health 2018, 72, 404-408. Available from https://jech.bmj.com/content/jech/72/5/404.full.pdf [accessed 05 September 2020].

5. Faragher, R. (2017). Is austerity really to blame for stalling life expectancy in England? The Conversation, 20 July, 2017. Available from http://theconversation.com/is-austerity-really-to-blame-for-stalling-life-expectancy-in-england-81206 [accessed 05 September 2020].

6. Dorling, D (2019). Austerity bites—falling life expectancy in the UK. BMJ, March 19. Available from https://blogs.bmj.com/bmj/2019/03/19/danny-dorling/ [accessed 05 September 2020].

7. Watkins J, Wulaningsih W, Da Zhou C, *et al* (2017). Effects of health and social care spending constraints on mortality in England: a time trend analysis. *BMJ Open* 2017, v7, 11. DOI: 10.1136/bmjopen-2017-017722 [accessed 05 September 2020].

8. Claxton, K., Lomas, J. and Martin, S. (2018). The impact of NHS expenditure on health outcomes in England: Alternative approaches to identification in all-cause and disease specific models of mortality. Health Economics, 27(6), pp.1017-1023. Available at: https://onlinelibrary.wiley.com/doi/abs/10.1002/hec.3650 [accessed 05 September 2020].

9. Martin, S., Lomas, J. and Claxton, K. (2020). Is an ounce of prevention worth a pound of cure? Estimates of the impact of English public health grant on mortality and morbidity. BMJ Open, volume 10, issue10. Available at: https://bmjopen.bmj.com/content/10/10/e036411 [accessed 20 October 2020].

10. Forder, J., Vadean, F., Rand, S. & Malley, J. (2018). The impact of long-term care on quality of life. *Health economics,* 27**,** e43-e58. Available from https://onlinelibrary.wiley.com/doi/10.1002/hec.3612 [accessed 05 September 2020].

11. Fernandez, J.-L. and Forder, J. (2011). Consequences of local variations in social care on the performance of the acute health care sector. *Applied Economics,* 40**,** 1503-1518.

Available from https://www.tandfonline.com/doi/full/10.1080/00036840600843939 [accessed from 05 September 2020].

12. Forder, J. (2009). Long-term care and hospital utilisation by older people: an analysis of substitution rates. *Health Economics,* 18**,** 1322-1338. Available from https://onlinelibrary.wiley.com/doi/abs/10.1002/hec.1438 [accessed 05 September 2020].

13. Gaughan, J., Gravelle, H. and Siciliani, L. (2015). Testing the bed-blocking hypothesis: does nursing and care home supply reduce delayed hospital discharges? *Health economics,* 24**,** 32-44. Available from https://onlinelibrary.wiley.com/doi/10.1002/hec.3150 [accessed 05 September 2020].

14. Forder, J., Gousia, K. & Saloniki, E.-C. (2018). The impact of long-term care on primary care doctor consultations for people over 75 years. *The European Journal of Health Economics***,** 1-13. Available from https://ideas.repec.org/a/spr/eujhec/v20y2019i3d10.1007_s10198-018-0999-6.html [accessed 05 September 2020].

15. NAO (2018). Adult social care at a glance. National Audit Office, July. Available from https://www.nao.org.uk/wp-content/uploads/2018/07/Adult-social-care-at-a-glance.pdf [accessed 05 September 2020].

16. Department of Health (2002). Fair access to care services guidance on eligibility criteria for adult social care. Available from 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 05 September 2020]

17. NAO (2014). Planning for the Better Care Fund. National Audit Office, November. Available from https://www.nao.org.uk/wp-content/uploads/2014/11/Planning-for-the-better-care-fund.pdf [accessed 05 September 2020].

18. NAO (2017). Health and social care integration. National Audit Office, February. Available from https://www.nao.org.uk/wp-content/uploads/2017/02/Health-and-social-care-integration.pdf [accessed 05 September 2020].

19. DH (2012). Exposition Book Public Health Allocations 2013-14 and 2014-15: Technical Guide. Available from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/213324/Public-Health-Weighted-Capitation-FormulaTechnical-Guide-v0.13.pdf [accessed 05 September 2020].

20. MCHLG (2015). Local authority revenue expenditure and financing England: 2013 to 2014 individual local authority data – outturn. Available from https://www.gov.uk/government/statistics/local-authority-revenue-expenditure-and-financing-england-2013-to-2014-individual-local-authority-data-outturn [accessed 05 September 2020].

21. NHS England (2012). Allocations for 20143/14. Available from https://www.england.nhs.uk/allocations/allocations-2013-14/ [accessed 05 September 2020].

22. Andrews, M. et al., 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), pp.23–41. Available from https://www.tandfonline.com/doi/full/10.1080/07474938.2016.1114205 [accessed 05 September, 2020].

23. DCLG (2013). Calculation of 2013/14 Formula Funding. January. See https://webarchive.nationalarchives.gov.uk/20140505105851/http://www.local.communities.gov.uk/finance/1314/CalcFFs.pdf [accessed 05 September 2020].

24. Forder, J, Malley, J, Towers A, and A Netten (2014). Using cost-effectiveness estimates from survey data to guide commissioning: an application to home care. Health Economics, 23, 8, pp979-992. Available from https://doi.org/10.1002/hec.2973 [accessed 05 September 2020].

25. Baum, C.F., Schaffer, M.E., Stillman, S. (2010). ivreg2: Stata module for extended instrumental variables/2SLS, GMM and AC/HAC, LIML and k-class regression. Available from http://ideas.repec.org/c/boc/bocode/s425401.html [accessed 05 September 2020].

26. NHS England (2015). 2013-14 CCG Programme Budgeting Benchmarking Tool. Available from https://www.england.nhs.uk/prog-budgeting/ [accessed 05 September 2020].

27. Edney, L.C., Afzali, H.H.A., Cheng, T.C., Karnon, J.(2018). Estimating the reference incremental cost-effectiveness ratio for the Australian Health System. Pharmacoeconomics 36(2), 239–252. Available from https://link.springer.com/article/10.1007/s40273-017-0585-2 [accessed 05 September 2020].

28. Siverskog, J. & Henriksson, M (2019). Estimating the marginal cost of a life year in Sweden's public healthcare sector. Eur J Health Econ (2019) 20: 751. Available from https://doi.org/10.1007/s10198-019-01039-0 [accessed 05 September 2020].

29. Vallejo-Torres, L., Garcia-Lorenzo, B., Serrano-Aguilar, P. (2018). Estimating a cost-effectiveness threshold for the Spanish NHS. Health Economics, 27(4), 746–761. Available from https://onlinelibrary.wiley.com/doi/10.1002/hec.3633 [accessed 05 September 2020].

30. Claxton, K., Martin, S., Soares M, Rice N, Spackman E, Hinde S, Devlin N, Smith PC and Sculpher M. (2015). Methods for the estimation of the National Institute for Health and

Care Excellence cost-effectiveness threshold. Health technology assessment, 19(14), pp.1-503. Available from https://www.ncbi.nlm.nih.gov/pubmed/25692211 [accessed 05 September 2020].

Table 1 Descriptive statistics for variables employed in study

Variable description	Obs	Mean	Std. Dev.	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	85.0	267.5	775.9
Local authority population, 2013/14	151	369,610	271,897	2,381	1,481,378
Social service spend per person, 2013/14, £	151	306.60	46.58	209.08	660.42
NHS healthcare spend per person, 2013/14, £	151	1152.13	75.81	1019.89	1479.11
Public health expenditure per person, 2013/14, £	152	52.60	25.15	18.52	186.21
Controls					
Index of Multiple Deprivation 2010	152	23.0753	8.6040	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	0.0208	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, 2013/14	152	1.0667	0.5362	0.5392	6.6247
Input price index (MFF), public health expenditure, 2013/14	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

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

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	All causes	All causes	All causes	All causes	All causes	All causes	All causes
	2013/14 PB/GSS/PH spend SYLLR 2013/14/15 outcome model	2013/14 PB/GSS/PH spend SYLLR 2013/14/15 outcome model	2013/14 PB/PSS/PH spend SYLLR 2013/14/15 outcome model instrument PB/GSS/PH spend	2013/14 PB/PSS/PH spend SYLLR 2013/14/15 outcome model instrument PB/GSS/PH spend	2013/14 PB/PSS/PH spend SYLLR 2013/14/15 outcome model instrument PB/GSS/PH spend	2013/14 PB/PSS/PH spend SYLLR 2013/14/15 outcome model instrument PB/GSS/PH spend	2013/14 PB/PSS/PH spend SYLLR 2013/14/15 outcome model instrument PB/GSS/PH spend
	weighted OLS	weighted OLS	weighted IV second stage	weighted IV second stage	weighted IV second stage	weighted IV second stage	weighted 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	0.029	0.017	0.010	0.017	-0.018	-0.019
	[0.027]	[0.027]	[0.032]	[0.039]	[0.042]	[0.041]	[0.041]
CCG (PB) healthcare spend per person	-0.406***	-0.492***	-0.840***	-0.609**	-0.514	-0.545**	-0.532**
	[0.139]	[0.119]	[0.142]	[0.251]	[0.337]	[0.243]	[0.259]
Social service (GSS) spend per person	0.044	0.039	-0.078	-0.272**	-0.326*	-0.344**	-0.336**
	[0.055]	[0.053]	[0.102]	[0.124]	[0.182]	[0.134]	[0.152]
Index of Multiple Deprivation 2010	0.219***	0.156**	0.239***	0.243***	0.238***	-0.504*	-0.505**
	[0.074]	[0.066]	[0.059]	[0.068]	[0.075]	[0.260]	[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***	0.227***	0.289***	0.309***	0.309***	0.321***	0.319***
	[0.054]	[0.036]	[0.036]	[0.038]	[0.041]	[0.041]	[0.046]
% population providing unpaid care	-0.455***	-0.233***	-0.214**	-0.251**	-0.230**	-0.188**	-0.190**
	[0.171]	[0.086]	[0.087]	[0.098]	[0.108]	[0.085]	[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*	0.217***	0.229***	0.262***	0.259***	0.271***	0.271***
	[0.097]	[0.069]	[0.071]	[0.087]	[0.098]	[0.080]	[0.079]
% 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***	-0.285***	-0.190***	-0.162***	-0.154**	-0.098	-0.100
	[0.063]	[0.044]	[0.050]	[0.051]	[0.060]	[0.062]	[0.065]
Index of Multiple Deprivation 2010 Squared						0.130***	0.130***
						[0.043]	[0.042]
Constant	7.319***	8.862***	11.187***	9.408***	8.710***	10.277***	10.199***
	[1.040]	[0.819]	[1.021]	[1.693]	[2.295]	[1.568]	[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
Sanderson-Windmeijer _PH p-value			0.000	0.000	0.000	0.000	0.000

Robust standard errors in brackets
*** p<0.01, ** p<0.05, * p<0.1

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)

	(1)	(2)	(3)	(4)
	All causes	All causes	All causes	All causes
	2013/14 PB/PSS/PH spend	2013/14 PB/PSS/PH spend	2013/14 PB/PSS/PH spend	2013/14 PB/PSS/PH spend
	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15
	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
	weighted	weighted	weighted	weighted
	IV second stage	IV second stage	IV second stage	IV second stage
	parsimonious specification	specification_2	specification_3	specification_4
VARIABLES	11 instruments	7 instruments	5 instruments	4 instruments
Public health expenditure per person	-0.051	-0.043	-0.060	-0.099**
	[0.039]	[0.047]	[0.044]	[0.045]
CCG (PB) healthcare spend per person	-0.862***	-0.461	-0.637*	-0.693**
	[0.223]	[0.313]	[0.369]	[0.333]
Social service (GSS) spend per person	-0.206	-0.469***	-0.370*	-0.471**
	[0.133]	[0.161]	[0.205]	[0.237]
% population aged 16-74 that are permanently sick	0.649***	0.651***	0.672***	0.528***
	[0.046]	[0.054]	[0.052]	[0.073]
% population providing unpaid care	-0.381***	-0.388***	-0.400***	-0.143
	[0.086]	[0.096]	[0.097]	[0.118]
% population in white ethnic group	0.163***	0.195***	0.180***	0.299***
	[0.042]	[0.043]	[0.046]	[0.078]
Older adult: social service need per person				0.416***
				[0.143]
Constant	13.352***	10.204***	11.655***	12.245***
	[1.733]	[2.389]	[2.873]	[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 standard errors in brackets
*** p<0.01, ** p<0.05, * p<0.1

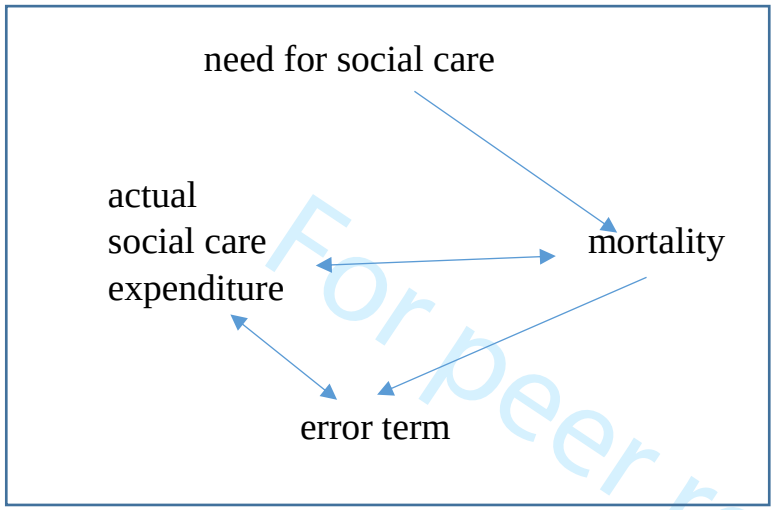
Table 4 Results summary

Type of health-related expenditure	Health outcome elasticity		Spending gap per capita between 2001/02- 2009/10 and 2010/11-2014/15	Deaths attributable to spending gap (=annual deaths*elasticity*gap)		Deaths attributable to spending gap from time trend analysis[7]
	Backward Selection	Forward Selection		Backward Selection	Forward Selection	
	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% confidence interval]	[-0.031, -0.640]	[0.003, -0.945]		[2,183, 45,071]	[-211, 66,550]	
Healthcare expenditure	-0.532	-0.693	13.64%	33,888	44,143	n/a
[95% confidence interval]	[-0.014, -1.050]	[-0.027, -1.359]		[892, 66,884]	[1,720, 86,567]	
Total social care and healthcare	n/a	n/a	n/a	57,550	77,313	45,368
[95% confidence interval]				[3,075, 111,955]	[1,509, 153,117]	[34,530, 56,206]

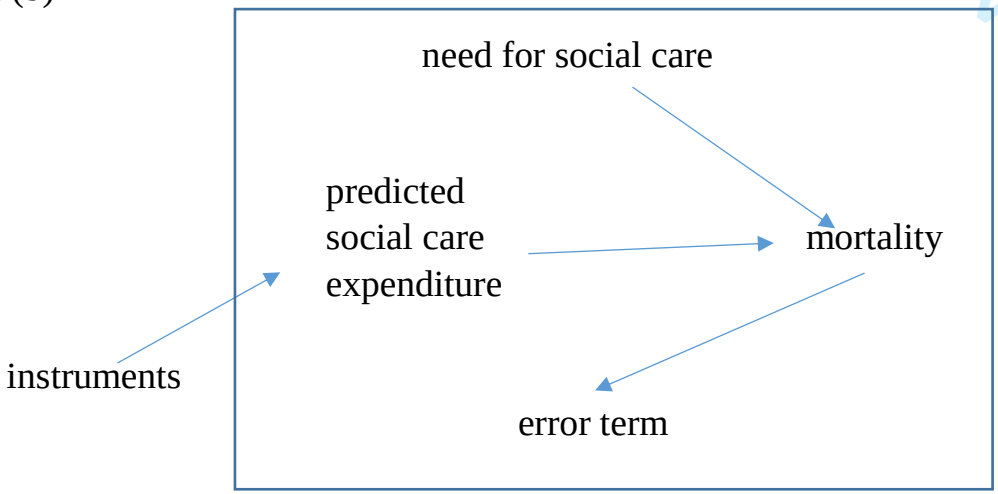
Figure 1 Illustration of the reverse causation issue and its resolution

Figure 1 Illustration of the reverse causation issue and its resolution

Part (a)



Part (b)



The mortality effects of social care, public health and healthcare expenditure: cross-sectional evidence from England for 2013/14

Appendices

Appendix A1: Further details about the instruments for healthcare expenditure

For 2013/14 the Department of Health allocated each Clinical Commissioning Group (CCG) a fixed proportion of the national budget (£65bn). CCGs used this allocation to fund expenditure on most types of healthcare except primary care, specialised commissioning and public health. CCGs reported their actual expenditure across various programmes of care and this data can be found in the programme budgeting dataset. This is available from https://www.england.nhs.uk/prog-budgeting/ [accessed 05 September 2020].

Healthcare expenditure is instrumented in a similar way to social care expenditure and in line with equation (2) in the main text. The selection of the relevant funding rule variables for healthcare expenditure for 2013/14 is more difficult than usual due to the changes enacted by the Health and Social Care Act 2012. Normally, resource allocation formulae are updated annually but the approaching replacement of Primary Care Trusts (one set of local health authorities) with CCGs (a different set with different responsibilities) led to the freezing of the weighted capitation formula for 2012/13, with all Primary Care Trusts (PCTs) receiving the same (3%) growth rate over their 2011/12 allocations. Because CCGs were not responsible for the same set of services as PCTs (CCGs lost responsibility for primary care public health, specialised services, and primary care), there was a baseline exercise in 2012 that identified actual PCT expenditure on CCG service responsibilities and, for 2013/14, each CCG enjoyed an uplift of 2.3% on these 2012/13 baselines.

As a result of these changes, the most appropriate funding rule variables for CCG healthcare expenditure in 2013/14 are drawn from the 2011/12 allocations for PCTs, appropriately converted to the new (CCG) geography. These allocations reflect components of the funding formulae (one for the total allocation, one for Hospital and Community Health Services (HCHS), and one for prescribing), and we select three funding rule variables employed in these formulae which we believe are uncorrelated with mortality. More precisely, the funding rule variables for CCG

healthcare expenditure for 2013/14 are: (i) the age index from the prescribing component of the total allocation; (ii) the MFF for the HCHS component of the total allocation; and (iii) the DFT for the total allocation to PCTs for 2011/12.

If the additional funding for areas with high unit costs exactly compensates for these additional costs then this additional nominal spending will not improve health outcomes because there is no increase in real spending. We assume that this adjustment for higher costs is not perfect and that some CCGs receive too much compensation and that others receive too little but that the imprecision associated with this adjustment is small relative to the size of the adjustment. This imperfect adjustment for local conditions provides the link between this instrument, expenditure and mortality. The same argument applies to the use of the age index as an instrument for healthcare expenditure.

Appendix A2: Further details about the instruments for local public health expenditure

The resource allocation formula used to distribute the total public health budget to local authorities has three components. These are for substance misuse services, for non-mandatory services, and for mandatory services. Each of these three service areas has its own resource allocation formula but each formula has a similar structure to that outlined in equation (2) in the main text and two of the four variables in equation (2) (the MFF and the DFT) are present for all three components. Hence we use these variables as instruments for public health expenditure.

As noted in the main text, the DFT index reflects how far an authority's actual budget is from its target allocation. This difference will reflect the product of three factors for the public health DFT index: (i) the size of PCT expenditure in 2010/11 on those public health activities that were transferred to local authorities in 2013/14; (ii) the public health grant funding formula for 2013/14; and (iii) the 'pace of change' policy for the 2013/14 public health allocations. Clearly, the last two elements will be policy choices but it is not obvious that the resulting DFT will be endogenous with respect to mortality and hence we feel justified in using the DFT index as an instrument for public health expenditure. And, of course, the validity of this instrument is empirically tested using the Hansen-Sargan test.

Appendix A3

This appendix contains the first-stage regressions associated with the second-stage results reported in the main body of the text.

Table A1 Obtaining a preferred health outcome specification for social care, healthcare and public health expenditure, backward selection, first-stage results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All causes	All causes	All causes	All causes	All causes	All causes	All causes	All causes	All causes
	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend
	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15
	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model
	first-stage	first-stage	first-stage	first-stage	first-stage	first-stage	first-stage	first-stage	first-stage
	weighted	weighted	weighted	weighted	weighted	weighted	weighted	weighted	weighted
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
	parsimonious specification	parsimonious specification	parsimonious specification	parsimonious_v2	parsimonious_v2	parsimonious_v2	parsimonious_v3	parsimonious_v3	parsimonious_v3
VARIABLES									
DFT index, public health expenditure, 2013/14	0.011	0.054	0.737***	0.022	0.033	0.736***	0.021	0.039	0.755***
	[0.027]	[0.061]	[0.050]	[0.026]	[0.067]	[0.045]	[0.026]	[0.064]	[0.054]
MFF, public health expenditure, 2013/14	0.099	1.033	0.945						
	[0.438]	[1.010]	[1.016]						
DFT index, NHS healthcare expenditure	0.537***	0.012	0.590**	0.536***	0.009	0.587**	0.541***	0.045	0.633*
	[0.155]	[0.359]	[0.276]	[0.151]	[0.380]	[0.279]	[0.158]	[0.391]	[0.326]
Age index, prescribing cost formula	0.234***	0.230	-1.080***	0.226***	0.179	-1.129***	0.250***	0.077	-1.423***
	[0.084]	[0.197]	[0.270]	[0.084]	[0.201]	[0.276]	[0.076]	[0.208]	[0.262]
MFF, resource allocation HCHS formula	-0.425	-1.459	-1.619						
	[0.488]	[1.093]	[1.203]						
Type of LA: London borough	0.036	-0.113**	-0.034						
	[0.024]	[0.054]	[0.058]						
Type of LA: Metropolitan district	0.017	-0.113***	0.010	0.017	-0.068**	0.041	0.008	-0.056**	0.030
	[0.017]	[0.030]	[0.043]	[0.015]	[0.030]	[0.038]	[0.013]	[0.023]	[0.029]
Type of LA: Unitary authority	0.002	-0.025	0.053	0.003	0.004	0.075***			
	[0.011]	[0.026]	[0.032]	[0.009]	[0.026]	[0.028]			
Area cost adj for older people's social services	0.270	0.527	0.444	0.215	-0.131	-0.051			
	[0.281]	[0.590]	[0.454]	[0.182]	[0.425]	[0.407]			
Population sparsity measure	0.820	-4.418*	-8.406***	1.300**	-3.199	-6.998***			
	[0.719]	[2.314]	[2.403]	[0.653]	[2.360]	[2.250]			
% households that are owner occupied	-0.114**	-0.356***	-0.163	-0.107**	-0.466***	-0.233**	-0.148***	-0.377***	0.007
	[0.055]	[0.107]	[0.128]	[0.053]	[0.106]	[0.117]	[0.051]	[0.091]	[0.099]
Index of Multiple Deprivation 2010	-0.028	0.135	0.218*	-0.007	0.062	0.192*	-0.008	0.041	0.122
	[0.051]	[0.106]	[0.119]	[0.053]	[0.103]	[0.102]	[0.054]	[0.110]	[0.113]
% population in white ethnic group	0.079*	0.135*	0.152*	0.073*	0.208***	0.194**	0.073*	0.190***	0.180*
	[0.042]	[0.071]	[0.084]	[0.044]	[0.072]	[0.078]	[0.041]	[0.065]	[0.092]
% population providing unpaid care	-0.101	0.385*	-0.017	-0.073	0.429*	0.048	-0.053	0.340*	-0.270
	[0.092]	[0.230]	[0.205]	[0.091]	[0.220]	[0.207]	[0.093]	[0.194]	[0.236]
% population aged 16-74 permanently sick	0.039	-0.019	0.270**	0.036	0.007	0.284**	0.021	0.072	0.481***
	[0.061]	[0.116]	[0.111]	[0.061]	[0.118]	[0.110]	[0.059]	[0.111]	[0.124]
% aged 16-74 in managerial/prof occupations	-0.104**	0.211**	-0.121	-0.097**	0.186*	-0.129	-0.083**	0.183**	-0.158*
	[0.045]	[0.094]	[0.094]	[0.046]	[0.103]	[0.092]	[0.038]	[0.090]	[0.093]
Constant	6.841***	-0.557	3.800***	6.844***	-0.241	4.028***	6.863***	-0.166	4.191***
	[0.294]	[0.533]	[0.542]	[0.300]	[0.551]	[0.555]	[0.300]	[0.569]	[0.609]
Observations	150	150	150	150	150	150	150	150	150
Robust standard errors in brackets									
*** p<0.01, ** p<0.05, * p<0.1									

Table A1 continued Obtaining a preferred health outcome specification for social care, healthcare and public health expenditure, backward selection, first-stage results

	(10)	(11)	(12)	(13)	(14)	(15)
	All causes	All causes	All causes	All causes	All causes	All causes
	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend
	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15
	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model
	first-stage	first-stage	first-stage	first-stage	first-stage	first-stage
	weighted	weighted	weighted	weighted	weighted	weighted
	OLS	OLS	OLS	OLS	OLS	OLS
	parsimonious_v4	parsimonious_v4	parsimonious_v4	parsimonious_v5	parsimonious_v5	parsimonious_v5
VARIABLES						
DFT index, public health expenditure, 2013/14	0.014	0.062	0.764***	0.027	0.083	0.761***
	[0.027]	[0.055]	[0.058]	[0.026]	[0.054]	[0.056]
DFT index, NHS healthcare expenditure	0.592***	-0.136	0.566*	0.594***	-0.131	0.565*
	[0.158]	[0.344]	[0.340]	[0.161]	[0.344]	[0.340]
Age index, prescribing cost formula	0.218***	0.190	-1.382***	0.227***	0.205	-1.384***
	[0.080]	[0.217]	[0.286]	[0.085]	[0.226]	[0.284]
Type of LA: Metropolitan district	0.012	-0.069***	0.026	0.004	-0.082***	0.027
	[0.013]	[0.023]	[0.029]	[0.013]	[0.024]	[0.027]
% households that are owner occupied	-0.175***	-0.282***	0.042			
	[0.051]	[0.100]	[0.117]			
Index of Multiple Deprivation 2010	0.195	-0.680*	-0.145	0.079	-0.868**	-0.117
	[0.171]	[0.351]	[0.455]	[0.154]	[0.350]	[0.421]
% population in white ethnic group	0.078*	0.173**	0.173*	0.063	0.149**	0.177*
	[0.040]	[0.067]	[0.096]	[0.040]	[0.068]	[0.095]
% population providing unpaid care	-0.037	0.284	-0.291	-0.189**	0.039	-0.254
	[0.092]	[0.205]	[0.244]	[0.094]	[0.207]	[0.232]
% population aged 16-74 permanently sick	0.025	0.055	0.475***	0.056	0.104	0.467***
	[0.058]	[0.107]	[0.124]	[0.063]	[0.109]	[0.124]
% aged 16-74 in managerial/prof occupations	-0.108***	0.273***	-0.125	-0.061	0.348***	-0.136
	[0.039]	[0.096]	[0.110]	[0.041]	[0.083]	[0.103]
Index of Multiple Deprivation 2010 Squared	-0.038	0.137**	0.051	-0.011	0.180***	0.044
	[0.028]	[0.058]	[0.081]	[0.025]	[0.056]	[0.073]
Constant	6.615***	0.716	4.518***	6.605***	0.700	4.520***
	[0.382]	[0.736]	[0.815]	[0.361]	[0.763]	[0.811]
Observations	150	150	150	150	150	150
Robust standard errors in brackets						
*** p<0.01, ** p<0.05, * p<0.1						

Table A2 Obtaining a preferred health outcome specification for social care, healthcare and public health expenditure, forward selection, first-stage results

	(1)	(2)	(3)	(4)	(5)	(6)
	All causes	All causes	All causes	All causes	All causes	All causes
	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend
	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15
	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model
	first-stage	first-stage	first-stage	first-stage	first-stage	first-stage
	weighted	weighted	weighted	weighted	weighted	weighted
	OLS	OLS	OLS	OLS	OLS	OLS
	'initial' specification	'initial' specification	'initial' specification	specification 2	specification 2	specification 2
VARIABLES						
DFT index, public health expenditure, 2013/14	0.004	0.062	0.716***	0.016	0.048	0.717***
	[0.029]	[0.059]	[0.054]	[0.027]	[0.063]	[0.049]
MFF, public health expenditure, 2013/14	0.032	1.017	0.375			
	[0.430]	[0.988]	[1.038]			
DFT index, NHS healthcare expenditure	0.444***	0.215	0.530*	0.460***	0.221	0.371
	[0.144]	[0.342]	[0.286]	[0.140]	[0.348]	[0.256]
Age index, prescribing cost formula	0.228***	0.246	-1.077***	0.220***	0.176	-1.062***
	[0.084]	[0.199]	[0.269]	[0.079]	[0.194]	[0.270]
MFF, resource allocation HCHS formula	-0.359	-1.523	-1.314			
	[0.482]	[1.074]	[1.213]			
Type of LA: London borough	0.030	-0.090*	-0.003			
	[0.026]	[0.052]	[0.050]			
Type of LA: Metropolitan district	0.015	-0.105***	0.020	0.016	-0.070**	0.063**
	[0.016]	[0.031]	[0.041]	[0.014]	[0.028]	[0.031]
Type of LA: Unitary authority	0.004	-0.029	0.060*	0.005	-0.003	0.085***
	[0.010]	[0.026]	[0.032]	[0.009]	[0.025]	[0.026]
Area cost adj for older people's social services	0.143	0.718	0.076			
	[0.254]	[0.626]	[0.460]			
Population sparsity measure	0.843	-4.433*	-8.279***	1.319**	-3.410	-5.890***
	[0.720]	[2.392]	[2.362]	[0.666]	[2.354]	[2.141]
% households that are owner occupied	-0.101*	-0.403***	-0.211*	-0.102*	-0.502***	-0.209*
	[0.053]	[0.107]	[0.123]	[0.052]	[0.101]	[0.121]
% population aged 16-74 permanently sick	0.052*	0.026	0.519***	0.066***	-0.014	0.567***
	[0.029]	[0.073]	[0.067]	[0.024]	[0.066]	[0.064]
% population providing unpaid care	-0.086	0.300	-0.180	-0.074	0.394*	-0.107
	[0.086]	[0.217]	[0.196]	[0.084]	[0.215]	[0.202]
% population in white ethnic group	0.050*	0.161**	0.014	0.041	0.248***	0.048
	[0.028]	[0.062]	[0.070]	[0.027]	[0.065]	[0.060]
Older adults: social service need per person						
Constant	6.962***	-0.480	4.991***	7.038***	-0.434	5.291***
	[0.158]	[0.403]	[0.367]	[0.150]	[0.370]	[0.382]
Observations	150	150	150	150	150	150
Robust standard errors in brackets						
*** p<0.01, ** p<0.05, * p<0.1						

Table A2 continued

Obtaining a preferred health outcome specification for social care, healthcare and public health expenditure, forward selection, first-stage results

	(7) All causes 2013/14 PB spend SYLLR 2013/14/15 outcome model first-stage weighted OLS specification 3	(8) All causes 2013/14 G_SS spend SYLLR 2013/14/15 outcome model first-stage weighted OLS specification 3	(9) All causes 2013/14 PH spend SYLLR 2013/14/15 outcome model first-stage weighted OLS specification 3	(10) All causes 2013/14 PB spend SYLLR 2013/14/15 outcome model first-stage weighted OLS preferred specification	(11) All causes 2013/14 G_SS spend SYLLR 2013/14/15 outcome model first-stage weighted OLS preferred specification	(12) All causes 2013/14 PH spend SYLLR 2013/14/15 outcome model first-stage weighted OLS referred specification
VARIABLES						
DFT index, public health expenditure, 2013/14	0.012	0.057	0.734***	0.020	0.075	0.728***
	[0.026]	[0.064]	[0.057]	[0.026]	[0.061]	[0.056]
DFT index, NHS healthcare expenditure	0.413***	0.321	0.352	0.451***	0.291	0.255
	[0.132]	[0.351]	[0.285]	[0.127]	[0.338]	[0.284]
Age index, prescribing cost formula	0.266***	0.050	-1.345***	0.279***	0.212	-1.279***
	[0.072]	[0.210]	[0.253]	[0.077]	[0.207]	[0.257]
Type of LA: Metropolitan district	0.009	-0.057**	0.039	0.004	-0.080***	0.037
	[0.012]	[0.023]	[0.027]	[0.013]	[0.023]	[0.026]
% households that are owner occupied	-0.129***	-0.422***	0.026			
	[0.049]	[0.085]	[0.100]			
% population aged 16-74 permanently sick	0.056**	0.019	0.699***	0.069**	-0.088	0.610***
	[0.024]	[0.045]	[0.059]	[0.029]	[0.062]	[0.064]
% population providing unpaid care	-0.055	0.328*	-0.372	-0.158*	0.178	-0.245
	[0.088]	[0.191]	[0.227]	[0.085]	[0.191]	[0.212]
% population in white ethnic group	0.048*	0.235***	0.064	0.047*	0.294***	0.100
	[0.026]	[0.064]	[0.068]	[0.026]	[0.068]	[0.068]
Older adults: social service need per person				0.068	0.583***	0.193
				[0.058]	[0.113]	[0.120]
Constant	7.052***	-0.473	5.208***	6.925***	-0.914**	5.218***
	[0.154]	[0.361]	[0.421]	[0.152]	[0.360]	[0.423]
Observations	150	150	150	150	150	150

Robust standard errors in brackets
*** p<0.01, ** p<0.05, * p<0.1

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1, 4
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6
Objectives	3	State specific objectives, including any prespecified hypotheses	4, 6
Methods			
Study design	4	Present key elements of study design early in the paper	6-7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-13
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8-13
Bias	9	Describe any efforts to address potential sources of bias	8-12
Study size	10	Explain how the study size was arrived at	12-13
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8-13
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8-12, Fig 1
		(*b*) Describe any methods used to examine subgroups and interactions	None
		(*c*) Explain how missing data were addressed	n/a
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	n/a
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Table 1
		(b) Give reasons for non-participation at each stage	n/a
		(c) Consider use of a flow diagram	n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Table 1
Outcome data	15*	Report numbers of outcome events or summary measures	Table 1

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Tables 2, 3,& 4
		(*b*) Report category boundaries when continuous variables were categorized	n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Cf Table 2 & Table 3
Discussion			
Key results	18	Summarise key results with reference to study objectives	Table 4
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16-17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	16-17
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

The causal impact of social care, public health and healthcare expenditure on mortality in England: cross-sectional evidence for 2013/14

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-046417.R1
Article Type:	Original research
Date Submitted by the Author:	24-May-2021
Complete List of Authors:	Martin, Stephen; University of York Department of Economics and Related Studies, Longo, Francesco; University of York, Centre for Health Economics Lomas, James; University of York, Centre for Health Economics Claxton, Karl; University of York, Centre for Health Economics & Department of Economics
Primary Subject Heading:	Health economics
Secondary Subject Heading:	Health policy, Public health
Keywords:	HEALTH ECONOMICS, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, STATISTICS & RESEARCH METHODS

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

The causal impact of social care, public health and healthcare expenditure on mortality in England: cross-sectional evidence for 2013/14

Author/position/address
Dr Stephen Martin
Research Fellow, Department of Economics, University of York, York, YO10 5DD.

Dr Francesco Longo
Research Fellow, Centre for Health Economics, University of York, York, YO10 5DD.

Dr James Lomas
Research Fellow, Centre for Health Economics, University of York, York, YO10 5DD.

Dr Karl Claxton
Professor, Department of Economics & Centre for Health Economics, University of York, York, YO10 5DD.

Corresponding author and email address
Dr Stephen Martin Email: sdm1@york.ac.uk

Transparency declaration
The lead author (the manuscript's guarantor) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Details of ethical approval
Ethical approval was not required because neither human participants nor animals were involved in the study.

Details of the role of the study sponsors
The views expressed in this publication are those of the authors and not necessarily those of the NHS, the National Institute for Health Research or the Department of Health and Social Care (DHSC).

Statement of independence of researchers from funders
Although funded by the funded by the National Institute for Health Research Policy Research Programme, neither the NIHR nor the DHSC had any influence on the study design, the way in which the research was undertaken, or the results.

Acknowledgements
We should like to thank NHS Digital for supplying the mortality data. We should also like to acknowledge the assistance received from various individuals including Michael Chaplin at the Department of Health and Social Care. In addition, we should like to acknowledge the comments received from various individuals at the Department of Health and Social Care and NHS England on an earlier version of this paper. Their suggestions have substantially improved the final version.

Word count
The text consists of 5,819 words. There are four tables in this document. There is one figure in a separate file.

The causal impact of social care, public health and healthcare expenditure on mortality in England: cross-sectional evidence for 2013/14

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 2010/11 – 2014/15 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 2013/14. Next, we compare the growth in healthcare and social care expenditure pre- and post-2010. We use the difference between these growth rates and the responsiveness of mortality to changes in expenditure taken from the 2013/14 cross-sectional analysis to estimate the additional mortality generated by post-2010 spending constraints.

Results

Our most conservative results suggest that: (i) a 1% increase in healthcare expenditure reduces mortality by 0.532%; (ii) a 1% increase in social care expenditure reduces mortality by 0.336%; and (iii) 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 2001/02 - 2009/10 and 2010/11 – 2014/15, we find that there were 57,550 [CI: 3,075-111,955] more deaths in the latter period than would have been observed had spending growth during this period matched that in 2001/02 - 2009/10.

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- 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 2013/14 may not hold in other years and there may be other factors affecting mortality beyond those included in this study.

The causal impact of social care, public health and healthcare expenditure on mortality in England: cross-sectional evidence for 2013/14

1. Introduction

The rate of improvement in life expectancy in England and Wales has slowed markedly since 2010.[1 2 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 at a single point in time (2013/14). 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 and healthcare services so that an increase in social care services may improve hospital outcomes, for example, by reducing delayed discharges.[12 13 14 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 policymakers. 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. Secondly, 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. Section 2 describes the institutional arrangements associated with the three types of health-related expenditure that are the focus of this study. Section 3 describes the health outcome equation to be estimated and how we address the issue of reverse causation (i.e., that mortality may affect expenditure as well as vice versa). Section 4 describes our estimation approach and section 5 presents brief details of the dataset. Section 6 presents our results and there is a discussion of them in section 7.

2. Institutional arrangements for health-related expenditure in England in 2013/14

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 local authority pay for; and/or informally by family, friends, or neighbours.[17]

Funding for local authorities (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, local authorities 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 local authority 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 £2,500mn of expenditure in 2013/14 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 2013/14.[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 (2013/14). These were administered centrally and expenditure on these items has been excluded from the study because data are not available by local area.

3. 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 local authorities in 2013/14. We estimate:

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

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.

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.

Insert Figure 1 near here

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 (2013/14) 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 relative needs formulae: one for people aged 18-64, and another for those aged over 65. The relative needs formula for the older people's social care included a basic amount per client with top-ups for age, deprivation, low income, population sparsity and local input prices.[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 relative needs formula 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 (2013/14), each local health authority (212 CCGs) was assigned a fixed share of the national budget (£65bn) 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: (i) the age index reflects the demographic profile of the local population; (ii) the additional needs index reflects local deprivation and other factors likely to influence the need for health care and includes a measure of historical mortality; (iii) the input price index (the Market Forces Factor (MFF)) reflects prices in the local health economy; and (iv) 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 appendix A1 but, in summary, these funding rule variables are: (i) the DFT index for the total allocation; (ii) the Market Forces Factor for the Hospital and Community Health Services (HCHS) component of the total allocation; and (iii) 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 local authorities 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 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 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]

4. 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 socio-economic variables -- 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 relative need formula 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 multi-collinearity 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 (for example, 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 local authority'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.

5. Data

We use the gross current expenditure on adult social services by each local authority in 2013/14 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 is available from each CCG's programme budgeting return.[30] These are converted to a local authority basis using a mapping that translates population levels in mid-2012 from (parts of) CCGs to LAs. The average LA healthcare spend was £1,152 per person in 2013/14. Public health expenditure data is available from the local authority revenue expenditure and financing document for 2013/14.[22] The average public health spend for this year was £53 per person. Total healthcare expenditure (£65bn) is about four times the size of social service expenditure (£17bn), and the latter is six times the size of public health expenditure (£2.5bn).

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 socio-economic 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 & 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).

6. 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 six 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 ten or better). The three first-stage equations used to predict healthcare, social care and public health expenditure are in columns 1 to 3 respectively of Table A1 in 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 local authority 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 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 IMD 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 ten 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 to 15 of table A1 in 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 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 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 ten).

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 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 is not available before 2013/14 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 (2013/14) is the first year for which public health expenditure data is 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 2001/02 and 2009/10 but decreased by 1.57% between 2010/11 and 2014/15. If this annual difference (3.77%) is applied to each of the latter four 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 1,569 lives (=0.336% of 467,000). Hence the 'loss' of 15.08% of social care expenditure over the period 2010/11 to 2014/15 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 2001/02 and 2009/10 but by 0.41% between 2010/11 and 2014/15. If this annual difference (3.41%) is applied to each of the latter four years then the total spending gap attributable to austerity is 13.64%. Our healthcare elasticity suggests that a 1% increase in spend would save 2,484 lives (=0.532% of 467,000). Hence the 'loss' of 13.64% of healthcare expenditure over the period 2010/11 to 2014/15 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 an

even larger number 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]

7. 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 social care expenditure variables have a significant negative effect on mortality in both the backward and 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 2013/14 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 health care expenditure.[31 32 33 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 (for example, 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), their 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 (2013/14) is the first year for which there were resource allocation formulae for both health care and public health expenditure, and a relative needs formula 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 2013/14 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.

8. 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.

Contributorship statement

All (SM, FL, JL and KC) authors contributed to the concept and design of this paper. SM led on the analysis and drafting, and the final paper was edited and approved by all four authors. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting these criteria have been omitted. SM is the paper's guarantor.

Competing interest statement

All authors have completed the Unified Competing Interest form (available on request from the corresponding author) and declare: financial support from the National Institute for Health Research Policy Research Programme for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; and no other relationships or activities that could appear to have influenced the submitted work.

Details of funding

This paper reports independent research funded by the National Institute for Health Research Policy Research Programme (NIHR PRP) through its Policy Research Unit in Economic Evaluation of Health & Care Interventions (EEPRU, grant reference PR-PRU-1217-20401).

Data sharing statement

All of the raw data are in the public domain. The social care expenditure data is available from the publication 'Local authority revenue expenditure and financing England: 2013 to 2014 individual local authority data – outturn' at https://www.gov.uk/government/statistics/local-authority-revenue-expenditure-and-financing-england-2013-to-2014-individual-local-authority-data-outturn [accessed 05 September 2020]. The sparsity and input price adjustment variable from the older person's relative needs formula are available from the publication 'Calculation of 2013/14 Formula Funding' at https://webarchive.nationalarchives.gov.uk/20140505105851/http://www.local.communities.

gov.uk/finance/1314/CalcFFs.pdf [accessed 05 September 2020]. The 'type of local authority' dummies are available from the data dictionary in the zip file at https://digital.nhs.uk/data-and-information/publications/statistical/adult-social-care-activity-and-finance-report/2017-18 [accessed 20 October 2020]. The healthcare expenditure data are available in the 2013-14 CCG Programme Budgeting Benchmarking Tool. This is available from https://www.england.nhs.uk/prog-budgeting/ [accessed 05 September 2020]. The socio-economic variables are constructed using the 2011 Population Census. Census data is available from the Office for National Statistics at https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/2011censuskeystatisticsforlocalauthoritiesinenglandandwales [accessed 05 September 2020]. The cells used to construct the socio-economic variables are listed in Table 92 of Claxton, K., Martin, S., Soares M, Rice N, Spackman E, Hinde S, Devlin N, Smith PC and Sculpher M. (2015). Methods for the estimation of the National Institute for Health and Care Excellence cost-effectiveness threshold. Health technology assessment, 19(14), pp.1-503. Available from https://www.ncbi.nlm.nih.gov/books/NBK274318/ [accessed 05 September 2020]. The public health expenditure data are available from 'Local authority revenue expenditure and financing England: 2013 to 2014 individual local authority data – outturn' which is available from https://www.gov.uk/government/statistics/local-authority-revenue-expenditure-and-financing-england-2013-to-2014-individual-local-authority-data-outturn [accessed 05 September 2020]'. The instruments for public health expenditure are available in 'Exposition Book Public Health Allocations 2013-14 and 2014-15: Technical Guide' and this is available from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/213324/Public-Health-Weighted-Capitation-FormulaTechnical-Guide-v0.13.pdf [accessed 05 September 2020]. The DFT variable for healthcare expenditure is available from the Department of Health's website at https://www.networks.nhs.uk/nhsnetworks/health-investment-network/news/2012-13-programme-budgeting-data-is-now-available [accessed 05 September 2020], and the MFF and prescribing cost age indices are available from the exposition books for the 2011/12 allocations at https://www.gov.uk/government/publications/exposition-book-2011-2012 [accessed 05 September 2020].

References

1. Demakakos, P. (2019). Austerity, socioeconomic inequalities and stalling life expectancy in the UK: Two parallel stories or one? Maturitas, 123, pp89-90. Available from https://doi.org/10.1016/j.maturitas.2018.12.007 [accessed 05 September 2020].

2. Hiam, L., Dorling, D. and McKee, M. (2018). The cuts and poor health: when and how can we say that one thing causes another? Journal of the Royal Society of Medicine, 111(6), 199–202. Available from https://doi.org/10.1177/0141076818779237 [accessed 05 September 2020].

3. Marmot M. J (2018). J Epidemiol Community Health, May, Vol 72 No 5, pp359-360. Available from https://jech.bmj.com/content/jech/72/5/359.full.pdf [accessed 05 September 2020].

4. Hiam L, Harrison D, McKee M and D Dorling (2018). Why is life expectancy in England and Wales 'stalling'? J Epidemiol Community Health 2018, 72, 404-408. Available from https://jech.bmj.com/content/jech/72/5/404.full.pdf [accessed 05 September 2020].

5. Faragher, R. (2017). Is austerity really to blame for stalling life expectancy in England? The Conversation, 20 July, 2017. Available from http://theconversation.com/is-austerity-really-to-blame-for-stalling-life-expectancy-in-england-81206 [accessed 05 September 2020].

6. Loopstra, R., McKee, M., Katikireddi, S. V, Taylor-Robinson, D., Barr, B. and Stuckler, D. (2016). Austerity and old-age mortality in England: a longitudinal cross-local area analysis, 2007–2013. Journal of the Royal Society of Medicine, 109(3), 109-116. DOI: 10.1177/0141076816632215 [accessed 12 May 2021].

7. Dorling, D (2019). Austerity bites—falling life expectancy in the UK. BMJ, March 19. Available from https://blogs.bmj.com/bmj/2019/03/19/danny-dorling/ [accessed 05 September 2020].

8. Watkins J, Wulaningsih W, Da Zhou C, *et al* (2017). Effects of health and social care spending constraints on mortality in England: a time trend analysis. *BMJ Open* 2017, v7, 11. DOI: 10.1136/bmjopen-2017-017722 [accessed 05 September 2020].

9. Claxton, K., Lomas, J. and Martin, S. (2018). The impact of NHS expenditure on health outcomes in England: Alternative approaches to identification in all-cause and disease specific models of mortality. Health Economics, 27(6), pp.1017-1023. Available at: https://onlinelibrary.wiley.com/doi/abs/10.1002/hec.3650 [accessed 05 September 2020].

10. Martin, S., Lomas, J. and Claxton, K. (2020). Is an ounce of prevention worth a pound of cure? Estimates of the impact of English public health grant on mortality and morbidity. BMJ Open, volume 10, issue10. Available at: https://bmjopen.bmj.com/content/10/10/e036411 [accessed 20 October 2020].

11. Forder, J., Vadean, F., Rand, S. & Malley, J. (2018). The impact of long-term care on quality of life. *Health economics,* 27**,** e43-e58. Available from https://onlinelibrary.wiley.com/doi/10.1002/hec.3612 [accessed 05 September 2020].

12. Fernandez, J.-L. and Forder, J. (2011). Consequences of local variations in social care on the performance of the acute health care sector. *Applied Economics,* 40**,** 1503-1518. Available from https://www.tandfonline.com/doi/full/10.1080/00036840600843939 [accessed from 05 September 2020].

13. Forder, J. (2009). Long-term care and hospital utilisation by older people: an analysis of substitution rates. *Health Economics,* 18**,** 1322-1338. Available from https://onlinelibrary.wiley.com/doi/abs/10.1002/hec.1438 [accessed 05 September 2020].

14. Gaughan, J., Gravelle, H. and Siciliani, L. (2015). Testing the bed-blocking hypothesis: does nursing and care home supply reduce delayed hospital discharges? *Health economics,* 24**,** 32-44. Available from https://onlinelibrary.wiley.com/doi/10.1002/hec.3150 [accessed 05 September 2020].

15. Forder, J., Gousia, K. & Saloniki, E.-C. (2018). The impact of long-term care on primary care doctor consultations for people over 75 years. *The European Journal of Health Economics***,** 1-13. Available from https://ideas.repec.org/a/spr/eujhec/v20y2019i3d10.1007_s10198-018-0999-6.html [accessed 05 September 2020].

16. Bradley, E. H., Canavan, M., Rogan, E., Talbert-Slagle,K., Ndumele, C., Taylor, L. and Curry, L. A. (2016). Variation in health outcomes: the role of spending on social services, public health and health care, 2000-09. *Health Affairs*, 35, 5. Available from https://doi.org/10.1377/hlthaff.2015.0814 [accessed 30 April 2021].

17. NAO (2018). Adult social care at a glance. National Audit Office, July. Available from https://www.nao.org.uk/wp-content/uploads/2018/07/Adult-social-care-at-a-glance.pdf [accessed 05 September 2020].

18. Department of Health (2002). Fair access to care services guidance on eligibility criteria for adult social care. Available from 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 05 September 2020]

19. NAO (2014). Planning for the Better Care Fund. National Audit Office, November. Available from https://www.nao.org.uk/wp-content/uploads/2014/11/Planning-for-the-better-care-fund.pdf [accessed 05 September 2020].

20. NAO (2017). Health and social care integration. National Audit Office, February. Available from

https://www.nao.org.uk/wp-content/uploads/2017/02/Health-and-social-care-integration.pdf [accessed 05 September 2020].

21. DH (2012). Exposition Book Public Health Allocations 2013-14 and 2014-15: Technical Guide. Available from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/213324/Public-Health-Weighted-Capitation-FormulaTechnical-Guide-v0.13.pdf [accessed 05 September 2020].

22. MCHLG (2015). Local authority revenue expenditure and financing England: 2013 to 2014 individual local authority data – outturn. Available from https://www.gov.uk/government/statistics/local-authority-revenue-expenditure-and-financing-england-2013-to-2014-individual-local-authority-data-outturn [accessed 05 September 2020].

23. NHS England (2012). Allocations for 2013/14. Available from https://www.england.nhs.uk/allocations/allocations-2013-14/ [accessed 05 September 2020].

24. Andrews, M. et al., 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), pp.23–41. Available from https://www.tandfonline.com/doi/full/10.1080/07474938.2016.1114205 [accessed 05 September, 2020].

25. DCLG (2013). Calculation of 2013/14 Formula Funding. January. See https://webarchive.nationalarchives.gov.uk/20140505105851/http://www.local.communities.gov.uk/finance/1314/CalcFFs.pdf [accessed 05 September 2020].

26. Forder, J, Malley, J, Towers A, and A Netten (2014). Using cost-effectiveness estimates from survey data to guide commissioning: an application to home care. Health Economics, 23, 8, pp979-992. Available from https://doi.org/10.1002/hec.2973 [accessed 05 September 2020].

27. Sanderson, E. and F. Windmeijer, (2016). A Weak Instrument F-Test in Linear IV Models with Multiple Endogenous Variables. Journal of Econometrics, 190, 2, 212-221. Availalble from https://doi.org/10.1016/j.jeconom.2015.06.004 [accessed 12 May 2021].

28. Baum, C.F., Schaffer, M.E., Stillman, S. (2010). ivreg2: Stata module for extended instrumental variables/2SLS, GMM and AC/HAC, LIML and k-class regression. Available from http://ideas.repec.org/c/boc/bocode/s425401.html [accessed 05 September 2020].

29. Pesaran, M.H. and L.W. Taylor, *Diagnostics for IV regressions.* Oxford Bulletin of Economics and Statistics, 1999. **61**(2): p. 255-265.

30. NHS England (2015). 2013-14 CCG Programme Budgeting Benchmarking Tool. Available from https://www.england.nhs.uk/prog-budgeting/ [accessed 05 September 2020].

31. Edney, L.C., Afzali, H.H.A., Cheng, T.C., Karnon, J.(2018). Estimating the reference incremental cost-effectiveness ratio for the Australian Health System. Pharmacoeconomics 36(2), 239–252. Available from https://link.springer.com/article/10.1007/s40273-017-0585-2 [accessed 05 September 2020].

32. Siverskog, J. & Henriksson, M (2019). Estimating the marginal cost of a life year in Sweden's public healthcare sector. Eur J Health Econ (2019) 20: 751. Available from https://doi.org/10.1007/s10198-019-01039-0 [accessed 05 September 2020].

33. Vallejo-Torres, L., Garcia-Lorenzo, B., Serrano-Aguilar, P. (2018). Estimating a cost-effectiveness threshold for the Spanish NHS. Health Economics, 27(4), 746–761. Available from https://onlinelibrary.wiley.com/doi/10.1002/hec.3633 [accessed 05 September 2020].

34. Claxton, K., Martin, S., Soares M, Rice N, Spackman E, Hinde S, Devlin N, Smith PC and Sculpher M. (2015). Methods for the estimation of the National Institute for Health and Care Excellence cost-effectiveness threshold. Health technology assessment, 19(14), pp.1-503. Available from https://www.ncbi.nlm.nih.gov/pubmed/25692211 [accessed 05 September 2020].

Table 1 Descriptive statistics for variables employed in study

Variable description	Obs	Mean	Std. Dev.	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	85.0	267.5	775.9
Local authority population, 2013/14	151	369,610	271,897	2,381	1,481,378
Social service spend per person, 2013/14, £	151	306.60	46.58	209.08	660.42
NHS healthcare spend per person, 2013/14, £	151	1152.13	75.81	1019.89	1479.11
Public health expenditure per person, 2013/14, £	152	52.60	25.15	18.52	186.21
Controls					
Index of Multiple Deprivation 2010	152	23.0753	8.6040	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	0.0208	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, 2013/14	152	1.0667	0.5362	0.5392	6.6247
Input price index (MFF), public health expenditure, 2013/14	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

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

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	All causes	All causes	All causes	All causes	All causes	All causes	All causes
	2013/14 PB/GSS/PH spend SYLLR 2013/14/15 outcome model	2013/14 PB/GSS/PH spend SYLLR 2013/14/15 outcome model	2013/14 PB/GSS/PH spend SYLLR 2013/14/15 outcome model instrument PB/GSS/PH spend	2013/14 PB/GSS/PH spend SYLLR 2013/14/15 outcome model instrument PB/GSS/PH spend	2013/14 PB/GSS/PH spend SYLLR 2013/14/15 outcome model instrument PB/GSS/PH spend	2013/14 PB/GSS/PH spend SYLLR 2013/14/15 outcome model instrument PB/GSS/PH spend	2013/14 PB/GSS/PH spend SYLLR 2013/14/15 outcome model 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
VARIABLES							
Public health expenditure per person	0.037	0.029	0.017	0.010	0.017	-0.018	-0.019
	[0.027]	[0.027]	[0.032]	[0.039]	[0.042]	[0.041]	[0.041]
CCG (PB) healthcare spend per person	-0.406***	-0.492***	-0.840***	-0.609**	-0.514	-0.545**	-0.532**
	[0.139]	[0.119]	[0.142]	[0.251]	[0.337]	[0.243]	[0.259]
Social service (GSS) spend per person	0.044	0.039	-0.078	-0.272**	-0.326*	-0.344**	-0.336**
	[0.055]	[0.053]	[0.102]	[0.124]	[0.182]	[0.134]	[0.152]
Index of Multiple Deprivation 2010	0.219***	0.156**	0.239***	0.243***	0.238***	-0.504*	-0.505**
	[0.074]	[0.066]	[0.059]	[0.068]	[0.075]	[0.260]	[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***	0.227***	0.289***	0.309***	0.309***	0.321***	0.319***
	[0.054]	[0.036]	[0.036]	[0.038]	[0.041]	[0.041]	[0.046]
% population providing unpaid care	-0.455***	-0.233***	-0.214**	-0.251**	-0.230**	-0.188**	-0.190**
	[0.171]	[0.086]	[0.087]	[0.098]	[0.108]	[0.085]	[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*	0.217***	0.229***	0.262***	0.259***	0.271***	0.271***
	[0.097]	[0.069]	[0.071]	[0.087]	[0.098]	[0.080]	[0.079]
% 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***	-0.285***	-0.190***	-0.162***	-0.154**	-0.098	-0.100
	[0.063]	[0.044]	[0.050]	[0.051]	[0.060]	[0.062]	[0.065]
Index of Multiple Deprivation 2010 Squared						0.130***	0.130***
						[0.043]	[0.042]
Constant	7.319***	8.862***	11.187***	9.408***	8.710***	10.277***	10.199***
	[1.040]	[0.819]	[1.021]	[1.693]	[2.295]	[1.568]	[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
Sanderson-Windmeijer _PH p-value			0.000	0.000	0.000	0.000	0.000

Robust standard errors in brackets

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

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)

	(1)	(2)	(3)	(4)
	All causes	All causes	All causes	All causes
	2013/14 PB/PSS/PH spend	2013/14 PB/PSS/PH spend	2013/14 PB/PSS/PH spend	2013/14 PB/PSS/PH spend
	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15
	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
	weighted	weighted	weighted	weighted
	IV second stage	IV second stage	IV second stage	IV second stage
	parsimonious specification	specification_2	specification_3	specification_4
VARIABLES	11 instruments	7 instruments	5 instruments	4 instruments
Public health expenditure per person	-0.051	-0.043	-0.060	-0.099**
	[0.039]	[0.047]	[0.044]	[0.045]
CCG (PB) healthcare spend per person	-0.862***	-0.461	-0.637*	-0.693**
	[0.223]	[0.313]	[0.369]	[0.333]
Social service (GSS) spend per person	-0.206	-0.469***	-0.370*	-0.471**
	[0.133]	[0.161]	[0.205]	[0.237]
% population aged 16-74 that are permanently sick	0.649***	0.651***	0.672***	0.528***
	[0.046]	[0.054]	[0.052]	[0.073]
% population providing unpaid care	-0.381***	-0.388***	-0.400***	-0.143
	[0.086]	[0.096]	[0.097]	[0.118]
% population in white ethnic group	0.163***	0.195***	0.180***	0.299***
	[0.042]	[0.043]	[0.046]	[0.078]
Older adult: social service need per person				0.416***
				[0.143]
Constant	13.352***	10.204***	11.655***	12.245***
	[1.733]	[2.389]	[2.873]	[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 standard errors in brackets

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

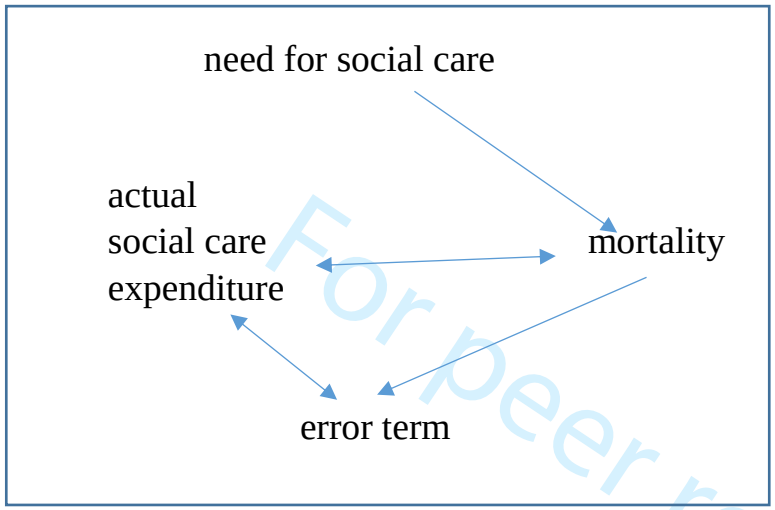
Table 4 Results summary

Type of health-related expenditure	Health outcome elasticity		Spending gap per capita between 2001/02- 2009/10 and 2010/11-2014/15	Deaths attributable to spending gap (=annual deaths*elasticity*gap)		Deaths attributable to spending gap from time trend analysis[7]
	Backward Selection	Forward Selection		Backward Selection	Forward Selection	
	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% confidence interval]	[-0.031, -0.640]	[0.003, -0.945]		[2,183, 45,071]	[-211, 66,550]	
Healthcare expenditure	-0.532	-0.693	13.64%	33,888	44,143	n/a
[95% confidence interval]	[-0.014, -1.050]	[-0.027, -1.359]		[892, 66,884]	[1,720, 86,567]	
Total social care and healthcare	n/a	n/a	n/a	57,550	77,313	45,368
[95% confidence interval]				[3,075, 111,955]	[1,509, 153,117]	[34,530, 56,206]

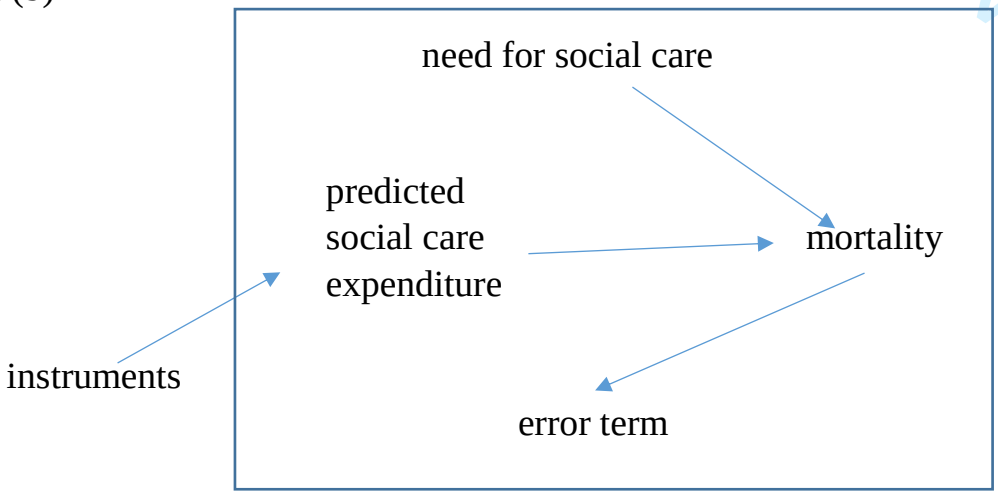
Figure 1 Illustration of the reverse causation issue and its resolution

Figure 1 Illustration of the reverse causation issue and its resolution

Part (a)



Part (b)



The causal impact of social care, public health and healthcare expenditure on mortality in England: cross-sectional evidence for 2013/14

Appendices

Appendix A1: Further details about the instruments for healthcare expenditure

For 2013/14 the Department of Health allocated each Clinical Commissioning Group (CCG) a fixed proportion of the national budget (£65bn). CCGs used this allocation to fund expenditure on most types of healthcare except primary care, specialised commissioning and public health. CCGs reported their actual expenditure across various programmes of care and this data can be found in the programme budgeting dataset. This is available from https://www.england.nhs.uk/prog-budgeting/ [accessed 05 September 2020].

Healthcare expenditure is instrumented in a similar way to social care expenditure and in line with equation (2) in the main text. The selection of the relevant funding rule variables for healthcare expenditure for 2013/14 is more difficult than usual due to the changes enacted by the Health and Social Care Act 2012. Normally, resource allocation formulae are updated annually but the approaching replacement of Primary Care Trusts (one set of local health authorities) with CCGs (a different set with different responsibilities) led to the freezing of the weighted capitation formula for 2012/13, with all Primary Care Trusts (PCTs) receiving the same (3%) growth rate over their 2011/12 allocations. Because CCGs were not responsible for the same set of services as PCTs (CCGs lost responsibility for primary care public health, specialised services, and primary care), there was a baseline exercise in 2012 that identified actual PCT expenditure on CCG service responsibilities and, for 2013/14, each CCG enjoyed an uplift of 2.3% on these 2012/13 baselines.

As a result of these changes, the most appropriate funding rule variables for CCG healthcare expenditure in 2013/14 are drawn from the 2011/12 allocations for PCTs, appropriately converted to the new (CCG) geography. These allocations reflect components of the funding formulae (one for the total allocation, one for Hospital and Community Health Services (HCHS), and one for prescribing), and we select three funding rule variables employed in these formulae which we believe are uncorrelated with mortality. More precisely, the funding rule variables for CCG

healthcare expenditure for 2013/14 are: (i) the age index from the prescribing component of the total allocation; (ii) the MFF for the HCHS component of the total allocation; and (iii) the DFT for the total allocation to PCTs for 2011/12.

Appendix A2: Further details about the instruments for local public health expenditure

The resource allocation formula used to distribute the total public health budget to local authorities has three components. These are for substance misuse services, for non-mandatory services, and for mandatory services. Each of these three service areas has its own resource allocation formula but each formula has a similar structure to that outlined in equation (2) in the main text and two of the four variables in equation (2) (the MFF and the DFT) are present for all three components. Hence we use these variables as instruments for public health expenditure.

Appendix A3 Are the selected instruments valid?

We noted in section 3 that valid instruments should be both uncorrelated with unobserved determinants of expenditure and mortality (i.e., instruments should be exogenous) and excludable from the second-stage regression equation (i.e., have no direct impact on mortality other than through their impact on expenditure). Let us consider whether the proposed instruments for our three expenditure variables are likely to meet these requirements.

The MFF instrument for healthcare, public health and social care expenditure

The MFF (input price index) adjustment reflects prices in the local health economy and is used as an instrument for all three types of expenditure. It is designed to compensate health authorities for the unavoidable higher costs they incur when hiring staff and buying other goods and services. If the MFF adjustment is perfect then each authority would be able to buy the same bundle of inputs. The instrument could have no impact on mortality because it has no impact on real expenditure. In practice, however, the MFF adjustment will be imperfect and these imperfections will generate differences in the volume of real resources available to health authorities (we assume that this error is small relative to the adjustment for local prices). We have no reason to believe that errors in the MFF adjustment will have any effect on mortality other than through their effect on expenditure (this is required for the excludability assumption). However, the MFF index reflects characteristics of the local (health) economy that could potentially be correlated with unmeasured determinants of

mortality and this instrument's exogeneity is therefore conditional on the socio-economic variables included in the estimated specification.

The age-cost index instrument for healthcare

A similar argument can be made for the age-cost index that is used as an instrument for healthcare expenditure. This is designed to compensate health authorities for the unavoidable additional expenditure they incur due to the demographic profile of their population. If the age-cost adjustment is perfect for every health authority then all authorities would be able to offer the same level of healthcare irrespective of whether their population is a particularly old or young one. Again, this (age-cost) index will be a useful predictor of nominal expenditure but, if the adjustment is perfect, this instrument can have no impact on mortality because it has no impact on real expenditure. Although an imperfect age-cost adjustment will generate differences in the volume of real resources available to health authorities, there is no reason to believe that these errors will have any effect on mortality other than through their effect on expenditure. The age-cost index reflects the impact of the local population's demographic profile on healthcare costs. As is the case for the MFF, this profile could potentially be correlated with unmeasured determinants of mortality and this instrument's exogeneity is therefore conditional on the control variables employed in the estimated specification.

The distance from target index instrument for public health and healthcare expenditure

The share of the national budget for both public health and healthcare expenditure apportioned to each health authority is governed by the Department of Health's allocation formula or 'funding rule'. This reflects each authority's need for expenditure and this, in turn, reflects the authority's population size, its age profile, local input prices, and other 'need for health care' factors. Periodically, the Department of Health revises its funding rule and this, together with data updates, generates a new target allocation for each authority. The new funding rule might generate a large change in the target allocation for some authorities and, to avoid sudden large reductions in actual budgets, such changes are usually incorporated into annual budgets over a number of years. The DFT index measures how far an authority's actual budget is below or above its target allocation.

A DFT index is used as an instrument for public health and healthcare expenditure. The DFT for healthcare will reflect the various funding formulae and 'pace of change' policies implemented under several governments of various political persuasions over the past thirty years. While there are undeniably policy choices involved, such as the setting of the 'pace of change' (POC) adjustment that transitions PCTs towards their target, over the recent past the POC policy focussed

on providing a minimum basic budget uplift for all authorities with a larger increase for those that were most under-target. We have no evidence to suggest that these policy choices were made on the basis of other factors such as outcomes (excludability). Moreover, health authority allocations usually include a relatively small component that seeks to address health inequalities directly and it is at this point that outcomes are considered rather than at the POC policy stage. We also have no evidence to suggest that, conditional on our controls, the DFT index will be correlated with unmeasured/unobserved determinants of mortality (exogeneity).

As noted above, a DFT index reflects how far an authority's actual budget is from its target allocation. This difference will reflect the product of three factors for the public health DFT index: (i) the size of PCT expenditure in 2010/11 on those public health activities that were transferred to local authorities in 2013/14; (ii) the public health grant funding formula for 2013/14; and (iii) the 'pace of change' policy for the 2013/14 public health allocations (i.e., the extent to which actual allocations for 2013/14 moved budgets away from what had been spent on public health by PCTs and towards the target allocations generated by the new funding rule for 2013/14). We have no evidence to suggest that the resulting public health DFT was selected on the basis of factors such as mortality (excludability assumption). We also have no evidence to suggest that, conditional on our controls, the public health DFT index will be correlated with unmeasured/unobserved determinants of mortality (exogeneity).

The population sparsity index as an instrument for social care expenditure

The population sparsity index is designed to compensate health authorities for the unavoidable higher costs they incur by having to serve a sparsely populated area. If this sparsity adjustment is perfect then each authority would be perfectly compensated for any additional costs and be able to provide the same service level. The instrument could have no impact on mortality because it has no impact on real expenditure. In practice, of course, the sparsity adjustment will be imperfect and these imperfections will generate differences in the volume of real resources available to health authorities. As was the case for the MFF index, we have no reason to believe that errors in the sparsity adjustment will have any effect on mortality other than through their effect on expenditure. However, the sparsity index may be correlated with characteristics of the local (health) economy that could potentially be correlated with unmeasured determinants of mortality. This instrument's exogeneity is therefore conditional on the socio-economic variables included in the estimated specification.

The type of local authority as an instrument for social care expenditure

A study of the impact of LA expenditure on home care services 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. Conditional on the controls for social care need, we have no reason to believe that there will be a direct effect of the type of LA on mortality. The type of LA could be correlated with unmeasured determinants of mortality and so this instrument's exogeneity is also conditional on the socio-economic variables included in the estimated specification.

The proportion of households that are owner occupied as an instrument for social care expenditure

Conditional on the controls for social care need included in the estimated specification, we have no reason to believe that there will be a direct effect of the proportion of households that are owner occupied on mortality. The proportion of households that are owner occupied could be correlated with unmeasured determinants of mortality and so this instrument's exogeneity is also conditional on the socio-economic variables included in the estimated specification.

In addition to the theoretical considerations outlined above, the validity of all instruments is tested empirically using the Hansen-Sargan test. The set of instruments associated with our preferred specifications pass this empirical test.

Appendix A4

This appendix contains the first-stage regressions associated with the second-stage results reported in the main body of the text.

Table A1 Obtaining a preferred health outcome specification for social care, healthcare and public health expenditure, backward selection, first-stage results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All causes	All causes	All causes	All causes	All causes	All causes	All causes	All causes	All causes
	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend
	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15
	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model
	first-stage	first-stage	first-stage	first-stage	first-stage	first-stage	first-stage	first-stage	first-stage
	weighted	weighted	weighted	weighted	weighted	weighted	weighted	weighted	weighted
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
	parsimonious specification	parsimonious specification	parsimonious specification	parsimonious_v2	parsimonious_v2	parsimonious_v2	parsimonious_v3	parsimonious_v3	parsimonious_v3
VARIABLES									
DFT index, public health expenditure, 2013/14	0.011	0.054	0.737***	0.022	0.033	0.736***	0.021	0.039	0.755***
	[0.027]	[0.061]	[0.050]	[0.026]	[0.067]	[0.045]	[0.026]	[0.064]	[0.054]
MFF, public health expenditure, 2013/14	0.099	1.033	0.945						
	[0.438]	[1.010]	[1.016]						
DFT index, NHS healthcare expenditure	0.537***	0.012	0.590**	0.536***	0.009	0.587**	0.541***	0.045	0.633*
	[0.155]	[0.359]	[0.276]	[0.151]	[0.380]	[0.279]	[0.158]	[0.391]	[0.326]
Age index, prescribing cost formula	0.234***	0.230	-1.080***	0.226***	0.179	-1.129***	0.250***	0.077	-1.423***
	[0.084]	[0.197]	[0.270]	[0.084]	[0.201]	[0.276]	[0.076]	[0.208]	[0.262]
MFF, resource allocation HCHS formula	-0.425	-1.459	-1.619						
	[0.488]	[1.093]	[1.203]						
Type of LA: London borough	0.036	-0.113**	-0.034						
	[0.024]	[0.054]	[0.058]						
Type of LA: Metropolitan district	0.017	-0.113***	0.010	0.017	-0.068**	0.041	0.008	-0.056**	0.030
	[0.017]	[0.030]	[0.043]	[0.015]	[0.030]	[0.038]	[0.013]	[0.023]	[0.029]
Type of LA: Unitary authority	0.002	-0.025	0.053	0.003	0.004	0.075***			
	[0.011]	[0.026]	[0.032]	[0.009]	[0.026]	[0.028]			
Area cost adj for older people's social services	0.270	0.527	0.444	0.215	-0.131	-0.051			
	[0.281]	[0.590]	[0.454]	[0.182]	[0.425]	[0.407]			
Population sparsity measure	0.820	-4.418*	-8.406***	1.300**	-3.199	-6.998***			
	[0.719]	[2.314]	[2.403]	[0.653]	[2.360]	[2.250]			
% households that are owner occupied	-0.114**	-0.356***	-0.163	-0.107**	-0.466***	-0.233**	-0.148***	-0.377***	0.007
	[0.055]	[0.107]	[0.128]	[0.053]	[0.106]	[0.117]	[0.051]	[0.091]	[0.099]
Index of Multiple Deprivation 2010	-0.028	0.135	0.218*	-0.007	0.062	0.192*	-0.008	0.041	0.122
	[0.051]	[0.106]	[0.119]	[0.053]	[0.103]	[0.102]	[0.054]	[0.110]	[0.113]
% population in white ethnic group	0.079*	0.135*	0.152*	0.073*	0.208***	0.194**	0.073*	0.190***	0.180*
	[0.042]	[0.071]	[0.084]	[0.044]	[0.072]	[0.078]	[0.041]	[0.065]	[0.092]
% population providing unpaid care	-0.101	0.385*	-0.017	-0.073	0.429*	0.048	-0.053	0.340*	-0.270
	[0.092]	[0.230]	[0.205]	[0.091]	[0.220]	[0.207]	[0.093]	[0.194]	[0.236]
% population aged 16-74 permanently sick	0.039	-0.019	0.270**	0.036	0.007	0.284**	0.021	0.072	0.481***
	[0.061]	[0.116]	[0.111]	[0.061]	[0.118]	[0.110]	[0.059]	[0.111]	[0.124]
% aged 16-74 in managerial/prof occupations	-0.104**	0.211**	-0.121	-0.097**	0.186*	-0.129	-0.083**	0.183**	-0.158*
	[0.045]	[0.094]	[0.094]	[0.046]	[0.103]	[0.092]	[0.038]	[0.090]	[0.093]
Constant	6.841***	-0.557	3.800***	6.844***	-0.241	4.028***	6.863***	-0.166	4.191***
	[0.294]	[0.533]	[0.542]	[0.300]	[0.551]	[0.555]	[0.300]	[0.569]	[0.609]
Observations	150	150	150	150	150	150	150	150	150
Robust standard errors in brackets									
*** p<0.01, ** p<0.05, * p<0.1									

Table A1 continued

Obtaining a preferred health outcome specification for social care, healthcare and public health expenditure, backward selection, first-stage results

	(10)	(11)	(12)	(13)	(14)	(15)
	All causes	All causes	All causes	All causes	All causes	All causes
	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend
	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15
	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model
	first-stage	first-stage	first-stage	first-stage	first-stage	first-stage
	weighted	weighted	weighted	weighted	weighted	weighted
	OLS	OLS	OLS	OLS	OLS	OLS
	parsimonious_v4	parsimonious_v4	parsimonious_v4	parsimonious_v5	parsimonious_v5	parsimonious_v5
VARIABLES						
DFT index, public health expenditure, 2013/14	0.014	0.062	0.764***	0.027	0.083	0.761***
	[0.027]	[0.055]	[0.058]	[0.026]	[0.054]	[0.056]
DFT index, NHS healthcare expenditure	0.592***	-0.136	0.566*	0.594***	-0.131	0.565*
	[0.158]	[0.344]	[0.340]	[0.161]	[0.344]	[0.340]
Age index, prescribing cost formula	0.218***	0.190	-1.382***	0.227***	0.205	-1.384***
	[0.080]	[0.217]	[0.286]	[0.085]	[0.226]	[0.284]
Type of LA: Metropolitan district	0.012	-0.069***	0.026	0.004	-0.082***	0.027
	[0.013]	[0.023]	[0.029]	[0.013]	[0.024]	[0.027]
% households that are owner occupied	-0.175***	-0.282***	0.042			
	[0.051]	[0.100]	[0.117]			
Index of Multiple Deprivation 2010	0.195	-0.680*	-0.145	0.079	-0.868**	-0.117
	[0.171]	[0.351]	[0.455]	[0.154]	[0.350]	[0.421]
% population in white ethnic group	0.078*	0.173**	0.173*	0.063	0.149**	0.177*
	[0.040]	[0.067]	[0.096]	[0.040]	[0.068]	[0.095]
% population providing unpaid care	-0.037	0.284	-0.291	-0.189**	0.039	-0.254
	[0.092]	[0.205]	[0.244]	[0.094]	[0.207]	[0.232]
% population aged 16-74 permanently sick	0.025	0.055	0.475***	0.056	0.104	0.467***
	[0.058]	[0.107]	[0.124]	[0.063]	[0.109]	[0.124]
% aged 16-74 in managerial/prof occupations	-0.108***	0.273***	-0.125	-0.061	0.348***	-0.136
	[0.039]	[0.096]	[0.110]	[0.041]	[0.083]	[0.103]
Index of Multiple Deprivation 2010 Squared	-0.038	0.137**	0.051	-0.011	0.180***	0.044
	[0.028]	[0.058]	[0.081]	[0.025]	[0.056]	[0.073]
Constant	6.615***	0.716	4.518***	6.605***	0.700	4.520***
	[0.382]	[0.736]	[0.815]	[0.361]	[0.763]	[0.811]
Observations	150	150	150	150	150	150
Robust standard errors in brackets						
*** p<0.01, ** p<0.05, * p<0.1						

Table A2 Obtaining a preferred health outcome specification for social care, healthcare and public health expenditure, forward selection, first-stage results

	(1)	(2)	(3)	(4)	(5)	(6)
	All causes	All causes	All causes	All causes	All causes	All causes
	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend
	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15
	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model
	first-stage	first-stage	first-stage	first-stage	first-stage	first-stage
	weighted	weighted	weighted	weighted	weighted	weighted
	OLS	OLS	OLS	OLS	OLS	OLS
	'initial' specification	'initial' specification	'initial' specification	specification 2	specification 2	specification 2
VARIABLES						
DFT index, public health expenditure, 2013/14	0.004	0.062	0.716***	0.016	0.048	0.717***
	[0.029]	[0.059]	[0.054]	[0.027]	[0.063]	[0.049]
MFF, public health expenditure, 2013/14	0.032	1.017	0.375			
	[0.430]	[0.988]	[1.038]			
DFT index, NHS healthcare expenditure	0.444***	0.215	0.530*	0.460***	0.221	0.371
	[0.144]	[0.342]	[0.286]	[0.140]	[0.348]	[0.256]
Age index, prescribing cost formula	0.228***	0.246	-1.077***	0.220***	0.176	-1.062***
	[0.084]	[0.199]	[0.269]	[0.079]	[0.194]	[0.270]
MFF, resource allocation HCHS formula	-0.359	-1.523	-1.314			
	[0.482]	[1.074]	[1.213]			
Type of LA: London borough	0.030	-0.090*	-0.003			
	[0.026]	[0.052]	[0.050]			
Type of LA: Metropolitan district	0.015	-0.105***	0.020	0.016	-0.070**	0.063**
	[0.016]	[0.031]	[0.041]	[0.014]	[0.028]	[0.031]
Type of LA: Unitary authority	0.004	-0.029	0.060*	0.005	-0.003	0.085***
	[0.010]	[0.026]	[0.032]	[0.009]	[0.025]	[0.026]
Area cost adj for older people's social services	0.143	0.718	0.076			
	[0.254]	[0.626]	[0.460]			
Population sparsity measure	0.843	-4.433*	-8.279***	1.319**	-3.410	-5.890***
	[0.720]	[2.392]	[2.362]	[0.666]	[2.354]	[2.141]
% households that are owner occupied	-0.101*	-0.403***	-0.211*	-0.102*	-0.502***	-0.209*
	[0.053]	[0.107]	[0.123]	[0.052]	[0.101]	[0.121]
% population aged 16-74 permanently sick	0.052*	0.026	0.519***	0.066***	-0.014	0.567***
	[0.029]	[0.073]	[0.067]	[0.024]	[0.066]	[0.064]
% population providing unpaid care	-0.086	0.300	-0.180	-0.074	0.394*	-0.107
	[0.086]	[0.217]	[0.196]	[0.084]	[0.215]	[0.202]
% population in white ethnic group	0.050*	0.161**	0.014	0.041	0.248***	0.048
	[0.028]	[0.062]	[0.070]	[0.027]	[0.065]	[0.060]
Older adults: social service need per person						
Constant	6.962***	-0.480	4.991***	7.038***	-0.434	5.291***
	[0.158]	[0.403]	[0.367]	[0.150]	[0.370]	[0.382]
Observations	150	150	150	150	150	150
Robust standard errors in brackets						
*** p<0.01, ** p<0.05, * p<0.1						

Table A2 continued

Obtaining a preferred health outcome specification for social care, healthcare and public health expenditure, forward selection, first-stage results

	(7)	(8)	(9)	(10)	(11)	(12)
	All causes	All causes	All causes	All causes	All causes	All causes
	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend
	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15
	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model
	first-stage	first-stage	first-stage	first-stage	first-stage	first-stage
	weighted	weighted	weighted	weighted	weighted	weighted
	OLS	OLS	OLS	OLS	OLS	OLS
	specification 3	specification 3	specification 3	preferred specification	preferred specification	referred specification
VARIABLES						
DFT index, public health expenditure, 2013/14	0.012	0.057	0.734***	0.020	0.075	0.728***
	[0.026]	[0.064]	[0.057]	[0.026]	[0.061]	[0.056]
MFF, public health expenditure, 2013/14						
DFT index, NHS healthcare expenditure	0.413***	0.321	0.352	0.451***	0.291	0.255
	[0.132]	[0.351]	[0.285]	[0.127]	[0.338]	[0.284]
Age index, prescribing cost formula	0.266***	0.050	-1.345***	0.279***	0.212	-1.279***
	[0.072]	[0.210]	[0.253]	[0.077]	[0.207]	[0.257]
MFF, resource allocation HCHS formula						
Type of LA: London borough						
Type of LA: Metropolitan district	0.009	-0.057**	0.039	0.004	-0.080***	0.037
	[0.012]	[0.023]	[0.027]	[0.013]	[0.023]	[0.026]
Type of LA: Unitary authority						
Area cost adj for older people's social services						
Population sparsity measure						
% households that are owner occupied	-0.129***	-0.422***	0.026			
	[0.049]	[0.085]	[0.100]			
% population aged 16-74 permanently sick	0.056**	0.019	0.699***	0.069**	-0.088	0.610***
	[0.024]	[0.045]	[0.059]	[0.029]	[0.062]	[0.064]
% population providing unpaid care	-0.055	0.328*	-0.372	-0.158*	0.178	-0.245
	[0.088]	[0.191]	[0.227]	[0.085]	[0.191]	[0.212]
% population in white ethnic group	0.048*	0.235***	0.064	0.047*	0.294***	0.100
	[0.026]	[0.064]	[0.068]	[0.026]	[0.068]	[0.068]
Older adults: social service need per person				0.068	0.583***	0.193
				[0.058]	[0.113]	[0.120]
Constant	7.052***	-0.473	5.208***	6.925***	-0.914**	5.218***
	[0.154]	[0.361]	[0.421]	[0.152]	[0.360]	[0.423]
Observations	150	150	150	150	150	150
Robust standard errors in brackets						
*** p<0.01, ** p<0.05, * p<0.1						

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1, 4
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6
Objectives	3	State specific objectives, including any prespecified hypotheses	4, 6
Methods			
Study design	4	Present key elements of study design early in the paper	6-7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-13
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8-13
Bias	9	Describe any efforts to address potential sources of bias	8-12
Study size	10	Explain how the study size was arrived at	12-13
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8-13
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8-12, Fig 1
		(*b*) Describe any methods used to examine subgroups and interactions	None
		(*c*) Explain how missing data were addressed	n/a
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	n/a
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Table 1
		(b) Give reasons for non-participation at each stage	n/a
		(c) Consider use of a flow diagram	n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Table 1
Outcome data	15*	Report numbers of outcome events or summary measures	Table 1

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Tables 2, 3,& 4
		(*b*) Report category boundaries when continuous variables were categorized	n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Cf Table 2 & Table 3
Discussion			
Key results	18	Summarise key results with reference to study objectives	Table 4
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16-17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	16-17
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

The causal impact of social care, public health and healthcare expenditure on mortality in England: cross-sectional evidence for 2013/14

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-046417.R2
Article Type:	Original research
Date Submitted by the Author:	12-Jul-2021
Complete List of Authors:	Martin, Stephen; University of York Department of Economics and Related Studies, Longo, Francesco; University of York, Centre for Health Economics Lomas, James; University of York, Centre for Health Economics Claxton, Karl; University of York, Centre for Health Economics & Department of Economics
Primary Subject Heading:	Health economics
Secondary Subject Heading:	Health policy, Public health
Keywords:	HEALTH ECONOMICS, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, STATISTICS & RESEARCH METHODS

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

The causal impact of social care, public health and healthcare expenditure on mortality in England: cross-sectional evidence for 2013/14

Author/position/address
Dr Stephen Martin
Research Fellow, Department of Economics, University of York, York, YO10 5DD.

Dr Francesco Longo
Research Fellow, Centre for Health Economics, University of York, York, YO10 5DD.

Dr James Lomas
Research Fellow, Centre for Health Economics, University of York, York, YO10 5DD.

Dr Karl Claxton
Professor, Department of Economics & Centre for Health Economics, University of York, York, YO10 5DD.

Corresponding author and email address
Dr Stephen Martin Email: sdm1@york.ac.uk

Transparency declaration
The lead author (the manuscript's guarantor) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Details of ethical approval
Ethical approval was not required because neither human participants nor animals were involved in the study.

Details of the role of the study sponsors
The views expressed in this publication are those of the authors and not necessarily those of the NHS, the National Institute for Health Research or the Department of Health and Social Care (DHSC).

Statement of independence of researchers from funders
Although funded by the funded by the National Institute for Health Research Policy Research Programme, neither the NIHR nor the DHSC had any influence on the study design, the way in which the research was undertaken, or the results.

Acknowledgements
We should like to thank NHS Digital for supplying the mortality data. We should also like to acknowledge the assistance received from various individuals including Michael Chaplin at the Department of Health and Social Care. In addition, we should like to acknowledge the comments received from various individuals at the Department of Health and Social Care and NHS England on an earlier version of this paper. Their suggestions have substantially improved the final version.

Word count
The text consists of 5,899 words. There are four tables in this document. There is one figure in a separate file.

The causal impact of social care, public health and healthcare expenditure on mortality in England: cross-sectional evidence for 2013/14

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 2010/11 – 2014/15 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 2013/14. Next, we compare the growth in healthcare and social care expenditure pre- and post-2010. We use the difference between these growth rates and the responsiveness of mortality to changes in expenditure taken from the 2013/14 cross-sectional analysis to estimate the additional mortality generated by post-2010 spending constraints.

Results

Our most conservative results suggest that: (i) a 1% increase in healthcare expenditure reduces mortality by 0.532%; (ii) a 1% increase in social care expenditure reduces mortality by 0.336%; and (iii) 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 2001/02 - 2009/10 and 2010/11 – 2014/15, we find that there were 57,550 [CI: 3,075-111,955] more deaths in the latter period than would have been observed had spending growth during this period matched that in 2001/02 - 2009/10.

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- 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 2013/14 may not hold in other years and there may be other factors affecting mortality beyond those included in this study.

The causal impact of social care, public health and healthcare expenditure on mortality in England: cross-sectional evidence for 2013/14

1. Introduction

The rate of improvement in life expectancy in England and Wales has slowed markedly since 2010.[1 2 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 at a single point in time (2013/14). 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 13 14 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 policymakers. 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. Secondly, 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. Section 2 describes the institutional arrangements associated with the three types of health-related expenditure that are the focus of this study. Section 3 describes the health outcome equation to be estimated and how we address the issue of reverse causation (i.e., that mortality may affect expenditure as well as vice versa). Section 4 describes our estimation approach and section 5 presents brief details of the dataset. Section 6 presents our results and there is a discussion of them in section 7.

2. Institutional arrangements for health-related expenditure in England in 2013/14

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 local authority 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 (e.g. 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 local authorities (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, local authorities 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 local authority 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 £2,500mn of expenditure in 2013/14 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 2013/14.[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 (2013/14). These were administered centrally and expenditure on these items has been excluded from the study because data are not available by local area.

3. 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 local authorities in 2013/14. We estimate:

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

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.

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.

Insert Figure 1 near here

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 (2013/14) 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 relative needs formulae: one for people aged 18-64, and another for those aged over 65. The relative needs formula 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 relative needs formula 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 (2013/14), each local health authority (212 CCGs) was assigned a fixed share of the national budget (£65bn) 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: (i) the age index reflects the demographic profile of the local population; (ii) the additional needs index reflects local deprivation and other factors likely to influence the need for health care and includes a measure of historical mortality; (iii) the input price index (the Market Forces Factor (MFF)) reflects prices in the local health economy; and (iv) 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 appendix A1 but, in summary, these funding rule variables are: (i) the DFT index for the total allocation; (ii) the Market Forces Factor for the Hospital and Community Health Services (HCHS) component of the total allocation; and (iii) 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 local authorities 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 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 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]

4. 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 socio-economic variables -- 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 relative need formula 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 multi-collinearity 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 (for example, 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 local authority'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.

5. Data

We use the gross current expenditure on adult social services by each local authority in 2013/14 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 is available from each CCG's programme budgeting return.[30] These are converted to a local authority basis using a mapping that translates population levels in mid-2012 from (parts of) CCGs to LAs. The average LA healthcare spend was £1,152 per person in 2013/14. Public health expenditure data is available from the local authority revenue expenditure and financing document for 2013/14.[22] The average public health spend for this year was £53 per person. Total healthcare expenditure (£65bn) is about four times the size of social service expenditure (£17bn), and the latter is six times the size of public health expenditure (£2.5bn).

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 socio-economic 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 & 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).

6. 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 six 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 ten or better). The three first-stage equations used to predict healthcare, social care and public health expenditure are in columns 1 to 3 respectively of Table A1 in 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 local authority 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 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 IMD 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 ten 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 to 15 of table A1 in 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 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 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 ten).

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 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 is not available before 2013/14 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 (2013/14) is the first year for which public health expenditure data is 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 2001/02 and 2009/10 but decreased by 1.57% between 2010/11 and 2014/15. If this annual difference (3.77%) is applied to each of the latter four 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 1,569 lives (=0.336% of 467,000). Hence the 'loss' of 15.08% of social care expenditure over the period 2010/11 to 2014/15 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 2001/02 and 2009/10 but by 0.41% between 2010/11 and 2014/15. If this annual difference (3.41%) is

applied to each of the latter four years then the total spending gap attributable to austerity is 13.64%. Our healthcare elasticity suggests that a 1% increase in spend would save 2,484 lives (=0.532% of 467,000). Hence the 'loss' of 13.64% of healthcare expenditure over the period 2010/11 to 2014/15 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]

7. 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 social care expenditure variables have a significant negative effect on mortality in both the backward and 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 2013/14 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 health care expenditure.[31 32 33 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 (for example, 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), their 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 (2013/14) is the first year for which there were resource allocation formulae for both health care and public health expenditure, and a relative needs formula 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 2013/14 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.

8. 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.

Contributorship statement

All (SM, FL, JL and KC) authors contributed to the concept and design of this paper. SM led on the analysis and drafting, and the final paper was edited and approved by all four authors. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting these criteria have been omitted. SM is the paper's guarantor.

Competing interest statement

All authors have completed the Unified Competing Interest form (available on request from the corresponding author) and declare: financial support from the National Institute for Health Research Policy Research Programme for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; and no other relationships or activities that could appear to have influenced the submitted work.

Details of funding

This paper reports independent research funded by the National Institute for Health Research Policy Research Programme (NIHR PRP) through its Policy Research Unit in Economic Evaluation of Health & Care Interventions (EEPRU, grant reference PR-PRU-1217-20401).

Data sharing statement

All of the raw data are in the public domain. The social care expenditure data is available from the publication 'Local authority revenue expenditure and financing England: 2013 to 2014 individual local authority data – outturn' at https://www.gov.uk/government/statistics/local-authority-revenue-expenditure-and-financing-england-2013-to-2014-individual-local-authority-data-outturn [accessed 05 September 2020]. The sparsity and input price adjustment variable from the older person's relative needs formula are available from the publication 'Calculation of 2013/14 Formula Funding' at https://webarchive.nationalarchives.gov.uk/20140505105851/http://www.local.communities.

gov.uk/finance/1314/CalcFFs.pdf [accessed 05 September 2020]. The 'type of local authority' dummies are available from the data dictionary in the zip file at https://digital.nhs.uk/data-and-information/publications/statistical/adult-social-care-activity-and-finance-report/2017-18 [accessed 20 October 2020]. The healthcare expenditure data are available in the 2013-14 CCG Programme Budgeting Benchmarking Tool. This is available from https://www.england.nhs.uk/prog-budgeting/ [accessed 05 September 2020]. The socio-economic variables are constructed using the 2011 Population Census. Census data is available from the Office for National Statistics at https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/2011censuskeystatisticsforlocalauthoritiesinenglandandwales [accessed 05 September 2020]. The cells used to construct the socio-economic variables are listed in Table 92 of Claxton, K., Martin, S., Soares M, Rice N, Spackman E, Hinde S, Devlin N, Smith PC and Sculpher M. (2015). Methods for the estimation of the National Institute for Health and Care Excellence cost-effectiveness threshold. Health technology assessment, 19(14), pp.1-503. Available from https://www.ncbi.nlm.nih.gov/books/NBK274318/ [accessed 05 September 2020]. The public health expenditure data are available from 'Local authority revenue expenditure and financing England: 2013 to 2014 individual local authority data – outturn' which is available from https://www.gov.uk/government/statistics/local-authority-revenue-expenditure-and-financing-england-2013-to-2014-individual-local-authority-data-outturn [accessed 05 September 2020]'. The instruments for public health expenditure are available in 'Exposition Book Public Health Allocations 2013-14 and 2014-15: Technical Guide' and this is available from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/213324/Public-Health-Weighted-Capitation-FormulaTechnical-Guide-v0.13.pdf [accessed 05 September 2020]. The DFT variable for healthcare expenditure is available from the Department of Health's website at https://www.networks.nhs.uk/nhsnetworks/health-investment-network/news/2012-13-programme-budgeting-data-is-now-available [accessed 05 September 2020], and the MFF and prescribing cost age indices are available from the exposition books for the 2011/12 allocations at https://www.gov.uk/government/publications/exposition-book-2011-2012 [accessed 05 September 2020].

References

1. Demakakos, P. (2019). Austerity, socioeconomic inequalities and stalling life expectancy in the UK: Two parallel stories or one? Maturitas, 123, pp89-90. Available from https://doi.org/10.1016/j.maturitas.2018.12.007 [accessed 05 September 2020].

2. Hiam, L., Dorling, D. and McKee, M. (2018). The cuts and poor health: when and how can we say that one thing causes another? Journal of the Royal Society of Medicine, 111(6), 199–202. Available from https://doi.org/10.1177/0141076818779237 [accessed 05 September 2020].

3. Marmot M. J (2018). J Epidemiol Community Health, May, Vol 72 No 5, pp359-360. Available from https://jech.bmj.com/content/jech/72/5/359.full.pdf [accessed 05 September 2020].

4. Hiam L, Harrison D, McKee M and D Dorling (2018). Why is life expectancy in England and Wales 'stalling'? J Epidemiol Community Health 2018, 72, 404-408. Available from https://jech.bmj.com/content/jech/72/5/404.full.pdf [accessed 05 September 2020].

5. Faragher, R. (2017). Is austerity really to blame for stalling life expectancy in England? The Conversation, 20 July, 2017. Available from http://theconversation.com/is-austerity-really-to-blame-for-stalling-life-expectancy-in-england-81206 [accessed 05 September 2020].

6. Loopstra, R., McKee, M., Katikireddi, S. V, Taylor-Robinson, D., Barr, B. and Stuckler, D. (2016). Austerity and old-age mortality in England: a longitudinal cross-local area analysis, 2007–2013. Journal of the Royal Society of Medicine, 109(3), 109-116. DOI: 10.1177/0141076816632215 [accessed 12 May 2021].

7. Dorling, D (2019). Austerity bites—falling life expectancy in the UK. BMJ, March 19. Available from https://blogs.bmj.com/bmj/2019/03/19/danny-dorling/ [accessed 05 September 2020].

8. Watkins J, Wulaningsih W, Da Zhou C, *et al* (2017). Effects of health and social care spending constraints on mortality in England: a time trend analysis. *BMJ Open* 2017, v7, 11. DOI: 10.1136/bmjopen-2017-017722 [accessed 05 September 2020].

9. Claxton, K., Lomas, J. and Martin, S. (2018). The impact of NHS expenditure on health outcomes in England: Alternative approaches to identification in all-cause and disease specific models of mortality. Health Economics, 27(6), pp.1017-1023. Available at: https://onlinelibrary.wiley.com/doi/abs/10.1002/hec.3650 [accessed 05 September 2020].

10. Martin, S., Lomas, J. and Claxton, K. (2020). Is an ounce of prevention worth a pound of cure? Estimates of the impact of English public health grant on mortality and morbidity. BMJ Open, volume 10, issue10. Available at: https://bmjopen.bmj.com/content/10/10/e036411 [accessed 20 October 2020].

11. Forder, J., Vadean, F., Rand, S. & Malley, J. (2018). The impact of long-term care on quality of life. *Health economics,* 27**,** e43-e58. Available from https://onlinelibrary.wiley.com/doi/10.1002/hec.3612 [accessed 05 September 2020].

12. Fernandez, J.-L. and Forder, J. (2011). Consequences of local variations in social care on the performance of the acute health care sector. *Applied Economics,* 40**,** 1503-1518. Available from https://www.tandfonline.com/doi/full/10.1080/00036840600843939 [accessed from 05 September 2020].

13. Forder, J. (2009). Long-term care and hospital utilisation by older people: an analysis of substitution rates. *Health Economics,* 18**,** 1322-1338. Available from https://onlinelibrary.wiley.com/doi/abs/10.1002/hec.1438 [accessed 05 September 2020].

14. Gaughan, J., Gravelle, H. and Siciliani, L. (2015). Testing the bed-blocking hypothesis: does nursing and care home supply reduce delayed hospital discharges? *Health economics,* 24**,** 32-44. Available from https://onlinelibrary.wiley.com/doi/10.1002/hec.3150 [accessed 05 September 2020].

15. Forder, J., Gousia, K. & Saloniki, E.-C. (2018). The impact of long-term care on primary care doctor consultations for people over 75 years. *The European Journal of Health Economics***,** 1-13. Available from https://ideas.repec.org/a/spr/eujhec/v20y2019i3d10.1007_s10198-018-0999-6.html [accessed 05 September 2020].

16. Bradley, E. H., Canavan, M., Rogan, E., Talbert-Slagle,K., Ndumele, C., Taylor, L. and Curry, L. A. (2016). Variation in health outcomes: the role of spending on social services, public health and health care, 2000-09. *Health Affairs*, 35, 5. Available from https://doi.org/10.1377/hlthaff.2015.0814 [accessed 30 April 2021].

17. NAO (2018). Adult social care at a glance. National Audit Office, July. Available from https://www.nao.org.uk/wp-content/uploads/2018/07/Adult-social-care-at-a-glance.pdf [accessed 05 September 2020].

18. Department of Health (2002). Fair access to care services guidance on eligibility criteria for adult social care. Available from 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 05 September 2020]

19. NAO (2014). Planning for the Better Care Fund. National Audit Office, November. Available from https://www.nao.org.uk/wp-content/uploads/2014/11/Planning-for-the-better-care-fund.pdf [accessed 05 September 2020].

20. NAO (2017). Health and social care integration. National Audit Office, February. Available from

https://www.nao.org.uk/wp-content/uploads/2017/02/Health-and-social-care-integration.pdf [accessed 05 September 2020].

21. DH (2012). Exposition Book Public Health Allocations 2013-14 and 2014-15: Technical Guide. Available from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/213324/Public-Health-Weighted-Capitation-FormulaTechnical-Guide-v0.13.pdf [accessed 05 September 2020].

22. MCHLG (2015). Local authority revenue expenditure and financing England: 2013 to 2014 individual local authority data – outturn. Available from https://www.gov.uk/government/statistics/local-authority-revenue-expenditure-and-financing-england-2013-to-2014-individual-local-authority-data-outturn [accessed 05 September 2020].

23. NHS England (2012). Allocations for 2013/14. Available from https://www.england.nhs.uk/allocations/allocations-2013-14/ [accessed 05 September 2020].

24. Andrews, M. et al., 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), pp.23–41. Available from https://www.tandfonline.com/doi/full/10.1080/07474938.2016.1114205 [accessed 05 September, 2020].

25. DCLG (2013). Calculation of 2013/14 Formula Funding. January. See https://webarchive.nationalarchives.gov.uk/20140505105851/http://www.local.communities.gov.uk/finance/1314/CalcFFs.pdf [accessed 05 September 2020].

26. Forder, J, Malley, J, Towers A, and A Netten (2014). Using cost-effectiveness estimates from survey data to guide commissioning: an application to home care. Health Economics, 23, 8, pp979-992. Available from https://doi.org/10.1002/hec.2973 [accessed 05 September 2020].

27. Sanderson, E. and F. Windmeijer, (2016). A Weak Instrument F-Test in Linear IV Models with Multiple Endogenous Variables. Journal of Econometrics, 190, 2, 212-221. Availalble from https://doi.org/10.1016/j.jeconom.2015.06.004 [accessed 12 May 2021].

28. Baum, C.F., Schaffer, M.E., Stillman, S. (2010). ivreg2: Stata module for extended instrumental variables/2SLS, GMM and AC/HAC, LIML and k-class regression. Available from http://ideas.repec.org/c/boc/bocode/s425401.html [accessed 05 September 2020].

29. Pesaran, M.H. and L.W. Taylor, *Diagnostics for IV regressions.* Oxford Bulletin of Economics and Statistics, 1999. **61**(2): p. 255-265.

30. NHS England (2015). 2013-14 CCG Programme Budgeting Benchmarking Tool. Available from https://www.england.nhs.uk/prog-budgeting/ [accessed 05 September 2020].

31. Edney, L.C., Afzali, H.H.A., Cheng, T.C., Karnon, J.(2018). Estimating the reference incremental cost-effectiveness ratio for the Australian Health System. Pharmacoeconomics 36(2), 239–252. Available from https://link.springer.com/article/10.1007/s40273-017-0585-2 [accessed 05 September 2020].

32. Siverskog, J. & Henriksson, M (2019). Estimating the marginal cost of a life year in Sweden's public healthcare sector. Eur J Health Econ (2019) 20: 751. Available from https://doi.org/10.1007/s10198-019-01039-0 [accessed 05 September 2020].

33. Vallejo-Torres, L., Garcia-Lorenzo, B., Serrano-Aguilar, P. (2018). Estimating a cost-effectiveness threshold for the Spanish NHS. Health Economics, 27(4), 746–761. Available from https://onlinelibrary.wiley.com/doi/10.1002/hec.3633 [accessed 05 September 2020].

34. Claxton, K., Martin, S., Soares M, Rice N, Spackman E, Hinde S, Devlin N, Smith PC and Sculpher M. (2015). Methods for the estimation of the National Institute for Health and Care Excellence cost-effectiveness threshold. Health technology assessment, 19(14), pp.1-503. Available from https://www.ncbi.nlm.nih.gov/pubmed/25692211 [accessed 05 September 2020].

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

Variable description	Obs	Mean	Std. Dev.	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	85.0	267.5	775.9
Local authority population, 2013/14	151	369,610	271,897	2,381	1,481,378
Social service spend per person, 2013/14, £	151	306.60	46.58	209.08	660.42
NHS healthcare spend per person, 2013/14, £	151	1152.13	75.81	1019.89	1479.11
Public health expenditure per person, 2013/14, £	152	52.60	25.15	18.52	186.21
Controls					
Index of Multiple Deprivation 2010	152	23.0753	8.6040	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	0.0208	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, 2013/14	152	1.0667	0.5362	0.5392	6.6247
Input price index (MFF), public health expenditure, 2013/14	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

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
	2013/14 PB/GSS/PH spend SYLLR 2013/14/15 outcome model	2013/14 PB/GSS/PH spend SYLLR 2013/14/15 outcome model	2013/14 PB/GSS/PH spend SYLLR 2013/14/15 outcome model instrument PB/GSS/PH spend	2013/14 PB/GSS/PH spend SYLLR 2013/14/15 outcome model instrument PB/GSS/PH spend	2013/14 PB/GSS/PH spend SYLLR 2013/14/15 outcome model instrument PB/GSS/PH spend	2013/14 PB/GSS/PH spend SYLLR 2013/14/15 outcome model instrument PB/GSS/PH spend	2013/14 PB/GSS/PH spend SYLLR 2013/14/15 outcome model instrument PB/GSS/PH spend
	weighted OLS	weighted OLS	weighted IV second stage	weighted IV second stage	weighted IV second stage	weighted IV second stage	weighted 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	0.029	0.017	0.010	0.017	-0.018	-0.019
	[0.027]	[0.027]	[0.032]	[0.039]	[0.042]	[0.041]	[0.041]
CCG (PB) healthcare spend per person	-0.406***	-0.492***	-0.840***	-0.609**	-0.514	-0.545**	-0.532**
	[0.139]	[0.119]	[0.142]	[0.251]	[0.337]	[0.243]	[0.259]
Social service (GSS) spend per person	0.044	0.039	-0.078	-0.272**	-0.326*	-0.344**	-0.336**
	[0.055]	[0.053]	[0.102]	[0.124]	[0.182]	[0.134]	[0.152]
Index of Multiple Deprivation 2010	0.219***	0.156**	0.239***	0.243***	0.238***	-0.504*	-0.505**
	[0.074]	[0.066]	[0.059]	[0.068]	[0.075]	[0.260]	[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***	0.227***	0.289***	0.309***	0.309***	0.321***	0.319***
	[0.054]	[0.036]	[0.036]	[0.038]	[0.041]	[0.041]	[0.046]
% population providing unpaid care	-0.455***	-0.233***	-0.214**	-0.251**	-0.230**	-0.188**	-0.190**
	[0.171]	[0.086]	[0.087]	[0.098]	[0.108]	[0.085]	[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*	0.217***	0.229***	0.262***	0.259***	0.271***	0.271***
	[0.097]	[0.069]	[0.071]	[0.087]	[0.098]	[0.080]	[0.079]
% 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***	-0.285***	-0.190***	-0.162***	-0.154**	-0.098	-0.100
	[0.063]	[0.044]	[0.050]	[0.051]	[0.060]	[0.062]	[0.065]
Index of Multiple Deprivation 2010 Squared						0.130***	0.130***
						[0.043]	[0.042]
Constant	7.319***	8.862***	11.187***	9.408***	8.710***	10.277***	10.199***
	[1.040]	[0.819]	[1.021]	[1.693]	[2.295]	[1.568]	[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
Sanderson-Windmeijer _PH p-value			0.000	0.000	0.000	0.000	0.000

Robust standard errors in brackets

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

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)

	(1)	(2)	(3)	(4)
	All causes	All causes	All causes	All causes
	2013/14 PB/PSS/PH spend	2013/14 PB/PSS/PH spend	2013/14 PB/PSS/PH spend	2013/14 PB/PSS/PH spend
	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15
	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
	weighted	weighted	weighted	weighted
	IV second stage	IV second stage	IV second stage	IV second stage
	parsimonious specification	specification_2	specification_3	specification_4
VARIABLES	11 instruments	7 instruments	5 instruments	4 instruments
Public health expenditure per person	-0.051	-0.043	-0.060	-0.099**
	[0.039]	[0.047]	[0.044]	[0.045]
CCG (PB) healthcare spend per person	-0.862***	-0.461	-0.637*	-0.693**
	[0.223]	[0.313]	[0.369]	[0.333]
Social service (GSS) spend per person	-0.206	-0.469***	-0.370*	-0.471**
	[0.133]	[0.161]	[0.205]	[0.237]
% population aged 16-74 that are permanently sick	0.649***	0.651***	0.672***	0.528***
	[0.046]	[0.054]	[0.052]	[0.073]
% population providing unpaid care	-0.381***	-0.388***	-0.400***	-0.143
	[0.086]	[0.096]	[0.097]	[0.118]
% population in white ethnic group	0.163***	0.195***	0.180***	0.299***
	[0.042]	[0.043]	[0.046]	[0.078]
Older adult: social service need per person				0.416***
				[0.143]
Constant	13.352***	10.204***	11.655***	12.245***
	[1.733]	[2.389]	[2.873]	[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 standard errors in brackets
*** p<0.01, ** p<0.05, * p<0.1

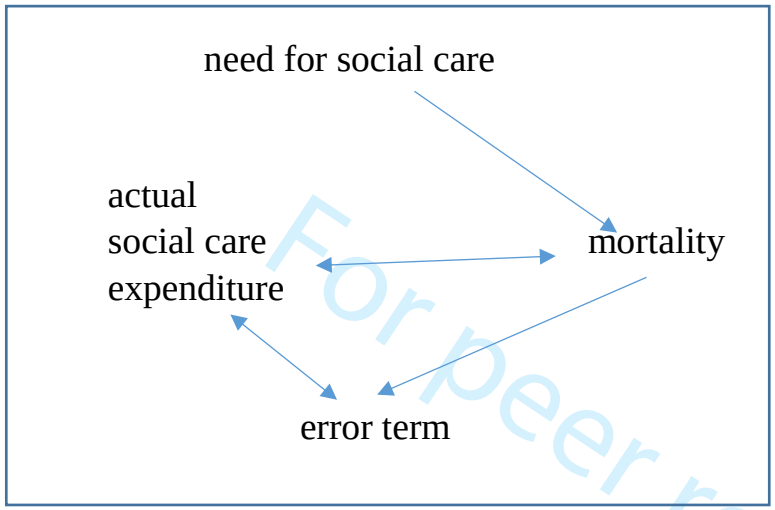
Table 4 Results summary (created by the authors)

Type of health-related expenditure	Health outcome elasticity		Spending gap per capita between 2001/02- 2009/10 and 2010/11-2014/15	Deaths attributable to spending gap (=annual deaths*elasticity*gap)		Deaths attributable to spending gap from time trend analysis[7]
	Backward Selection	Forward Selection		Backward Selection	Forward Selection	
	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% confidence interval]	[-0.031, -0.640]	[0.003, -0.945]		[2,183, 45,071]	[-211, 66,550]	
Healthcare expenditure	-0.532	-0.693	13.64%	33,888	44,143	n/a
[95% confidence interval]	[-0.014, -1.050]	[-0.027, -1.359]		[892, 66,884]	[1,720, 86,567]	
Total social care and healthcare	n/a	n/a	n/a	57,550	77,313	45,368
[95% confidence interval]				[3,075, 111,955]	[1,509, 153,117]	[34,530, 56,206]

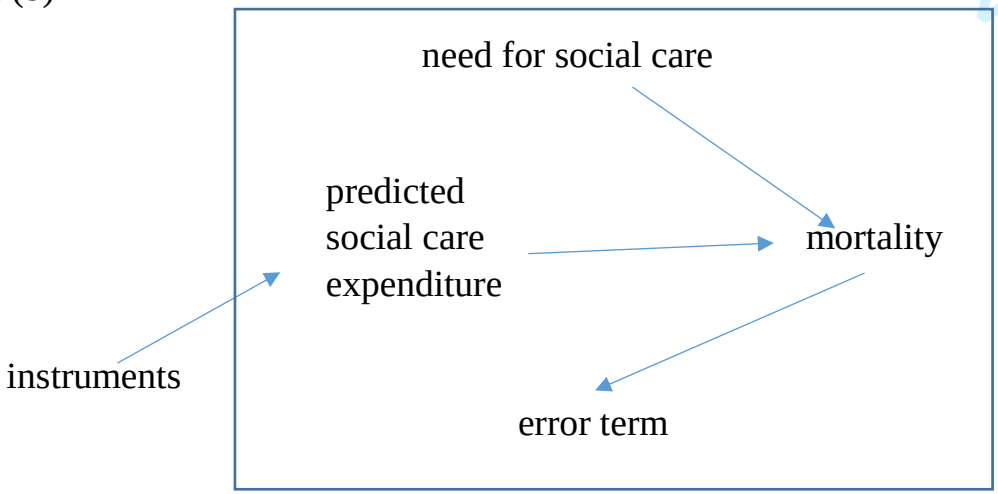
Figure 1 Illustration of the reverse causation issue and its resolution (created by the authors)

Figure 1 Illustration of the reverse causation issue and its resolution

Part (a)



Part (b)



The causal impact of social care, public health and healthcare expenditure on mortality in England: cross-sectional evidence for 2013/14

Appendices

Appendix A1: Further details about the instruments for healthcare expenditure

For 2013/14 the Department of Health allocated each Clinical Commissioning Group (CCG) a fixed proportion of the national budget (£65bn). CCGs used this allocation to fund expenditure on most types of healthcare except primary care, specialised commissioning and public health. CCGs reported their actual expenditure across various programmes of care and this data can be found in the programme budgeting dataset. This is available from https://www.england.nhs.uk/prog-budgeting/ [accessed 05 September 2020].

Healthcare expenditure is instrumented in a similar way to social care expenditure and in line with equation (2) in the main text. The selection of the relevant funding rule variables for healthcare expenditure for 2013/14 is more difficult than usual due to the changes enacted by the Health and Social Care Act 2012. Normally, resource allocation formulae are updated annually but the approaching replacement of Primary Care Trusts (one set of local health authorities) with CCGs (a different set with different responsibilities) led to the freezing of the weighted capitation formula for 2012/13, with all Primary Care Trusts (PCTs) receiving the same (3%) growth rate over their 2011/12 allocations. Because CCGs were not responsible for the same set of services as PCTs (CCGs lost responsibility for primary care public health, specialised services, and primary care), there was a baseline exercise in 2012 that identified actual PCT expenditure on CCG service responsibilities and, for 2013/14, each CCG enjoyed an uplift of 2.3% on these 2012/13 baselines.

As a result of these changes, the most appropriate funding rule variables for CCG healthcare expenditure in 2013/14 are drawn from the 2011/12 allocations for PCTs, appropriately converted to the new (CCG) geography. These allocations reflect components of the funding formulae (one for the total allocation, one for Hospital and Community Health Services (HCHS), and one for prescribing), and we select three funding rule variables employed in these formulae which we believe are uncorrelated with mortality. More precisely, the funding rule variables for CCG

healthcare expenditure for 2013/14 are: (i) the age index from the prescribing component of the total allocation; (ii) the MFF for the HCHS component of the total allocation; and (iii) the DFT for the total allocation to PCTs for 2011/12.

Appendix A2: Further details about the instruments for local public health expenditure

The resource allocation formula used to distribute the total public health budget to local authorities has three components. These are for substance misuse services, for non-mandatory services, and for mandatory services. Each of these three service areas has its own resource allocation formula but each formula has a similar structure to that outlined in equation (2) in the main text and two of the four variables in equation (2) (the MFF and the DFT) are present for all three components. Hence we use these variables as instruments for public health expenditure.

Appendix A3 Are the selected instruments valid?

We noted in section 3 that valid instruments should be both uncorrelated with unobserved determinants of expenditure and mortality (i.e., instruments should be exogenous) and excludable from the second-stage regression equation (i.e., have no direct impact on mortality other than through their impact on expenditure). Let us consider whether the proposed instruments for our three expenditure variables are likely to meet these requirements.

The MFF instrument for healthcare, public health and social care expenditure

The MFF (input price index) adjustment reflects prices in the local health economy and is used as an instrument for all three types of expenditure. It is designed to compensate health authorities for the unavoidable higher costs they incur when hiring staff and buying other goods and services. If the MFF adjustment is perfect then each authority would be able to buy the same bundle of inputs. The instrument could have no impact on mortality because it has no impact on real expenditure. In practice, however, the MFF adjustment will be imperfect and these imperfections will generate differences in the volume of real resources available to health authorities (we assume that this error is small relative to the adjustment for local prices). We have no reason to believe that errors in the MFF adjustment will have any effect on mortality other than through their effect on expenditure (this is required for the excludability assumption). However, the MFF index reflects characteristics of the local (health) economy that could potentially be correlated with unmeasured determinants of

mortality and this instrument's exogeneity is therefore conditional on the socio-economic variables included in the estimated specification.

The age-cost index instrument for healthcare

A similar argument can be made for the age-cost index that is used as an instrument for healthcare expenditure. This is designed to compensate health authorities for the unavoidable additional expenditure they incur due to the demographic profile of their population. If the age-cost adjustment is perfect for every health authority then all authorities would be able to offer the same level of healthcare irrespective of whether their population is a particularly old or young one. Again, this (age-cost) index will be a useful predictor of nominal expenditure but, if the adjustment is perfect, this instrument can have no impact on mortality because it has no impact on real expenditure. Although an imperfect age-cost adjustment will generate differences in the volume of real resources available to health authorities, there is no reason to believe that these errors will have any effect on mortality other than through their effect on expenditure. The age-cost index reflects the impact of the local population's demographic profile on healthcare costs. As is the case for the MFF, this profile could potentially be correlated with unmeasured determinants of mortality and this instrument's exogeneity is therefore conditional on the control variables employed in the estimated specification.

The distance from target index instrument for public health and healthcare expenditure

The share of the national budget for both public health and healthcare expenditure apportioned to each health authority is governed by the Department of Health's allocation formula or 'funding rule'. This reflects each authority's need for expenditure and this, in turn, reflects the authority's population size, its age profile, local input prices, and other 'need for health care' factors. Periodically, the Department of Health revises its funding rule and this, together with data updates, generates a new target allocation for each authority. The new funding rule might generate a large change in the target allocation for some authorities and, to avoid sudden large reductions in actual budgets, such changes are usually incorporated into annual budgets over a number of years. The DFT index measures how far an authority's actual budget is below or above its target allocation.

A DFT index is used as an instrument for public health and healthcare expenditure. The DFT for healthcare will reflect the various funding formulae and 'pace of change' policies implemented under several governments of various political persuasions over the past thirty years. While there are undeniably policy choices involved, such as the setting of the 'pace of change' (POC) adjustment that transitions PCTs towards their target, over the recent past the POC policy focussed

on providing a minimum basic budget uplift for all authorities with a larger increase for those that were most under-target. We have no evidence to suggest that these policy choices were made on the basis of other factors such as outcomes (excludability). Moreover, health authority allocations usually include a relatively small component that seeks to address health inequalities directly and it is at this point that outcomes are considered rather than at the POC policy stage. We also have no evidence to suggest that, conditional on our controls, the DFT index will be correlated with unmeasured/unobserved determinants of mortality (exogeneity).

As noted above, a DFT index reflects how far an authority's actual budget is from its target allocation. This difference will reflect the product of three factors for the public health DFT index: (i) the size of PCT expenditure in 2010/11 on those public health activities that were transferred to local authorities in 2013/14; (ii) the public health grant funding formula for 2013/14; and (iii) the 'pace of change' policy for the 2013/14 public health allocations (i.e., the extent to which actual allocations for 2013/14 moved budgets away from what had been spent on public health by PCTs and towards the target allocations generated by the new funding rule for 2013/14). We have no evidence to suggest that the resulting public health DFT was selected on the basis of factors such as mortality (excludability assumption). We also have no evidence to suggest that, conditional on our controls, the public health DFT index will be correlated with unmeasured/unobserved determinants of mortality (exogeneity).

The population sparsity index as an instrument for social care expenditure

The population sparsity index is designed to compensate health authorities for the unavoidable higher costs they incur by having to serve a sparsely populated area. If this sparsity adjustment is perfect then each authority would be perfectly compensated for any additional costs and be able to provide the same service level. The instrument could have no impact on mortality because it has no impact on real expenditure. In practice, of course, the sparsity adjustment will be imperfect and these imperfections will generate differences in the volume of real resources available to health authorities. As was the case for the MFF index, we have no reason to believe that errors in the sparsity adjustment will have any effect on mortality other than through their effect on expenditure. However, the sparsity index may be correlated with characteristics of the local (health) economy that could potentially be correlated with unmeasured determinants of mortality. This instrument's exogeneity is therefore conditional on the socio-economic variables included in the estimated specification.

The type of local authority as an instrument for social care expenditure

A study of the impact of LA expenditure on home care services 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. Conditional on the controls for social care need, we have no reason to believe that there will be a direct effect of the type of LA on mortality. The type of LA could be correlated with unmeasured determinants of mortality and so this instrument's exogeneity is also conditional on the socio-economic variables included in the estimated specification.

The proportion of households that are owner occupied as an instrument for social care expenditure

Conditional on the controls for social care need included in the estimated specification, we have no reason to believe that there will be a direct effect of the proportion of households that are owner occupied on mortality. The proportion of households that are owner occupied could be correlated with unmeasured determinants of mortality and so this instrument's exogeneity is also conditional on the socio-economic variables included in the estimated specification.

In addition to the theoretical considerations outlined above, the validity of all instruments is tested empirically using the Hansen-Sargan test. The set of instruments associated with our preferred specifications pass this empirical test.

Appendix A4

This appendix contains the first-stage regressions associated with the second-stage results reported in the main body of the text.

Table A1 Obtaining a preferred health outcome specification for social care, healthcare and public health expenditure, backward selection, first-stage results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All causes	All causes	All causes	All causes	All causes	All causes	All causes	All causes	All causes
	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend
	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15
	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model
	first-stage	first-stage	first-stage	first-stage	first-stage	first-stage	first-stage	first-stage	first-stage
	weighted	weighted	weighted	weighted	weighted	weighted	weighted	weighted	weighted
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
	parsimonious specification	parsimonious specification	parsimonious specification	parsimonious_v2	parsimonious_v2	parsimonious_v2	parsimonious_v3	parsimonious_v3	parsimonious_v3
VARIABLES									
DFT index, public health expenditure, 2013/14	0.011	0.054	0.737***	0.022	0.033	0.736***	0.021	0.039	0.755***
	[0.027]	[0.061]	[0.050]	[0.026]	[0.067]	[0.045]	[0.026]	[0.064]	[0.054]
MFF, public health expenditure, 2013/14	0.099	1.033	0.945						
	[0.438]	[1.010]	[1.016]						
DFT index, NHS healthcare expenditure	0.537***	0.012	0.590**	0.536***	0.009	0.587**	0.541***	0.045	0.633*
	[0.155]	[0.359]	[0.276]	[0.151]	[0.380]	[0.279]	[0.158]	[0.391]	[0.326]
Age index, prescribing cost formula	0.234***	0.230	-1.080***	0.226***	0.179	-1.129***	0.250***	0.077	-1.423***
	[0.084]	[0.197]	[0.270]	[0.084]	[0.201]	[0.276]	[0.076]	[0.208]	[0.262]
MFF, resource allocation HCHS formula	-0.425	-1.459	-1.619						
	[0.488]	[1.093]	[1.203]						
Type of LA: London borough	0.036	-0.113**	-0.034						
	[0.024]	[0.054]	[0.058]						
Type of LA: Metropolitan district	0.017	-0.113***	0.010	0.017	-0.068**	0.041	0.008	-0.056**	0.030
	[0.017]	[0.030]	[0.043]	[0.015]	[0.030]	[0.038]	[0.013]	[0.023]	[0.029]
Type of LA: Unitary authority	0.002	-0.025	0.053	0.003	0.004	0.075***			
	[0.011]	[0.026]	[0.032]	[0.009]	[0.026]	[0.028]			
Area cost adj for older people's social services	0.270	0.527	0.444	0.215	-0.131	-0.051			
	[0.281]	[0.590]	[0.454]	[0.182]	[0.425]	[0.407]			
Population sparsity measure	0.820	-4.418*	-8.406***	1.300**	-3.199	-6.998***			
	[0.719]	[2.314]	[2.403]	[0.653]	[2.360]	[2.250]			
% households that are owner occupied	-0.114**	-0.356***	-0.163	-0.107**	-0.466***	-0.233**	-0.148***	-0.377***	0.007
	[0.055]	[0.107]	[0.128]	[0.053]	[0.106]	[0.117]	[0.051]	[0.091]	[0.099]
Index of Multiple Deprivation 2010	-0.028	0.135	0.218*	-0.007	0.062	0.192*	-0.008	0.041	0.122
	[0.051]	[0.106]	[0.119]	[0.053]	[0.103]	[0.102]	[0.054]	[0.110]	[0.113]
% population in white ethnic group	0.079*	0.135*	0.152*	0.073*	0.208***	0.194**	0.073*	0.190***	0.180*
	[0.042]	[0.071]	[0.084]	[0.044]	[0.072]	[0.078]	[0.041]	[0.065]	[0.092]
% population providing unpaid care	-0.101	0.385*	-0.017	-0.073	0.429*	0.048	-0.053	0.340*	-0.270
	[0.092]	[0.230]	[0.205]	[0.091]	[0.220]	[0.207]	[0.093]	[0.194]	[0.236]
% population aged 16-74 permanently sick	0.039	-0.019	0.270**	0.036	0.007	0.284**	0.021	0.072	0.481***
	[0.061]	[0.116]	[0.111]	[0.061]	[0.118]	[0.110]	[0.059]	[0.111]	[0.124]
% aged 16-74 in managerial/prof occupations	-0.104**	0.211**	-0.121	-0.097**	0.186*	-0.129	-0.083**	0.183**	-0.158*
	[0.045]	[0.094]	[0.094]	[0.046]	[0.103]	[0.092]	[0.038]	[0.090]	[0.093]
Constant	6.841***	-0.557	3.800***	6.844***	-0.241	4.028***	6.863***	-0.166	4.191***
	[0.294]	[0.533]	[0.542]	[0.300]	[0.551]	[0.555]	[0.300]	[0.569]	[0.609]
Observations	150	150	150	150	150	150	150	150	150
Robust standard errors in brackets									
*** p<0.01, ** p<0.05, * p<0.1									

Table A1 continued (created by the authors)

Obtaining a preferred health outcome specification for social care, healthcare and public health expenditure, backward selection, first-stage results

	(10)	(11)	(12)	(13)	(14)	(15)
	All causes	All causes	All causes	All causes	All causes	All causes
	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend
	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15
	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model
	first-stage	first-stage	first-stage	first-stage	first-stage	first-stage
	weighted	weighted	weighted	weighted	weighted	weighted
	OLS	OLS	OLS	OLS	OLS	OLS
	parsimonious_v4	parsimonious_v4	parsimonious_v4	parsimonious_v5	parsimonious_v5	parsimonious_v5
VARIABLES						
DFT index, public health expenditure, 2013/14	0.014	0.062	0.764***	0.027	0.083	0.761***
	[0.027]	[0.055]	[0.058]	[0.026]	[0.054]	[0.056]
DFT index, NHS healthcare expenditure	0.592***	-0.136	0.566*	0.594***	-0.131	0.565*
	[0.158]	[0.344]	[0.340]	[0.161]	[0.344]	[0.340]
Age index, prescribing cost formula	0.218***	0.190	-1.382***	0.227***	0.205	-1.384***
	[0.080]	[0.217]	[0.286]	[0.085]	[0.226]	[0.284]
Type of LA: Metropolitan district	0.012	-0.069***	0.026	0.004	-0.082***	0.027
	[0.013]	[0.023]	[0.029]	[0.013]	[0.024]	[0.027]
% households that are owner occupied	-0.175***	-0.282***	0.042			
	[0.051]	[0.100]	[0.117]			
Index of Multiple Deprivation 2010	0.195	-0.680*	-0.145	0.079	-0.868**	-0.117
	[0.171]	[0.351]	[0.455]	[0.154]	[0.350]	[0.421]
% population in white ethnic group	0.078*	0.173**	0.173*	0.063	0.149**	0.177*
	[0.040]	[0.067]	[0.096]	[0.040]	[0.068]	[0.095]
% population providing unpaid care	-0.037	0.284	-0.291	-0.189**	0.039	-0.254
	[0.092]	[0.205]	[0.244]	[0.094]	[0.207]	[0.232]
% population aged 16-74 permanently sick	0.025	0.055	0.475***	0.056	0.104	0.467***
	[0.058]	[0.107]	[0.124]	[0.063]	[0.109]	[0.124]
% aged 16-74 in managerial/prof occupations	-0.108***	0.273***	-0.125	-0.061	0.348***	-0.136
	[0.039]	[0.096]	[0.110]	[0.041]	[0.083]	[0.103]
Index of Multiple Deprivation 2010 Squared	-0.038	0.137**	0.051	-0.011	0.180***	0.044
	[0.028]	[0.058]	[0.081]	[0.025]	[0.056]	[0.073]
Constant	6.615***	0.716	4.518***	6.605***	0.700	4.520***
	[0.382]	[0.736]	[0.815]	[0.361]	[0.763]	[0.811]
Observations	150	150	150	150	150	150
Robust standard errors in brackets						
*** p<0.01, ** p<0.05, * p<0.1						

Table A2 Obtaining a preferred health outcome specification for social care, healthcare and public health expenditure, forward selection, first-stage results

	(1)	(2)	(3)	(4)	(5)	(6)
	All causes	All causes	All causes	All causes	All causes	All causes
	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend
	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15
	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model
	first-stage	first-stage	first-stage	first-stage	first-stage	first-stage
	weighted	weighted	weighted	weighted	weighted	weighted
	OLS	OLS	OLS	OLS	OLS	OLS
	'initial' specification	'initial' specification	'initial' specification	specification 2	specification 2	specification 2
VARIABLES						
DFT index, public health expenditure, 2013/14	0.004	0.062	0.716***	0.016	0.048	0.717***
	[0.029]	[0.059]	[0.054]	[0.027]	[0.063]	[0.049]
MFF, public health expenditure, 2013/14	0.032	1.017	0.375			
	[0.430]	[0.988]	[1.038]			
DFT index, NHS healthcare expenditure	0.444***	0.215	0.530*	0.460***	0.221	0.371
	[0.144]	[0.342]	[0.286]	[0.140]	[0.348]	[0.256]
Age index, prescribing cost formula	0.228***	0.246	-1.077***	0.220***	0.176	-1.062***
	[0.084]	[0.199]	[0.269]	[0.079]	[0.194]	[0.270]
MFF, resource allocation HCHS formula	-0.359	-1.523	-1.314			
	[0.482]	[1.074]	[1.213]			
Type of LA: London borough	0.030	-0.090*	-0.003			
	[0.026]	[0.052]	[0.050]			
Type of LA: Metropolitan district	0.015	-0.105***	0.020	0.016	-0.070**	0.063**
	[0.016]	[0.031]	[0.041]	[0.014]	[0.028]	[0.031]
Type of LA: Unitary authority	0.004	-0.029	0.060*	0.005	-0.003	0.085***
	[0.010]	[0.026]	[0.032]	[0.009]	[0.025]	[0.026]
Area cost adj for older people's social services	0.143	0.718	0.076			
	[0.254]	[0.626]	[0.460]			
Population sparsity measure	0.843	-4.433*	-8.279***	1.319**	-3.410	-5.890***
	[0.720]	[2.392]	[2.362]	[0.666]	[2.354]	[2.141]
% households that are owner occupied	-0.101*	-0.403***	-0.211*	-0.102*	-0.502***	-0.209*
	[0.053]	[0.107]	[0.123]	[0.052]	[0.101]	[0.121]
% population aged 16-74 permanently sick	0.052*	0.026	0.519***	0.066***	-0.014	0.567***
	[0.029]	[0.073]	[0.067]	[0.024]	[0.066]	[0.064]
% population providing unpaid care	-0.086	0.300	-0.180	-0.074	0.394*	-0.107
	[0.086]	[0.217]	[0.196]	[0.084]	[0.215]	[0.202]
% population in white ethnic group	0.050*	0.161**	0.014	0.041	0.248***	0.048
	[0.028]	[0.062]	[0.070]	[0.027]	[0.065]	[0.060]
Older adults: social service need per person						
Constant	6.962***	-0.480	4.991***	7.038***	-0.434	5.291***
	[0.158]	[0.403]	[0.367]	[0.150]	[0.370]	[0.382]
Observations	150	150	150	150	150	150
Robust standard errors in brackets						
*** p<0.01, ** p<0.05, * p<0.1						

Table A2 continued (created by the authors)

Obtaining a preferred health outcome specification for social care, healthcare and public health expenditure, forward selection, first-stage results

	(7)	(8)	(9)	(10)	(11)	(12)
	All causes	All causes	All causes	All causes	All causes	All causes
	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend	2013/14 PB spend	2013/14 G_SS spend	2013/14 PH spend
	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15	SYLLR 2013/14/15
	outcome model	outcome model	outcome model	outcome model	outcome model	outcome model
	first-stage	first-stage	first-stage	first-stage	first-stage	first-stage
	weighted	weighted	weighted	weighted	weighted	weighted
	OLS	OLS	OLS	OLS	OLS	OLS
	specification 3	specification 3	specification 3	preferred specification	preferred specification	referred specification
VARIABLES						
DFT index, public health expenditure, 2013/14	0.012	0.057	0.734***	0.020	0.075	0.728***
	[0.026]	[0.064]	[0.057]	[0.026]	[0.061]	[0.056]
MFF, public health expenditure, 2013/14						
DFT index, NHS healthcare expenditure	0.413***	0.321	0.352	0.451***	0.291	0.255
	[0.132]	[0.351]	[0.285]	[0.127]	[0.338]	[0.284]
Age index, prescribing cost formula	0.266***	0.050	-1.345***	0.279***	0.212	-1.279***
	[0.072]	[0.210]	[0.253]	[0.077]	[0.207]	[0.257]
MFF, resource allocation HCHS formula						
Type of LA: London borough						
Type of LA: Metropolitan district	0.009	-0.057**	0.039	0.004	-0.080***	0.037
	[0.012]	[0.023]	[0.027]	[0.013]	[0.023]	[0.026]
Type of LA: Unitary authority						
Area cost adj for older people's social services						
Population sparsity measure						
% households that are owner occupied	-0.129***	-0.422***	0.026			
	[0.049]	[0.085]	[0.100]			
% population aged 16-74 permanently sick	0.056**	0.019	0.699***	0.069**	-0.088	0.610***
	[0.024]	[0.045]	[0.059]	[0.029]	[0.062]	[0.064]
% population providing unpaid care	-0.055	0.328*	-0.372	-0.158*	0.178	-0.245
	[0.088]	[0.191]	[0.227]	[0.085]	[0.191]	[0.212]
% population in white ethnic group	0.048*	0.235***	0.064	0.047*	0.294***	0.100
	[0.026]	[0.064]	[0.068]	[0.026]	[0.068]	[0.068]
Older adults: social service need per person				0.068	0.583***	0.193
				[0.058]	[0.113]	[0.120]
Constant	7.052***	-0.473	5.208***	6.925***	-0.914**	5.218***
	[0.154]	[0.361]	[0.421]	[0.152]	[0.360]	[0.423]
Observations	150	150	150	150	150	150
Robust standard errors in brackets						
*** p<0.01, ** p<0.05, * p<0.1						

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1, 4
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6
Objectives	3	State specific objectives, including any prespecified hypotheses	4, 6
Methods			
Study design	4	Present key elements of study design early in the paper	6-7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-13
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8-13
Bias	9	Describe any efforts to address potential sources of bias	8-12
Study size	10	Explain how the study size was arrived at	12-13
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8-13
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8-12, Fig 1
		(*b*) Describe any methods used to examine subgroups and interactions	None
		(*c*) Explain how missing data were addressed	n/a
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	n/a
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Table 1
		(b) Give reasons for non-participation at each stage	n/a
		(c) Consider use of a flow diagram	n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Table 1
Outcome data	15*	Report numbers of outcome events or summary measures	Table 1

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Tables 2, 3,& 4
		(*b*) Report category boundaries when continuous variables were categorized	n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Cf Table 2 & Table 3
Discussion			
Key results	18	Summarise key results with reference to study objectives	Table 4
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16-17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	16-17
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.