Time to death and health expenditure: an improved model for the impact of demographic change on health care costs

MEENA SESHAMANI1,2, ALASTAIR GRAY2

1University of Pennsylvania School of Medicine, Philadelphia, PA, USA
2Health Economics Research Centre, University of Oxford, Oxford, UK

Abstract

Background: Obtaining well-founded estimates of the effect of demographic change on future health expenditures is a pressing issue in all developed countries. Thus far, expenditure projections have examined the effect of age on health care costs, but fail to account for the influence of remaining life expectancy on costs.

Objective: This paper seeks to create a more accurate projection model that considers the concentration of costs towards the end of life, and to compare this model with the more traditional approach that holds age- and sex-specific per capita expenditures constant.

Methods: We used a longitudinal hospital dataset which followed 90,929 patients aged 65 and older from 1970 to death, to create an economic model of hospital costs based on patient age and time remaining to death. We then applied the model to England population projections to predict the effect of demographic changes on hospital expenditures from 2002 to 2026.

Results: The decline in age-specific mortality rates over time postpones death to later ages, pushing back death-related costs. Accounting for this in expenditure projections gave a predicted annual growth rate of 0.40%—half of the rate predicted with a traditional method.

Conclusions: Using richer data and more refined methods than have hitherto been employed, this study strongly confirms that the pressure of population increases and ageing demographic structure on hospital expenditures will be partially countered by the postponement of death-related hospital costs to later in life—a finding consistent with emerging epidemiological evidence, and heartening for policy makers and physicians alike.

Keywords: health expenditures, projection, ageing, England, hospital cost, elderly

Introduction

Forecasts of the impact of an ageing population on health expenditures are traditionally made by multiplying projected population numbers in the different age–sex groups by current age- and sex-specific per capita costs [1, 2]. Because these costs rise steeply in older age groups, this method typically forecasts substantial increases in health expenditures to keep up with population ageing. However, in recent years severe doubts have been raised about this forecasting method [1]. In particular, it has been suggested that the epidemiology of ageing cannot be ignored: if additional years are lived in health, as has been demonstrated in recent international epidemiological literature, [3–8] then most medical care may actually be concentrated towards the end of life.

Studies from the USA [9–11], Netherlands [12], Switzerland [13] and England [14] have all confirmed that age is a much less significant determinant of health care expenditures than proximity to death. Consequently, to predict accurately the effects of ageing on national health expenditures, these effects of proximity to death should be quantified and incorporated. This was done by HM Treasury for the Wanless Report projections of future expenditures in the National Health Service [15]. Using Scottish hospital activity rate data for people in their last year of life (decedents) and people not in their last year of life (survivors), projections were made including the effects of impending death as well as other factors such as technological change. These suggested that the percentage of gross domestic product (GDP) invested in health care might rise from 6.5% in 2002–03 to 11.3% in 2022–23 [15], but this prediction would have been substantially higher had changes in proximity to death not been considered.

However, the Wanless Report only considered the effect of approaching death on health care costs in the last year of life, while it has been shown that the effect could extend further back [14, 16]. Also, the study assumed that the
effects of age and proximity to death on health care costs would remain stable over time—an assumption which may be invalid, as management of old and dying patients is continually re-evaluated and adjusted.

To make improved estimates of the effect of demographic change on future health expenditures in England, we used English longitudinal hospital data to derive a more detailed economic model of the association between hospital costs and proximity to death. The extremely long time frame of the dataset (from 1970 to 1999) enabled us to estimate this association up to 24 years before death, while the large cross-sectional spread of the dataset (90,929 patients) enabled us to assess whether different calendar year cohorts showed a changing relationship between age and cost and between proximity to death and cost over time. Incorporating these findings, we were able to derive a more sophisticated model than hitherto possible.

**Methods**

**Data**

The Oxford Record Linkage Study (ORLS) began in 1963, collecting statistical abstracts longitudinally by patient for all hospital inpatient and day case care, with linkage to birth certificates and death certificates in a defined geographical area of Oxfordshire, England [17]. The population of counties in the ORLS area are broadly representative of England and Wales as a whole [18]. We selected those people who were aged 65 years and over at the end of 1970, and tracked their general and psychiatric hospital and death records to 1999. We chose to include only those people in the older ages to avoid problems of right censoring: mortality data from 1970 English life tables estimate that 96.4% of people who were 65 years old would have died within 29 years, and even with declines in mortality in recent years, life tables with 2000 mortality rates still predicted 91.2% to die. Given that many people in the dataset were older than age 65 years in 1970, it is anticipated that very few patients survived the end of the dataset. Most of the people without a death record would have migrated out of the areas covered by the dataset, and so were excluded from the analysis. The average age in 1970 of the excluded patient cohort was 72.5 years, which was significantly younger than the average age of the included cohort (75.0 years), reflecting increased likelihood of migration or survival.

The cleaned dataset contained 90,929 patients: 36,712 men and 54,757 women (Table 1). We used 1997–99 cost data collected by the Department of Health from all hospitals in England to obtain a weighted average cost per inpatient day specific to each specialty. 26.8% of patients (25,678) did not have any hospitalizations from 1970 to death. The proportion of patients who died in hospital (53%) or nursing home (16%) versus private address (30%) corroborated with available mortality statistics collected by the Office of National Statistics [19].

**The hospital costs model**

We developed a longitudinal economic model which examined annual hospital costs per person in relation to patient age, sex, number of years until death, marital status, social class, hospital diagnosis, cause of death, place of admission, place of discharge, and calendar year [20]. Using a two-step approach, a probit model was first run to see how the variables described above affected the annual likelihood of being in hospital, and then a linear regression model was run to see how these variables affected the annual costs of patients who had been hospitalized. Multiplying the probability of being in hospital by the costs once in hospital provided us with estimates of average yearly hospital costs for different patient characteristics. We found that approaching death led to a rise in hospital costs that was significant as far back as 15 years prior to death [20]. Hospital costs in the last year of life rose from age 65 to 85 but decreased thereafter, consistent with previous literature [9–11]. We then repeated our models with three cohorts, patients who were aged 85 and older in 1970, 1980 and 1990, to see if results changed by calendar year. The pattern of costs based on time to death were consistent across the 1970, 1980 and 1990 cohorts, but the decline in costs seen in patients older than age 85 was mitigated over the calendar years, possibly due to more intensive treatments, better access to care, and less reliance on nursing homes. In the projections reported below, we held the effect of age on hospital costs in the oldest old constant over time. In sensitivity analyses, we simulated a continuation of the trend towards more intensive care for the oldest old.

**The projection model**

We obtained age-specific per capita hospital cost figures for 1999–2000 from the Department of Health. 2002-based population projections by single-year ages for males and females separately were provided by the Government Actuary’s Department for England from 2002 to 2040, incorporating predictions on changing mortality, fertility (birth cohort sizes), and migration rates over time. First, we divided up each age and sex group by time to death—from 1 to 15+ years prior to death—using age- and sex-specific mortality rates, assuming that all migration occurred at the end of the calendar year and that immigrants were subject to the same mortality rates as English residents. For the population aged 65 years and older, we calculated the predicted yearly per capita hospital cost using the economic model described above, for each age, sex, and time to death category, holding all other patient characteristics constant. (We scaled up the cost figures to match the more recent Department of Health figures.) For the younger ages, we could not directly predict costs from our economic model because it was designed on a population aged 65 years and older. Instead, we estimated what the per capita costs would be at different

---

**Table 1. Descriptive statistics for individuals extracted from the Oxford Record Linkage Study for the analysis [mean (SD)]**

<table>
<thead>
<tr>
<th>Sex</th>
<th>No. of patients</th>
<th>Age at death (1970 to death)</th>
<th>Hospital days (1970 to death)</th>
<th>Hospital cost (1970 to death)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>36,172</td>
<td>76.2 ± 5.8</td>
<td>33.3 ± 56.9</td>
<td>£8,901 ± £16,090</td>
</tr>
<tr>
<td>Female</td>
<td>54,757</td>
<td>78.8 ± 6.0</td>
<td>43.3 ± 70.4</td>
<td>£11,730 ± £21,329</td>
</tr>
<tr>
<td>Both</td>
<td>90,929</td>
<td>77.8 ± 6.1</td>
<td>39.3 ± 65.6</td>
<td>£10,605 ± £19,465</td>
</tr>
</tbody>
</table>
times from death, using the age-specific per capita cost figures provided by the Department of Health and the time to death relationship seen with the 65 year olds in our ORLS dataset. Given that there were very small proportions of people in the last year of life in these younger age groups (0.2%), this approximation will not greatly influence our expenditure calculations.

Multiplying the per capita costs by the population numbers in each age, sex and time to death group and summing within each calendar year provided new national estimates of hospital expenditures from 2002 to 2026. As a point of comparison, we repeated the predictions holding age-specific per capita expenditures constant at the values provided by the Department of Health. We then reran the entire model to focus only on expenditure changes associated with increased longevity after age 65 (controlling for the effects of changing birth cohort sizes, migration, and survival to age 65).

Results

The total population in England was predicted to increase at an annual rate of 0.38%, from 50 million in the year 2002 to 55 million in 2026. Concurrent with the overall population growth was an ageing of the population, with increased proportions of people dying at older ages (Table 2).

The concentration of costs in people in the last year of life was noticeable; while decedents comprised 1% of the population in the year 2002, they used 28.9% of hospital expenditures. Comparing the age groups, the cost of dying was most noticeable in the oldest age group. Over time, with the decline in age-specific mortality rates, decedents made up a smaller percentage of the population and expenditures of the different age groups (Table 3).

Due to the concentration of costs in the last year of life, as age-specific mortality rates declined over time and death was postponed, the real average age-specific per capita costs of the older population decreased (Figure 1). This finding corroborated previous work with Medicare data [21].

Calculating national expenditures using per capita costs adjusted for proximity to death, we estimated an annual growth rate of 0.40% between 2002 and 2026. This was approximately half of the rate estimated without adjusting for proximity to death (Figure 2). As is evident in Figure 2, the discrepancies between the traditional forecasting method and updated forecasting method were initially small, but quickly widened over the time period of projection. Over this period, there was also a shift in expenditures towards the middle-aged (45–64) and towards the oldest old (Table 2).

Examining the isolated effects of increased longevity after age 65, we found ageing played little independent role in generating additional hospital costs over time. Most of the increase in hospital costs for the older populations due to demographic change will stem instead from the surge in birth cohort sizes post-WWII (the ‘baby boom').

Table 2. Share of population and hospital expenditures by age group, 2002 and 2026, England

<table>
<thead>
<tr>
<th>Age group</th>
<th>% of population 2002</th>
<th>% of population 2026</th>
<th>% of expenditures 2002</th>
<th>% of expenditures 2026</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–4</td>
<td>0.03</td>
<td>1.54</td>
<td>0.02</td>
<td>1.02</td>
</tr>
<tr>
<td>5–15</td>
<td>0.01</td>
<td>0.65</td>
<td>0.01</td>
<td>0.44</td>
</tr>
<tr>
<td>16–44</td>
<td>0.09</td>
<td>3.83</td>
<td>0.07</td>
<td>3.10</td>
</tr>
<tr>
<td>45–64</td>
<td>0.56</td>
<td>18.97</td>
<td>0.47</td>
<td>16.48</td>
</tr>
<tr>
<td>65–74</td>
<td>2.35</td>
<td>43.06</td>
<td>1.68</td>
<td>36.81</td>
</tr>
<tr>
<td>75–84</td>
<td>6.24</td>
<td>55.94</td>
<td>4.63</td>
<td>51.44</td>
</tr>
<tr>
<td>85+</td>
<td>15.90</td>
<td>64.63</td>
<td>13.47</td>
<td>63.04</td>
</tr>
<tr>
<td>All ages</td>
<td>1.02</td>
<td>28.88</td>
<td>1.02</td>
<td>27.98</td>
</tr>
</tbody>
</table>

Table 3. Percent of population and hospital expenditures attributable to people in their last year of life, 2002 and 2026, England

<table>
<thead>
<tr>
<th>Age group</th>
<th>% Age group in last year of life 2002</th>
<th>% Expenditures 2002</th>
<th>% Age group in last year of life 2026</th>
<th>% Expenditures 2026</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–4</td>
<td>0.03</td>
<td>1.54</td>
<td>0.02</td>
<td>1.02</td>
</tr>
<tr>
<td>5–15</td>
<td>0.01</td>
<td>0.65</td>
<td>0.01</td>
<td>0.44</td>
</tr>
<tr>
<td>16–44</td>
<td>0.09</td>
<td>3.83</td>
<td>0.07</td>
<td>3.10</td>
</tr>
<tr>
<td>45–64</td>
<td>0.56</td>
<td>18.97</td>
<td>0.47</td>
<td>16.48</td>
</tr>
<tr>
<td>65–74</td>
<td>2.35</td>
<td>43.06</td>
<td>1.68</td>
<td>36.81</td>
</tr>
<tr>
<td>75–84</td>
<td>6.24</td>
<td>55.94</td>
<td>4.63</td>
<td>51.44</td>
</tr>
<tr>
<td>85+</td>
<td>15.90</td>
<td>64.63</td>
<td>13.47</td>
<td>63.04</td>
</tr>
<tr>
<td>All ages</td>
<td>1.02</td>
<td>28.88</td>
<td>1.02</td>
<td>27.98</td>
</tr>
</tbody>
</table>
Finally, we allowed for changes over time in age-based practice patterns, increasing the intensity of use among the oldest old in later years. Doing so only increased our growth rate from 0.40% to 0.43%, leaving the expenditure projections that included proximity to death still well below more traditional projections.

**Discussion**

**Healthy ageing and the compression of costs to the end of life**

The findings reported above demonstrate the importance of considering remaining time to death as a major demographic driver of hospital costs when estimating the future health care needs of a population. We estimate that, for the population aged 65 and over in 2002, the 5% of patients in the last year of life generated approximately half the hospital expenditures for that age group.

Since imminent death is a main driver of costs, lower mortality rates and rising life expectancy can be expected to push down average real per capita hospital expenditures in each population age group, holding other factors constant. This economic result follows in part from the epidemiological theory that with increased life expectancy, morbidity is delayed at least slightly, such that persons within a given age group are healthier and will cost the health system less in future years. The traditional projection approach that keeps age-specific per capita costs constant would not pick up this dynamic aspect of ageing. Additionally, postponement of death to the older ages may mitigate population-level hospital costs, as dying in the oldest old costs less, possibly due

---

**Figure 1.** Average time until death and predicted average real per capita cost for the population aged 65+, 2002 to 2026, England.

**Figure 2.** Projections of aggregate hospital costs, traditional versus proximity-to-death models, 2002–2026.
to shifts in care to long term care and social services, or physician reluctance to pursue acute interventions. Hence, our results differ significantly from those obtained by more traditional forecasting methods, which predict a more substantial impact of demographic change on future health expenditures.

Considerations
It should be stressed that the models described above focus specifically on the impact of population ageing on health care costs, and do not include the important effect of changes in technology. Differential technology diffusion by age group may also compound demographic effects; for example, improved surgical and anaesthetic techniques now permit more varied surgeries at older ages. Expenditure projections that include both the impact of population ageing and of technological change should take this interaction into consideration.

The models presented above only projected hospital expenditures. Analyses in other sectors, such as nursing home care and general practice, are hindered by the lack of suitable longitudinal datasets. The effects of age and proximity to death on costs in these sectors may not necessarily corroborate those found with hospital costs, particularly for nursing home care, where use increases with age. However, hospital costs predominate in total health expenditures, and even with the inclusion of other social service costs, studies have still found a concentration of costs towards the end of life [22, 23]. Therefore, adding these other components may modify, but is unlikely to negate, the findings reported here. Finally, we fully recognise that budgetary constraints, policy objectives, or other supply-side forces will also affect future health care expenditures.

Conclusions
Using richer data and more refined methods than have hitherto been employed, the analyses described here strongly confirm that changes in age-specific health service use related to proximity to death must be taken into account when determining the impact of demographic changes on future health expenditure projections. The pressure of population increases and ageing demographic structure on hospital expenditures will be partially countered by the post-mortality effects of ongoing care. The pressure of population increases and ageing demographic structure on hospital expenditures will be partially countered by the post-mortem management of death-related hospital costs to later in life. In our enthusiastic pursuit of healthy ageing, this finding is consistent with emerging epidemiological evidence, and should be heartening for policy makers and physicians alike.

Key Points
- Morbidity and health care costs may be concentrated towards the end of life, and therefore the costs of ageing may actually reflect the costs of impending death.
- This paper uses a more robust economic model that includes both the effect of age and the effect of proximity to death to project the impact that population ageing will have on hospital expenditures in England from 2002 to 2026.
- Increasing longevity postpones death-related costs. Projections that consider this effect predict half the annual expenditure growth rate of traditional projection models that hold age- and sex-specific expenditures constant over time.
- Proper inclusion of the effects of time to death is critical for more accurate assessment of the effect of population ageing on health care costs.

References
A national census of care home residents

CLIVE BOWMAN, JOANNE WHISTLER, MARK ELLERBY

BUPA Care Services, Bridge House, Outwood Lane, Horsforth, Leeds LS18 4UP, UK

Address correspondence to: C. Bowman. Fax: (+44) 113 381 6250. Email: bowmanc@bupa.com

Abstract

Background: the medical and dependency characteristics of UK care home residents have not been well described. This undermines care commissioning, development and regulation. Data to inform policy and practice are needed.

Objective: to survey the dependency and clinical diagnoses of 16,043 people resident in the 244 care homes distributed across the UK managed by the largest provider of care in the UK.

Results: (i) Return rate of 97% (15,483 returns suitable for analysis). (ii) 25% were ‘residential’ and 75% in ‘nursing’ care. (iii) Medical morbidity and associated disability rather than non-specific frailty and social needs had driven admission in over 90% of residents. (iv) More than 50% of residents had dementia, stroke or other neurodegenerative disease. (v) Overall, 76% of residents required assistance with their mobility or were immobile. 78% had at least one form of mental impairment and 71% were incontinent. 27% of the population were immobile, confused and incontinent. (vi) Considerable overlap in dependency between residential and nursing care observed: only 40% of those in residential care were ambulant without assistance and 46% were incontinent.

Conclusions: the practicality of acquiring information on care home residents has been demonstrated. The care needs of people in care homes are largely determined by progressive chronic diseases. A single assessment and commissioning at the point of entry to care services is unlikely to address changing needs. Alternatives to institutional long-term care should only be considered in the context of current resident profiles, the practicality of providing alternative models and likely projected population needs.

Keywords: geriatric assessment, long-term care, diagnosis, dependency, public policy, elderly, residential care, nursing home care

Introduction

Development and resourcing of services for older people have principally been targeted at maximising independence and avoiding admission to long-term care through active intervention, rehabilitation and care in the community, whilst the development of long-term care has been relatively neglected [1, 2]. The paucity of information regarding present and future long-term care provision undermined the report of the Royal Commission on Long Term Care [3]. Subsequently, limited data on care home residents have emerged from the Health Survey for England 2000, which drew on interviews with over 2,400 people [4]. It reported that, of those aged 65 and over, 4% were resident in care homes: a percentage similar to that in the 1991 Census of England and Wales. Overall, 75% of all residents in care homes were severely disabled and a high hospital utilisation rate by care home residents was noted. Acute hospital usage