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RESEARCH ARTICLE

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Investigating the relationship between formal and informal care: An application using panel data for people living together

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Abstract

There is limited evidence on the relationship between formal and informal care using panel data in a U.K. setting and focused specifically on people living together (co-residents). Using all 18 waves of the British Household Panel Survey (1991–2009), we analyse the effect of informal care given by co-residents on the use of formal home care and health care services more generally. To account for endogeneity, we estimate models using random effects instrumental variable regression using the number of daughters as a source of exogenous variation. We find that a 10% increase in the monthly provision of informal care hours decreases the probability of using home help (formal home care) by 1.02 percentage points ($p < .05$), equivalent to a 15.62% relative reduction. This effect was larger for home help provided by the state ($\beta = -.117$) compared with non-state home help ($\beta = -.044$). These results provide evidence that significant increases in the supply of informal care would reduce the demand for home-help provision.

KEYWORDS

BHPS, endogeneity, formal care, informal care

1 | INTRODUCTION

1.1 | Background

Ageing populations in the developed world are predicted to place a greater strain on the resources of health and social care systems, including the United Kingdom (Institute for Fiscal Studies, 2015). Based on Office for National Statistics (ONS) forecasts, the U.K. population is projected to increase by 9.7 million between 2014 and 2039 (ONS, 2013). Expenditure on health care in the United Kingdom accounted for 9.1% of gross domestic product in 2014 (World Bank, 2016).

Enhanced understanding of the relationships between health and social care allows for more informed policymaking decisions to be made. In particular, the nature of the relationship between the supply of formal and informal care is of interest to policymakers. For individuals with family/friends in need of assistance, their decision as to whether to supply care informally is related to their labour market participation. In deciding public policy, policymakers require information regarding the processes behind the utilisation of different aspects of health and social care (Bolin, Lindgren, & Lundborg, 2008a), and whether formal and informal care act as complements or substitutes is particularly relevant in this context.

Use of informal care has become increasingly prevalent in the United Kingdom: According to census data, it is estimated that there were 5.8 million people providing informal care in England and Wales in 2011—an increase of 600,000 (10%) from 2001 (ONS, 2013). Meanwhile, the current adult social care system in England has attracted renewed debate. The Local Government Association have noted that the pressures on adult social care funding (caused by increased demand, reductions in local government funding, and increases in care costs) have become particularly acute since 2010 (Parliament, House of Commons, 2017). A U.K. government commission stated that (Commission on Funding of Care and Support, 2011)

the current adult social care funding system in England is not fit for purpose and needs urgent and lasting reform.

Publicly funded adult social care is means tested and primarily funded through local government in England (Parliament, House of Commons, 2017). It comprises the largest proportion of discretionary expenditure for local authorities. However, publicly funded care constitutes only a minority of the total cost of care—and this proportion is decreasing (Parliament, House of Commons, 2017). Unlike the National Health Service (NHS), adult social care is not free at the point of use—it depends on the needs assessment(s) of local authorities, and these assessments vary from one local authority to another. Whilst the details vary between local authorities, individuals are only eligible to receive public funding for their care if they meet the needs assessment criteria of the local authority and if means-testing finds them to be suitable.

1.2 | Literature review

The theoretical framework around the relationship between formal and informal care involves an alteration of the Grossman demand for health model presented in Van Houtven and Norton (2004) to include informal care. In this particular paper, the focus was on the choices of the parent and their adult child (Van Houtven & Norton, 2004). All components of the model when applied to co-residential care would thus involve the choices of those who have ever received co-residential care and other potential carers (household members). The effect of informal care on formal care, when considering the production of health, is thus derived from the sign of the derivative of the marginal product of formal care with respect to informal care (Bonsang, 2009). Therefore, the relationship this paper and others have explored is fundamentally an empirical issue (Bolin, Lindgren, & Lundborg, 2008a).

Studies regarding the relationship between formal and informal care have often found a substitution effect with formal home care. But for hospital visits, doctor visits, and outpatient visits, the relationship varies depending on the study and its context. Van Houtven and Norton (2004) found that informal care provided for single-living elderly by their adult children was a substitute for doctor visits, hospital nights, and formal home care but a complement for outpatient surgery. Bolin et al. (2008a) explored the same type of informal care analysed in Van Houtven and Norton (2004), except using European data. This type of informal care was found to be a substitute for formal home care but a complement for doctor and hospital visits. However, these effects varied by geography. Bonsang (2009), using the same European SHARE data as Bolin et al. (2008a), obtained a complementary effect with nursing care (high skilled formal home care) and a substitution effect with paid domestic help (low skilled formal home care). The substitution effect weakened as the level of recipient disability increased. Lee and Kim (2012) found substitution effects that varied in magnitude by the morbidity of the recipient. Gannon and Davin (2010) used SHARE data for France and Ireland and examined a substitution relationship between informal care and formal home care for those over 50 years old. Bremer et al. (2017) found informal care a substitute for formal home care and nurse visits but a complement to outpatient visits for a population of individuals with dementia in Europe.

Other studies' findings may not be applicable to a U.K. setting due to institutional and cultural differences between countries. There is limited literature on this subject for the United Kingdom. Mentzakis, McNamee, and Ryan (2009) used panel data methods in a U.K. setting with the British Household Panel Survey (BHPS), analysing the determinants of informal care from the provider's perspective on a limited set of formal care measures.

There are two potential sources of endogeneity bias in these types of studies. First, endogeneity may exist given that formal and informal care are inputs into the production and maintenance of health, and there may be unobserved heterogeneity affecting both formal and informal care most likely related to the health of the recipient. Second, both types of care could be simultaneously determined as the direction of causality is inherently complex.

The most common estimation method in the literature is two-stage least squares applied to cross-sectional data. Bremer et al. (2017) is an exception as they do not use two-stage least squares methods instead arguing that they adequately

control for health. Nonetheless, informal care is often instrumented using the availability and intensity of caregivers in the family as these measures may offer a source of exogenous variation. For example, Van Houtven and Norton (2004) used the number of children of the care recipient and whether their eldest child was a daughter. Most studies only analysed extra-residential informal care; however, Bonsang (2009) found that co-residential care substituted for nursing care.

1.3 | Contribution to the literature

This study makes four contributions to the literature on the relationship between formal and informal care. It firstly adds to the limited evidence on the effect of co-resident informal care where previously the majority of studies have analysed extra-residential care or care received by the single-living elderly. Second, unlike the majority of studies that have used cross-sectional data or data with only two time periods (with the exception of Mentzakis et al., 2009), we use panel data spanning nearly 20 years. Third, we add to the limited evidence on this relationship for the U.K. setting. Given that the health and social care system in the United Kingdom is structured and funded differently to the rest of Europe and the United States, it is of significance to see how informal care affects formal care in this context, particularly in light of recent efforts to reform long term care (Parliament, House of Commons, 2018). Finally, we consider a period of 18 years in which the market for the provision for social care (and public services more broadly) became a more diverse "quasi-market" that included a mixture of state and non-state providers (see, e.g., Baxter, Glendinning, & Greener, 2011; Commission for Social Care Inspection, 2009; Wilberforce, Baxter, & Glendinning, 2012). We show in Figure 1 that there has been a steady increase since Wave 1 of the BHPS (1991) in the proportional share of respondents receiving care from non-state providers. This allows for assessment of the relationship between formal and informal care for different types of providers (state vs. non-state).

2 | DATA

2.1 | The BHPS

The BHPS is a longitudinal survey running annually from 1991 to 2009. Every member of the household aged 16 years and over is interviewed. In the first year, approximately 10,300 individuals were interviewed from 5,500 households across Great Britain, and this representative group was subsequently interviewed each year. In order to give the data greater U.K. wide representation, extra samples were added; 1,500 households from Scotland and Wales were added in 1999 and 2,000 households from Northern Ireland added in 2001. The data available allowed for detailed analysis of informal and formal care. Information on both carers and recipients was available permitting a wide range of socio-economic and health status variables to be used as controls.

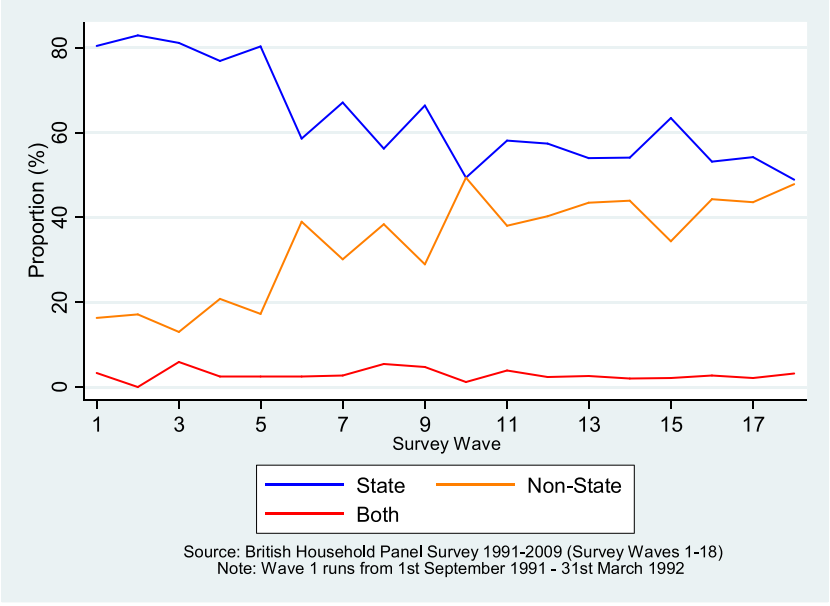

FIGURE 1 Provider mix of home help services in the British Household Panel Survey [Colour figure can be viewed at wileyonlinelibrary.com]

2.2 | Dependent variables

In the BHPS, questions asked the interviewee to recall their formal and health care utilisation since September 1 of the previous survey year. We analysed two variants of formal care: formal home care and health care services (e.g., GP visits).

2.2.1 | Formal home care

Analysis of formal home care (provided in the household) consisted of four separate dummy variables, which were as follows: any home help, any home help provided solely by the NHS or social services department (which is part of a local authority's functions, and this category will be referred to as state home help hereafter), any home help provided solely by a private or voluntary organisations (referred to as non-state home help hereafter), and any health visitor use that could also include district nurse usage (it was not possible to distinguish between these two in the BHPS and is referred to health visitor hereafter). The definition of home help from the NHS choices website included tasks that an informal carer could also undertake (NHS Choices, 2016). The majority of home help is provided by local authorities who are responsible for means testing those requiring assistance, although the NHS does provide home help for those with long-term complex health needs, known as NHS continuing health care (NHS Choices, 2016). For the variables of specific home-help providers, we removed cases where respondents used both types and used the alternative provider. Health visitors typically deal with children and young families, whereas district nurses often interact with informal carers, identifying their needs and acting as a facilitator of access to other health care services.

2.2.2 | Health care

Health care measures included GP visits and any hospital inpatient use. The former variable was initially coded in the BHPS in intervals (0, 1–2, 3–5, 6–10, >10) but were recoded to the midpoint of each band (1.5, 4, 8, 10) and capped at 10. The latter was a dummy variable coded as one if a respondent had been an inpatient, excluding stays due to child birth.

2.3 | Informal care

Our independent variable of interest was the total hours of monthly informal care each respondent received from all adults living in the same household. We took the logarithm of this variable to account for extreme values, as evidence has suggested carers may overestimate care hours via the recall method (Van den Berg & Spauwen, 2006) but also added one to preserve the zero values.

Within the BHPS, questions relating to informal care were asked of providers (and not recipients). This led to the following assumptions when generating the hours of informal care. We assumed that the reported total hours of care were divided equally between all recipients (both co-residential and extra-residential). Responses were recorded in bands (hours per week), which we recoded in the following way as shown in Table 1.

TABLE 1 Assigned values for the provision of weekly informal care hours

Reported category	Assigned value
0–4	2
5–9	7
10–19	14.5
20–34	27
35–49	42
50–99	74.5
100+	100
Varies under 20	10
Varies over 20	30
Some other times	2

2.4 | Covariates

The covariates used for analysis accounted for a variety of characteristics of the informal care recipient, their carers, and their household.

Typical respondent characteristics of gender, age, age-squared, nominal household income quintiles, home ownership (=1 if home owner, mortgage, or shared ownership), marital status (=1 if married), and education (=1 if holds a higher education qualification) were included. These were included because it was important to control for socio-economic characteristics, which would affect formal care usage but that are also correlated with the receipt of informal care. Age-squared was demeaned in order to prevent multicollinearity between the age variables.

To capture the health of the informal care recipient, we used the self-assessed health question, which asks the interviewee to rate on a scale of 1–5 (1 = *excellent* and 5 = *very poor*) their subjective health status over the past 12 months compared with people of their own age. For 1 year, in 1999 (Wave 9), the wording of the self-assessed health question in the BHPS is altered. The variable for all years is transformed to a four-category scale (where *good* and *very good* were combined in Wave 9 and *poor* and *very poor* were combined in all other waves) in accordance with Hernandez-Quevedo, Jones, and Rice (2005), who found that this did not affect the relationship between health status and socio-economic characteristics. We included a count for the number of activity of daily living (ADL) restrictions and a separate count for the number of health problems. Data in 1999 and 2004 did not contain ADL questions as these questions were not asked. Individual responses from 1998 and 2003 were used and applied to 1999 and 2004, respectively. Omission of ADL variables across all years may have induced bias in the informal care coefficient as it is correlated with both informal and formal care. Finally, we included dummies for London, England, Scotland, and Wales to reflect the institutional differences across these countries and regions.

2.5 | Instrumental variable and sample restriction

We used the availability of informal care as a source of exogenous variation in our model. Specifically, the characteristics of adult children have been primarily used as instruments in previous studies. For example, Van Houtven and Norton (2004) used the number of siblings and whether the eldest child was a daughter, Bolin et al. (2008a) used the number of children, age of the oldest child, and distance of the oldest child from the parent, whereas Bonsang (2009) used the proportion of daughters and distance of the nearest child. After we used a variety of instruments of these types found in the literature, the instrument with the strongest predictive power of informal care receipt was the number of adult daughters (natural, step, adopted or fostered, and over the age of 18 years). Information about a BHPS respondent's children is only asked in the first wave they are present in the survey. To exploit the panel, we assigned this information to all the waves a respondent was present in these data.

Our sample was restricted to respondents who were at least 65 years old and had children over the age of 18 years. The former restriction was important for two reasons. First, the relationship between formal and informal care is more relevant for this age group (the highest users of health care and home help), and 65 years old is the state retirement age. Second, the number of adult daughters is more likely to remain constant for respondents of this age group, given that child information is only reported in one instance in the BHPS. The latter restriction was also important to ensure the exogeneity of our instrument because the decision to have children may be influenced by expectations of informal care later in life. Among those respondents who have adult children, it is not possible to influence gender and therefore the number of daughters, which, to some degree, mimics randomisation. To alleviate any generalisability concerns with the sample restriction, approximately 73.97% of respondents in the BHPS who are at least 65 years old are parents to adult children.

3 | METHODS

In this study, for our main analysis, we use random effects instrument variable (REIV) estimation in order to account for the potential endogeneity of informal care. This endogeneity bias can be in the form of unobservables related to health or a reverse causal relationship between formal and informal care (Bolin et al., 2008a; Bonsang, 2009; Gannon & Davin, 2010; Van Houtven & Norton, 2004).

We first estimate a random effects (RE) model with survey wave dummies (Equation 1), which assumes strict exogeneity of informal care:

$$fc_{it} = \alpha_{1i} + y_{1t} + \gamma ic_{it} + \delta x_{it} + u_{1it}, \quad (1)$$

where subscripts it denote individual i in time period t, ic_{it} denotes informal care, fc_{it} denotes formal care, x_{it} is the vector of exogenous control variables, α_{1i} is the time invariant individual unobserved heterogeneity, y_{1t} is the survey wave dummies, and u_{1it} is the idiosyncratic error term.

In order to correct for endogeneity bias, the first stage equation of REIV estimation is Equation (2) where h_{it} is the number of adult daughters. It is assumed that the number of adult daughters is not correlated with the unobservable effect, which is a stronger assumption than with fixed effects (FE) estimation, however.

$$ic_{it} = \alpha_{2i} + y_{2t} + \beta_1 h_{it} + \delta x_{2it} + u_{2it}, \tag{2}$$

Our equation of interest (Equation 3), the second stage, estimated the instrumented effect of informal care on formal care:

$$fc_{it} = \alpha_{3i} + y_{3t} + \theta \widehat{IC_{3it}} + \delta x_{3it} + u_{3it}. \tag{3}$$

In this equation, the coefficient θ is of interest indicating a substitution effect if $\theta < 0$, a complementarity effect if $\theta > 0$ or no evidence of an effect if $\theta = 0$.

Hospital inpatient, health visitor, and home-help models are estimated via a linear probability model for Equations (1) and (3). GP visit models are estimated via a continuous ordinary least squares (OLS) model for Equations (1) and (3).

We report the first stage F statistic of excluded instruments and a test of the endogeneity of informal care modified to accommodate RE estimation (Wooldridge, 2010). Standard errors are heteroskedastic robust, clustered at the individual level.

Our primary robustness check explored the robustness of the main results (specifically the validity of our instrument) when we restricted the sample to the years in which respondents reported child characteristics. This produced a cross-sectional sample. Additionally, we used fixed effects (FE) estimation controlling for individual time-invariant unobservables, which is considered an advantage to RE estimation. Finally, we estimated non-linear models using probit regression (with individual RE) or by maximum likelihood an ivprobit (depending on whether endogeneity was found in our main analysis). We performed the latter specifications on a pooled sample (with clustered standard errors) due to the difficulty in accommodating non-linear IV estimation with panel data.

4 | RESULTS

4.1 | Summary statistics

In our final sample in Table 2, 6.5% had used home help, 11.6% had used a health visitor, and 15.5% had been a hospital inpatient and had used a GP 3.949 times on average. The average number of hours of co-residential informal care received per month in the whole sample was 14.20 hours. Out of 31,036 observations in the sample, 2,881 (9.3%) had received informal care. Respondents had, on average, 1.235 adult daughters.

4.2 | Home-help models

Informal care was a substitute for all types of home help, albeit more negative, when we corrected for endogeneity using REIV compared with an RE specification (Table 3). Our instrument passed the relevance test for all home-help models; for example, the any home-help model had an F statistic well above 10 at 18.50 and a first stage R^2 of 21%. The endogeneity test statistics were all significant except for the non-state home-help model, which was only significant at the 10%, providing evidence for the endogeneity of informal care. Thus, REIV models were the preferred specification for home-help outcomes.

A 10% increase in informal care hours per month resulted in a statistically significant reduction in the probability of any home help in the past year by 1.02 percentage points given by the REIV estimation method, a reduction in likelihood from 6.53% to 5.51% (equivalent to a 15.62% relative reduction). Females were more likely to use any home help than males. The probability of home help use decreased with age (at a decreasing rate) until 77 years old where it increased thereafter. Those with more ADL restrictions and health problems were more likely to use home help. The informal care

TABLE 2 Summary statistics

	Mean	*SD*
Dependent variables		
Any home help (=1)	0.065	0.247
Any home help: state[a] (=1)	0.036	0.186
Any home help: non-state[b] (=1)	0.020	0.139
Any health visitor use (=1)	0.116	0.320
Number of GP visits	3.949	3.333
Hospital inpatient (=1)	0.155	0.362
Informal care variables		
Log (monthly informal care hours +1)	0.398	1.313
Monthly informal care hours	14.20	65.98
Instrumental variable		
Number of adult daughters	1.235	1.079
Control variables		
Female (=1)	0.573	0.495
Age	74.03	6.580
Household income quartile 1 (=1, low)	0.455	0.498
Household income quartile 2 (=1)	0.292	0.455
Household income quartile 3 (=1)	0.137	0.344
Household income quartile 4 (=1)	0.077	0.267
Household income quartile 5 (=1, high)	0.039	0.193
Married (=1)	0.583	0.493
Higher education qualification (=1)	0.203	0.402
Number of ADLs	0.598	1.154
Number of Health problems	2.041	1.503
Self-assessed health: Excellent (=1)	0.138	0.345
Self-assessed health: Good (=1)	0.714	0.452
Self-assessed health: Fair (=1)	0.113	0.317
Self-assessed health: Poor (=1)	0.035	0.183
Home owner (=1)	0.733	0.443
Resides in London (=1)	0.048	0.215
Resides in England, excluding London (=1)	0.538	0.499
Resides in Wales (=1)	0.164	0.370
Resides in Scotland (=1)	0.160	0.367
Resides in Northern Ireland (=1)	0.090	0.286

Abbreviation: ADL, activity of daily living.

[a]Contains 30,395 observations and 4,108 individuals.

[b]Contains 29,898 observations and 4,056 individuals.

coefficient for the state home-help REIV model was −0.117 and significant at the 0.1% level, whereas for the non-state home-help REIV model, the informal care coefficient was smaller at −0.044 and significant at the 5% level.

4.3 | Health visitor and health care models

All models estimated via RE in Table 4 show informal care to be a complement with health visitor and health care usage. When these models are estimated using REIV, the informal care coefficients tended towards zero except for the GP visits model where the coefficient increased; however, none were statistically significant. The endogeneity test indicated that RE was the preferred estimation method and provided evidence against the endogeneity of informal care. A 10% increase in informal care hours per month given by RE estimation increased the probability of health visitor use by 0.15% points (significant at the 0.01% level), from 11.6% to 11.45% (a 1.29% relative increase). A 10% increase in informal care increased the probability of being a hospital inpatient by 0.16% points and the number of GP visits by 0.0079.

TABLE 3 Home-help LPM models estimated using RE and REIV

	Any home help		Any home help: State		Any home help: Non-state	
	RE	REIV	RE	REIV	RE	REIV
Log (informal care hours +1)	−0.004* (0.002)	−0.102* (0.041)	−0.016*** (0.001)	−0.117*** (0.032)	−0.011*** (0.001)	−0.044* (0.019)
Female	0.023*** (0.005)	0.015* (0.006)	0.014** (0.004)	0.005 (0.005)	0.007* (0.003)	0.005 (0.003)
Age	−0.071*** (0.009)	−0.077*** (0.009)	−0.033*** (0.007)	−0.043*** (0.008)	−0.043*** (0.007)	−0.045*** (0.007)
Age-squared	0.001*** (0.000)	0.001*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)
Household income quartile 2	0.007 (0.004)	0.024** (0.009)	−0.002 (0.003)	0.014* (0.006)	0.004 (0.003)	0.010* (0.004)
Household income quartile 3	0.011* (0.005)	0.041** (0.014)	−0.005 (0.004)	0.023* (0.010)	0.002 (0.003)	0.012 (0.006)
Household income quartile 4	0.012* (0.006)	0.043** (0.015)	−0.006 (0.004)	0.024* (0.011)	0.002 (0.004)	0.013 (0.007)
Household income quartile 5	−0.000 (0.008)	0.033* (0.016)	−0.013** (0.005)	0.019 (0.012)	−0.005 (0.004)	0.006 (0.007)
Married	−0.036*** (0.006)	0.001 (0.017)	−0.029*** (0.006)	0.008 (0.013)	−0.017*** (0.004)	−0.005 (0.008)
Higher education qualification	0.020*** (0.006)	0.008 (0.008)	0.004 (0.004)	−0.007 (0.007)	0.012** (0.004)	0.008 (0.005)
Number of ADLs	0.028*** (0.002)	0.059*** (0.012)	0.018*** (0.002)	0.046*** (0.009)	0.011*** (0.002)	0.021*** (0.006)
Number of health problems	0.006*** (0.001)	0.011*** (0.003)	0.002* (0.001)	0.007*** (0.002)	0.003*** (0.001)	0.005*** (0.001)
Self-assessed health: Good	0.001 (0.003)	0.007 (0.004)	0.002 (0.002)	0.006* (0.003)	−0.000 (0.002)	0.001 (0.002)
Self-assessed health: Fair	0.031*** (0.007)	0.073*** (0.018)	0.019*** (0.005)	0.060*** (0.014)	0.014** (0.004)	0.027** (0.009)
Self-assessed health: Poor	0.075*** (0.014)	0.147*** (0.032)	0.057*** (0.011)	0.129*** (0.026)	0.019* (0.008)	0.045** (0.016)
Home owner	−0.015* (0.007)	−0.017* (0.007)	−0.025*** (0.007)	−0.025*** (0.007)	0.003 (0.004)	0.002 (0.004)
London	−0.008 (0.016)	−0.002 (0.015)	−0.014 (0.009)	0.010 (0.010)	0.009 (0.012)	−0.017 (0.009)
Wales	−0.005 (0.007)	0.010 (0.011)	−0.002 (0.006)	−0.005 (0.005)	0.011 (0.008)	−0.007* (0.004)
Scotland	0.042*** (0.009)	0.050*** (0.010)	0.009 (0.006)	0.022** (0.007)	0.030*** (0.008)	0.007 (0.005)
Northern Ireland	0.056*** (0.011)	0.063*** (0.013)	0.001 (0.007)	0.034*** (0.008)	0.041*** (0.009)	0.004 (0.006)
Constant	2.406*** (0.314)	2.527*** (0.327)	1.113*** (0.237)	1.372*** (0.272)	1.499*** (0.248)	1.548*** (0.242)
Survey Wave Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	31,036	31,036	30,165	30,165	29,886	29,886
Individuals	4,117	4,117	4,108	4,108	4,052	4,052
Average number of individuals	7.54	7.54	7.40	7.40	7.38	7.38
First Stage F statistic	—	18.50***	—	19.89***	—	16.57***
Endogeneity test [$\chi^2(1)$]	—	7.82**	—	12.06***	—	3.13

Note. Cluster robust standard errors in parentheses.

Abbreviations: ADL, activity of daily living; LPM, linear probability model; RE, random effects; REIV, random effects instrument variable.

*$p < .05$. **$p < .01$. ***$p < .001$.

TABLE 4 Health visitor and health care models estimated using RE and REIV

	Any health visitor (LPM)		GP visits		Any hospital inpatient (LPM)	
	RE	REIV	RE	REIV	RE	REIV
Log (informal care hours +1)	0.015*** (0.003)	0.002 (0.039)	0.079*** (0.020)	0.256 (0.449)	0.016*** (0.003)	0.002 (0.043)
Female	0.013* (0.005)	0.012* (0.006)	0.071 (0.068)	0.086 (0.073)	−0.025*** (0.006)	−0.027*** (0.006)
Age	−0.041*** (0.008)	−0.040*** (0.008)	0.376*** (0.073)	0.382*** (0.074)	0.002 (0.008)	0.003 (0.007)
Age-squared	0.000*** (0.000)	0.000*** (0.000)	−0.003*** (0.000)	−0.003*** (0.001)	0.000 (0.000)	−0.000 (0.000)
Household income quartile 2	−0.004 (0.005)	−0.003 (0.010)	−0.081 (0.053)	−0.104 (0.095)	0.000 (0.006)	0.002 (0.012)
Household income quartile 3	−0.008 (0.007)	−0.003 (0.015)	−0.073 (0.069)	−0.121 (0.153)	0.002 (0.007)	0.004 (0.019)
Household income quartile 4	−0.006 (0.008)	−0.001 (0.017)	−0.231** (0.081)	−0.278 (0.166)	−0.003 (0.009)	0.005 (0.019)
Household income quartile 5	−0.009 (0.010)	−0.005 (0.018)	−0.368*** (0.105)	−0.422* (0.179)	0.022 (0.012)	0.032 (0.022)
Married	−0.026*** (0.006)	−0.019 (0.017)	0.053 (0.068)	−0.015 (0.192)	−0.017** (0.006)	−0.013 (0.018)
Higher education qualification	0.006 (0.006)	0.005 (0.008)	−0.092 (0.079)	−0.054 (0.099)	0.017* (0.007)	0.013 (0.009)
Number of ADLs	0.035*** (0.003)	0.042*** (0.012)	0.199*** (0.023)	0.161 (0.119)	0.023*** (0.003)	0.028 (0.015)
Number of health problems	0.014*** (0.002)	0.015*** (0.003)	0.423*** (0.017)	0.447*** (0.027)	0.011*** (0.002)	0.013*** (0.003)
Self-assessed health: Good	0.009* (0.004)	0.010* (0.005)	0.957*** (0.045)	0.981*** (0.049)	0.052*** (0.005)	0.054*** (0.005)
Self-assessed health: Fair	0.091*** (0.009)	0.095*** (0.020)	2.362*** (0.080)	2.349*** (0.195)	0.210*** (0.011)	0.216*** (0.023)
Self-assessed health: Poor	0.182*** (0.017)	0.192*** (0.032)	2.787*** (0.119)	2.715*** (0.325)	0.329*** (0.018)	0.335*** (0.033)
Home owner	−0.006 (0.007)	−0.008 (0.007)	−0.051 (0.077)	−0.038 (0.075)	0.009 (0.007)	0.008 (0.006)
London	−0.038*** (0.010)	−0.039*** (0.010)	−0.253 (0.160)	−0.202 (0.156)	−0.014 (0.013)	−0.010 (0.014)
Wales	−0.004 (0.008)	−0.004 (0.009)	0.127 (0.096)	0.105 (0.112)	0.000 (0.008)	0.001 (0.009)
Scotland	0.038*** (0.008)	0.038*** (0.008)	0.181 (0.100)	0.187 (0.100)	0.018* (0.008)	0.018* (0.008)
Northern Ireland	−0.007 (0.009)	−0.007 (0.009)	0.326** (0.108)	0.329** (0.111)	0.019* (0.009)	0.020* (0.009)
Constant	1.289*** (0.302)	1.260*** (0.307)	−11.764*** (2.722)	−11.858*** (2.714)	−0.142 (0.288)	−0.171 (0.279)
Survey wave dummies	Yes	Yes	Yes	Yes	Yes	Yes
First stage F statistic	—	18.50***	—	18.50***	—	18.50***
Endogeneity test [$\chi^2(1)$]	—	0.08	—	0.28	—	0.11

Note. All models are estimated using 31,036 observations and 4,117 individuals. Cluster robust standard errors in parentheses.

Abbreviations: ADL, activity of daily living; LPM, linear probability model; RE, random effects; REIV, random effects instrument variable.

*$p < .05$. **$p < .01$. ***$p < .001$.

4.4 | Robustness checks

Home-help models estimated on the first wave respondents indicated their child's characteristics showed a larger negative magnitude once endogeneity was corrected for (Table 5), which corresponds with panel results shown in Table 3. The IV home-help model produced a coefficient of −0.182 ($p < .1$), whereas OLS estimation produced a coefficient of −0.022 ($p < .001$).

Any health visitor, hospital inpatient, and GP visit models increased in magnitude with both methods of IV estimation (as in Table 4 and 5), and no evidence of endogeneity was detected on the basis of the Durbin–Wu–Hausman tests (Table 5).

There was little difference in the coefficients between FE and RE estimation across all outcomes (Tables A1 and A2), although the coefficients from the FE specification were smaller compared with coefficients from the RE specification except health visitor and hospital inpatient models. Non-linear models showed results that were broadly similar to their linear counterparts for both the main sample and the robustness check cross-sectional sample (Tables A3 and A4, respectively). The home-help ivprobit model produced a coefficient of −0.09 ($p > .05$), whereas the respective IV linear probability model coefficient was −0.110 ($p < .05$; Table A3).

5 | DISCUSSION

This paper was the first to apply panel data methods when analysing the effect of informal care provision for people living together on a wide range of different health and social care sectors. Our main results indicated that among those aged at least 65 years and over (with adult children), co-residential informal care was endogenous with home help as an outcome, but we found no evidence of this with the health visitor and health care outcomes. We found that informal care was a substitute for home help for both state and no-nstate providers but was a complement to health visitor use, GP visits, and hospital inpatient use.

A possible explanation for the complementary effect found for health visitor use, GP visits, and hospital inpatient use relates to the nature of the tasks that these health care professionals perform. It would be plausible to assume that activities performed by home-help professionals (such as personal care and household tasks) could be performed by a spouse or adult child caregiver. But the medical services provided by a doctor or district nurse would not be expected to be performed or replaced by a caregiver.

A notable finding was that informal care was a substitute for home help via RE estimation, but became a stronger substitute with RE IV estimation. This indicates that failing to account for endogeneity biases the estimated result by suggesting weaker substitution between the two variables. This supports the identification strategy used in this study.

State-provided home help was found to be a stronger substitute for informal care than home help provided by a non-state organisation. It would be possible to speculate that this finding relates to potential differences in the nature of the care provided in these different sectors, or to explain it in terms of possible unobserved characteristics of the two groups in receipt of state and non-state care. The limitations of the survey data used does not allow for a qualitative understanding of the differences between the home help provided by state and non-state organisations. This is, however, an important question for future research given the trends illustrated in Figure 1. Research that uses more detailed information on home help (and long-term care more generally) such as the English Longitudinal Study of Ageing could help address this.

In general, studies have found that informal care and formal home care are substitutes (see, e.g., Bolin et al., 2008a; Van Houtven & Norton, 2004). This is consistent with the findings in this paper. We found that informal care and health care services are complements, a finding that is consistent with Bolin et al. (2008a), who also uses a sample from Europe.

TABLE 5 Cross-sectional linear IV estimation using the first year each respondent reported information on their children

	Any home help (LPM)		Any health visitor (LPM)		GP visits		Any hospital inpatient (LPM)	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Log (informal care hours +1)	−0.022***	−0.182**	0.005	0.086	0.156**	0.631	0.017*	0.023
	(0.005)	(0.063)	(0.007)	(0.068)	(0.057)	(0.600)	(0.008)	(0.070)
Durbin–Wu–Hausman	—	13.171***	—	1.542	—	0.653	—	0.007

Note. All models are estimated using 2,448 individuals. First stage F statistic: 13.65. Robust standard errors in parentheses.

Abbreviations: LPM, linear probability model; OLS, ordinary least squares.

*$p < .05$. **$p < .01$. ***$p < .001$.

Differences in the magnitude and direction of these relationships may have partly been explained by a combination of the different types of informal care analysed (all types of informal care in this study as opposed to a parent–child relationship in others), age differences (65+ in this study compared with 70+ in Van Houtven & Norton, 2004), and institutional and cultural differences, in addition to differences in the social safety net. A particular difference is that this study considers co-residential care whereas others previously mentioned have only considered extra-residential care. Our results add to the limited knowledge of this subject in the United Kingdom, compared with the United States and Europe where this relationship has already been explored in relatively more depth with cross-sectional data. The use of panel data methods and the different settings makes direct comparison difficult. However, it is practical to assume that carers who live with their care recipients are more able to partake in caregiving tasks and those who do not are less able. As a result, we may expect weaker substitution effects with extra-residential informal care.

5.1 | Limitations

Limitations in the data, in terms of data on nursing home entry, is not available, which otherwise could have potentially explained some attrition. Studies in a U.S. setting have found that it substitutes for informal care (Charles & Sevak, 2005; Van Houtven & Norton, 2004).

Further limitations centre on the accurate reporting of informal, formal home and health care. First, it may be difficult, particularly for the elderly where a spouse or adult child would organise their care, to distinguish between state and non-state formal care provision and the number of GP visits. However, as we are analysing co-residential care, it is likely that a caregiver is present to assist with the questionnaire. It must be noted that there is a lack of clarity and information regarding what is meant by home help in the BHPS, which may have affected responses. Second, there is limited evidence on the validity and reliability of informal care time reports. The available evidence suggests little stability with the recall method (Van den Berg & Spauwen, 2006) but is mixed regarding whether there is differences in reported hours across recall and diary methods (Bittman, Fisher, Hill, & Thomson, 2005; Van den Berg & Spauwen, 2006; Wimo, Jonsson, & Zbrozek, 2010). Third, we are not able to account for informal care provided by those who do not coreside with their recipient (referred to as extra-residential informal care). Inclusion of these hours could skew the results, although our results followed a similar direction to other studies that analysed extra-residential care (Bolin et al., 2008a; Gannon & Davin, 2010). Finally, we make the assumption that care hours are divided equally across all care recipients. As 82% of co-residential carers provide care to one recipient, we expect that changing this assumption would have little impact on our results.

Causality can only be inferred from the results if the instrument used is truly exogenous. If the instrument has a direct effect on formal care and/or is correlated with some time-varying unobserved variable then the results cannot be treated as casual effects. Unobserved variation in the error component of the model is likely to be related to health and/or accessibility issues of formal care (omitted variable bias). A wide range of health variables are used as controls, which would limit the former bias. RE estimation requires stricter exogeneity assumptions than FE, and we note this as a study limitation.

Furthermore, as the binary outcomes in our main analysis are estimated linearly, there are limitations with this approach. We have showed that the results were largely robust to alternate estimation with non-linear models. We were unable to estimate non-linear models for state and non-state home-help outcomes as no respondents who used either type received informal care. Restriction of the sample to the years in which a respondent gave information about their adult children provided results similar to our main analysis, and our instrument was sufficiently strong for all models.

5.2 | Policy implications

This study can serve to inform specific policies in the United Kingdom, such as the devolution of health and social care budgets to localised areas (Walshe, Coleman, McDonald, Lorne, & Munford, 2016). For these policies to achieve their goals of more people managing their own health and enabling long term management of the health and social care budget, it is essential to consider the relationship between informal care and formal home care.

The implications of a substitution relationship can be greater understood through a simple cost estimate shown in Table 6 using national unit costs (Curtis, 2012). A 10% increase in monthly informal care provision (or 1.42 hr from the mean of 14.32 hr) resulted in a £5.14 per-person per-month reduction in the cost of all types of home help (using the coefficient in Table 4 column 2 based on the £18 hourly cost of home help). The reduction is greater for state home

TABLE 6 Application of model estimates (from Table 3) to national unit costs (home help)

	Monthly saving per-person		
Increase in monthly informal care	**All types (monthly cost) [substitution rate]**	**State home help (monthly cost) [substitution rate]**	**Non-state home help (monthly cost) [substitution rate]**
10% or 1.42 hr (at the mean)	£5.14[a] (£504) [−1.02]	£10.48[b] (£896) [−1.17]	£1.85[c] (£420) [−0.44]

Note. All cost information was taken from the PSSRU unit costs for 2012 (Curtis, 2012). The mean hourly cost for all home help was £18, for state home help was £34, and for non-state home help was £15. The monthly cost of home help for all types was based on 7 hr per week of care. [abc]Inflating the costs in the table from 2011/12 using the personal social services pay and prices index produces monthly savings per person of [a]£5.87 for all home help, [b]£11.92 for state home help, and [c]£2.11 for non-state home help at 2017/2018 prices.

help at £10.48 per-person per-month but lower for non-state home help at £1.85 per-person per-month, mainly due to the larger hourly cost of state home help.

Similarly, for the complementary effects we found for health care models, increases in informal care would result in added cost pressure to the NHS. More research would be required to understand the content of this extra use and whether this was preventative.

Consideration of health outcomes for the carer and recipient, the implications on the labour market, receipt of any benefits, and inclusion of nursing home care in our model would be required to understand the total cost implications of informal care. Especially as there is substantial evidence that points to a trade-off between informal care and labour market participation and/or intensity of work, highlighting an important opportunity cost of informal care (Bolin, Lindgren, & Lundborg, 2008b; Carmichael & Charles, 2003; Carmichael, Charles, & Hulme, 2010; Heitmueller, 2007; Michaud, Heitmueller, & Nazarov, 2010; Van Houtven, Coe, & Skira, 2013). If labour market effects were to increase the total cost of informal care, the effect of this on the health outcomes of the informal care recipient may outweigh this increase. Further research could examine if this is the case as there is already evidence to suggest that caregiving has a negative effect on an informal carers health (Do, Norton, Stearns, & Van Houtven, 2015). Similarly, without considering health outcomes, if formal and informal care together is cheaper or more expensive than nursing home care, this effect on total costs is important for health and social care budget allocations.

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APPENDIX A

TABLE A1 Home-help LPM models estimated with fixed effects (also random effects for comparison)

	Any home help		Any home help: state		Any home help: non-state	
	RE	FE	RE	FE	RE	FE
Log (informal care hours +1)	−0.004* (0.002)	−0.001 (0.002)	−0.016*** (0.001)	−0.013*** (0.001)	−0.011*** (0.001)	−0.009*** (0.001)

Note. The state home-help models are estimated using 30,395 observations and 4,108 individuals. The non-state home-help models are estimated using 29,898 observations and 4,056 individuals. Any home help, health service visitor, GP visitor, and hospital inpatient models are estimated using 31,036 observations and 4,117 individuals. Cluster robust standard errors in parentheses.

Abbreviations: FE, fixed effects; RE, random effects.

*$p < .05$. **$p < .01$. ***$p < .001$.

TABLE A2 Health visitor and health care models estimated with FE (also RE for comparison)

	Any health visitor (LPM)		GP visits		Any hospital inpatient (LPM)	
	RE	FE	RE	FE	RE	FE
Log (informal care hours +1)	0.015*** (0.003)	0.016*** (0.003)	0.079*** (0.020)	0.048* (0.024)	0.016*** (0.003)	0.018*** (0.003)

Note. All models are estimated using 30,395 observations and 4,108 individuals. Cluster robust standard errors in parentheses.

Abbreviations: FE, fixed effects; LPM, linear probability model; RE, random effects.

*$p < .05$. **$p < .01$. ***$p < .001$.

TABLE A3 Non-linear models on the main sample

	Any home help		Any health service use	Any hospital inpatient
	Pooled IV-Probit	Pooled IV-LPM	Probit RE	Probit RE
Log (informal care hours +1)	−0.095 (0.064)	-0.110* (0.048)	0.010*** (0.001)	0.011*** (0.002)

Note. Probit specifications report the average marginal effects. Any home-help first stage F statistic: 15.54. All models are estimated using 30,395 observations and 4,108 individuals. Cluster robust standard errors in parentheses.

Abbreviations: LPM, linear probability model; RE, random effects.

*$p < .05$. **$p < .01$. ***$p < .001$.

TABLE A4 Cross-sectional non-linear IV models using the first year each respondent reported information on their children

	Any home help		Any health visitor		Any hospital inpatient	
	Probit	ivprobit	Probit	ivprobit	Probit	ivprobit
Log (informal care hours +1)	−0.006 (0.004)	−0.158* (0.062)	0.008 (0.004)	0.091 (0.048)	0.012* (0.005)	0.104 (0.304)
Wald test of exogeneity $\chi^2(1)$	—	10.91***	—	2.87	—	0.03

Note. All models are estimated using 2,448 individuals and report average marginal effects. First stage F statistic: 13.65. Cluster robust standard errors in parentheses.

*$p < .05$. **$p < .01$. ***$p < .001$.