METHOD ARTICLE

Formal health care costs among older people in Ireland: methods and estimates using The Irish Longitudinal Study on Ageing (TILDA) [version 1; peer review: 3 approved, 1 approved with reservations]

Peter May[1-3], Frank Moriarty[2,4], Eimir Hurley[1], Soraya Matthews[1], Anne Nolan[2,5], Mark Ward[2], Bridget Johnston[1], Lorna Roe[1,2], Charles Normand[1,3], Rose Anne Kenny[2], Samantha Smith[1]

[1]Cicely Saunders Institute of Palliative Care, Policy & Rehabilitation, King's College London, London, UK
[2]Centre for Health Policy and Management, School of Medicine, Trinity College Dublin, Dublin, Ireland
[3]The Irish Longitudinal Study on Ageing, School of Medicine, Trinity College Dublin, Dublin, Ireland
[4]School of Pharmacy and Biomolecular Sciences, Royal College of Surgeons in Ireland, Dublin, Ireland
[5]Economic and Social Research Institute, Dublin, Ireland

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Abstract

Background: Reliable data on health care costs in Ireland are essential to support planning and evaluation of services. New unit costs and high-quality utilisation data offer the opportunity to estimate individual-level costs for research and policy.
Methods: Our main dataset was The Irish Longitudinal Study on Ageing (TILDA). We used participant interviews with those aged 55+ years in Wave 5 (2018) and all available end-of-life interviews (EOLI) to February 2020. We weighted observations by age, sex and last year of life at the population level. We estimated total formal health care costs by combining reported usage in TILDA with unit costs (non-acute care) and public payer reimbursement data (acute hospital admissions, medications). All costs were adjusted for inflation to 2022, the year of analysis. We examined distribution of estimates across the population, and the composition of costs across categories of care, using descriptive statistics. We identified factors associated with total costs using generalised linear models.
Results: There were 5,105 Wave 5 observations, equivalent at the population level to 1,207,660 people aged 55+ years and not in the last year of life, and 763 EOLI observations, equivalent to 28,466 people aged 55+ years in the last year of life. Mean formal health care costs in the weighted sample were EUR 8,053; EUR 6,624 not in the last year of life and EUR 68,654 in the last year of life. Overall, 90% of health care costs were accounted for by 20% of users. Multiple

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1. **Paddy Gillespie**, National University of Ireland, Galway, Galway, Ireland
2. **John Mullahy**, University of Wisconsin-Madison, Madison, USA
3. **Rachel Milte**, Flinders University, Adelaide, Australia
4. **Sara Olofsson**, The Swedish Institute for Health Economics, Lund, Sweden

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functional limitations and proximity to death were the largest predictors of costs. Other factors that were associated with outcome included educational attainment, entitlements to subsidised care and serious chronic diseases.

Conclusions: Understanding the patterns of costs, and the factors associated with very high costs for some individuals, can inform efforts to improve patient experiences and optimise resource allocation.

Keywords

costs, ageing, demography, policy, functional limitations, end of life, proximity to death

This article is included in the TILDA gateway.

This article is included in the Ageing Populations collection.

Corresponding author: Peter May (mayp2@tcd.ie)

Author roles: May P: Conceptualization, Data Curation, Formal Analysis, Funding Acquisition, Investigation, Methodology, Project Administration, Resources, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Moriarty F**: Data Curation, Formal Analysis, Investigation, Methodology, Supervision, Validation, Writing – Original Draft Preparation, Writing – Review & Editing; **Hurley E**: Data Curation, Formal Analysis, Investigation, Methodology, Writing – Review & Editing; **Matthews S**: Formal Analysis, Investigation, Project Administration, Writing – Review & Editing; **Nolan A**: Data Curation, Investigation, Resources, Supervision, Writing – Review & Editing; **Ward M**: Data Curation, Investigation, Resources, Supervision, Validation, Writing – Review & Editing; **Johnston B**: Conceptualization, Funding Acquisition, Writing – Review & Editing; **Roe L**: Conceptualization, Investigation, Writing – Review & Editing; **Normand C**: Conceptualization, Data Curation, Funding Acquisition, Investigation, Methodology, Supervision, Writing – Review & Editing; **Kenny RA**: Data Curation, Funding Acquisition, Investigation, Resources, Supervision, Writing – Review & Editing; **Smith S**: Conceptualization, Data Curation, Investigation, Methodology, Supervision, Validation, Writing – Original Draft Preparation, Writing – Review & Editing

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Introduction

Background

Health care spending accounted for approximately 9% of gross domestic product in Organisation for Economic Co-Operation and Development (OECD) countries in 2019, the last complete year before the COVID-19 pandemic[1]. Resource allocation decisions in health care therefore have substantial impacts at the macroeconomic level, but also at the microeconomic level, where funding and availability of services may affect individual health, wealth and productivity[2].

Health-related demands will always exceed available resources, placing a moral and practical imperative on decision-makers to fund those services that provide the best value[3]. This challenge, which economists frame in terms of 'scarcity', will be increasingly complex through the 21st century as populations age. Research has repeatedly shown that at the individual level the most important drivers of rising costs are not age *per se*, but instead, on the demand side, proximity to death, and, on the supply side, technology and staffing[4,5]. At the population level, costs will increase due to the rising total number of people living and dying with serious medical illness[6], the demand for health care workers growing more quickly than supply[7,8], and the number of medical technologies increasing persistently[5,9–11].

Ireland is early in the demographic ageing process compared to other high-income countries[12], but faces the same structural challenges and the same need to reform health care services for the population health needs and resource constraints of the 21st century[13,14]. A relatively young population today translates to faster-growing future needs: Ireland has the fastest ageing population in the European Union, with an expected three-fold increase in those aged 80+ years and near doubling of annual deaths in the next 20 years[15]. Compared to other western European nations, the Irish health care system has long been distinguished by a combination of relatively high per-capita spending and a relatively limited basket of entitlements under universal coverage[16]. Notable system characteristics include a reliance on acute inpatient hospital admissions given weak primary care capacity, high medications spending, non-compulsory insurance that improves access to some services for policyholders, and fast-growing population health needs[16–18]. Partly in recognition of these issues, Ireland has engaged in a wide-ranging health policy update since 2017, known as the 'Sláintecare' reforms, with mixed progress[19–22].

Context, rationale and aims

High-quality data on individual-level health care costs in Ireland are essential to support monitoring, planning and evaluation of services, and the allocation of scarce resources to maximise public welfare. The lack of a unique patient identifier prevents researchers from using routine administrative data to estimate individual-level costs[23]. In 2021 researchers published the first standardised set of unit costs for non-acute health care in Ireland[24], a long-awaited development and a critical step for health economics research in the state[25].

The Irish Longitudinal Study on Ageing (TILDA) is a biennial study of people aged 50+ years in the Republic of Ireland that started in 2009–2011. Among many individual-level variables in a rich dataset, TILDA collects data on participants' demographic, socioeconomic, early life, physical and mental health, and household characteristics[26]. Utilisation data are collected via frequency questions on categories of health, social and residential care in the preceding year, *e.g.*, 'how many times did you visit the GP in the last 12 months?' While previous papers have estimated costs in TILDA[27,28], these have been constrained by incomplete availability of unit costs in non-acute care and crude casemix estimates for acute care.

Combining the new unit cost database with TILDA offers the opportunity to estimate in the greatest detail yet health, social and residential care costs (henceforth, 'health care costs') among a population-representative sample of older people in Ireland. We supplement this new non-acute unit cost database with our own analyses of hospital inpatient admissions, adjusting for age, sex, diagnoses and discharge status, and a costing exercise of medications reported by TILDA respondents. The arising estimates can inform ongoing research studies, including those evaluating specific policies and models of delivery[29], delineating patterns and trajectories of health care use[30], surveying end-of-life needs[31,32], and projecting future needs and costs[33–35]. They can also contribute to future studies both within TILDA, for example prediction exercises to identify high-cost users[27]; and in wider modelling frameworks, for example cost-effectiveness analyses that have to characterise disease trajectories and costs in different clinical populations[36].

Our aims in this paper are to first document the methods by which health care costs are estimated in TILDA, and then to address the following research questions:

1. What are the health care costs for older people in Ireland? How are costs distributed across the population?
2. What is the underlying composition of these costs between primary and community care, hospital care, home care, residential care, and medications?
3. What individual-level predictors are associated health care costs?

Methods

Study design, participants and data

This is a costing study using secondary data sources. Our main data source was TILDA, which recruited a population-representative sample of more than 8,000 community-dwelling people aged 50+ years at Wave 1 (2009–2011)[37]. Full details of the study design, recruitment, consent and data collection are available elsewhere[26]. Briefly, computer-assisted personal interview (CAPI) and a self-completion questionnaire (SCQ) are used to collect data on demographic and socioeconomic characteristics such as early life, household composition, employment history, income and asset levels, as well as detailed information on health status (*e.g.*, diagnoses, functional

status, self-reported physical and mental health) and healthcare utilisation. When a participant dies, a family member or close friend is approached to conduct a voluntary end-of-life interview (EOLI) on the decedent's experiences in the last 12 months of life. This process, including the ethical guidelines and procedures, has been detailed elsewhere[28]. The EOLI represents a shortened version of the CAPI, asking the respondent questions on the decedent's living situation, health, health care use and other factors.

The baseline sample were invited to participate in CAPI and SCQ follow-up at Wave 2 (2012), Wave 3 (2014), Wave 4 (2016), Wave 5 (2018) and Wave 6 (2021, delayed from 2020 by the COVID-19 pandemic). Ethical approval for each wave is obtained from the Faculty of Health Sciences Research Ethics Committee in Trinity College Dublin. Participants make an informed decision about their participation, receiving advanced notice and information booklets; they may refuse to take part in any study section or withdraw at any time without justification; for each CAPI and EOLI question, available answers include "Refuse to answer" and "Don't know".

Secondary data sources were two unit cost databases for non-acute costs[24,38], and the Hospital Inpatient Enquiry (HIPE) database of admissions to public acute hospitals[39]. We also draw on Census data from the Central Statistics Office (CSO), for the purposes of population weighting, and the General Register Office (GRO) to identify deaths[40]. All deaths in the Republic of Ireland must be recorded with the GRO, and TILDA is linked to the GRO in a process described previously[41].

In terms of perspective, we estimate the cost associated with providing the formal health care that TILDA participants and EOLI respondents report. We do not analyse or report out-of-pocket spending, which has implications for how costs are distributed between the system and households, and we do not analyse or report unpaid care provided by family and friends.

Variables

Dependent variable

The primary dependent variable is formal health care costs, which combines the estimated costs associated with acute and non-acute care, and medications, reported by participants.

For acute and non-acute care, TILDA collects data on the frequency (f) of use for a number (n) of categories (h), where n varies slightly between CAPI and EOLI, because hospice inpatient stays are not asked in the CAPI (implicitly assumed as zero). A unit cost (c) was identified for each category. Therefore, for each individual CAPI or EOLI (i), a specific acute or non-acute category (h) has associated costs ($y_{i,h}$) given by:

$$y_{i,h} = f_{i,h} * c_h$$

Unit costs for non-acute care have been calculated in two prior costing exercises by Brick *et al.*[38] and Smith *et al.*[24] Hospital emergency department and outpatient unit costs have been calculated previously by Keegan *et al.*[34] We were not aware of any unit costing exercise for acute inpatient admissions that was coherently linkable with individual TILDA data, and so we calculated acute inpatient unit costs using HIPE data in a procedure detailed in 'Appendix 1', which can be found as *Extended data*[42]. Briefly, in TILDA, we categorised each CAPI and/or EOLI to a category based on age, sex and diagnostic profile. In HIPE, we calculated the reimbursement due for each overnight adult admission to a public acute hospital in Ireland between 2009 and 2019 using the Healthcare Pricing Office (HPO) activity-based funding (ABF) guidance[43], which determines reimbursement rates according to primary diagnosis and length of stay. We categorised each of these admissions by age, sex and diagnostic profile, and then calculated acute unit costs for each age/sex/diagnostic group as the mean reimbursement for an overnight stay in that group. We linked these acute unit costs to each CAPI and EOLI by age/sex/diagnostic profile, incorporating for EOLIs the additional cost associated with a death in hospital.

In all cases we chose the most recently available unit costs available. These most recent unit costs were calculated in different years. We standardised all unit costs to 2022, the year that the analyses were conducted, using the Consumer Price Index (CPI) for health[44,45]. In data processing we created subgroups for ease of interpretation: primary and community care, hospital care, home care, residential care, and medications. Each category of care, its' variable name in the most recent publicly available CAPI and EOLI, the unit cost source, the unit cost after adjusting to 2022 prices, and the sub-group to which it was allocated are presented in Table 1.

For medications, CAPI respondents detail the medications that they take "on a regular basis", which includes prescribed medications, as well as those purchased over-the-counter, vitamins and supplements, and herbal products. Medication names are recorded as they are reported (either branded/generic product name or drug name), however strength and dosage are not captured. Each medication is assigned a WHO Anatomical Therapeutic Chemical (ATC) code where available relating to the drug they contain. We excluded reported products that do not have an ATC code, and any non-prescription items not reimbursed on Ireland's community drug schemes (*i.e.*, certain vitamins and over-the-counter products). For each included medication (m) we identified the associated cost (c), assuming the respondent was prescribed the WHO Defined Daily Dosage corresponding to the ATC code for one year, in the 2020 Health Service Executive reimbursement list[46]. Therefore, for each individual CAPI (i), reported regular usage of n medications has associated annual costs ($y_{i,m}$) given by:

$$y_{i,m} = \sum_{m=1}^{n} c_{i,m}$$

The EOLI does not collect medications data, but age- and sex-adjusted mean costs in the last year of life have been calculated previously[47]. We imputed into EOLIs $y_{i,m}$ using this mean by age and sex, after adjusting to 2022 using the CPI for health.

Table 1. Unit costs for categories of health care use collected in the CAPI and EOLI.

Sub-Group	Category	Unit cost source	Unit cost (2022 EUR)	CAPI[48]	EOLI[§]
Hospital	Emergency department	Keegan *et al.*[34] (i)	EUR 321 per visit	hu007	xt_hu010
	Outpatient visit	Keegan *et al.*[34] (i)	EUR 184 per visit	hu008	xt_hu011
	Overnight inpatient admits	*Authors' own* (ii)	*By age/sex/dx*	hu010	xt_hu013 (iii) xt_cs021 (iv)
Primary and community	General Practitioner	Smith *et al.*[24] (v)	EUR 49 per visit	hu005	xt_hu005
	Public Health Nurse	Smith *et al.*[24] (v)	EUR 60 per visit	hu015_01 (vi)	xt_hu029_01
	Occupational therapist	Smith *et al.*[24] (v)	EUR 69 per visit	hu015_02 (vi)	xt_hu029_02
	Chiropodist	Smith *et al.*[24] (v)	EUR 69 per visit	hu015_03 (vi)	xt_hu029_03
	Physiotherapist	Smith *et al.*[24] (v)	EUR 69 per visit	hu015_04 (vi)	xt_hu029_04
	Speech & lang. therapist	Smith *et al.*[24] (v)	EUR 69 per visit	hu015_05 (vi)	xt_hu029_05
	Social worker	Smith *et al.*[24] (v)	EUR 47 per visit	hu015_06 (vi)	xt_hu029_06
	Psychologist	Smith *et al.*[24] (v)	EUR 106 per visit	hu015_07 (vi)	xt_hu029_07
	Day care	Brick *et al.*[38] (vii)	EUR 48 per visit	hu015_11 (vi)	xt_hu029_08
	Dentist	Smith *et al.*[24] (v)	EUR 35 per visit	hu015_13 (vi)	xt_hu029_10
	Dietician	Smith *et al.*[24] (v)	EUR 69 per visit	hu015_15 (vi)	xt_hu029_12
Home	Home help (xiii)	Smith *et al.*[24] (v)	EUR 35 per hour	hu015A	xt_hu022
	Personal care attendant (ix)	Smith *et al.*[24] (v)	EUR 36 per hour	hu015B	xt_hu025
	Meals on wheels	Brick *et al.*[38] (vii)	EUR 12 per visit	hu015C	xt_hu027
	Home care package (ix)	Smith *et al.*[24] (v)	EUR 36 per hour	hu015D	xt_hu074
Residential	Nursing home (x)	Smith *et al.*[24] (v)	EUR 1,722 per week	hu032	xt_cs025
	Hospice	Brick *et al.*[38] (vii)	EUR 999 per night	n/a (xi)	xt_cs023 (iv)

[§] EOLIs are not published on the study website (tilda.tcd.ie), but access may be applied for at that location. (i) Keegan *et al.*, estimated costs for 2018; per the CSO CPI Health, the multiplier from December 2018 to December 2022 was 1.076. (ii) Overnight admissions were costed using HIPE, detailed 'Appendix 1' in *Extended data*[42] (iii). Where EOLI reports death in hospital, the unit cost for that admission is adjusted (see Appendix 1)[42]. (iv) Where EOLI reports people admitted to hospital or hospice as an inpatient, these episodes were costed using the relevant category unit cost and reported under that sub-group; where EOLI reports a decedent was living in a hospital or hospice as their main residence, these episodes were costed using the nursing home unit cost and reported under the sub-group 'residential care'. (v) Smith *et al.*, estimated costs for 2019; per the CSO CPI Health, the multiplier from December 2019 to December 2022 was 1.066. Smith *et al.*, report different scenarios, we use the baseline public system unit cost in all cases. (vi) In the CAPI at Wave 1 and 2, these frequencies were binary (*i.e.*, do you use this service?); for non-users we set $y_{i,h}$=0; for those using the service we set $y_{i,h}$ to equal the age- and sex-adjusted median among service users in Waves 3-5. (vii) Brick *et al.*, estimated costs for 2011; per the CSO CPI Health, the multiplier from December 2011 to December 2022 was 1.122. (viii) 'Home help' in TILDA is termed 'Health Care Support Assistant' in Smith *et al.* (ix) For 'Home care package' and 'Personal care attendant' in TILDA, we used 'Health Care Support Assistant' in Smith *et al.* (x) For 'Nursing home' in TILDA, we used 'Long-term residential care' in Smith *et al.* (xi) Hospice use is not part of the CAPI. CAPI, computer-assisted personal interview; EOLI, end-of-life interview; CSO, Central Statistics Office; CPI, Consumer Price Index; HIPE, Hospital Inpatient Enquiry; TILDA, The Irish Longitudinal Study on Ageing.

The primary outcome, an individual CAPI or EOLI's total formal health care costs (Y_i), expressed in euro (€, EUR) adjusted to 2022, is then calculated by summing $y_{i,h}$ for n categories of acute and non-acute care and adding the medications costs:

$$Y_i = \sum_{h=1}^{n} y_{i,h} + y_{i,m}$$

This outcome variable does not include some CAPI formal health care use data that might be considered relevant to health care costs. These variables, and the rationale for not including in this paper, are summarised in Table 2.

We did not identify any health care use variables in the EOLI that are not in either Table 1 or Table 2. Those interested may check the full suite of TILDA variables at any time *via* the study website.

Independent variables

In multivariate regressions for our third research question, we identified predictors on a hypothesis-driven basis using

Table 2. Formal health care utilisation categories recorded in TILDA but excluded from this paper.

Category	CAPI[48]	Reason for exclusion
Optician	hu015_12	No unit cost reported in Brick *et al.*, Smith *et al.*, or PSSRU 2019[49]
Hearing	hu015_14	
Respite care	hu015_16	
Consultant	hu062	Binary, no frequency data to calculate costs
Operations	hu011	No operation-specific data on which to base unit costs.
Public or private hospital?	hu014	No unit costs available for private hospitals.
Private home care	hu076	Not collected for all CAPI waves, and/or in all EOLI waves; excluded for consistency.
Private allied health and social care	hu084	

CAPI, computer-assisted personal interview; EOLI, end-of-life interview; TILDA, The Irish Longitudinal Study on Ageing.

the Andersen model of health care utilisation, which categorises potential predictors as predisposing, enabling, need or prior use[50]. Additionally we controlled for proximity-to-death effects using death dates for both CAPI and EOLI observations. The variables employed in multivariate regressions are summarised in Table 3.

Sample eligibility and timeframe for analysis

In the main paper we focus on two sets of interviews: CAPIs at Wave 5, and EOLIs at any wave. We choose Wave 5 as the most recent conducted prior to the COVID-19 pandemic; Wave 6 interviews were conducted during 2021, which was an atypical period of health care utilisation and is likely not generalizable to other years. By Wave 5 (2018), the baseline sample (aged 50+ years in 2009–2011) are nearly all aged 55+ years (the only exceptions are those who enrolled aged <50 years old while participating as the spouse of a participant aged >50 years old). Therefore, we excluded those aged <55 years from all analyses; the numbers are presented with the population-level weights in 'Appendix 2', found as *Extended data*[42].

We include EOLIs from all waves prior to March 2020, since wave-by-wave samples are relatively small, these observations heavily influence cost estimates (see Results for full details), and we consider it a reasonable assumption that pre-pandemic deaths in all TILDA years are substantively comparable. The sample eligibility was therefore defined as all Wave 5 CAPI participants aged 55+ years, and all EOLIs aged 55+ years at any wave, except (i) deaths occurring after 29/2/20, and (ii) the deaths for participants at Wave 5 and so individuals already in our sample. We summarise how this sample is reached in the Results and present the characteristics of those excluded in 'Appendix 2'[42].

As such our reported estimates reflect our best understanding of health care costs among older people in Ireland in 2019, updated for inflation to 2022.

Missing data, final sample size and sensitivity analyses

Prior studies have found that missing data in both CAPIs and EOLIs is relatively rare; *e.g.*, at baseline this was less than 1% for predisposing, enabling and need characteristics (Table 3 in May *et al.*, 2022[33]), although there have been small increases in such missingness wave-on-wave. For the dependent variable, prior analyses of TILDA have suggested that of all categories in Table 1, four account for over 80% of total costs in the CAPI: GP, inpatient, outpatient and home help[27,28]. Any sample-eligible CAPI or EOLI that was missing two or more of these four categories was flagged and removed from primary analysis as having insufficient outcome data. For those interviews missing one or fewer of these categories, and or missing any other categories of health care frequency, we imputed age- and sex-adjusted medians. For independent variables, any sample-eligible CAPI or EOLI that was missing three or more baseline predictors was removed from primary analysis as having insufficient baseline data. For those interviews missing two or fewer baseline variables, we imputed the same individual's data from the most recently available prior wave.

Bias

TILDA in Wave 1 aimed to recruit a population-representative sample of community-dwelling adults aged 50+ years but the sample inevitably differs from the population, and this variation will have increased if those who die or drop out or have missing data differ systematically from those who continue to take part. We addressed this sampling uncertainty, and the concomitant risk of bias, through sampling weights

Table 3. Independent predictors in multivariate regression.

Group	Variable	Categorisation
Predisposing	Age[§]	Years
	Sex[§]	Male | Female
Enabling	Education: Highest achieved[§]	Primary | Secondary | Tertiary
	Medical card or GP card?*[#]	Yes, either/or
	Private insurance?*[ε]	Yes, either as policy holder or on another's policy
	Marital status	Married | Living with a partner ==1 Single | Widowed | Divorced | Separated ==0
	Local region*	Dublin city and county | Urban area, not Dublin | Rural area
Need	Cancer[¥]	Has a doctor ever told you that you have ___?
	Heart disease[¥]	Has a doctor ever told you that you have ___?
	Multimorbidity[¥]	Has a doctor ever told you that you have 2+ of the following: cancer, heart disease, kidney disease, liver disease, lung disease, Alzheimer's disease and related dementias, hypertension; diabetes; stroke; arthritis; psychological issues including anxiety and depression; alcohol and/or drug abuse?
	Instrumental Activities of Daily Living (IADLs)*[51]	Because of a health or memory problem, do you have difficulty doing any of the following activities: preparing a hot meal, shopping for groceries, making telephone calls, taking medications, managing money, doing household chores? Total difficulties (/6)= 0 | 1 | 2+
	Physical exercise[β]	Do you engage in vigorous physical exercise at least weekly?
Prior use	Emergency department (ED) admissions[+]	How many ED admissions in the prior interview? Total admissions = 0 | 1 | 2+
Proximity to death	Last two years of life (L2YOL)[θ]	Among CAPI sample, did the participant die within two years of the interview?
	Last year of life (LYOL)[α]	Was the participant in the last year of life (*i.e.*, is this a CAPI observation or an EOLI observation)?

[§] For both CAPI and EOLI observations, these variables are taken from the baseline enrolment data (and EOLI age adjusted to age at death using date of death). [#] Medical cards are provided on a means-tested basis, and provide free access to inpatient and outpatient public hospital care, to GPs, and to prescription drugs; GP cards are means-tested under the age of 70 years and provided universally thereafter, and afford free access to the GP.[52] [ε] Private insurance is voluntary in Ireland; it provides access to some additional facilities and expedites access to certain services. * For CAPI observations, these variables are taken from the Wave 5 responses: for EOLI observations, these variables are taken from the EOLI or if the respondent did not know or refused to answer they are taken from the last CAPI prior to death. [¥] Diagnoses are treated as absorbing states; for CAPI observations, a reported diagnosis at any Wave up to and including Wave 5; for EOLI observations, a reported diagnosis at any CAPI or in the EOLI. [β] For CAPI observations, these variables are taken from Wave 5; for EOLI observations, these variables are taken from the last CAPI prior to death. [+] For CAPI observations, prior use variables are taken from Wave 4; for EOLI observations, these variables are taken from the last CAPI prior to death. [θ] Identified *via* GRO linkage; included in CAPI and pooled regressions only; always ==0 in EOLI sample. [α] Included in pooled regression only, has a fixed value within CAPI (==0) and EOLI (==1) samples. CAPI, computer-assisted personal interview; EOLI, end-of-life interview; GRO, General Register Office.

that used the CSO population data to calculate the probability of any given participant having been included in the sample. For this paper we weighted by age (five-year bands), sex (male or female), and last year of life (=1 for EOLIs, 0 for CAPIs). Weights were calculated using the CSO population data for 2019, the most recent pre-pandemic year full data were available. See 'Appendix 2'[42].

Statistical methods

All analyses were performed in Stata version 15 (RRID: SCR_012763)[53]; an open access alternative that can perform equivalent tasks is R (RRID:SCR_001905)[54]. For research questions 1 and 2, we report descriptive and distributional statistics after applying the population weights. For research question 3, we run multivariate regressions in the eligible Wave 5 CAPIs, in the eligible EOLIs, and in the CAPIs and the EOLIs pooled. In all cases we modelled outcomes using a generalised linear model with a power link, selected using information criteria before inspecting or interpreting results[55]. Prior to estimating results we assessed collinearity of predictors using the –collin- command. For each association between predictor and outcome, we report dy/dx using

the –margins- command; this reflects the estimated mean association with outcome of increasing the value of the predictor by one point while holding all other values in the model constant.

Additional data and sensitivity analyses

For reader information, we present the following data before and after weighting in supplementary materials:

- Characteristics of the sample, and those excluded per Figure 1 (Appendix 2)[42]
- Research Question 1 (Appendix 3, which can be found as *Extended data*)[42]
- Research Question 2 (Appendix 4)[42]
- Summary statistics and distributions for total health care costs in CAPI waves 1–4 (Appendix 5)[42]

We performed sensitivity analyses on our regressions, presented in Appendices:

I. Research Question 3 for CAPI and EOLI without weights (Appendix 6)[42]

II. Research Question 3 for CAPI and EOLI with alternative acute inpatient costs as outlined in Appendix 1 (Appendix 6)[42]

III. Research Question 3 for CAPI and EOLI using those with complete outcome data only (Appendix 6)[42]

Diagnostic checks for model choice and collinearity are presented in 'Appendix 7'[42]. Additional information on the medications costing exercise are presented in 'Appendix 8'[42].

Results

Sample

Figure 1 details how the analytic samples were reached. There were 5,222 completed CAPI interviews at Wave 5, of which 96 were aged <55 years, one had insufficient baseline data, and 20 had insufficient outcome data. This gave a CAPI analytic sample of 5,105 Wave 5 participants. There were 892 completed EOLI interviews at time of data analysis (Q3 2022), of which seven were for people aged <55 years, three concerned deaths occurring March 2020 onwards, 11 had insufficient outcome data, and 108 were already in the CAPI sample. This gave an EOLI analytic sample of 763 deceased participants. When the CAPI and EOLI data were pooled, this was an analytic sample of 5,868 unique individuals (Figure 1).

Descriptive data

The analytic samples are provided in Table 4, after weighting. The 5,105 CAPI observations were equivalent to 1,207,660 people at the population level, and the 763 EOLI observations were equivalent to 28,466. Combined this was 1,236,126 people aged 55+ years in Ireland in 2019.

There were large differences between the EOLI (last year of life) and CAPI (not last year of life) samples on all

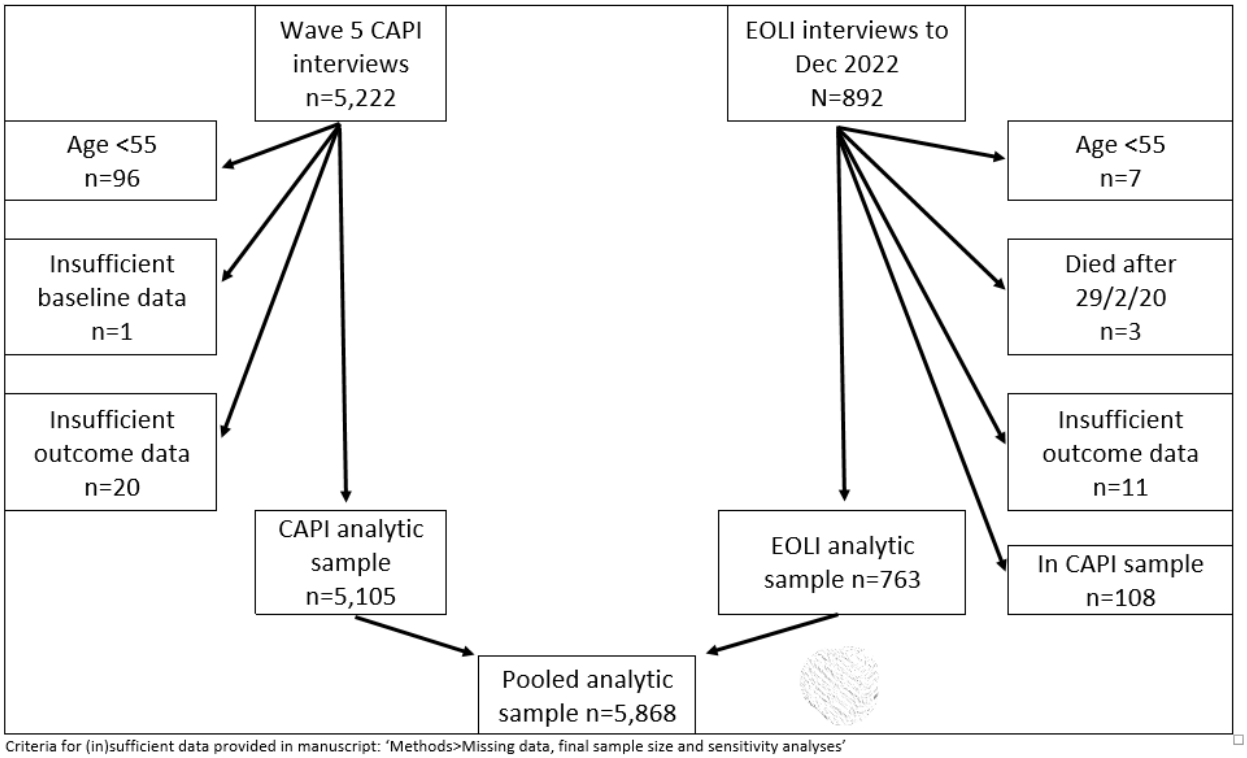

Figure 1. How the analytic samples were reached. CAPI, computer-assisted personal interview; EOLI, end-of-life interview.

Table 4. Baseline characteristics, all samples, after weighting.

Baseline characteristics		CAPI (N_{TILDA}=5,105)		EOLI (N_{TILDA} =763)		ALL (N_{TILDA} =5,868)	
		N_{pop}=1,207,660		N_{pop}=28,466		N_{pop}=1,236,126	
		%	n_{pop}	%	n_{pop}	%	n_{pop}
Age	*55–64yrs*	44.4%	536,486	10.2%	2,903	43.6%	539,389
	65–74yrs	33.0%	398,755	19.8%	5,629	32.7%	404,384
	75–84yrs	17.1%	205,879	31.4%	8,942	17.4%	214,821
	85yrs<=	5.5%	66,210	38.6%	10,992	6.2%	77,202
Sex	*Male*	48.0%	579,195	51.1%	14,545	48.0%	593,740
Education	*Primary*	19.9%	240,498	53.1%	15,105	20.7%	255,603
	Secondary	43.3%	522,604	29.4%	8,374	42.9%	530,978
	Tertiary	36.8%	444,558	17.5%	4,987	36.4%	449,545
Married	*Yes*	70.3%	848,914	41.8%	11,890	69.7%	860,804
Medical card	*Yes*	55.0%	663,481	91.5%	26,055	55.8%	689,536
Insurance	*Yes*	61.9%	747,063	37.9%	10,801	61.3%	757,864
Region	*Dublin*	24.3%	293,099	21.6%	6,166	24.2%	299,265
	Urban, not Dublin	29.0%	350,345	32.4%	9,211	29.1%	359,556
	Rural area	46.7%	564,216	46.0%	13,089	46.7%	577,305
Diagnoses	*Cancer*	10.6%	127,571	42.4%	12,057	11.3%	139,628
	Heart disease	27.3%	329,769	47.5%	13,518	27.8%	343,287
	Multimorbidity	41.4%	499,818	82.4%	23,443	42.3%	523,261
IADLs	*0*	92.6%	1,118,607	35.8%	10,192	91.3%	1,128,799
	1	2.6%	30,933	20.9%	5,955	3.0%	36,888
	2+	4.8%	58,120	43.3%	12,319	5.7%	70,439
Phys. exercise	*Yes*	24.9%	300,950	5.5%	1,562	24.5%	302,512
ED visits	*0*	84.7%	1,023,048	67.9%	19,340	84.4%	1,042,388
	1	12.3%	148,229	19.0%	5,403	12.4%	153,632
	2+	3.0%	36,383	13.1%	3,723	3.2%	40,106
L2YOL	*Yes*	2.1%	21,584	-	-	1.8%	21,584
LYOL	*Yes*	-	-	100%	28,466	2.3%	28,466

N_{TILDA} is the number of observations in each sample (CAPI/EOLI/ALL). N_{pop} is the number of people in each sample (CAPI/EOLI/ALL) at the population level after weighting; n_{pop} is the number of people in each cell at the population level after weighting. For unweighted samples and TILDA cell sizes, see 'Appendix 2' in *Extended data*[42]. For definitions of variables, see Table 3.
CAPI, computer-assisted personal interview; EOLI, end-of-life interview; TILDA, The Irish Longitudinal Study on Ageing; IADL, Instrumental Activities of Daily Living; ED, Emergency department; L2YOL, last two years of life; LYOL, last year of life.

baseline predictors except region. More than two thirds of those in the last year of life were aged over 75 years, and more than three quarters not in the last year of life were aged under 75 years. Males were slightly more represented among the EOLI than CAPI samples, reflecting higher male mortality rates. The younger CAPI interviewees had higher average educational achievement, reflecting cohort effects in access, and higher prevalence of marriage, reflecting rising marriage rates in the middle of the 20th century and lower widowhood effects. Those in the last year of life were much more likely to have a medical card, reflecting wider entitlement from the age of 70 years, but less likely to have private insurance. EOLI observations had much higher prevalence of serious illness, functional impairment, and ED attendance;

but much lower prevalence of regular physical exercise. In the pooled sample, patterns of characteristics substantively reflect the CAPI sample as these are 87% of observations before weighting and 98% after weighting.

Main results

What are the health care costs for older people in Ireland? How are costs distributed across the population?

Total formal care costs, in the CAPI and EOLI samples and pooled together, are presented in Table 5. Mean costs in the weighted sample were EUR 8,053, comprising EUR 6,624 in the CAPI sample and EUR 68,654 in the EOLI. Typical for cost data, there is considerable right-hand skew in all samples.

Table 5. Distribution of estimated mean formal costs (2022 EUR), after weighting.

	CAPI	EOLI	ALL
Mean	**EUR 6,624**	**EUR 68,654**	**EUR 8,053**
Percentile			
10th	EUR 98	EUR 12,806	EUR 98
25th	EUR 328	EUR 28,077	EUR 332
50th	EUR 848	EUR 49,974	EUR 887
75th	EUR 2,545	EUR 95,326	EUR 2,945
90th	EUR 16,500	EUR 131,865	EUR 18,775
Largest	EUR 671,529	EUR 945,983	EUR 945,983

CAPI, computer-assisted personal interview; EOLI, end-of-life interview.

The distribution of formal costs across deciles are presented in Figure 2, after weighting. The skew is again heavily evidenced here: over 70% of people have costs less than EUR 2,000 a year, and the top 10% of people have mean costs of EUR 59,654.

The corresponding population-level costs are presented in Table 6. Total estimated population-level costs are EUR 9,954,054,582. Almost three quarters (74%) of these costs are accounted for by the 10th decile and another 16% by the ninth decile. Therefore, an estimated 90% of health care costs among people aged 55+ years are accounted for by 20% of users.

For equivalent data in the CAPI and EOLI samples separately, see Appendix 3[42].

What is the underlying composition of these costs between primary and community care, hospital care, home care, residential care, and medications?

The composition of costs for CAPI, EOLI and pooled samples are presented in Figures 3a, 3b and 3c, respectively. Hospital costs accounted for the majority of the dependent variable in all three cases; the most visible difference between CAPI and EOLI costs were those for residential care, which accounted for a far higher overall proportion among those in the last year of life.

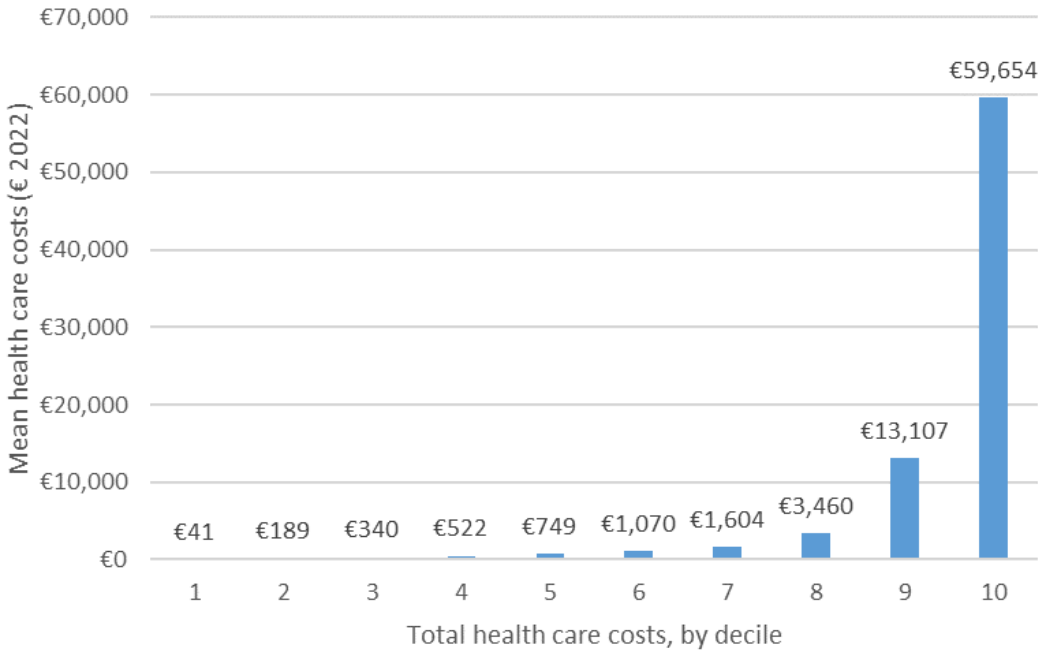

Figure 2. Distribution of costs by decile in pooled (ALL) sample.

The composition of costs across deciles of total health care costs in the pooled sample is presented in Figure 4. The substantive jump between the eighth and ninth decile, already highlighted in Table 6, is mainly explained by hospital costs. The even larger jump between the ninth and 10th decile is explained by large increases in hospital, home and residential care costs.

Table 6. Distribution of population-level costs by decile in pooled (ALL) sample.

Decile	Total costs	% of TOTAL
1	EUR 6,124,598	<0.5%
2	EUR 18,333,207	<0.5%
3	EUR 42,035,469	<0.5%
4	EUR 64,543,771	1%
5	EUR 92,453,829	1%
6	EUR 132,231,904	1%
7	EUR 198,341,926	2%
8	EUR 427,823,171	4%
9	EUR 1,624,557,991	16%
10	EUR 7,347,608,716	74%
TOTAL	EUR 9,954,054,582	

The composition of costs among non-zero users, across 20 quantiles of total health care costs in the pooled sample, is presented in Figure 5. Among lower cost users, primary care and pharmacy costs dominate. From the second to 17th quantile, hospital costs account for a consistently increasing proportion. Home care costs are close to zero until the top five quantiles, thereafter, accounting for 2–12%. Residential care costs are close to zero until the top two quantiles, accounting for over a quarter of costs in the highest-cost group.

For equivalent data in the CAPI and EOLI samples separately, see Appendix 4[42].

What individual-level predictors are associated health care costs?

The results of the multivariate regressions are presented in Table 7. Statistically significant results are highlighted in bold.

In the CAPI sample, the largest associations were 2+ IADLs, which was associated with EUR 21,376 higher costs compared to none (95% confidence interval: 11,714 to 31,037) and being in the last two years of life (+ EUR 16,250; 7,304 to

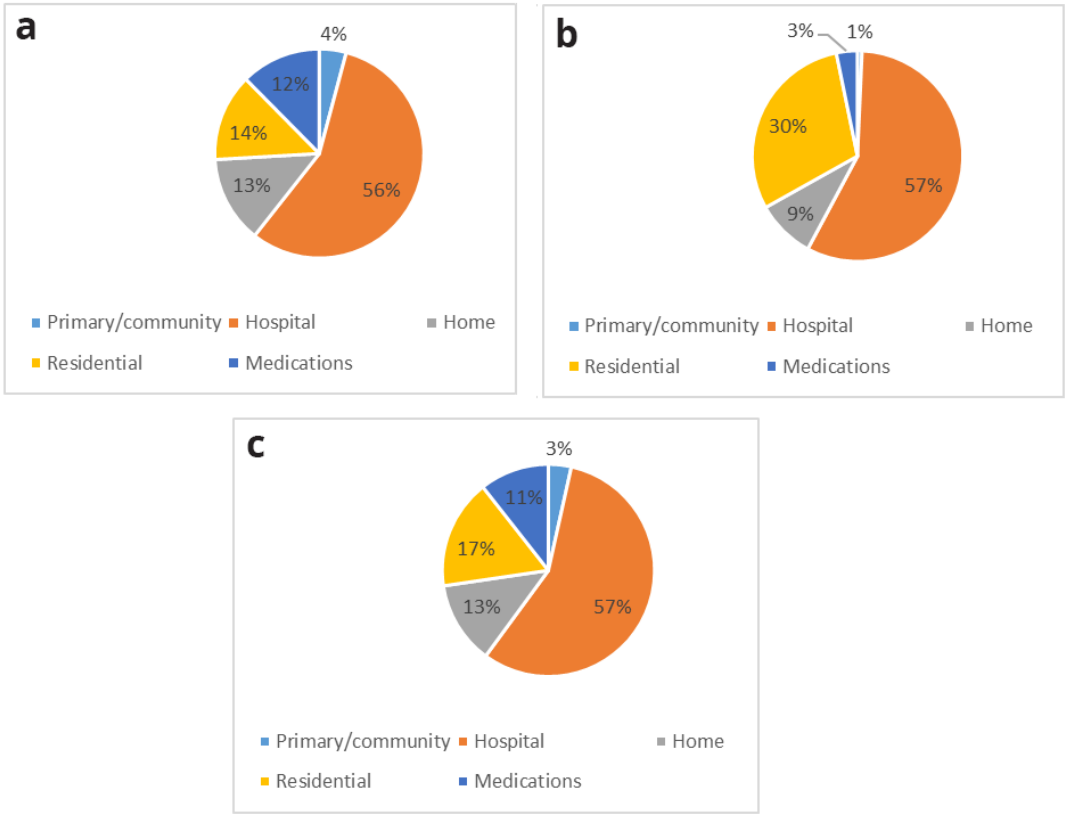

Figure 3. Composition of costs. (**a**) CAPI, (**b**) EOLI and (**c**) pooled (ALL) sample. CAPI, computer-assisted personal interview; EOLI, end-of-life interview.

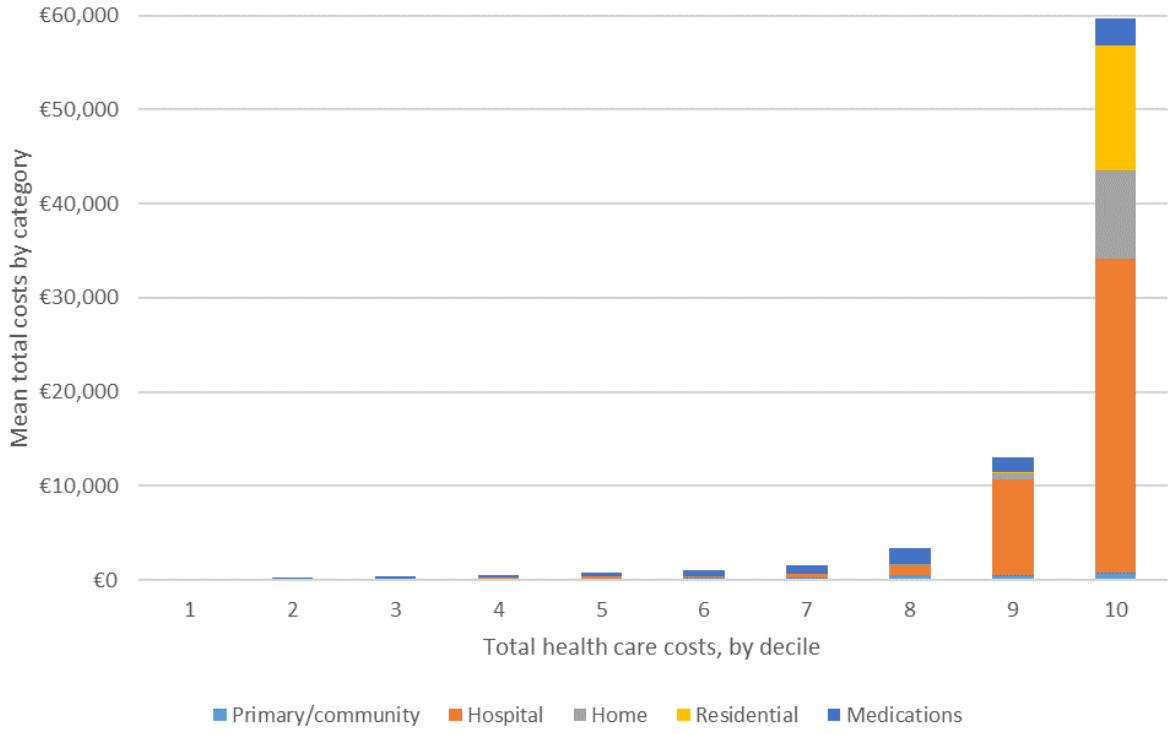

Figure 4. Distribution and composition of costs by decile in pooled (ALL) sample.

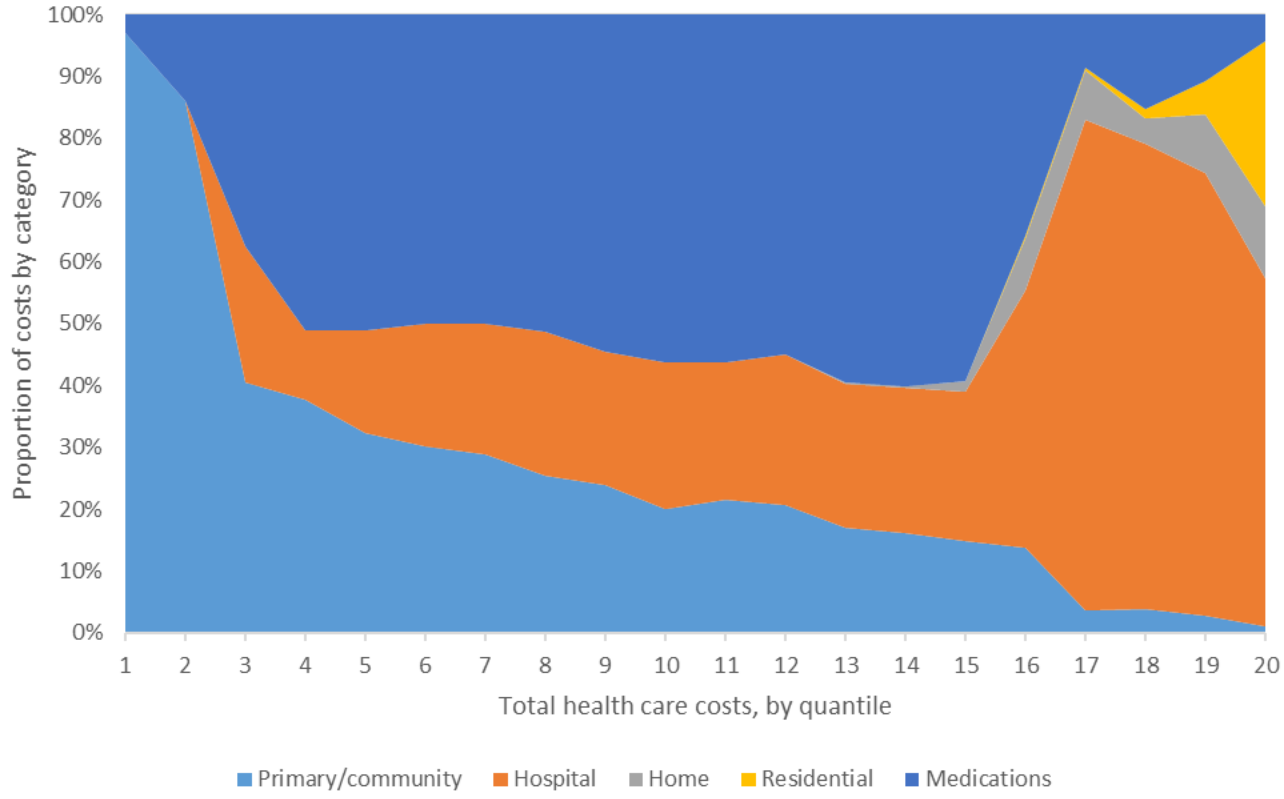

Figure 5. Composition of costs by quantile in pooled (ALL) sample.

Table 7. Associations between individual characteristics and total health care costs.

Individual characteristics		CAPI		EOLI		ALL	
		dy/dx	*95% CI*	*dy/dx*	*95% CI*	*dy/dx*	*95% CI*
Age	*65-74yrs*	**699**	**118 to 1,279**	13,401	-1,151 to 27,954	**747**	**170 to 1,324**
	75-84yrs	765	-320 to 1,850	3,053	-11,299 to 17,406	818	-261 to 1,897
	85yrs<=	**3,639**	**1,132 to 6,147**	-35	-14,658 to 14,587	**3,776**	**1,337 to 6,215**
Sex	*Male*	-242	-704 to 219	**-11,764**	**-20,624 to -2,904**	-260	-719 to 198
Education	*Primary*	-224	-1,025 to 576	-653	-10,710 to 9,404	-241	-1,036 to 554
	Tertiary	**-768**	**-1,295 to -241**	3,794	-9,053 to 16,642	**-817**	**-1,341 to -294**
Married	*Yes*	-256	-871 to 359	-110	-9,387 to 9,167	-273	-884 to 339
Med. card	*Yes*	**1,346**	**665 to 2,028**	6,805	-8,512 to 22,122	**1,434**	**757 to 2,112**
Insurance	*Yes*	491	-78 to 1,060	-2,695	-13,240 to 7,849	520	-46 to 1,086
Region	*Urban*	**1,048**	**316 to 1,780**	**-16,025**	**-29,642 to -2,408**	**1,109**	**383 to 1,835**
	Rural	-384	-948 to 180	**-17,840**	**-30,812 to -4,869**	-413	-975 to 149
Diagnoses	*Cancer*	**3,890**	**2,361 to 5,419**	**14,796**	**5,810 to 23,782**	**4,166**	**2,647 to 5,685**
	Heart	**2,185**	**1,299 to 3,071**	6,444	-3,075 to 15,963	**2,328**	**1,448 to 3,208**
	Multim.	**2,679**	**1,930 to 3,428**	**17,580**	**6,964 to 28,196**	**2,855**	**2,111 to 3,598**
IADLs	*1*	1,969	-723 to 4,660	**11,572**	**799 to 22,345**	2,147	-517 to 4,811
	2+	**21,376**	**11,714 to 31,037**	**30,637**	**20,287 to 40,987**	**21,437**	**12,763 to 30,112**
Exercise	*Yes*	**-1,645**	**-2,137 to -1,154**	**-24,751**	**-39,619 to -9,884**	**-1,751**	**-2,240 to -1,263**
ED visits	*1*	**1,737**	**663 to 2,812**	6,968	-4,853 to 18,789	**1,844**	**784 to 2,905**
	2+	**4,542**	**915 to 8,170**	**15,717**	**67 to 31,366**	**4,837**	**1,282 to 8,392**
L2YOL	*Yes*	**16,250**	**7,304 to 25,195**	-	-	**17,325**	**8,439 to 26,210**
LYOL	*Yes*	-	-	-	-	**17,865**	**9,875 to 25,855**

For variable definitions, including reference cases, see Table 3. For full regression output including p-values, see Appendix 6 in *Extended data*[42]. dy/dx: the marginal effect; the estimated mean association with outcome of increasing the value of the predictor by one point while holding all other values in the model constant. CI, confidence interval; CAPI, computer-assisted personal interview; EOLI, end-of-life interview; IADL, Instrumental Activities of Daily Living; ED, Emergency department; L2YOL, last two years of life; LYOL, last year of life.

25,195). Other variables positively associated with outcome were: older age; medical card entitlement; living in a town or city other than Dublin; diagnoses of cancer, heart disease or multimorbidity; and prior ED attendance. Negative associations were college education and engaging in regular physical exercise, which in this context is a proxy for unobserved general health. In the EOLI sample, the largest association was again 2+ IADLs (+ EUR 30,637; 20,287 to 40,987). Other positive associations were cancer diagnosis and multimorbidity. Negative associations were male sex, living outside Dublin, regular exercise and multiple prior ED attendances.

In the pooled sample, results were substantively consistent with the CAPI, reflecting the fact that these are 98% of observations in the weighted sample. The largest associations were again multiple IADLs (+ EUR 21,437; 12,763 to 30,112), and proximity to death variables in the last two years of life (+ EUR 17,325; 8,439 to 26,210) and in the last year of life (+ EUR 17,865; 9,875 to 25,855).

Discussion

Key findings

This paper presents the most comprehensive picture to date on individual-level health care costs for older people in Ireland. We found that, adjusted to end 2022, mean costs among people aged 55+ years were EUR 8,053, with a large differential between those in the last year of life (EUR 68,654), and not in the last year of life (EUR 6,624). Hospital costs accounted for over half of costs in all three sampling

frames. There was a very large skew in the data: the top 20% of users accounted for 90% of all costs at the population level, and the top 10% accounted for 74%. In multivariate regressions, multiple IADLs and proximity to death had the largest associations with outcome. In sensitivity analyses, our results are substantively similar for the IADL and proximity to death associations, and >95% of all associations in Table 7 have the same interpretation in these sensitivity analyses (Appendix 6)[42].

Interpretation

The large association between multiple IADLs and costs is not surprising, and in part reflects the high level of health care worker time that are required to support this population. Nevertheless, the magnitude of association, and in particular that this variable is more strongly predictive of costs than proximity to death, is somewhat unexpected and has important policy implications. As the population ages, and in particular as dementia becomes more prevalent, the number of people living with multiple IADLs will grow[33,56–58]. Optimising care and supports for this group, in particular to support ageing in place and to minimise avoidable acute hospital admissions and residential care costs, remains an urgent priority[29–32].

The significant differential between those in the last two years of life and not approaching end of life reflects a long-standing evidence base that proximity to death is a key determinant of health care costs. There were 31,184 deaths recorded in Ireland in 2019, of which over 28,000 (91%) occurred in people aged over 55 years[59]. The population-level costs of end-of-life care are therefore approximately EUR 2 billion annually. Total health spending in Ireland in 2019 was EUR 25.3 billion[60,61]. This suggests that the <1% of people who die each year in Ireland account for around 8% of health care spending, although the true ratio is sensitive to recent rapid increases in both inflation and public health spending, and the fact that our estimates likely undervalue total spend by using public service unit costs only. This ratio is consistent with what has been reported in other high-income countries[62]. The large projected growth in the number of older people dying annually as the population ages emphasises the urgent need to plan and fund palliative and end-of-life care services.

Some of the other associations were predictable in the context of prior literature. Older age is associated with somewhat higher costs compared to younger people (though this is heavily tempered by proximity-to-death dynamics, and more observable for social care than health care)[5]. Men have lower costs in the last-year-of-life cohort due to the higher prevalence of sudden death, but there is no apparent association in the whole population. Socioeconomic disparities in health are reflected in lower costs among those who stayed longer in education[63]. Medical card entitlements lead to higher health care use in the general population[64,65], but in the end-of-life cohort where entitlements are more universal, they have no relationship. This relationship between entitlements and costs is complicated by potential confounding by socioeconomic and health status; those entitled to a medical card are more likely to have care needs that are not captured in the model. Diagnoses of serious disease necessitate higher health care costs[66–68] and regular physical exercise protects against episodes of ill-health[69,70], although in our data this is likely not causal but reflects the better health of regular exercisers. Prior patterns of hospital admittance strongly predict costs[71]. One surprising result was the association between region and outcome: those living outside Dublin in other urban settings had higher costs in the general population, but both urban and rural dwellers had substantially lower costs than those in the capital in the end-of-life cohort. Complex patterns of use by geographical region are commonplace among older populations[72,73], and this warrants further investigation to pick apart issues of need, access and value[74].

While skew in health care costs is a long-established phenomenon, the distribution in our data is still unusual. The historic interest has been in an '80–20 ratio', where 20% of people account for 80% of spending, but we find that 20% of people account for 90%. Taking into account that our calculations are in the population aged 55+ years, and older people account disproportionately for health care spending, the ratio at the population level must be still more imbalanced. Ex ante identification of people who account heavily for health care costs, identifying and addressing low-value care, and reforming provision for an age of multimorbidity and ongoing supportive care are all strategies with enormous potential fiscal pay-offs, as well as improved outcomes for patients.

The estimation that hospital costs account for nearly 60% of total costs is higher than comparable data in England (50%)[75]. This is potentially associated with Ireland's historic reliance on acute care and weak primary care capacity, and implies opportunity to reduce hospital costs through more cost-effective models of community care delivery[16,21]. Such aims are consistent with the ongoing Sláintecare reforms.

Limitations

TILDA collects all CAPI data by self-report, and all EOLI by interview with a family member or friend, which may result in omissions and recall bias among both predictors and outcome. Absent a unique identifier in routine data, TILDA is nevertheless among the most powerful sources of individual-level data for understanding health care costs among older people in Ireland.

Our unit cost estimates do not take account of differential costs in private settings, which by volume account for approximately 20% of care in Ireland's mixed system[18,65]. This means that our total reported costs are likely underestimates, and that interpreting associations between outcome and variables strongly associated with use of private care (*e.g.*, health insurance, socioeconomic status) must be done with caution. TILDA collects frequency data on private hospital and home care use, meaning that future work can address this gap if credible unit costs of private care can be identified.

Proportion of use that is private among different allied and social care categories varies widely, and as such so does the public/private distinction. We are unable to quantify the distribution of costs between payers (public and private care, and out-of-pocket costs). Many hospital engagements in Ireland are 'day cases'; engagements not requiring an overnight stay. While TILDA captures ED attendances and same-day discharge following emergency admissions are included in our reported costs, we don't include diagnosis-specific costs for outpatient engagements or procedures but instead estimate resources at a flat unit cost rate. Healthcare Pricing Office costs for inpatient stays do not include superannuation, while unit costs for other types of care do.

Hospital costs account for a majority of overall costs, but unit costs for acute care are age/sex/diagnosis-adjusted national averages only. While we have adjusted for discharge status (alive/dead; see Appendix 1)[42], and age/sex/diagnostic profiles capture a significant proportion of proximity to death among those discharged alive, hospital costs are still highly heterogeneous within each age/sex/diagnostic category, reflecting myriad factors including physician and patient preferences, access, specific hospital setting, and discharge location options. Future work might address this to some extent; *e.g.*, HIPE records whether a person was discharged home or to a hospice or a nursing home. However, arising estimated costs would be contingent on additional unverifiable assumptions and so come with increased risk of new biases. The promised implementation of a unique identifier would provide 'true' individual-level costs in HIPE against which different cost mix methods in TILDA could then be benchmarked.

The COVID-19 pandemic complicated choice of an appropriate timeframe. For CAPI observations, we used Wave 5 as the most recent pre-pandemic wave (2018), and for EOLI observations, we used all pre-pandemic observations to maximise sample size in a group that has disproportionate influence on estimates. Our reported estimates reflect best understanding of health care costs among older people in Ireland in 2019, updated for inflation to 2022. The information provided in this manuscript and in the appendices equips readers to revise group averages using the CPI for health, and/or to weight at the population level for other years using CSO data, should they choose to do so. Parsing the effects of COVID-19 on general health care use, both during the heights of the pandemic 2020–2021, and into the future, have been examined to some extent in other TILDA analyses and are an important topic for ongoing study.

TILDA recruited a population-representative sample in 2009–2011, but attrition to Wave 5 (2018) may have undermined this representativeness. We weighted using age, sex and last year of life since these data are theoretically associated with outcome and easily available from the CSO. Prior weighting exercises in the TILDA CAPI have also incorporated education, marital status and geographical location to maximise generalisability[76]. While these data are available *via* the census for the CAPI, the last matching exercise by the CSO to the GRO was after the 2016 Census. Our strategy therefore reflects the best approach with publicly available data for all CAPI and EOLI observations. Future work may seek to improve the precision of weighting, for example by getting additional 'enabling' variables on decedents from the CSO's data controllers.

Conclusions

High-quality data on health care costs are essential to support monitoring, planning and evaluation of services, and the allocation of scarce resources to maximise public welfare. By combining newly available unit cost data in non-acute care, our own estimates of acute costs, and the rich data in TILDA, we present the most comprehensive picture to date on individual-level costs among older people in Ireland. We quantify more precisely some well-known relationships, particularly the high costs associated with end-of-life care, and also identify some potentially underestimated dynamics, in particular that multiple functional impairments appear a more significant driver of costs than age, diagnosis, multimorbidity or proximity to death. The derived estimates can inform multiple ongoing research studies and policy activities, as well as providing a foundation for future work, which should include consideration of private provider costs in Ireland's unusual mixed system.

Consent

Ethical approval for each wave of the TILDA study is obtained from the Faculty of Health Sciences Research Ethics Committee in Trinity College Dublin. Participants are provided with sufficient information to make an informed decision about their participation including advance notice of the study. Written consent is obtained for separate components of the study (i.e., interview, health assessment, blood samples); participants may refuse to take part in or withdraw at any time without justification. Ethical approval for the secondary analysis of TILDA data used in this study was part of this overall approval.

Data availability

Underlying data

Researchers interested in using regular waves of TILDA data may access the data for free from the following sites: Irish Social Science Data Archive (ISSDA) at University College Dublin (http://www.ucd.ie/issda/data/tilda/); Inter-university Consortium for Political and Social Research (ICPSR) at the University of Michigan (http://www.icpsr.umich.edu/icpsrweb/NACDA/studies/34315).

Replication of the results reported in this article requires access to the full TILDA dataset, which is held on secure servers at the study site at Trinity College Dublin (TCD). Researchers seeking access to the full TILDA dataset may apply to access the data on the TCD campus (tilda.tcd.ie); applications are considered on a case-by-case basis; all Stata do files and code employed in this paper will be made available to applicants on request.

Extended data

Open Science Framework: Appendices to 'Formal health care costs among older people in Ireland: methods and estimates using The Irish Longitudinal Study on Ageing (TILDA)'. https://doi.org/10.17605/OSF.IO/76SYK[42].

This project contains the following extended data:

- Appendix 1.docx (information on calculations of costs associated with inpatient hospital admissions in TILDA)
- Appendix 2.xlsx (characteristics of the sample, and those excluded per Figure 1)
- Appendix 3.docx (calculations of health care costs for older people in Ireland and distribution across the population)
- Appendix 4.docx (calculations of underlying composition of health care costs between primary and community care, hospital care, home care, residential care, and medications)
- Appendix 5.docx (summary statistics and distributions for total health care costs in CAPI waves 1–4)
- Appendix 6.docx (sensitivity analysis)
- Appendix 7.docx (diagnostic checks for model choice and collinearity)
- Appendix 8.docx (information on the medications costing exercise)
- STROBE checklist

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Current Peer Review Status: ? ✓ ✓ ✓

Version 1

Reviewer Report 13 October 2023

https://doi.org/10.21956/hrbopenres.14977.r36274

✓ **Sara Olofsson**
The Swedish Institute for Health Economics, Lund, Sweden

Review of "Formal health care costs among older people in Ireland: methods and estimates using the Irish Longitudinal Study on Ageing (TILDA)"

I would like to start by congratulating the authors on a well-performed and well-presented study. The work is of importance for policymakers as well as for future research. Overall, the study design seems well-constructed and outlined. It is easy to follow the authors' considerations behind the study approach and limitations are also well described. Additional material in the appendix (not reviewed) can make the result transparent and offer the reader additional insight. I believe that the manuscript is close to publishable as it is.

However, below are some suggestions for clarification:

1. The study is based on a sample enrolled in interviews. It is well known that this might create a selection bias. The authors also adjust for this by applying a weighting approach. They also refer to appendices/other articles for more information. As a reader it would be informative to state/discuss in the manuscript (1) what characteristics the enrolled sample differs most from the general population, and (2) whether is there a risk that those enrolled could differ in cost due to unobservable characteristics and what would that imply?

2. Predictors of costs are analyzed using multivariate regression. In these kinds of studies, it is often difficult to identify the causes of costs as there are often confounding factors. The authors use careful language but draw some conclusions that indicate that associations are interpreted as causes. The manuscript could perhaps benefit from making it more clear to the reader that although there may be significant associations, this might not mean this should be interpreted as a cause of higher costs.

3. Finally, some notes on the terminology. Health care is often differentiated from caregiving (home, residential) as they usually serve different purposes. However, sometimes they are difficult to separate. Maybe a brief note or discussion of this could be added to the manuscript. Also, formal care differs from informal care provided by relatives/friends.

Maybe I missed a clarification on these concepts, but if not, it would be beneficial to include them in the manuscript. Maybe it should also be highlighted in the discussion that informal caregiving could be substantial and that the true cost to society is therefore expected to be even higher.

Is the rationale for developing the new method (or application) clearly explained?
Yes

Is the description of the method technically sound?
Yes

Are sufficient details provided to allow replication of the method development and its use by others?
Yes

If any results are presented, are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions about the method and its performance adequately supported by the findings presented in the article?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Health economics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 10 October 2023

https://doi.org/10.21956/hrbopenres.14977.r36205

Rachel Milte
Flinders University, Adelaide, South Australia, Australia

Thank you for the opportunity to review this manuscript, which clearly reports this excellent piece of work. I find it makes a significant contribution to the literature in terms of healthcare costs among older people in Ireland, but also provides interesting findings making it of interest more broadly internationally. I find the data acquisition, preparation, and analysis and interpretation have all been undertaken with care and clearly a detailed understanding of the Irish health system

and the strengths and limitations of the data available, which are acknowledged and at times potential recommendations to address these in the future are presented in the discussion (which is fantastic to see, so many papers miss out on providing concrete and practical ways their work can be built upon in the future). I have some minor comments which it would be good to address for clarity.

Firstly, I find the use of the term multiple IADLs in the results strange - as I think you mean multiple impairments in IADLs as compared to having multiple IADLs. Secondly, I was unclear on the time to death variable less than 1 year - it seems this is solely based on whether they were part of the EOLI or CAPI interviews. But was there a chance that people in the EOLI interview lived for more than 1 year or than some people in the CAPI group died within 1 year? It seems that for the death within 2 years variable this was done by datalinkage - is there the option to do this for the 1 year variable and if so why was this not done? I think in this I am thinking about whether this variable represents the 'actual' costs associated with death, as compared to whether it is a cost associated with 'expecting death' in the next year? I would also like to see potentially trials of different models from the GLM family compared with the GLM with (these could be mentioned in the text and presented as an appendix) to check for the robustness of the results across different models. I find the discussion provides really clear and tangible implications for policy, and excellent suggestions for future research. I do hope that the authors go on and undertake some of this further research.

Is the rationale for developing the new method (or application) clearly explained?

Yes

Is the description of the method technically sound?

Yes

Are sufficient details provided to allow replication of the method development and its use by others?

Yes

If any results are presented, are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions about the method and its performance adequately supported by the findings presented in the article?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Dementia care, health economics, health services research

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 03 October 2023

https://doi.org/10.21956/hrbopenres.14977.r36272

John Mullahy
University of Wisconsin-Madison, Madison, Wisconsin, USA

This is an exceptionally careful and well-executed paper studying questions that are hugely challenging yet important to answer. The authors have written a forthright manuscript that details lucidly what they have done—or, in some instances, have not done—and why. Many assumptions and decisions must be made in such a micro-costing exercise and the authors have gone to great pains to be clear about the nature of these assumptions and decisions. Micro-costing exercises will generally be an amalgam of art and science and the authors have succeeded in making clear where the science ends and the art (i.e. assumptions) begins.

Given existing data it is difficult to imagine gleaning better insights into the nature and composition of healthcare costs among older people in Ireland than by learning from the results offered in this paper. The authors have evidently been excruciatingly careful in assembling their sample and have deployed what appear to be suitable empirical methods in their analyses.

I would like to pose several questions, more in the spirit of clarification than criticism.

1. The data from the EOLI are intriguing and permit insights into healthcare resource use in older populations that are often not available in other surveys. In light of the magnitudes of the costs in the EOLI subsample I might hope that the authors could shed some further light on its nature in the Methods section. It would be interesting to know, for instance, how well or poorly the demographics of the decedents in EOLI sample correspond to those in the main sample before weighting (the weighted results appearing in table 4), with concerns about possible non-random selection into the EOLI sample being prominent.

2. Do the authors have access to any supplemental data that would help readers estimate the extent to which the costs associated with the omitted categories (table 2) are large or small or trivial as compared with costs in those categories that are included?

3. On page 6 appears: "Any sample-eligible CAPI or EOLI that was missing two or more of these four categories was flagged and removed from primary analysis as having insufficient outcome data. For those interviews missing one or fewer of these categories, and or missing any other categories of health care frequency, we imputed age- and sex-adjusted medians." In general I am not a fan of imputation methods and in this instance would be keen to know how the results presented in the paper would differ from those obtained if subjects having missing data for any category were deleted from the analytical sample.

4. I am curious to know why the authors (p. 7) elected to use a power-link in their GLM analysis rather than the more-standard log-link. They allude to "information criteria" but a bit more

detail might be helpful.

5. On page 11 appears: "The composition of costs among non-zero users, across 20 quantiles of total health care costs in the pooled sample, is presented in Figure 5." Is this the only analysis in the paper that drops the zero-users or are there others? Either way the rationales for dropping zero-users in figure 5 might be made clearer.

6. Finally it is both obvious and defensible why the authors have undertaken a micro-costing analysis: Assigning currency values to different forms of healthcare utilization permits aggregation of the different categories of healthcare utilization. That being said I often suggest—and indeed am suggesting here—that in addition to their spending outcomes the authors also consider the merits of studying utilization data themselves as outcomes of potential interest. Such analyses would obviously need to be conducted category-by-category. But what such analyses can reveal is the extent to which variations in healthcare resource utilization are due to prices or quantities. This is perhaps a paper for another day but one whose merits might be given some thought.

Is the rationale for developing the new method (or application) clearly explained?
Yes

Is the description of the method technically sound?
Yes

Are sufficient details provided to allow replication of the method development and its use by others?
Yes

If any results are presented, are all the source data underlying the results available to ensure full reproducibility?
No source data required

Are the conclusions about the method and its performance adequately supported by the findings presented in the article?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: health economics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 25 April 2023

https://doi.org/10.21956/hrbopenres.14977.r33506

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Paddy Gillespie
Health Economics & Policy Analysis Centre, National University of Ireland, Galway, Galway, Ireland

Overview:
I would like to commend the authors on this excellent paper, which is the most comprehensive descriptive analysis of healthcare costs for older people that I have encountered in the Irish context. More generally, I believe that it makes a significant contribution to the literature relating to the nature, distribution, composition, and correlates of Irish healthcare costs. In particular, it covers a wide-ranging list of healthcare resources in its estimation of formal healthcare costs. This is far from a minor achievement given the historical paucity of available healthcare resource use and unit cost data in Ireland. The costing approaches applied to value each individual healthcare resource item appears to be pragmatically appropriate. In addition, the study includes an explicit consideration of proximity to death in its examination of the correlates of healthcare cost. This variable has been shown to be a significant driver of costs in the literature, but it is often omitted from applied papers of this kind given the difficulty in acquiring the data. To this end, the research team took on a number of additional and challenging lines of data collection, merging, and analysis, and the final paper is the richer for it. A minor criticism, which is related to these additional efforts in compiling the data, is that the paper does not flow as it might in places, but this is understandable given the need to describe the multiple methods employed. The authors employ appropriate statistical techniques for the multivariate analysis, although in places, they need to provide additional information. The extrapolation approach also appears to be appropriate. The authors clearly consider the limitations of their analysis, undertake sensitivity analysis, and highlight potential lines for future research. Finally, while the major contributions of the paper are descriptive in nature, this is not a flaw or limitation of the work. Indeed, this paper may prove to be a starting point in a future body of research that considers issues of causality as they relate to formal healthcare costs for older people in Ireland. This future work may be more impactful for policy and practice decision-making, but this paper provides a significant step forward. Congratulations to all of the team involved on the project.

I have included a number of suggestions below that the authors may wish to consider, as I believe they will go to further enhance the paper. I look forward to reading the authors' responses and to reviewing the next iteration of the paper.

I should note that I was unable to access the appendices (which may well be a problem of my own making). However, I do not believe this is detrimental to my review and recommendation overall. I am aware that some of my suggestions may be addressed in the appendices.

Key Points:

- ***Main Contribution***: The authors make a significant contribution in respect of the nature, distribution, composition and correlates of healthcare costs for older people in Ireland. This is clearly articulated in the paper.

- ***Main Multivariate Regression Result***: The authors highlight the both the *IADLs* and *proximity*

to death findings as the key results from the multivariate regression analysis, given their economic and statistical significance. I wonder would the authors be better served by placing the emphasis on the *proximity to death* variable? My rationale is as follows, but I would be happy to hear a counter argument from the authors if they wish to make one.

- The authors adopt the Andersen framework to inform their choice of independent variables for the multivariate regression analysis. This approach, which categorises variables as *predisposing, enabling, need,* and *prior use,* is appropriate and the authors faced the not-insignificant challenge of selecting a list of variables from those available within TILDA to represent these categories. In particular, I would imagine the selection of variables to represent the 'need' category was challenging, and the authors went with a limited, informed and sensible set.
- The selection of IADLs variable proved to be an important one. This is interesting not just of its impact on the formal care system, but also for the potential and related impacts on the informal care system. That said, I do wonder if the inclusion of additional or alternative 'need' variables would impact on the economic and statistical significance of this variable? Indeed, the choice of GLM family and link function may also influence this outcome (see below for further comments). My suggestion would be to frame the IADLs finding in the context of the Andersen 'need' category: i.e. it indicates that 'need' factors appear to be strong predictors of healthcare costs and not to emphasise it individually as the key take-away.
- The authors also include a variable for *proximity to death*, and I think this is the key independent variable and should be interpreted as the key finding from the multivariate regression analysis. It proves to be economically and statistically significant, but it also highlights the importance of this variable in such costing studies, and the need for researchers to try to capture it.
- This is not to say the IADLs and other results should not be highlighted, but I think the focus on *proximity to death* may prove to be a cleaner and more robust foundation stone for the paper.

- ***Summary Data for Healthcare Resource Usage and Individual Healthcare Costs***: As the authors suggest, their findings will be of interest to and use for future research projects. To this end, it would be helpful to report summary statistics (i.e. means, SDs, 95% Cis) for individual resource utilisation (e.g. GP, Hospital Inpatient Nights, OPD visits, etc.) and individual resource costs. These could be reported in the appendix (if they are not already).

- ***Descriptive and Distributional Analysis***: The authors present descriptive and distributional summary statistics of the total healthcare cost variable in tabular and graphical forms. As the authors suggest, these findings will be of interest to and use for future research projects. To this end, I think it would be valuable to include standard deviations and 95% confidence intervals for each of the mean cost estimates for the CAPI, EOLI, ALL samples in Table 5. The authors could also include 95% confidence intervals to Figure 2.

- ***Compositional Analysis***: The authors provide an informative graphical analysis of the distribution and composition of costs in Figures 3, 4 and 5. I wonder is there a way to include additional information to aid interpretation in the form of % of total figures for each decile (within or alongside the figures) of Figure 4, and € values for Figure 5? As mentioned, I could not access the appendix and the appendix may well be the best place for this data, but I think this is valuable information.

- ***Multivariate Regression Analysis***: The authors employ a GLM regression framework for the multivariate analyses. This is a standard and appropriate method for the statistical analysis of healthcare cost data, which can exhibit extreme skew and kurtosis in distribution. I think the authors need to provide additional information for the reader on the multivariate regression analysis (some of which may be presented in the appendix). In particular:
  - The authors should provide a rationale for the choice of GLM for the analysis of cost data.
  - GLM regression requires the selection of a 'family' and 'link' function. The authors used 'information criteria' to inform these choices. My understanding is that this approach is not quite correct. That is, the selection of 'family' is typically informed by a Modified Park test, and 'link' function by a combination of a Pearson correlation test, a Pregibon link test and a Modified Hosmer and Lemeshow test. I think that the authors should undertake these tests to make their 'family' and 'link' choices, and provide these results along with the regression results in Table 7 (or in the footnotes of Table 7).
  - The authors may wish to add further sensitivity analyses, which assume different 'family' and 'link' combinations, as results may be sensitive to this choice.
  - The approach adopted for the generation of standard errors in the regression analysis is also of interest. For example, given the nature of the TILDA dataset and how it is compiled, I wonder if there are issues relating to 'clustering' or 'hierarchical data' that need to be considered in the regression analysis? This information should be included and again, perhaps this is something that could be tested and explored in sensitivity analysis.

- ***Unconditional Quantile Regression***: Given that the authors rightly highlight the importance of the distribution of the estimated healthcare costs, and describe these results in the descriptive parts of the paper, I wonder if the authors considered conducting quantile regression to estimate and explore the associations between the independent variables and healthcare costs across the full distribution: e.g. deciles of the total healthcare cost distribution? While this would constitute additional analysis, I think it would provide complementary findings to those reported for research questions 1 and 2.
- ***Appendix:*** Please make these resources available

<u>Minor Points</u>:

Abstract:

- *Methods*: replace the term 'main dataset'; use the term '2022 prices';
- *Concussions:* align more closely to Conclusions section in the Discussion.

Methods:

- Table 2 and Figure 1 could be moved to the appendix.
- Provide more specific details on the imputation method employed (e.g. multiple imputation?).

Results:

- Update results to reflect suggested changes.
- Update tables to reflect suggested changes.

- Add further sensitivity analyses as suggested.

Discussion:

- Update as suggested: *proximity to death* variable should be the key variable of interest.
- The Andersen framework should be used to discuss the implications of the other regression findings.

Is the rationale for developing the new method (or application) clearly explained?
Yes

Is the description of the method technically sound?
Yes

Are sufficient details provided to allow replication of the method development and its use by others?
Partly

If any results are presented, are all the source data underlying the results available to ensure full reproducibility?
No source data required

Are the conclusions about the method and its performance adequately supported by the findings presented in the article?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Health Economics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.