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Health Care Management Science

A Structured Review of Long-Term Care Demand Modelling

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Abstract

Long-term care (LTC) represents a significant and substantial proportion of healthcare spends across the globe. Its main aim is to assist individuals suffering with more or more chronic illnesses, disabilities or cognitive impairments, to carry out activities associated with daily living. Shifts in several economic, demographic and social factors have raised concerns surrounding the sustainability of current systems of LTC. Substantial effort has been put into modelling the LTC demand process itself so as to increase understanding of the factors driving demand for LTC and its related services. Furthermore, such modeling efforts have also been used to plan the operation and future composition of the LTC system itself. The main aim of this paper is to provide a structured review of the literature surrounding LTC demand modeling and any such industrial application, whilst highlighting any potential direction for future researchers.

1. Introduction

Long-term care (LTC) comprises of the health and social support services provided to those with chronic illness, physical or mental disability to help them both obtain and maintain an optimal level of functioning. In recent times, the topic of long-term care (LTC) has received increasing attention *(Brau & Bruni, 2008)*, particularly from policy makers *(Martini, Garrett, Lindquist, & Isham, 2007)*. In part, this appears to be largely due to the belief that changes in population demographics this century as a result of high birth rates in the post-war period, together with an increasing probability of surviving into older age *(Tamiya, et al., 2011) (Spillman & Lubitz, 2000)*, will further increase the burden on healthcare systems to provide LTC to elderly patients. Furthermore, a decrease in the ability of family-support networks to assist those in need of LTC could be cited as an additional pressure for many already overstretched LTC systems *(Pavolini & Ranci, 2008)*.

Several researchers have proceeded to pose serious questions surrounding both the ability of existing LTC systems to cater for potentially significant increases in the number of elderly patients *(Peng, Ling, & Qun, Self-rated health status transition and long-term care need,, 2010)* and the long-term viability of current models of funding. Within the literature a number of models have been proposed concerning the future pattern of demand for care and, in the majority of cases, have highlighted any implications for cost and resource use under different assumptions surrounding potential changes in socio-economic variables. In this paper we refer to such models as long-term policy models (LTPM).

Whilst LTPM have been used inform public health initiatives and support the policy debate surrounding future funding of LTC, in the majority of cases it is in fact at the local rather than national level where LTC is coordinated. At this level local and regional planners, typically operating over one to two year time horizons, coordinate the care that is to be delivered among different service providers and health or social care organisations. In the case of England and Wales, this is most likely to involve private sector care homes.

Even though demand modeling is critical for planning local budgets; investigating scope for changes in patterns of service; and in the design of contracts with service providers, the aims and objectives of local planners can be quite distinct from those at the national level and thus gives rise to a different modeling approach. In this paper, such models are referred to as short-term operational models (STOM). One challenge in developing STOM is that data at the local level often lacks sufficient quality, detail and volume to be able to generate reliable projections of patients and their future care needs. One reason for this is that much of the data collected about such patients may in fact be stored in paper based records, go unrecorded in the case of informal care and or lie in the hands of private sector organisations.

The aim of this paper is therefore to provide a structured review of the modeling efforts surrounding the development of LTPM and STOM in LTC. Since the literature on demand modeling in LTC is quite extensive, we have restricted our review to papers published in English and from 2005 onwards. At the same time, LTC has undergone a number of reforms over the last couple of decades, with significant changes taking place to the UK system of care during 2006-2007. We argue that such reforms cast doubt on the validity of using previous models

for demand prediction given that are quite often based on fundamentally different models of funding and service delivery. We hope that in this respect this paper will help researchers and practitioners understand the core developments in LTC demand modeling and the state-of-the-art methodologies, in addition to helping them to identify ways in which they can manage their future costs. For example, accurate forecasts enable planners to determine the amount of resources to set aside for care needs in the coming years and can also help them decide the mixture and duration of any long-term LTC contracts they might want to enter into so as to secure time or volume based discounts.

The paper is organised as follows. In section 2 we provide additional background information surrounding the demand for and expenditure on LTC around the world and report on how such expenditure has evolved over time. We also clarify the rationale for modeling demand for LTC and provide an overview of some of the challenges and complexity the problem presents. In section 3 we reaffirm the overriding objective of our paper and put this into context with the wider problem of modeling demand for LTC. Section 4 details the methods we used to identify relevant literature for use with our structured review, including our search strategy and inclusion criteria. Our results and findings are presented in section 5. Discussion of the results, together with the issues raised and the potential direction for future research work is provided in section 6.

2. Background

2.1. Expenditure on Long-Term Care

Internationally LTC systems around the world differ substantially in many key areas, including: provision; access to care; coverage and method of funding, and as a result make direct comparison between them problematic. However a common feature across many health care systems is that expenditure on LTC, including contributions from the private sector, is massive. In England, between 2010 and 2011, expenditure on LTC by councils was reported to be £8.92 billion *(HSCIC, 2012)*. During the same period the NHS was estimated to have spent £4.81 billion, roughly 4% of the total NHS England budget, on LTC related health services.

In the case of the US in 2000, 65% of the total expenditure on LTC (US$ 123 billion) was met through the Medicaid and Medicare federal state based health programs *(Freedman, Martin, & Schoeni, 2002)*. By 2004, expenditure on LTC in the US had risen to US$ 134.9 billion nationally, with Medicaid accounting for 35.1% of the cost, despite the US government's overall share of the total expenditure falling by 5.7% to 59.3% *(Congressional Budget Office, 2004)*. A report in 2009 for FY2008 found that LTC spending through Medicaid alone had passed the US$ 106 billion mark *(Burwell, Sredl, & Eiken, 2009)*. In Japan, the total LTC expenditure for FY2006 was US$ 54.7 billion and represented a growth in the LTC budget of 100% since the year 2000 following an overhaul in the system of funding *(Olivares-Tirado, Tamiya, Kashiwagi, & Kashiwagi, 2011)*.

Elsewhere a number of similar observations on the high levels of expenditure have also been noted. In the case of the Netherlands, "the first country to introduce a universal and mandatory insurance program for LTC", the expenditure on LTC in 2007 was €17.6 billion *(Van Den Berg & Schut, 2010)* (approximately US$ 24.27 billion as of November 2011) with 65% of the total expenditure allocated to the support of the elderly and chronically ill. On the other hand in Hong Kong, where no formal LTC system exists, the nation as a whole was estimated to have spent around 1.4% of its GDP on long-term related care in 2004 *(Chung, et al., 2009)*. A report into the expenditure on LTC in 2000 within OECD countries found that although there were large variations in spending as a percentage of GDP, public and private sector combined spending accounted for an average of 1.21% of GDP across the OECD with an interquartile range of 0.70% *(Haynes, Hill, & Banks, 2010)*. By 2009 the average spend in the OECD had risen to 1.3% of GDP *(OECD, 2011)* although we should point out that a number of reforms took place in this period in which LTC has shifted its focus towards meeting the needs of those with the highest levels of care needs.

2.2. Ageing and LTC Usage

Given the already high levels of spending and the upward trend in LTC expenditure witnessed in parts of the world to date, there is a clear need to assess how the demand and cost burden of LTC will evolve over the coming years. At the very least, this information may then feed into the current policy debate surrounding future methods of funding and decisions regarding the amount and composition of available LTC services - both at the local and national level. We note that, while the discussion on the extent of the relationship between ageing of a society and its LTC expenditure continues, the observation that current LTC systems exhibit a high proportion of elderly

patients is likely to be of concern to policy makers given that this is the very section of society expected to dramatically expand in the coming years.

In the US, it is suggested that the population 65 or over will rise from 40 million to 89 million by 2050 and that half of all countries worldwide will have an elderly support ratio of less than 5 *(Population Reference Bureau, 2010)*. Similarly in China, estimates show that the proportion of the population over 65 could rise from 10% in 2000 to 27% by 2050 *(Riley, 2004)*. Even if ageing per se does not bring about an increased need for LTC, all things being equal, a decline in the elderly support ratio does appear to suggest that the growth in expenditure on LTC will at the very least need to slow so as to remain sustainable.

2.3. Modelling the Demand for LTC

In response to such concerns and in recognition of the uncertainty with respect to the potential future demand and cost of care, a number of authors have attempted to model the operations of several LTC systems so as to produce forecasts of usage patterns and associated cost. However, producing accurate forecasts of the demand for LTC is highly complex *(De Block, Luijkx, Meijboom, & Schois, 2010; Karlsson M. , Mayhew, Plumb, & Rickayzen, 2006)*. Firstly, there is no single treatment or service used by patients to which practitioners can refer to for modeling purposes. This in itself may in part explain the high proportion of papers than have restricted their modeling efforts to a single care type or indeed setting.

The range of diseases frequently associated with LTC is vast and can include both mental and physical disabilities. To address this issue, authors have produced disease centric models which have focused on specific disease areas, such as dementia, where sharp rises in the number of sufferers has driven increased attention. Thirdly, data covering the social care services and informal care provided to LTC patients are often characteristically difficult to obtain *(Kinosian, Stallard, & Wieland, 2007)* and indeed link to other health-based services that the patient may have received. In essence, this can result in underestimation of the true cost of care and creates issues for modelers that wish to establish the progression of patients through the system.

Finally, like many healthcare systems LTC is not stagnant and has been host to a number of fundamental reforms *(Pavolini & Ranci, 2008)*, not least with respect to policy, scope and coverage. Where policy has changed in quick succession, modelers face the dilemma of taking into account the influences of past changes on increasingly limited intervals of historical data before being able to provide robust projections.

In terms of the drivers of LTC demand, we have observed an increase in studies that have investigated the effect of factors other than ageing to explain fluctuations in the demand and cost of LTC. Within this category of papers we can identify two distinct categories - those which aim to relate aggregate demand and cost of LTC with socio-economic variables and those which aim to understand the type and or level of LTC consumed by an individual patient. In the case of the former class of papers, such factors include: prevalence rates of disease *(Macdonald & Cooper, 2007)*; rates of mortality *(Comas-Herrera, Whittenberg, Pickard, & Knapp, 2007)*; cultural attitudes towards care of the elderly *(Kim & Kim, 2004)*; future patterns of care and general improvements in the level of health *(Karlsson M. , Mayhew, Plumb, & Rickayzen, 2006)*; and living status *(Martikainen, et al., 2009)*. In the latter class of papers, factors identified include: proximity to death *(Murphy & Martikainen, 2010) (Weaver, Stearns, Norton, & Spector, 2009) (De Meijer C. , Koopmanschap, Bago D'Uva, & Van Doorslaer, 2011)*; type and no of diagnoses *(Huang, Lin, & Li, 2008)*; level of disability *(De Meijer C. A., Koopmanschap, Koolman, & Van Doorslaer, 2009) (Imai & Fushimi, 2011)*; and marital status *(Woo, Ho, Yu, & Lau, 2000) (Wong, Elderkamp-de Groot, Polder, & Van Exel, 2010)*.

The degree to which authors have incorporated these additional factors varies considerably. Papers that focus on measuring the amount of LTC resources consumed by individuals or cohorts of patients, for instance number of nursing hours, often place greater emphasis on factors driving individual patient need. On the other hand those which quantify the number of future patients pay closer attention to aggregate health and social trends. We also point out that since a number of LTC systems provide LTC care on the basis of need, as defined by current health policy, additional attention needs to be paid to this aspect of LTC given that all things being equal it is policy which may allocate care on the basis of specific health related factors including need. Viewed in this way LTC policy acts as a rationing agent for care and to a large extent independent of other factors related to LTC demand.

3. Objective

To our knowledge we can find no structured review of the quality, quantity or consistency with respect to the methodologies proposed to forecast the future demand and cost of LTC services. We have therefore synthesised this structured review so as to address two key questions: what are the historical developments in LTC demand forecasting and what progress has been made in LTC demand forecasting since 2005. By presenting the forecasting models in this way we aim to assist LTC planners in anticipating future levels of LTC demand so as to be in a better position to more efficiently manage LTC services and plan for the future.

4. Method

The procedure and reporting of this structured review is broadly inspired by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis *(Moher, Liberati, Tetzlaff, & Altman, 2009)*.

The goal of the literature search was to identify papers which primarily focused on modeling the demand for LTC. Due to the fact that the definition of LTC is itself broad, we have used additional keywords as shown in the appendix to encapsulate papers which may focus one or more specific areas of the LTC system, including nursing home care, and in recognition of differences in LTC terminology across the world. In addition, we searched for papers that modeled LTC at the national or regional level, regardless of whether a formal LTC system was in place and the mode of funding for care. Papers published before 2005 together with those papers not available in English were excluded so as to limit the scope of the review to the most recent methodological developments. An initial screening of the papers found using some of the keywords used revealed a number of research models that largely focused on determining the demand for LTC insurance or the willingness of individuals to pay for LTC. Whilst forecasting demand for LTC insurance is clearly a related problem, we were more interested in models which provided insight into demand for tangible LTC services and hence such papers were also not included.

4.1. Search strategy

To find potentially relevant papers we searched PubMed (including MEDLINE) and ISI Web of Knowledge. In addition to these databases we also searched government websites and sites related to health care policy for documents related to future LTC needs, including: the Department of Health; Organization for Economic Development and Cooperation; Medicare; and British Medical Association. As LTC is referred to by different names around the world we used a wide range of different terms when carrying out our search in addition to the policy names of the most widely known funding programs for LTC, including NHS Continuing Healthcare in the UK.

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4.2. Inclusion criteria

Articles found within the search results were screened according to their title and abstract. The full text of the original article would be requested if and only these data items were believed to fall into the scope of the review. For each article in the search we reviewed the introduction, results and discussion as a basis for deciding whether the paper was suitable for inclusion in the analysis. The data abstracted from the studies which met the inclusion criteria included: the stated aims and objectives of the paper; source of data used for model development; country of origin; methodology; categories of patients modeled; findings and results; presence of any bias in the studies and stated level of forecast error.

We included papers published in peer-reviewed journals or published as a full paper in conference proceedings provided they contained (1) a model in which an ou was made to predict the future number of arrivals into LTC or incidence of LTC needs or (2) a model of future expenditure on LTC or a related service or (3) a model of patient progression through the LTC system and (4) the topic or setting related to population health or health service delivery. Papers for which two reviewers were independently in agreement were included; if there was doubt a third reviewer arbitrated.

5. Results

Our search of ISI Web of Knowledge across all keywords identified 9,526 potential papers, 3,439 of which were published in 2005 or after. By applying an initial screening test of title and abstract we disregarded 2,922 papers that were believed not to be relevant as demand modeling was not mentioned. Using the keywords under

consideration and the ability to filter papers by type we could find no review papers that dealt explicity with the topic of LTC modelling and current best practice. To an extent we found that a large proportion of the papers screened contained a short review on previous modelling work and we have therefore made an attempt to summarise their general findings within the background of this review. In addition, we found 4 papers where no English translation was available. We next screened the discussion and results section of the remaining articles to check whether the paper made a methodological contribution, in terms of a theoretical development or industrial application, which left us with 92 papers for which the entire article would be requested and analysed for potential inclusion.

The search of PubMed (including Medline) found a total of 15,629 papers across all keywords used. Using a date filter 10,281 papers were removed because they were published before the first of January 2005. Screening of abstract and title removed a further 8,019 papers. We next screened articles by their discussion and results section, to see whether each paper made an attempt to model the LTC demand process in some way, which left us with 288 papers for which the full article would be requested.

Across both databases we retrieved and considered 380 articles, 9 of which were removed due to being duplicates and 354 that did not fall into the scope of the review when the full description was considered. This left us with 17 papers that met our inclusion criteria and would therefore be included in the final structured review.

5.1. Study characteristics

Table 1 presents characteristics of the papers included in the structured review.

Table 1. Characteristics of papers forecasting demand for LTC health services

	Studies (n=17)	% Studies (100%)
Country studied		
UK	6	35%
Sweden	2	12%
China	1	6%
Hong Kong	1	6%
Taiwan	1	6%
EU (UK, Germany, Spain and Italy)	2	12%
Japan	1	6%
Finland	1	6%
Canada	1	6%
USA	1	6%
	17	100%
Forecasting time horizon		
Less than 5 years	1	6%
>= 5 years and < 10 years	1	6%
>= 10 years and < = 20 years	1	6%
21 years+	14	82%
	17	100%
Core forecasting methodology		
Extrapolative	6	35%
Simulation	7	41%
- Cell-based macro	6	35%
- Dynamic/Stochastic	1	6%
Transitional/Markovian	3	18%

	17	100%

5.2. General observations

Across all papers we found that the majority used a forecasting time horizon of several decades, with the average, median and standard deviation in years equal to 31.25, 21 and 14.168 respectively. It should be noted that such statistics may be skewed due to our review containing several papers corresponding to developments and adaptations of one of the most prominent UK LTC demand forecasting models – in which a common time horizon has been used. The longest forecasting horizon used within our review was 51 years (Wittenberg, Comas-Herrera, Pickard, & Hancock, 2004) whilst the shortest was 5 years (Ker-Tah & Tzung-Ming, 2008) (Manton, Lamb, & Gu, 2007). The longer time horizon seems to indicate that since 2005 more work has been carried out in LTPM compared with the STOM.

Within our review, papers that studied the UK system of LTC represented the largest proportion of the research literature. Outside of the UK, the international interest in LTC modeling is evident given the number and range of studies carried out in countries across the globe, for instance: United States (Manton, Lamb, & Gu, 2007); Sweden (Batljan, Lagergren, & Thorslund, 2009); Canada (Hare, Alimandad, Dodd, Ferguson, & Rutherford, 2009); Finland (Hakkinen, Martikainen, Noro, Nihtila, & Peltola, 2008); Japan (Fukawa, 2011); Taiwan (Ker-Tah & Tzung-Ming, 2008); Hong Kong (Chung, et al., 2009); and China (Peng, Ling, & He, 2010). Even though the focus of each paper was typically a single LTC system or country, our review did contain two papers that modeled and compared the projections of LTC cost and demand across several countries, including the UK, Germany Spain and Italy (Comas-Herrera, et al., 2006) (Costa-Font, et al., 2008).

The stated or implied aims of the papers were difficult to classify in the strict sense due to the fact that authors often stated several aims and objectives. In addition nearly all papers shared a common objective of modeling the impact of changes in demographics on LTC. We did however find that on the whole, using a fairly broad definition, the aims of the papers fell into one of three key categories. The most common aim surrounded investigating costs or demand of LTC under different demographic or socioeconomic scenarios (Hare, Alimadad, Dodd, Ferguson, & Rutherford, 2009) (Wittenberg, Comas-Herrera, Pickard, & Hancock, 2004) (Comas-Herrera, et al., 2006) (Karlsson M. , Mayhew, Plumb, & Rickayzen, 2006) (Caley & Sidhu, 2011) (Costa-Font, et al., 2008) (Hakkinen, Martikainen, Noro, Nihtila, & Peltola, 2008). (Peng, Ling, & He, 2010).

An additional class of papers placed more emphasis on investigating the impact of changes in non-demographic factors related to LTC, including rates of disability, educational level and life expectancy, on future LTC resource use and cost (Malley, et al., 2011) (Manton, Lamb, & Gu, 2007) (Batljan, Lagergren, & Thorslund, 2009) (Ker-Tah & Tzung-Ming, 2008) (Lagergren, 2005).

Finally, a third group of papers analysed the demand or cost of a specific LTC service or set of diseases associated with a corresponding need for LTC treatment (Comas-Herrera, Whittenberg, Pickard, & Knapp, 2007) (Hare, Alimadad, Dodd, Ferguson, & Rutherford, 2009) (Comas-Herrera, Northey, Wittenberg, Knapp, Bhattacharyya, & Burns, 2011) (Macdonald & Cooper, 2007).

A key input for many of the papers reviewed was data concerning future population projections across different gender specific age bands. In the majority of cases, studies used secondary sources of data obtained from their respective national bodies, including the UK's Office of National Statistics (ONS), Statistics Canada, Statistics Sweden, and the US Census Bureau. In the case of the UK, prior to 2007, population projections were the responsibility of the Government Actuary's Department and hence a number of papers in our study refer to their 2005 projections. Since 2007, such projections are now the responsibility of the ONS.

Whilst the United Nations (UN) population projections are commonly used in other areas of healthcare policy research, only one paper in our review used the UN worldwide population projections. One explanation is that the UN's population projections are not sufficiently broken down according to the demographic age profiles typically used in LTC modeling. Furthermore, the only other papers to use population projections that were not produced by their respective national agencies were those that made an attempt to compare forecasted costs across different EU member states. In such cases the European Eurostat population projections were used so as to provide a fair basis for comparison. One additional reason for studies using their own nation's population projections could be due to the UN projections using very general assumptions about keys trends, such as fertility rate being the same across

Europe, that empirical evidence disputes (Office for National Statistics) and the ease at which national projections can be broken down to the specific regions or localities of interest to LTC modelers.

During model construction, we found that population projections were most commonly supplemented with additional secondary data sources from public sector bodies and research institutes. Such data sets included: projected or current rates of disability (Ker-Tah & Tzung-Ming, 2008), household composition (Comas-Herrera, Whittenberg, Pickard, & Knapp, 2007), historic LTC care costs (Karlsson M. , Mayhew, Plumb, & Rickayzen, 2006) and hospital registers (Hakkinen, Martikainen, Noro, Nihtila, & Peltola, 2008). We could only find two studies which gathered their own data from primary sources, including a paper which used telephone surveying of care home residents was carried out to gauge the incidence of Dementia (Macdonald & Cooper, 2007) and one in which a Delphi process was used to gather expert opinion on assumptions surrounding future Dementia care (Comas-Herrera, Northey, Wittenberg, Knapp, Bhattacharyya, & Burns, 2011).

From a methodological standpoint, the most frequent way in which LTC demand and cost projections have been derived is through discrete time simulation modeling. Out of the 17 papers included in our review 7 (41%) used either micro or macro simulation as a basis for making their LTC forecasts. We also found several other methodologies that have been adapted to model LTC demand, including: trend extrapolation, markov chains and grey systems theory. For the remainder of the results section we outline the core features of the models proposed under each of the methodological categories and in chronological order.

5.3. Simulation modelling

Simulation modelling concerns the creation of a digital representation of a system of interest using parameters that are obtained by close observation of the system or via expert judgment (Morgan, 1984) Through reconfiguration of the parameters the operation of the actual system, together with its behavior, can be inferred (Maria, 1997).

The first investigation, in the time period under consideration, using simulation as its core modeling methodology was reported by Commas-Herrera et al (2006). In this paper, separate cell-based macro-simulation models using a common structure were developed for each of the four EU countries, namely UK, Germany, Spain and Italy, to project future expenditure on LTC services. Here, each cell represented a cohort of individuals by well-defined age-gender characteristics. Modeling the situation in this way appeared to stem from the observation that the LTC systems studied exhibited substantial differences in a number of key areas; in particular with respect to the level of means-testing for services, the level of targeting of resources to specific categories of dependency, the composition of care services offered in particular settings and indeed the definition of dependency. Therefore simulation represented a clear way to be able to represent these very different yet complex systems of LTC delivery, from an initial need for LTC identified through to service delivery and ongoing treatment.

The aims of the work were stated in terms of being able to increase understanding of the sensitivity of LTC expenditure in Europe with respect to changes in factors that are indeed found to drive it. Specific driving factors that were considered included: trends in life expectancy; trends in functional dependency; future availability of informal care and trends in unit costs of care. Outputs were generated according to EU projections on the number of older people (above 65) in each of the age, gender and level of dependency for each cell. In the second stage estimates of the probability usage of each type of care - informal, formal and institutional care – according to each dependency level combined with the unit costs of care in each dependency level was used to arrive at the total expenditure needed to manage all LTC cases.

Projections of expenditure were then made according to different assumptions about the future population composition and how other key trends may evolve. It was found that expenditure projections were sensitive to the future number of older people and dependency rates, whilst highly sensitive to anticipated unit costs of care and availability of informal care services. One issue not taken into consideration is the increasing healthcare expectation which could have further modelling implications.

Simulation modeling of LTC demand using the cell-based approach, a design originally inspired by the work of the PSSRU also known as the PSSRU LTC model, is a recurrent theme in current LTC demand forecasting. Indeed it has been the basis of a number of models that have adapted it in several ways to investigate specific LTC modeling problems. For instance, the demand for LTC services as a result of cognitive impairment was reported by Commas-Herrera et al. (2007) using population projections from the UK Government's Actuarys Department for 2005 on the number of older people until 2031. Future marital status and projections of rates of cohabitation, from the UK's Office for National Statistics, in conjunction with data concerning the prevalence of cognitive impairment taken from a cognitive function and ageing study carried out in 1998, was first to identify gender, age, cognitive impairment and disability specific cells. An additional component was then developed to assign a probability to the

specific amount of care required by each cell group according to historical rates of LTC usage for each cell. Once again, the final stage attributed unit costs of care to each cell for each year to arrive at projections of total expenditure. As in (Comas-Herrera, et al., 2006) the authors reported that such projections were highly sensitive to assumed growth rates in real unit costs of care and the availability of informal care from family and friends.

Closer inspection of the PSSRU model's projections under different official population projections and demographic scenarios was carried out by Costa-Font et al. (2008). In this work, variability in expenditure projections we calculated by running each country specific model on both the Eurostat 1999 based population projections for that country, namely the UK, Germany, Italy and Spain, and each countries' official statistics from their respective national bodies. Different demographic scenarios including levels of future fertility, which might influence the number of informal care givers, together with mortality and migration were analyzed according to whether they were assumed to be high or low in the future. For instance, high migration could have an effect on the future supply of informal caregivers whereas high mortality was assumed to increase the proportion of the elderly population that would have a need for LTC. For Germany and the UK, the difference in projected expenditure for LTC constituted 1% of GDP under the low and high population estimates. Except for Germany, the projected numbers of elderly people exhibited little deviation between national projections and the model's projections using the Eurostat data.

Chung et al. (2009) adapted the PSSRU model further to address the need of understanding the factors that drive individual need for specific LTC services and generate expenditure projections for Hong Kong as a whole. Additional emphasis was placed on the need to understand the relationship between changes in demographic factors and overall expenditure on LTC. In contrast to the PSSRU model, they used separate logistic regression models to derive the probability of individuals within each age-gender specific cell requiring a specific service as in the 2004 Thematic Household Survey 2004. The regression model itself was based on historic data obtained from the Hong Kong domestic accounts from 1989-2002, in conjunction with Hong Kong specific population projections from 2007-2032 and the Hong Kong annual digest of statistics. The probabilities obtained for service usage within each cell was then calibrated according to current observed levels of LTC usage before being multiplied by future population projections in each cell to obtain usage in future years. Costs were reported as a percentage of real GDP, adjusted according to different real annual growth rates in unit costs of care. Further scenarios assumed different changes in the demographic structure up until 2032.

The authors' key findings were that demographic changes were more significant in explaining changes in LTC expenditure compared with real unit rises in the cost of care. It was also found that the expenditure on institutional care could rise from 37% in 2004 to 46% in 2006 if existing patterns of service continued, although expenditure could be contained within 2.3-2.5% of total GDP in 2036 if some institutional care could be substituted by home and day care services.

Whilst the parameters used in the PSSRU model and its derivatives were largely driven by historic data, Comas-Herrera et al. (2011) have also demonstrated how it can be used to incorporate expert opinion. In this case, a variant of the PSSRU model called the PSSRU CI model was developed to test the PSSRUs original projections for a specific class of patients – namely those with cognitive impairments (CI). The authors used a Delphi-style approach to gauge the opinions surrounding future incidence of CI and related patterns of care from 19 experts in the field of dementia and Alzheimer's disease. The results of the Delphi panel were then incorporated into the model as assumptions.

In contrast with previous work, the responses collected favored a slight fall in the incidence of dementia over the next 50 years and a freeze in the numbers of people in care homes. The result would be an increase in the numbers cared for at home or in the community, which would be met by an increase in the qualifications and pay of care assistants. Overall this led the projection model to the conclusion that although expenditure on this group of patients will rise as a result of increases in wages to between 0.82% and 0.96% of GDP in 2032, the effect is less so than in the base case whereby expenditure could be as much as 0.99% of GDP at the end of the period.

A related problem to estimating expenditure on LTC is determining the proportions of the total cost paid by different economic actors. In the UK for instance, LTC provided on the basis that the need for care is due to an underlying chronic condition is paid for in total by the National Health Service (NHS). Elsewhere the extent to which an individual has to contribute towards their can vary widely as can the services covered by government funded schemes. In their paper Malley et al. (2011) extended the PSSRU model to partition the expenditure projection for each cell according to different sources of funding. This was achieved by developing a simulation model of the assets and future incomes of older cohorts of individuals according to previous rounds of the Family Resources Survey. When the cells and the cohorts from the PSSRU and CARESIM models were matched up the authors found that LTC expenditure would rise faster than expenditure on pensions. This higher growth rate was

found to be partly a consequence of the expansion in the numbers of very old people (those aged 85 and over) compared with the older population as a whole that receive a pension. Indeed, this is the very section of society where need for LTC has been found to be the greatest.

While static macro-simulation models have been the most prevalent simulation models in LTC, whereby underlying assumptions are constant throughout the projection period, Fukawa (2011) has shown how a more dynamic methodology can be used to trace time-based household composition and thus deliver a more accurate picture of each elderly person's respective living situation over time. Although the initial population used in their model was taken from a sample of census data for Japan in 2005, from an initial set of simulated data households were transitioned according to the probabilities of specific live changing events, which for instance included death, marriage, the birth of children and divorce to arrive at the number of persons with specific attributes in each year. At the end of the period, this information was used to calculate the expected long-term care costs for each household according to how many elderly people were present and their respective level of disability. In many ways this approach has a lot of merits given the high probability of an individual's condition worsening over time and giving rise to different care needs. Thus rather than using forecasts of population by age-gender specific brands, they ultimately derived their own population composition and designed a way for annual changes in key socioeconomic variables to be incorporated – albeit by an adjustment of the relative transitional probabilities.

Some of the findings from the work included the observation that future LTC expenditure was heavily dependent on future service usage by dependency level. Furthermore, according to the model the proportion of the elderly population that stay in LTC institutions will increase. The expectation that the fertility rate will stay constant at 1.3 throughout the period has the implication of increasing the ratio of parents to adults aged 40 and above. This study has therefore highlighted the possibility of more extensive informal care provision by younger relatives of LTC patients.

5.4. Grey Theory

In our structured review, we found only a single paper using grey theory as its core methodology. In essence grey theory is a methodology that can be used to approximate the relationships between variables in conditions of incomplete or very limited information. Grey models take the following general form, GM(n, m), where n represents the order of differencing used to smooth the data series and m the total number of predictors (Yao, Forrest, & Gong, 2012).

Ker-Tah & Tzung-Ming (2008) used a grey-inspired methodology, specifically a GM(1,1) model which represented a forecasting framework to estimate the disability rate for the aged section of Taiwanese population using time as the independent variable and one level of differencing. Under the assumption that the LTC population of Taiwan was equal to the disabled proportion of the elderly population, they forecasting future values of the disability rate and multiplied it by the expected elderly population in future years to obtain future demand.

Although the GM(1,1) model can appear somewhat naive in its assumptions, given the short length of time of the forecast, the fact that aggregate yearly data on expenditure was used and the overall aim of the model it represented a reasonable choice. Unlike previous work it more closely resembled the observation that the rate of disability in the population is variable and, in Taiwan's case, steadily increasing over time. Furthermore, this particular approach doesn't require a large body of data in which to base its projections which would seem to satisfy real world data constraints. Compared with historical values of LTC expenditure, the average absolute percentage error was found to be 7.27% under the grey model and hence demonstrated reasonable fit with the underlying data. At the end of the data period the grey model predicts that LTC in Taiwan will increase from 38,805 individuals receiving care to in 1991 to 606,305 by 2011, primary as a result of an increase in the disability rate for the elderly population.

5.5. Markovian and transitional models

Markov chains belong to a broader class of stochastic modelling methodologies than can be used to model the behavior of a stochastic process at discrete-time intervals. Essentially, they allow for the next realisation of a variable in a sequence to estimated based on a stationary set of probabilities associated with the likelihood of the variable assuming a particular future value (Winston, 1993)

Karlsson et al. (2006) analysed the sustainability of expenditure on LTC in the UK in light of expected changes in health status among the elderly population. The methodology was based on an extension of an earlier disability

model, proposed by Rickayzen and Walsh (2002), whereby cohorts of individuals by age and level of disability are transited in time, according to a markov process, into steadily worsening levels of disability. Crucially in this study, the transition probabilities were calculated at the start using current disability free life expectancy and other related mortality data but were updated at each period according to perceived trends in healthy life disability. To generate total future expenditure on LTC and the associated resource need, levels of care and associated services used were estimated for each cohort and multiplied by the respective costs so as to arrive at the total resource requirement for each cohort.

In their work the authors considered the integration of different assumptions surrounding mortality, levels of disability in the elderly population and the speed at which disability worsened by adjusting the respective values in the transition matrix. It transpired that as in previous LTC studies, assumptions of future disability were critical to the overall projections of both cost and service use. An additional result was that that if female care-giving patterns converged to those of males then under the baseline health improvement scenario there could be a shortage of between 10 and 20 million hours of LTC care giving per week in the UK by 2040.

Hare et al. (2009) studied the future number of LTC patients among different home and community care categories in British Columbia (BC) using a deterministic multi-state markov model. In this methodology, 10 care categories were defined across home and community care, 8 of which represented publically funded packages whilst the remainder represented care funded by private means.

Estimates of the number of people in each age range specific care category, together with the transitional probabilities for individuals moving between different packages of care were then estimated using historic data on service usage. Even though data on publically funded care were available from the BC Ministry of Health, little was available for non-publically funded care and so the authors used a telephone survey of usage across all care home facilities in BC as an approximation.

Using the ratio of publically funded to non-publically funded care packages, the total number of patients transitioning between different packages of care were calculated before being partitioned between the publicly funded and non-publically funded packages. Transitional probabilities were assumed to be fixed over the forecast range and estimates of future service usage were obtained by adding the incremental addition in the forecasted population at the beginning of each period. One weakness of this approach was that it largely based the transitional probabilities on historic data, including a period where demand for LTC in BC far outstripped supply, and that the model performed poorly when the numbers of privately funded cases were removed owing to the fact that a large proportion of LTC patients use a mixture of both publically and privately funded services.

Unlike previous studies that have used medical diagnosis and the extent to which a person needs assistance with activities of daily living as a basis for estimating level of individual disability, Peng et al. (2010) used self related health status collected from a sample of elderly people aged 80+ from the Chinese Longitudinal Healthy Longevity Survey in 1998, 2000 and 2002. In this case the transition between worsening levels of health across 5 different age bands between 80 and 100+ was modeled as a non-homogeneous Markov process, one for each of the genders and for each initial starting state of self reported health status. They considered that a response of "poor" health would identify a person as having a need for LTC, although individuals in the study also had an option of selecting "very good, "good" and "fair". The basis for this choice was because the relative risk of mortality was greatest, by the Mantel-Haenszel test statistic, between the fair and poor groups in the majority of the gender-age cohorts studied.

For a given start and end period, the authors transitioned individuals through time and noted the overall time each person spent in the "poor" health state. At the end of each period, the difference between their age when they entered the poor state and their estimated life expectancy was considered the number of years of unhealthy life expectancy - where LTC would be needed. By multiplying by the average annual LTC cost in China for an individual they arrived at the projection of total LTC costs.

The study highlighted how for men in China with very good or good reported self health, the probability of them maintaining their health status or changing to very good health is higher than that of women, but the result is the opposite when men are in fair or poor health. One issue is that by using self reported health status the percentage of the oldest Chinese requiring LTC was estimated at 44% while if defined by the notion of ADL then the proportion fell to 32%, given that care is provided on the later basis it could quite overstate true costs. Furthermore, the authors also assumed that transition rates between worsening states were constant throughout the period and thus may offer less precise results if there are underlying changes in the health status of the Chinese population.

Chahed et al (2011) used data from NHS continuing care patients in London between 2005 and 2008 to estimate the survival pattern and movement of patients in LTC. In this case, a continuous time markov model is used to capture the flow of patients between different care states and overall time in care, with the final state

corresponding to death of the patient. Demand projections were produced by considering the number of patients still likely to be in one of the non-death states at a given future time horizon in light of the fitted transition probabilities. In their approach the authors proposed using three distinct care states to represent the LTC system whilst in practice several different care pathways were known to exist. Similarly, the small sample size of certain categories of patients limited their application to just two groups of LTC patients - namely physically frail and palliative patients.

5.6. Extrapolative models

By an "extrapolative methodology", we are referring to a model whereby the principal method of generating forecasts of LTC demand or cost is through the application of historic trends to future population projections.

In Lagergren (2005) the ASIM-III model was proposed, a model which contains both a retrospective and prospective component to predict LTC usage across Sweden. The retrospective component, described in (Lagergren M. , 2005), although linked to LTC demand forecasting focuses on establishing the level of LTC need by population subgroup by studying its historic consumption. The prospective part, which is the attention of our review, addresses the need to understand how such consumption may vary in the future given specific assumptions about prevailing health trends that may be relevant. A key feature of the research is the recognition that future LTC need depends largely on the extent to which systems of informal care can be relied upon is highlighted.

Using the underlying simulated estimates of LTC consumption by gender, age group, civil status and degree of health the author obtained usage rates of three tiers of LTC services, including 3 levels of home or community help and a single institutional category. In this case, the levels of community support were defined by the number of hours of assistance required per day. The author then applied population projections, obtained from Statistics Sweden, covering the years 2005-2030 for each cohort and by multiplying with the corresponding estimate of LTC usage by group in 2000 obtained forecasts of the numbers of people requiring LTC. Although marital status has been shown to be a relevant factor in driving need for LTC, the authors were unable to obtain population projections by marital status and estimated this by linear extrapolation per 5 year age group and gender in the period 1985-2000.

In order to assign costs to the number of people requiring care in each subgroup, the authors used logarithmic extrapolation to derive levels of ill health and the associated level of LTC service usage based on survey data from the Swedish National Survey of Living Condition 1975-1997 and using fixed prices of care at 2000 levels. Different assumptions surrounding how levels of ill-health may improve or worsen can be incorporated by adjustment of the probabilities of different levels of ill-health across subgroups of the population, in the base case the authors assumed continued improvements in ill-health until 2020 where based on expert judgment it was believed to remain constant until the end of the forecast horizon.

A related methodology that also used survey data to obtain estimates of the incidence of disability was carried out by Macdonald & Cooper (2007). In this research, the focus was much narrower in the sense that only future costs and demand for home care placements by those suffering from dementia were considered.

In this study, the authors used the findings from a survey which reported the results of a mental state examination from a sample of 445 residents across 157 non-EMI (non- elderly mentally infirm) care homes in the south-east of England. The incidence of dementia among elderly patients (here aged 60 and above) from the survey was then linked to the total number of older people in care homes and the overall prevalence of dementia across the UK. The resulting age and gender specific incidence rates were then applied to future population projections provided by the Government Actuary's Department (GAD) population projections. Weaknesses of this particular study related to the fact that incidence for the UK was estimated on the basis of a survey carried out in a single region of the UK, the results of which may not be comparable with other areas of the UK where specific differences in funding arrangements or the supply of available places may exist. Indeed given supply constraints for LTC in the UK, such incidence rates may more closely resemble historic activity and not the underlying demand for dementia related care.

Manton, Lamb, & Gu (2007) investigated the observed decline in the disability rate for the US population and implications for LTC spending using data from enrollees in the US Medicare programme. In their work, samples of people aged 65 and above were taken from several National Long-Term Care Surveys between 1982 and 1999, surveys which directly draw samples from computerized Medicare enrollment files. Not only did each survey detail the costs and services delivered to each individual, they also contained a set of measures relating to the extent to which each person required help to perform six activities of daily living (ADL) and 10 instrumental activities of daily living (IADL). To this data, several additional variables describing the level of difficulty with physical performance of certain tasks and sensory limitations were also added.

An issue incorporating the disability data into the forecasting model related to the observation that many such indicators were correlated with each other and that the matrix of all disability measures, where each row represented an individual's patient, was sparse. The authors used latent class models (LCM) to reduce the disability measures into 7 distinct and homogeneous groups. Using the prevalence of these 7 disability groups estimated at each yearly interval, future Medicare costs are projected for 2004-2009 using age specific population projections applied to the estimated cost of care in each of the disability groups.

Owing to the fact that individuals may not be present in care for the entire year, perhaps due to death, the authors used an inverse survival function to weight their costs appropriately. Several variations were considered, including where the LCM of disability was taken for a specific year and used to estimate costs in the future assuming the disability rate would be constant in future years. A more dynamic approach used the changes in the LCM model between two time periods to model future costs.

Hakkinen et al. (2008) played more attention to the proximity to death in estimating the future care costs of the elderly where it was found that 55.2% of total health expenditure on those 65+ in Finland was due to LTC. Data used comprised of a 40% sample of the Finish population linked to hospital registers, death registers, social insurance and the Finish hospital benchmarking project. Although their projection of future care costs was not limited to LTC, they estimate costs due to LTC and non-LTC separately by firstly calculating the likelihood than an individual is a LTC patient. This was achieved using a logit model with age, gender, days from 31st December 1998 until death and an indicator if they died period to the end of 2002. Variants of this model included additional socio-economic data, such as income and region. A second model, using ordinary least squares, was then fitted to the resulting LTC costs of care over the period relating to the each individual patient.

The results of the model fitting showed that time to death and age were more significant in explaining LTC costs compared to just age on its own. Population projections by age-gender were obtained from Statistics Finland and used to extrapolate expenditure on LTC for the years 2016 to 2036 using the obtained gender-specific age-expenditure profiles and proximity to death. The authors found that for the year 2036, compared with an approach that didn't take into account proximity to death, total health care expenditure in Finland would 12% higher.

Weaknesses in the study related to the fact that LTC patients include only those that have been in receipt of care for at least 3 months. As a result, it may fail to capture costs due to respite and or palliative services. Furthermore only services provided by 24-hour institutions were considered and no attempt was made to break down the costs of LTC into their various components.

In neighboring Sweden Batljan, Lagergren, & Thorslund (2009) studied the link between educational status of the elderly and the need for LTC. Using the Swedish national survey of living conditions (SNSLC) carried out in the period 1975-99, they classified the educational status of the elderly population into one of three groups. In this case the low group represented those with less than 10 years of education whilst for the high group it was more than 11. Logistic regression were then fitted to estimate differences in the prevalence of severe ill health, specifically a health state that would require LTC, by different age, gender and educational level cohorts. The importance of including education level was stated in terms of being able to incorporate different mortality and morbidity differentials according to changing educational level.

By applying demographic extrapolation and taking into account educational level they developed several models, each representing a different scenario as to future overall levels of mortality and morbidity. A separate model for both males and females was used, to aid the alignment of results with how Swedish population projects are provided, and for each gender separate models were created reflecting improvements in mortality and declining mortality for both sexes. The authors also assumed that by age 35 the education level of an individual was fixed.

Their key finding was that severe ill health among higher levels of educational level was less than for lower levels. Dramatic increases in the educational level of the population between 2000, 2020 and 2025 will place a greater proportion of the population in higher levels of education. Specifically the percentage of women in the low category of education level will fall from 60% in 2000 to around 16% by 2025. Given that higher levels of educational level coincide with a decreased observed likelihood of severe ill-health, the effect of including educational level acts to counterbalance the effect of ageing on LTC needs and in one cases reduces the percentage of those in serve ill-health to 18% of the level estimated when only age in taken into account assuming continuing downward trends in mortality. Even when mortality rates are assumed to rise, the effect of increasing educational level was shown to reduce the percentage of SIH to less than half that when using age alone by 2035.

Proximity to death and the effects of changing life expectancy on future LTC demand in the UK was investigated by (Caley & Sidhu, 2011). In recognition of the limited availability of LTC data outside of the acute sector, they used published estimates of LTC by age provided by the Department of Health to generate estimates of total expenditure in light of future population projections. The effect of increases in life expectancy was considering

by postponing the cost of LTC by expected increases in life expectancy (provided by the Office for National Statistics), whilst a third model took into account how much of the additional life expectancy was spent disability free. To relate these estimates to cost, the authors revised the future age bands to put it in terms of cost at the present time. For instance, if life expectancy in the 80 year old group was expected to rise by 5 years but only 1 of these years was expected to be disability free, they would represent the same cost in present terms as an 84 year old individual.

Even though all three of their models highlighted an expected increase in LTC related costs by the end of the period, the percentage increase in the second model was only 47% of the increase estimated in the first model whilst this figure was 57% in the case of the third. Ultimately therefore, the authors have illustrated the potential for LTC models to significantly overstate cost if changes in life expectancy and or the associated years of disability free life expectancy are not considered.

6. Discussion

Based on the findings from our structured review, it is clear that LTC demand modeling has been an active area of healthcare research. Although the bulk of the studies included in our review have focused their attention on the UK system of care, LTC modeling is very much an international issue given the range and number of studies that have taken place elsewhere in the world. Regrettably we were unable to find any published modeling efforts, within the scope of our review, from the South American and Australasian continents even though LTC care systems are prevalent in these areas. It may be that the scope of our review has been overly narrow, in that we didn't include papers that focused on the more general area forecasting healthcare spend on the elderly population, a related problem to LTC forecasting, but our attempt here has been to focus on explicit LTC studies.

One of the key differences between the approaches we have included in our review, at the very highest level, relates to how the initial patient population is generated. In situations where less patient level data is available, or where quality is anticipated to be low, modelers appear to have placed more emphasis on using demographic estimates of future population cohorts to generate their underlying demand. On the other hand, where data permits a more transitional approach may yield more accurate and arguably more reliable projections of local demand and cost.

Depending on the precise definition used, LTC can encompass many different types of care and treatment services. As we have seen the extent to which different services are included in models that attempt to project future usage of LTC depends very much upon the country studied and in several cases on the availability of data concerning usage of said services. One issue is that whilst some of the services provided are clinical in nature, others more closely resemble social support and thus the modeler has to decide where the boundaries lie – particularly when determining the cost of providing care to each patient.

For example, although many LTC patients will be in receipt of specialist drugs – perhaps for the purposes of palliative pain management – little attempt has been made thus far to include those costs within LTC cost projections. Similarly, analysis of acute hospital activity within the LTC patient population has mostly concerned the identification of LTC sufferers rather than for the purposes of proportioning such costs to overall LTC expenditure. This is unusual as data relating to acute services are potentially one of the very few detailed sources of LTC episodic activity. The implication of not investigating these additional factors in more detail could lead to understating the true cost of LTC borne by society.

One possible way of incorporate some of these elements, especially in the case of the UK, would be to derive the drug usage patterns of those in receipt of LTC by matching GP practice records with historic prescribing activity. Alternatively, it may be possible with the help of LTC clinicians to derive a typical drug package for different LTC patients and use this information to add in the cost of drugs to existing models of LTC patient demand. However, to say that LTC models are fundamentally flawed due to lack of high quality data is a somewhat simplistic explanation to what in fact points to a broader issue within LTC demand modelling.

Firstly, although necessary data may be available modelers face what we propose to call the LTC boundary identification problem – that is to say that even when potentially relevant sources of health and social care data can be identified it is not clear which costs and what proportions of them should be incorporated into LTC planning models. In many ways the LTC boundary identification problem is an incredibly difficult challenge to address particularly given how coverage, access to funding, services and treatments within LTC can vary greatly between different systems of LTC and within different geographic regions of the same system. This element may explain the lack of generally applicable approaches to date.

The overwhelming majority of papers included in our study have used a forecast horizon of 20 or more years. One possible reason for this is that modelers thus far have focused their efforts on studying the impact of changes in long-term trends, such as the gradual ageing of populations, which due to the nature of such trends are less likely to be witnessed in the short to medium term. This focus could be explained by the way in which current models have been used to assess sustainability of current systems of care and investigate the implications for the future.

One issue with modeling the LTC system in this way is that such distant time horizons represent several times the age in years of the LTC systems under investigation and even though LTC is not a new healthcare service LTC systems have been host to a number of recent reforms. Secondly, perhaps owing to the difficulty in accurately forecasting them, the evolution of many key variables associated with LTC need have often been assumed to remain constant or in accordance with their historic trends. The classical example of this is the disability rate, a rate that despite falling in recent times could reasonably be expected to increase later this century in certain parts of the world as a result of rising obesity. Furthermore, modeling LTC in this way also appears to violate a key aspect of the nature of LTC namely patients will in fact require more intensive care to a greater or lesser extent over time.

In some respects this feature of existing modeling work may reflect how LTC models have been used thus far, in that they have largely been used to test certain assumptions about the impact of different scenarios rather than as a more deterministic style of model. For LTC models to be more relevant for local planing purposes it may be the case that more detailed investigation needs to be carried out to test key assumptions made within current methdologies, for instance those relating to disability amd incidence of illnesses affecting LTC patients, and to facilitate a more dynamic model of the impact of future health and social care policy.

In our review we found that the disability rate and specifically how the level of disability of a population is incorporated into LTC models remains critical for demand forecasting purposes. Logically those with greater disability should in principle require more care, but since there is no single measure for disability and indeed the extent to which an individual is disabled only makes sense in both the context of being able to carry out a specific task it is increasingly hard to observe and measure at the individual patient level. One way in which it has been incorporated in earlier research is to look at patients receiving the same types of treatments. Although this information can be obtained by health surveys it is not always optimal to assume the same level of disability for those receiving similar types of treatments as their overall care needs as evidenced by the high variability in cost within the same top level care group can be very different.

Even though measures of the ability to carry out instrumental activities of daily living and activities of daily living have been utilised in previous modeling attempts such measures need to be used with caution. Firstly, what precisely constitutes a specific activity of daily living will vary depending on the environment the person is in and the sub-activities considered. For instance, assuming there are two individuals with the same level of difficulty showering yet one has access to an easy-access shower, handrails surrounding the bathroom, voice activated shower operation and considers only washing the top half of the body then this person would in principle require less support in carrying out this key activity. In addition, one particular study has found that the matrix of IADLs and ADLs for a set of LTC patients can be highly sparse – with some individuals requiring assistance with just a few activities but almost no help in carrying out others – along with the need for help in a specific activity correlating with a need for help with another. To reduce the dimensions we have seen how latent class models have been used to successfully reduce the many IADLs and ADLs into a small number of related disability groups driven by data rather than strict notions of care groups. An interesting study in China (Peng, Ling, & He, 2010) has shown how using IADLs and ADLs may in fact overstate the true level of disability given that the results of a longitudinal survey carried out over several years showed that self-reported health status in the elderly population tended to decline less rapidly compared with the reported levels of help in carrying out IADLs and ADLs.

Despite being increasingly useful for regional LTC planners, the literature surrounding short term forecasting of LTC demand remains limited. In the time period considered we could only find one specific example of an approach that resembled a STOM, namely (Chahed, Demir, Chaussalet, Millard, & Toffa, 2011). It is not clear whether this is due to data availability, lack of motivation to publish such modeling work due to competitive reasons or whether this work is captured in more general modeling of healthcare usage. We suspect also that the types of analysis carried out to build such models is either too basic to warrant publication or is carried out internally by commissioning organisations and hence there may be issues relating to disclosure. When forecasting LTC in the short term factors such as demographic shifts play a much more limited role and instead are replaced by factors which drive each individuals continued need for care. However, as LTC is often provided in the community information surrounding the treatments and care provided to individual patients the necessary data for modeling purposes can be much more difficult to obtain – especially in a non-paper format.

Even though informal care, the care provided by friends or family members, is a highly important aspect of LTC few studies have included this aspect of care into their demand models. Although arguably it is only relevant for those with low to medium levels of LTC needs, informal care does provide an important role with respect to reducing the pressure placed on formal systems of care for specific groups of patients. Secondly, from a modeling perspective those in receipt of informal care currently serve to provide an indication as to the patients who are likely to enter formal LTC services at a later date as their condition worsens and their needs change. The problem with informal care modeling is that by its very nature this type of care is often difficult to observe since it goes unrecorded. As a consequence the level of informal care has historically tended to be assumed according to different potential future scenarios, i.e. low or high levels of informal care. Such levels have often been related to future levels of fertility as higher levels of children being born would - all things remaining equal - increase the potential number of care givers to elderly parents. Although surveying of those in LTC facilities with regards to the amount of informal care previous provided has been conducted, albeit on a limited basis, we would suggest that more detailed work needs to be carried out in this area. Potentially, since ordinarly those in receipt of informal care are not recorded within the formal LTC frameworks of many LTC systems, a investigatioin could be carried out on the amount of informal care currently in place for those that are assessed for LTC treatment but ultimately refused any formal services.

7. Appendix

Appendix1. Overview of Studies

Author, year	Study Objective	Data Sources	Aspects of LTC System(s) Studied	Methodology	Time Horizon	Key Findings
(Batljan, Lagergren, & Thorslund, 2009)	To investigate how changes in educational level of the older people may affect future prevalence of severe ill-health among old people in Sweden.	• Population projections by age, gender and educational level under different trends in mortality. • Swedish national survey of living conditions (SNSLC) carried out in the period 1975-99.	• The educational composition of the older population during the next three decades.	• Educational level classified into three categories based upon the years of education received. • Logistic regression models used to estimate differences in the prevalence of severe ill health in different age, gender and educational level cohorts. • Demographic extrapolation used, with constant morbidity, to project future no of those with ill health and in need of LTC. • Additional scenarios added to include falling rates of morbidity and severe health needs using educational adjusted trends in mortality.	2000-2035	• Population projections which take into account level of education within each age-gender subgroup can lead to higher expected numbers of elderly people. • Including mortality differentials by education level has a strong impact on the size of the older population and a significant impact on the number of people with severe ill health. • The number of people in Sweden suffering from severe health needs in old age will increase by 14% when the combined effects of age, education and gender are considered. This increase is small relative to the 75% projected increase over the same period, 2000-2035 when differentials in mortality among specific age groups are not considered. • Projections on LTC need that consider changes in population composition by education result in less than half the increase in the number of elderly persons with severe ill-health compared with demographic extrapolation alone.
(Caley & Sidhu, 2011)	To estimate the future healthcare costs facing healthcare organizations due population ageing.	• Age specific health care costs published by the Department of Health 2005. • Sub-national Population projections , death registrations and health expectations at birth from the Office for National Statistics 2009	• Future LTC health care costs using routinely available data. • LTC costs in the years before death. • Impact of changes in life expectancy with respect to LTC costs	• Three proposed models. • Expected annual health care costs are derived by calculating the sum of the product of the current average health care costs for different age bands and the projected number of people in each age band until 2031. • In the second model, age bands were adjusted to reflect an increase in life expectancy • In the third model, age bands were adjusted by the increase in LE in good health by using the ONS projections of disability free life expectancy.	2006-2031	• The rate of increase in health care cost differs substantially depending on how projections of future life expectancy are incorporated • The projected future cost of care was highest in the model which made not account for changes in life expectancy or disability free life expectancy. • The estimated annual health care expenditure due to ageing was almost double if expansions in life expectancy were not considered.
(Chahed, Demir, Chaussalet, Millard, & Toffa, 2011)	To predict length of stay in long-term care and the number of patients remaining in care at a specific future time horizon.	• Dataset containing funded admissions to NHS long-term care supplied by 26 London primary care trusts.	• Length of stay of patients with different characteristics, including which type of care they currently receive, age and gender. • Movements between different LTC settings	• A continuous time Markov model of the flow of elderly residents within and between residential and nursing care is used to model the flow of LTC patients between two conceptual states and a discharge state in which the patient leaves LTC. • The transition probabilities were estimated by fitting survival curves to historic patient movements in care to establish further sub states	2007-2008	• There were significant variations in the proportions of discharge and transition between types of care as well as care groups. • The proportions of discharge from home care are higher than from placement • The proportions of discharge from short-stay and medium-stay states for Physically Frail patients are lower than those of from Palliative care.

				corresponding to short, medium and long stay states. • By running the model over 356 days the estimated number of individuals remaining in each of the six defined care categories was used to predict the demand for care at each point in time.		
(Chung, et al., 2009)	Derive quantitative estimates of future LTC expenditure in Hong Kong	• Thematic Household Survey 2004 • Hong Kong Annual Digest of Statistics • Hong Kong population Projections 2007-2036 • Hong Kong Domestic Health Accounts 1989-2002	• The future number of elderly people and the number requiring LTC • Expenditure on LTC given individual factors that drive need • The future inflated costs of LTC and the disability benefits for older people.	• Macro-simulation approach based on PSSR model. • Probability of using each service estimated for each age-sex profile using logistic regression. • Total utilization is estimated for each service in each year and multiplied by the inflated unit cost of care. • Future projections obtained using population estimates	2004-2036	• Demographic changes have a larger impact than changes in unit costs of care on overall expenditure • Expenditure expected to increase by 1.5% of GDP in 200 4 to 3% by 2036. • By service mix, the proportion allocated to institutional care would increase from 37% in 2004 to 46% by 2036. • Spending on LTC could be contained within 2.3-2.5% of total GDP in 2036 if institutional care could be substituted by home and day care services.
(Wittenberg, Comas-Herrera, Pickard, & Hancock, 2004)	Project expenditure on long-term care services for older people in the UK to 2051	• Government Actuary's Department (Population Projections)	• Share of LTC expenditure between the public and private sector. • Impact of providing free personal and nursing care. • Impact of changes in patterns of care with respect to support for informal care givers.	• Linkage of two micro-simulation models (PSSRU and NCCSU) • PSSRU – demand for long-term care under different socio-economic assumptions • NCCSU – models long-term care charges and the ability of groups of older people to contribute towards care home fees.	2000-2051	• Demand for LTC sensitive to projected numbers of older people, future dependency rates and real rises in the unit costs of care • Much uncertainty surrounding how far expenditure on LTC as a proportion of GRP will need to rise to meet demographic pressures
(Comas-Herrera, et al., 2006)	To investigate which factors drive LTC in several EU countries and the sensitivity of the projections to alternative future scenarios	• Eurostat 1999 population projections. (in addition to official national population projections from each country studied)	• Expenditure on LTC in UK, Germany, Spain and Italy. • Future numbers of dependent persons (65+), their respective probabilities of using different types of LTC services and volume of services required.	• Distinct macro-simulation (cell-based) model for each country's LTC system, reflecting differences in entitlement, level of informal care and coverage of publicly available LTC. • Incorporates assumptions surrounding the future changes in the macroeconomic environment, including real costs of care.	2000-2050	• Proportion of GDP spent on LTC to double between 2000 and 2050 (assuming that the age-specific dependency rates remain constant). • Future demand sensitive to assumptions about the future number of older people and future dependency rates. • Future cost sensitive to real unit costs of care and the availability of informal care.
(Comas-Herrera, Northey, Wittenberg, Knapp, Bhattacharyya, & Burns, 2011)	To investigate how incorporating expert views on dementia would	• 19 responses to a question from experts in the field of Dementia care and Alzheimer's disease.	• Future demand and expenditure on long-term care by older people with dementia in	• Updated version of the PSSRU CI (Cognitive Impairment) macro-simulation model used to represent the LTC system in England	2002-2031	• Expert option suggesting that there will be a reduction in age-specific prevalence rates of dementia will reduce the number of future suffers and the associated total expenditure on care by approximately 16% compared with no change in prevalence of dementia..

	affect projections of future expenditure on dementia related care for older people.	(Carried out via a Delphi process) • Survey from the Medical Research Council Cognitive Function and Ageing Society 1998	England.	• The views of the Delphi panel were incorporated into the model as assumptions.		• The expenditure effects of reduced institutionalization combined with increased care assistant wages will in effect cancel each other out.
(Comas-Herrera, Whittenberg, Pickard, & Knapp, 2007)	To project the future number of older people with cognitive impairment in England, the demand for LTC and associated cost. To investigate the impact of specific assumptions surrounding future trends.	• Government Actuary's Department 2005 projections on the number of older people. • Future marital status and cohabitation projections from the Office for National Statistics 2005 • Prevalence of cognitive impairment from Cognitive Function and Ageing Studies study (1998) • Resource implications for CI from Resource Implication Study (1999) • General Household Survey for number of people in receipt of informal and non-residential care • Number of people in care homes from Department of Health 2003 data • Information about people in hospital for long –stays taken from 2001 Census data.	• Sensitivity of the factors related to LTC on projections of future demand and cost. • Use of services by those with cognitive impairment and or disability. • Future household composition and implications for levels of informal LTC	• Three part macro simulation model, built upon previous PSSRU model. • First part projects future population into cells which are defined by age, gender, cognitive impartment and disability. • Second component assigns receipt of LTC services to each cell in the first stage based on the probability of receiving such services. • Third stage projects unit cost of services for each composition of services in the second stage at constant 2002 prices. • Projections for future years revise unit costs by labor related inflation to derive future projections of total expenditure.	2002-2031	• Unless more effective treatments for cognitive impairment are development made widely available, expenditure on LTC for patients with CI will rise significantly over the next 30 years. • Demand for LTC care depends on availability of informal care from family and friends. • Total expenditure on care sensitive to the supply of informal care, where expenditure on LTC could represent 1.11% of GDP compared with 0.96% if the supply of informal care fell significantly. • Projected future LTC expenditure highly sensitive to assumed rate of growth in real unit costs of care.
(Costa-Font, et al., 2008)	To examine the sensitivity of estimates of future long term care demand under different official population projections.	• Euro Stat 1999 based population projections	• Variability in expenditure predictions across the UK, Germany, Italy and Spain. • Effects of demographic uncertainty on both population and expenditure predictions. • Future fertility rates and its influence on the numbers of	• Country wide macro simulation model based on the PSSRU model • Future population projections are partitioned by age, gender and level of dependency • A second model classified services used by dependent older people according to type of care received and setting • Expenditure projections are extrapolated by applying unit costs of the services in each group and multiplying by the respected population	2000- 2050	• The projected numbers of dependent elderly people were higher in Germany compared to the official national projections. Whilst in Spain and the UK there was a little deviation. • Differences in relative expenditure between the highest and lowest population assumption varied from 35-50%, with Italy exhibiting the smallest difference and the UK the largest. • For Germany and the UK, the difference in projected expenditure on LTC in 2050 constituted 1% of GDP under the low and high population estimates. • There is evidence of cross country convergence with respect to the cost of LTC as a percentage of GDP in Spain, UK, Italy and Germany. • Growth in LTC expenditure over the period varied

			informal care givers.	projection. • A number of parameters for instance prevalence rates of dependency by age can be adjusted to accommodate different future demographic scenarios. • Results were compared for both high and low population projections.		from 70-90% in the most optimistic scenario, to 150-180% in the most pessimistic.
(Fukawa, 2011)	To project long-term care expenditure in Japan between 2010-2050 by analysis of household transition	• Population projects for Japan from 2006-2055, National institute of population and social security research, 2007. • National Household survey Japan 2004.	• Numbers of elderly people according to dependency and/or other living situations. • Future cost of LTC relative to total healthcare expenditure • The effect of the ageing of the "baby boomers" on LTC demand • The household ratio or parents to children to asses potential future levels of informal care	• A dynamic micro simulation model which transitioned individuals forward in time, subject to stochastic events taking place. • An initial fixed population was simulated according to a sample taken from census data in 2005. • Individuals were transitioned through the model according to estimated probabilities of life changing events in addition to changes in household circumstances. • Transition probabilities dependant on age, sex and level of disability for those aged 65 and over. • Levels of dependency were classified into four groups and associated with the need for LTC. • Movements from these levels and into an institution were dependant on each individual's personal circumstances. • Future costs derived by applying future age specific population projections for each of the LTC insurance bands.	2010-2050	• The proportion of those elderly who stay in institutions will steadily increase until 2050. • The sum of health and LTC expenditure will increase from the preen 7.7% of GDP in 2010 to 11% of GDP by 2040 largely due to increased LTC expenditure. • The future level of expenditure on LTC is sensitive to assumptions about the level of service use by different levels of dependency. • Even if service use by level of dependency falls uniformly over the period by 20%, LTC expenditure in 2050 will be as a percentage of GDP will increase by 138% by 2050 when compared with 2005 levels.
(Hakkinen, Martikainen, Noro, Nihtila, & Peltola, 2008)	To investigate the claim that population ageing will not have a significant impact on healthcare expenditure	• Finnish population registration system • Finnish hospital discharge register. • Finnish death register • Registers from the Finnish Social Insurance Institution • Finnish hospital benchmarking project	• Impact of ageing on healthcare expenditure • Impact of proximity to death on healthcare expenditure	• Annual healthcare expenditure calculated for each individual aged 65 or over from 1998 until end of 2002 using 2000/01 deflated prices. • Likelihood of using LTC service found using a logit/profit model based on patient characteristics. • OLS regression model used to then estimate expenditure given patient predicted to	2016-2036	• LTC patients (excluding residential and home care) accounted for 55% of total healthcare expenditure despite the proportion aged 65 or over being 7%. • Age has an important positive and increasing effect on the probability of being a LTC user. • Females had a higher risk of needing LTC compared with males. • Home care and home services excluded due to lack of national data. • Projections based on the naïve age and gender specification showed an estimated annual LTC cost increase of 2.2% by 2036.

				require LTC using a general to specific selection of patient characteristics. • Future LTC expenditure projects obtained by multiplying calculated age-gender specific expenditure according to survival status by future population estimates. • In addition, an additional model where the probability of using LTC was delayed for three years was also used to consider falling rates of dependency with age.		• Taking into account proximity to death, the expected annual increase in total LTC cost was found to be lower at 1.9%. • The model's projections were found to sensitive to the probability of individuals being in need of LTC. • If LTC could be delayed by 3 years it was found that costs would decrease by 12% although part of this reduction would be met by a rise (2%) in other non-LTC healthcare costs.
(Hare, Alimandad, Dodd, Ferguson, & Rutherford, 2009)	To predict the future number of patients in different home and community care categories in British Columbia	• Future population projections from "Population Extrapolation for Organization Planning with Less Error" (2007) provided by the British Columbia Ministry of Health • Wealth demographics from Statistics Canada (2008) • Quantity of non-publically funded home and community care estimated from telephone survey of all privately run facilities in British Columba (2007) • Home and community care activity data from April 2001-March 2005 by client group provided by the British Columbia Ministry of Health.	• Distribution of patients between different types of care, including assisted living environments and home care. • Distribution of privately funded care to publically funded care.	• Multi-state deterministic Markov model • Home and community care groups divided into ten categories, 8 of which represent publicly funded care. • Patients are not individually tracked through the system but rather the collective behavior of each care and age specific group is studied. • Patients move between care categories and leave the model according to the age-independent transition rates. • Movement between public and privately funded care according to projected wealth distribution of the province. • Movement between services based on historical usage of home care vs. assisted environments using fixed transition rates, and then dividing movers between public and non-public services. Transition probabilities estimated from historical data. • Population projections used to estimate no of patients arriving to the system in each period.	2002-2031	• The model predicts that whilst patient counts will continue to rise over the next 20 years they will not reach their 2002 high levels until 2015. • Without taking into account the privately funded care, the models prediction accuracy was poor as a number of clients are believed to use some mixture of both public and privately funded care. • No attempt made to marry client counts with service loads for the prediction of budget requirements. • The available of services has increased over the period and hence the six fold growth in HCC between 2002-2004. It is difficult to model the numbers of people who are seeking care but not receiving at the current time.
(Karlsson M. , Mayhew, Plumb, & Rickayzen, 2006)	To analyse the sustainability of the UK system for provision of long-term care in the light of the	• OPCS survey of disability in Great Britain (1988) • Health survey of England, Bajekal M. Care homes and their	• Estimate of the future cost of LTC to the public purse as proportion of income tax • The potential	• Multicomponent projection model based on Multistate disability model proposed by Rickayzen and Walsh (2002) • The disability model generates an estimate of the number of	2000-2050	• Given our central assumptions, the demand for long-term care will start to increase considerably about 10 years from now, and reach a peak somewhere after 2040. • The most important increase will be in informal care, since the number of older recipients is projected

	changes in demography and health status among older people that are expected in the future	residents. London: The Stationery Office; 2002 for types of formal care by age and disability • Costs of formal care Laing, Buisson. Calculating a fair price for care—a toolkit for residential and nursing care costs. London: Rowntree; 2001. and Netten A, Rees T, Harrison G. Unit costs of health and social care. PSSRU; 2001.	surplus or shortfall in the number of informal carers relative to the demand for informal care.	individuals of each gender cohort split by age and severity of disease for each year of the projection period. • People are transitioned over time into different levels of disability e.g. people becoming more disabled and people dying. • Trend data on healthy life expectancy used to update transition probability according to how rates of disability may improve. • Different assumptions surrounding how these transition rates changes according to how mortality , speed of increased disability and level of disability may improve over time. • Cohots of disability are then mapped to care settings. • Estimates cost of LTC to the public purse as a percentage of income tax and the demand for informal care relative to no of care givers.		to increase from 2.2 million today to 3.0 million in 2050. • In relative terms, the increase is similar in all care settings, amounting to between 30 and 50% compared to the levels today. • The most noticeable increase is in formal home care, however, which is projected to be almost 60% greater than the current level in 2040. Yet, since those services are relatively cheap, this item has a relatively small impact on total spending. • The increasing demand for care will influence total costs. The total costs of formal long-term care defined in this paper amount to around £ 11 billion today and will, in constant prices, increase to around £ 15 billion around 2040. • It transpires that our findings are relatively sensitive to the assumptions made concerning the trend in future disability rates in the older population. When we contrast our baseline scenario with a more pessimistic one—assuming no future health gains—we find that total costs keep on growing for longer and peak only in 2051 at a total of £ 20 billion (£ 80 billion when informal care is also considered). This translates into an implied tax rate of 1.8%, which is considerably higher than in the baseline scenario (1.3%). • Regarding informal care, we find that under the baseline and optimistic scenarios, there is likely to be a sufficient supply of care to meet demand provided caregiving patterns remain as they are. However, if female care-giving patterns converge to those of males, then under the baseline health improvement scenario, there would be a shortage of between 10 and 20 million hours of care per week
(Ker-Tah & Tzung-Ming, 2008)	Predict values of the disability rate of the aged from 2006 to 2011 to estimate the future population in need of long-term care	• Historical rates of disability in Taiwan from the Ministry of the Interior and the Department for Statistics over the period 1991-2006	• The rates of disability in the Taiwanese elderly population that would require LTC services.	• Gathered data on rates of disability in the elderly population and used a Grey forecasting model to forecast future rates of disability under different assumptions about the growth in the disability rate over time. • Estimates of future rates of disability used to ascertain the size of the population in need of LTC in the future	2006-2011	• The continual increase in the disability rate of the aged leads to a dramatic increase in the growth rate of the aged demanding LTC services over the period studied. • A 1462% increase in the rate of aged related disability (from 1991-2011) far exceeds the expected growth rate in the aged population.
(Kinosian, Stallard, & Wieland, 2007)	Project long-term care service usage by enrolled veterans	• Veterans Health Administration Survey • National Long-Term Care Survey • National Nursing home Survey • National Health Interview Survey.	• Demand and cost of nursing home care and community-based long-term care Services • Persons who report receiving human or mechanical assistance to help	• Used a random sample of the Medicare-eligible VA population, to standardize the ADL and IADL disability levels from the 2002 VA Survey of Enrollees	2002-2012	• The level of long-term-care use generally follows the distribution of disabilities in a population

			with activities of daily living ADLs and instrumental activities of daily living.			
(Lagergren, 2005)	Investigate the impact of changes in factors related to future LTC resource need	• Official National Statistics on the Provision of Long-Term Care. • Swedish National Survey on Living Conditions (ULF) • ASIM Study in Solna municipality (1984-1994) • The Swedish National Survey on Ageing and Care at Kungsholmen, Stockholm (2001) • Population projections from Statistics Sweden	• Consumption of different forms of LTC services by age, gender, marital status and disability. • The future provision of LTC services in relation to care needs • Balance of institutional and non-institutional care.	• ASIM III-model subdivides the population into several cohorts by age group, gender, marital status and degree of ill health. • For each group the number of persons in receipt of LTC for older persons according to four different levels noted. • Prevalence of ill health for each age, gender, civil status subgroup used to create a health index of four degrees (full, slight, moderate, and severe) • Forecasts generated by multiplying population projections in each subgroup by respective proportion of persons in each group receiving services in 2000 levels. • Different future scenarios surrounding ill health used to make projections. • Two-step tend extrapolation of severe ill health from survey on living conditions.	2000-2030	• The population growth in the period 2000-2015 concerns mainly the younger old and thus does not have a large effect on the care service costs. • Cost increases from 2020 onwards stem from 85+ year group, for the youngest old the costs diminish. • Over period 2000-2030 35% increase in less than 1hour of public services in the community setting per day. • 27% more people in instructional care • More intensive community care is less affected by projected increases in demand. • By 2030 the oldest age group 85+ will account for 60% of all LTC expenditure from 50% in 2000. • Proportion of married rise from 17% to 22% given mortality is expected to fall more rapidly for men than for women. • Pessimistic future ill-health 69% increase in cost vs 25% increase in cost. At present 2.6% of GDP spent on care, could rise to 3.3-4.4% depending on future ill-health scenario.
(Macdonald & Cooper, 2007)	To estimate the future level of demand for care home placements from those suffering from dementia	• Survey of 445 residents drawn randomly from 157 non-EMI nursing homes in South-East England. • Commission for Social care and Inspection • The Medical Research Council Cognitive Function and Ageing Society. • UK Census 2001	• The number of dementia cases in England and their associated care needs up to 2043.	• Results from a local survey on the incidence of dementia are combined with age and sex specific prevalence ratios and extrapolated to estimate demand for dementia beds at the starting period. • Future levels of demand are estimated by applying population projections under different assumptions surrounding the prevalence rate of dementia in care homes.	2003-2043	• Assuming 50% of patients aged 60+ in care homes suffer from dementia, the number of dementia beds required would be around 740,000 by 2023 and over one million by 2043.
(Malley, et al., 2011)	To examine the effect of different assumptions about future trends in LE on the sustainability and affordability of both the	• 2001 General Household Survey (GHS) • 2002/3, 2003/4 and 2004/5 rounds of the Family Resources Survey (FRS)	• Likely future cost to the public purse • private expenditure on LTC • LTC by source of expenditure • Compare with GDP	• To project expenditure on LTC, we use two models: the CARESIM micro-simulation model and the Personal Social Services Research Unit (PSSRU) aggregate LTC finance model. The PSSRU model is cell-based: it divides	2007-2032	• expenditure on pensions and associated benefits is projected to rise in future years because of the increasing numbers of pensioners – more recent projections allowing for the further policy changes described above confirm this, and show even faster growth • expenditure on LTC is projected to rise, although at a faster rate than pensions expenditure. The faster rate of

	pensions and LTC system	• 2008 budget report (HM Treasury 2008).		the current and projected future population into a large number of sub-groups or 'cells'. It simulates future demand for LTC and disability benefits for each of these groups, based on analysis of a sample of older people from the 2001 General Household Survey (GHS)4. Adjustments are made to the GHS analysis to include the residential care population and to reflect changes in the targeting of publicly-funded care provision since 2001 (Wittenberg et al., 2006). CARESIM simulates the incomes and assets of future cohorts of older people and their ability to contribute towards care home fees or the costs of home-based care, should such care be needed (Hancock et al., 2003). It is based on a pooled sample of older people from the 2002/3, 2003/4 and 2004/5 rounds of the Family Resources Survey (FRS) with money values updated to the base year (here 2007) 5. Together these two models can be used to project future expenditure on LTC by source of expenditure, under different funding reform options. • The PSSRU model output on the characteristics of people requiring LTC is used as input to CARESIM to adjust the FRS sample to be representative of people receiving different LTC services in the projection year. CARESIM then simulates for each type of service the ability of older people to contribute to their care costs and the source of income used to pay for care. CARESIM output is used to break down expenditure in the PSSRU model into its constituent components and funding sources, i.e. NHS, Personal		growth in LTC expenditure is partly a consequence of the faster rate of growth of the oldest old group compared to the older population as a whole, as it is at the oldest ages where need for care is the greatest

				Social Services, social security disability benefits and private money (Hancock et al., 2007). The projected levels of expenditure by each of these sources are compared with projected economic output, Gross Domestic Product (GDP).		
(Manton, Lamb, & Gu, 2007)	How trends in disability prevalence and in inflation-adjusted per capita, per annum Medicare costs affected total projected medicare costs	• 1982, 1984, 1989, 1994, and 1999 National Long Term Care Surveys (NLTCS) -roughly 20,000 persons sampled in each of the NLTCS, of those 65+	• Implication of recent disability declines and their possible continuation for future Medicare costs	• Applied a grade of membership analysis to 27 measures of disability from the 1982 to 199 9 National Long term care surveys,. This identified 7 disability profiles for which individual scores were obtained. These were used to extrapolate future Medicare spends by assuming different trends in the level of disability across the different groups.	2004-2009	• At ages 85+ relatively more LTC and Medicaid expenditures are incurred for labor-intense maintenance and palliative care • 16% savings
(Martini, Garrett, Lindquist, & Isham, 2007)	To project the impact of populating aging on total US health care cost per capita	• 1.2 million years of health care plan data from the HealthPartners database 2002-2003 • US Census Bureau population projections 2000-2050 • Medical Expenditure Panel Survey 2001	• The monthly per capita costs of LTC covered by Medicare using insurance claims data. • Per capita pharmacy costs associated with various conditions in LTC.	• Medical and pharmacy claims data aggregated into individual episodes of care which are grouped by treatment group • The total cost of each treatment group is added to their respective higher level illness or condition category. • Monthly per capita costs estimated for each gender, age band and condition category and added together to estimate annual costs per capita. • Future cost extrapolated by multiplying projections of population in each gender-age brand and multiplying by MEPS adjusted per capita costs.	2000-2050	• Per capita costs a s result of ageing will increase by 18% from 2000 to 2035 as baby bombers and retirement and then level of as the age structure of the population stabilizes. • 80% of the increase in per capita costs can be explained by 7 of the 22 illness categories, including: heart and vascular conditions, lung conditions and neurologic disorders. • Pharmacy costs were estimated to account for 1.5% of all care costs. • The cost of care for males and females in the 85-89 year old group are 4.4 and 2.7 times as large as the per capita costs for the reference group of females aged 40-44.
(Peng, Ling, & Qun, 2010)	To project the future need of long-term care due to changes in demography and health status among the oldest Chinese	• Chinese Longitudinal Healthy Longevity Survey, 1998, 2000, 2002 • United Nations World Population Prospects of China in 2008 for population projections (2010-2050) assuming medium fertility and mortality		Calculated the observed self-rated health status transition probabilities for individuals with age I and gender j. Simulated this process using a non-homogeneous Markov process to obtain the simulation transition probabilities this was done separately for each initial health status k, using five-group discriminate analysis to estimate the probability of	2010-2050	• 8066 thousand persons aged 80+ need long-term care in 2010, while in 2050 this number will increase to 42,581 thousand • The care need person year number among males will increase from 23,159 in 2010 and to 115,460 in 2050, whereas the female person year number will increase from 40,401 to 208,210, and the total number for both genders will increase from 63,560 to 323,670, which implies a growth of more than 4 times during the 40 years. • If we assume that the average care expenditure is 15 US dollars (about 100 Yuan RMB) per hour in 2010, then the total care expenditure rises from around 83.52

				being in each of the five health status l 2 years later, as a function of a person's gender i and initial age j Health status transition probabilities were used to calculate the remaining years of life and remaining years of healthy life in terms of age, gender and initial health. L Long-term care expenditures can be calculated by multiplying unhealthy person-years number by the annual average expenditure of care In order to define what is healthy, we made a split between good and fair because the two groups had great differences in mortality. We used Mantel–Haenszel statistic to test mortality relative risk (RR) between two health states. Results showed that the mortality of the elderly people who rated their health fair or poor significantly increased compared to those in the good category except for women aged 85–89 (RR > 1, P-value < 0.05). People who rated their health very good and good had no significant difference in mortality risk except for women aged 85–89 and 95–99, and men aged 80–84 (RR > 1, Pvalue > 0.05).		hundred million dollars in 2010 to around 425.30 hundred million dollars in 2050 (in 2010 prices). • We have been able to show that,given our assumptions of average care cost is 15 US dol-R. Peng et al. / Health Policy 97 (2010) 259–266 265lars per hour, the care expenditure for long-term care will increase from 83.52 hundred million dollars to 425.30 hundred million dollars from 2010 to 2050. That means the total amount will grow more than 4 times over the next the 40 years, without considering inflation. The results also show that long-term care need is on the rise regardless of gender, and that the absolute number and increase rate of female care need are higher than those of male.

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