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Counting the Time Lived or the Time Left?
Age, Proximity to Death
&
Prescription Expenditures

A dissertation submitted to the University of Dublin
for the Degree of Doctor of Philosophy

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PhD in Med

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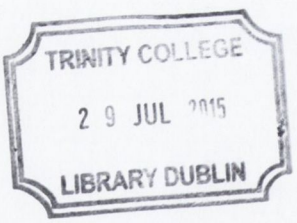

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Summary

This thesis set out to investigate whether ageing is a surrogate measure for proximity to death in the older population when estimating medication expenditures. The medication expenditures used were the ingredient cost of medications for the public health system.

Concerns about the long term sustainability of health care expenditures and in particular prescribing expenditures has become an important policy issue in most developed countries. Previous studies suggest that proximity to death (PTD) has a significant effect on total health care expenditures, with its exclusion leading to an overestimation of likely growth. There are limited studies of pharmaceutical expenditures taking PTD into account.

This thesis uses individual level dispensing data for the New Zealand and Irish population aged 70 years or more. The period used, 2006 – 2009, provides a unique experiment in Ireland when individuals aged 70 years or more were entitled to free health care and medications paid for by the state regardless of income, illness or socioeconomic status. Given this eligibility it was possible to use dispensing data automatically collected at pharmacies for reimbursement purposes as a national cohort.

A case control methodology is used to examine individual expenditure and medication use for a 12 month period for decedents (cases) and survivors (controls).The hypothesis was tested using a random effects two part model, consisting of a Probit regression to identify the probability of expenditure in any given month and a generalised linear model (GLM) to regress the positive expenditures. New Zealand was used as a comparator country given the similarities in demographics, socioeconomic circumstances and access to free medication.

The impact of proximity to death on prescription expenditure is not as dramatic as studies reporting on Acute and/or long term care. Decedents typically expenditure up to twice as much as their surviving counterparts in terms of medication expenditure in both countries.

In Ireland the average monthly medication expenditure for an individual in the last year of life is €2,107, compared to €1,180 for a similar survivor. Decedents consistently spend and use more medications up to three years before death. The data show a neutral effect for age once PTD is included which has a positive and statistically significant impact on prescribing expenditures. Medium term expenditure projections are overestimated when PTD is not taken into account.

A similar effect was reported for New Zealand the 12 month decedent to survivor mean expenditure ratio was 1.95, 2.09 for males and 1.82 for females. The additional expenditure of dying in terms of prescription drugs decreases with age, with those who die at 90 years of age or older consuming fewer drugs on average and having a lower mean expenditure than those who died in their 70s and 80s. The following variables were found to have a decreasing effect on the mean monthly prescription expenditures, a reduction of 2.2% for each additional year of age, 4.2% being in the Māori ethnic group and 7.8% for Pacific Islanders. Increases in monthly expenditure were associated with being a decedent 32.1%-62.6% (depending on month), being of Asian origin 16.2% or a male 12.6%.

Given the variance reported between survivors and decedents, to improve accuracy future projections should include PTD in their models. Policies targeted at reducing expenditures should not focus on age but on ensuring appropriate and cost effective prescribing especially towards the end of life.

Keywords: aged, medication, prescription drugs, proximity to death, healthcare expenditure, two-part model.

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I would like to express my gratitude to Professor Charles Normand who was extremely supportive at all stages of the process. Without his academic expertise, patience and generosity of time, this thesis would not have been possible.

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Publications and Conferences

The following publication is based on part of this thesis:

Moore PV, Bennett K, Normand C, (2014) The Importance of Proximity to Death in Modelling Community Medication Expenditures for Older People: Evidence From New Zealand. *Applied Health Economics and Health Policy*, 12(6): pages 623-633.

The following related publications were written during the thesis:

Murphy C, Moore PV, McHugh S, Nolan H. (2014) Health and Social Care Utilisation. In: Nolan A, O'Regan C, Dooley C, Wallace D, Hever A, Cronin H, et al., editors. *The over 50s in a changing Ireland: Economic circumstance, health and Well-being*. Dublin: The Irish Longitudinal Study on Ageing (TILDA)

Moore PV, Richardson K, Peklar J, Galvin R, Bennett K, Kenny RA.(2012) *Polypharmacy in adults over 50 in Ireland: Opportunities for expenditure savings and improved healthcare*. Dublin: The Irish Longitudinal Study on Ageing (TILDA)

Oral presentations were made at the following conferences:

Moore PV, Bennett K, Normand C, *Counting the Time Lived or the Time Left? Age, Proximity to Death and Prescription Expenditures.* International Association of Gerontology and Geriatrics (IAGG), Dublin, Ireland, 24th April 2015

Moore PV, Bennett K, Normand C, *Counting the Time Lived or the Time Left? Age, Proximity to Death and Prescription Expenditures.* SPHeRE Network, Dublin, Ireland 9th January 2015

Moore PV, Bennett K, Normand C, *The Importance of Proximity to Death in Modelling Future Drug Expenditures for Older People in New Zealand (La Importancia de la Proximidad de la Muerte para el Gasto Farmacéutica por los Ancianos en Nueva Zelanda)* Asociación de Economía de la Salud (AES), Santander, Spain, 21st June 2013

Moore PV, Bennett K, Normand C, *The Importance of Proximity to Death in Modelling Future Drug Expenditures for Older People in New Zealand*, European Conference on Health Economics (ECHE), Zurich, Switzerland 19th July 2012

Abbreviations

Abbreviation	Long form	Description
ADL	Activities of Daily Living	A list of the basic life skills used to assess functional status, such as feeding oneself, bathing, dressing, grooming, work, homemaking, and leisure.
AIDS	Acquired Immune Deficiency Syndrome	A spectrum of conditions in humans caused by the Human Immunodeficiency Virus (HIV) in which progressive failure of the immune system allows life-threatening opportunistic infections and cancers to thrive
ATC	Anatomical Therapeutic Chemical	World Health organisation (WHO) classification system for pharmaceuticals which are divided in to groups according to the organ or system on which they act and their therapeutic, pharmacological and chemical properties.
CSO	Central Statistics Office	Statistical agency of the Irish government.
COPD	Chronic Obstructive Pulmonary Disease	A type of obstructive lung disease characterized by chronically poor airflow. It typically worsens over time.
GDP	Gross Domestic Product	A national measure of the total income generated in an economy.
GLM	General linearized model	Regression estimation method
GMS	General Medical Services scheme	This scheme provides free at the point of care clinical services including GP and dental visits, along with prescription drugs and medical devices to certain residents in Ireland primarily based on income, age and illness status.
GNI	Gross National Income (Formerly known as Gross National Product (GNP))	A national measure of the total income generated by residents of a country both in the domestic and international economy.
GP	General Practitioner	A medical doctor who provides care in the community and can prescribe medications.

Abbreviations

Abbreviation	Long form	Description
HCE	Health Care Expenditure	All money spent on health care (in this thesis usually by the government)
HIV	Human Immunodeficiency Virus	A lentivirus that causes the Acquired Immune Deficiency Syndrome (AIDS).
HSE	Health Service Executive	Agency that managed public health services in Ireland.
IADL	Instrumental Activities of Daily Living	A list of activities used for daily living that are not necessary for fundamental functioning, but they let an individual live independently in a community and are used to assess functional status.
INN	International Nonproprietary Name	The generic name given to a pharmaceutical by the WHO.
NHI	National Health Index, New Zealand	Unique health identifier for users of New Zealand health care system.
NZIER	New Zealand Institute of Economic Research	Non-profit incorporated society conducting applied economic research, based in Wellington New Zealand.
OECD	Organisation for Economic Co-operation and Development	An organisation of 34 countries with the aim of promoting policies that will improve the economic and social well-being of people around the world.
OLS	Ordinary least squares	Regression estimation method
PCRS	Primary Care Reimbursement Service, Ireland	Section of HSE responsible for payments to pharmacists and general practitioners in Ireland.
PHARMAC	Pharmaceutical Management Agency, New Zealand	Agency tasked with managing medication reimbursement and formulary in New Zealand.
PTD	Proximity to Death	How close in time (months or years) an individual is to death
TPM	Two Part Model	A regression model which consists of two parts, in this thesis the first part models the use of medications and the second part models the expenditure on medications.

"Time present and time past
Are both perhaps present in time future,
And time future contained in time past."

Burnt Norton, Four Quartets, T.S Eliot 1935.

1 Introduction

Increasing longevity is one of humanity's major successes and challenges. However we have yet to fully understand the biological processes involved in ageing as well as its impact on our health and healthcare services. Longevity combined with declining birth rates in many countries is resulting in rising dependency ratios and requires new policies in all facets of public provision. Identifying ways to more accurately forecast expenditure is important for the development of appropriate policies to help prepare for and control future expenditure.

Health policies in many developed countries are in the process of shifting the emphasis from a hospital based delivery system to a community based one. Encouraging and facilitating individuals to avail of healthcare services and preventative care in the community setting is seen as a more effective and efficient use of resources. Pharmaceutical intervention is by far the most widely used aspect of healthcare in the community and has seen strong year on year growth in recent decades in terms of both expenditure and volume (OECD, 2011a). This high increase in expenditure is not as a result of improved health care or access, but higher prices (Gorecki et al., 2012). Given the finite nature of government budgets the opportunity expenditure of this rise in expenditure affects other health care or publicly provided services.

1.1 Aim

This thesis focuses on providing evidence to improve the accuracy of expenditure forecasts in the crucial area of prescription medication used by older people in the community setting. The main aim of the thesis is to test the hypothesis that proximity to death is a driver of prescribing expenditures and more important than ageing. By examining past expenditure, mortality and medication usage the thesis illuminates the possible impact on future expenditure estimates of not accounting for proximity to death. Specifically it quantifies the level of expenditure on prescription medication in Ireland and New Zealand, examines the variations between survivors and decedents and investigates the empirical relationship between expenditure, age and proximity to death.

The objectives are to:

- Review the evidence to date on ageing, proximity to death, health care expenditures and prescribing expenditures;
- Review the evidence on modelling of health care expenditures including prescribing expenditures;
- Use the reviewed evidence to inform a study on prescribing expenditures, proximity to death and ageing in Ireland;
- Explore the patterns of prescribing at the end of life;
- Identify and conduct a validation study on another country;
- Provide evidence to inform projection models of future expenditures.

1.2 Rationale

The science of ageing tells us about apoptosis, the process of biological cells killing themselves, the acceleration of which occurs as humans age. This acceleration is evident in increases in morbidity, frailty and disability (Chinta et al., 2013). But does this ageing process translate into higher healthcare expenditures? Studies frequently associate ageing with higher health care expenditures relative to the younger population (Miller, 2001,

Anderson and Hussey, 2000, Reinhardt, 2000, Westerhout, 2006). Anderson and Hussey (2000) estimated that the average person aged 65 years or more expenditures between 2.7 and 4.8 times more than the average person aged 0 to 64 years. The elderly population is estimated to expenditure between 30% and 50% of total health care expenditure in OECD countries (Jacobzone, 2002). If age is the predictor of high health care expenditure (HCE) then the increasing demographic trend for older people will result in substantial increases in HCE. However while age may be important to an extent, Fuchs (1984) first proposed the idea of proximity to death (PTD) having an important positive effect on healthcare expenditures. The closer someone is to death, possibly the more healthcare resources they use regardless of age.

It is vital for expenditure forecasts and ultimately health policy to fully understand the relationship between age, death and health care expenditure (HCE). In order to allocate scarce financial resources decision makers need accurate forecasts of future demand.

1.2.1 Prescribing expenditures

The market for medicines is unlike that for other consumer goods. Firstly the demand for medications is a derived demand for health. Nobody demands medication per se but rather the health benefits that taking the medication may bestow. Furthermore the patient, who is the consumer, does not decide which medication to use and may not directly pay for the medication either. The person who does decide which medication, the prescriber, often a doctor, neither consumes nor pays for the medication. The prescriber acts in the patient's interest but is also the gatekeeper of resource use. The pharmacist also provides another layer to the market which influences the medication dispensed. And the state who may pay for the medication does not consume nor choose the medicine. There is a complex interaction between the patient, the prescriber, the pharmacist and the state when a medicine is prescribed and dispensed.

There is a large body of literature examining the determinants of health care expenditures however as the review in chapter 2 uncovers there are limited studies of the drivers of prescription expenditures and in particular of the effect of ageing on these expenditures. Pharmaceutical expenditures accounted for approximately a fifth (19%) of all health care spending in OECD countries in 2009 and ranges from 0.9% of GDP in New Zealand to 1.7% in Ireland[1] and a maximum of 2.4% in Hungary, Greece and the Czech Republic (OECD, 2011a). Prescription medication is the most common healthcare intervention and has experienced substantial growth in Ireland in both expenditure and volume during the last two decades. The older population (≥70 years of age) account for 25% of public expenditure on prescription medication in Ireland and are forecast to double in size in the next forty years (Primary Care Reimbursement Service, 2009, Central Statistics Office (CSO), 2013). Ireland is an interesting case study on prescription expenditure within the context of developed countries. The prices for medicines have remained relatively high compared to other countries only lowering recently with policies in response to austerity pressure. The average annual rate of growth for medication expenditure over the decade to 2009 has been 8.7%, significantly higher than the OECD average of 3.5% and well above that of all other EU countries (OECD, 2011a). Given the finite nature of government budgets the increase in expenditures on medications comes at the expenditure of other services in health care or public provision.

The period 2001 to 2009 in Ireland provides a unique opportunity when health care and prescription medications were free for all those aged 70 years or more regardless of income, health or socioeconomic status. The Primary Care Reimbursement Service (PCRS), a division of the Health Service Executive (HSE)[2], maintains a database of all

[1] The Irish calculation includes medical devices and items such as bandages.

[2] The Health Service Executive is the agency tasked by the Department of Health to run the day to day provision of public health care in Ireland, chapter 4 provides more details.

dispensed medications which were paid for by the state. While the main purpose of this database is to reimburse pharmacists it provides a national cohort for this thesis.

1.2.2 New Zealand as a comparator

To validate the research findings from the Irish data used in chapter 5, a search was conducted for a suitable comparator as outlined in Appendix A3. New Zealand was identified as having a similar population aged 70 or more, similar medication provision, economic circumstances and available dispensing data for analysis.

While similar in demography and economic status New Zealand in contrast to Ireland has managed to maintain modest expenditure growth on pharmaceuticals (OECD, 2011b). This provides an interesting comparison for the case of Ireland, who has only recently managed to stem large year on year increases in prescription expenditures. The Ministry for Health in New Zealand has adopted an aggressive policy of expenditure control since the 1990s, with the formation of a government agency (PHARMAC) tasked with the cost effective use of the medications budget. Similar to Ireland the Ministry of Health maintains a database of all dispensed medications which provides a national cohort of medication users which could be linked to mortality records. The 70 years or more age group was selected to be comparable to the Irish data.

Similar to Ireland, New Zealand are expecting an almost doubling of the population aged 70 years or more in the next forty years (Statistics New Zealand, 2009). This predicted rapid expansion of the older population is in common with a lot of other developed countries (OECD, 2014a). Therefore policy makers in Ireland, New Zealand and other developed countries with ageing populations are understandably concerned about a health care expenditure expansion to accompany the anticipated population shift.

1.3 The Irish Healthcare System

The current health system has its origins in the Health Act 1970, while the structure of the system has changed over the decades the core idea of income eligibility for free services has remained. Ireland currently operates a public health insurance scheme which provides subsidised acute hospital care for all citizens and a wider range of services for those on low incomes and those over 70 years of age[3] via the General Medical Services (GMS) scheme. This scheme provides free at the point of care clinical services including GP and dental visits[4], along with prescription drugs (subject to co-payments summarised in table 4.5) and medical devices. The GMS service is awarded based on a means test of an individual's income and as a result is predominately provided for those with a low income, in receipt of social welfare or over 70 years of age (McDaid et al., 2009) with services being accessed by the use of a "medical card". In 2001 the government introduced free healthcare including medications for those aged 70 or more regardless of income or health status. Layte et al (2007) examined this new entitlement and found no evidence of a significant change in GP utilization rates.

In 2009 38% (1,615,809) of the total Irish population were in receipt of a medical card (Primary Care Reimbursement Service, 2011). Medical card status rises with age and the income thresholds were considerably higher for those over 70 years of age, which results in 91.6% (95%CI 90.5-92.7%) of that age group qualifying in 2010. The population who do not have a medical card can avail of subsidized acute hospital care only, other medical care is paid for out of pocket or by private health insurance. While health insurers have moved into the market of expenditure sharing on GP services there are only a few very limited schemes which provide payments for prescription medications[5]. In addition to the medical card (GMS scheme) the Drugs Payment Scheme (DPS) exists to alleviate the financial hardship of individuals who may face high

[3] From the 1st January 2010 a means test was introduced for the over 70's, allowing a new income of €700 per week, a further reduction was made effective from the 1st January 2014 allowing an income of €500 per week for a single person and €900 per week for couples. The medical card will be replaced with a GP Visit Card, which provides free GP care only, if weekly income is between €500 and €700 for a single person or between €900 and €1,400 for a couple.

[4] Dental services are limited to a service list.

[5] Health insurance schemes run by some semi-state and state organisations provide limited drugs reimbursement (Garda, ESB Provident Medical Fund)

expenditures on prescription medication, in 2010 the limit for the scheme was €132 per month, meaning any expenditure an individual incurred above this would be reimbursed[6].

While public expenditures account for 70-80% of the total spend on health care in Ireland (OECD, 2013), there is also high use of private medical insurance. In 2009 47.9% of the total population had private medical insurance (The Health Insurance Authority (IRE), 2014).

The government has overall responsibility for health care provision in Ireland. It is guided by the Department of Health and legislation. The department advises the government on the strategic development of health services, with the day to day running of the service currently left to the Health Service Executive (HSE). In 2007 the Health Information and Quality Authority (HIQA) was created to set and monitor national standards for quality and safety in health care. With these clear delegations in place it leaves the department more focused on the task of developing health policy.

In terms of policy the Department of Health have issued a number of high level strategy documents starting in 1994 with "Shaping a Healthier Future" (Department of Health & Children, 1994), and "Quality and Fairness a Health System for You" (Department of Health & Children, 2001) in 2001. None of these documents proposed any radical changes to the way in which prescription medicines were accessed, funded or priced in fact scant reference is made to the topic. Furthermore none of the strategies sought to change the public-private mix in health services provision (Burke, 2009). The Report of the Commission on Financial and Control Systems in the Health Service (The Brennan Report) was published in 2003 and highlighted a number of issues in the Irish health care system of the time: no single organization was responsible for the management of the service; there was no focus on cost-effectiveness or value for money; there was limited evaluation of the system and no investment in appropriate information systems. The creation of the HSE and the subsequent reform programme addressed many of the concerns raised in the Brennan Report.

[6] The current DPS ceiling has been raised to €144 per month since the 1st January 2012.

1.4 Contribution

Growth in healthcare expenditures and, in particular, prescribing expenditures increases pressure on government budgets, healthcare providers and individuals. Understanding drivers of this growth should enable more accurate forecasting of future expenditures and inform appropriate policies to reduce inefficiencies in expenditure. This thesis is of great relevance to countries seeking a greater understanding of the impact of ageing on their public medication expenditures.

The thesis addresses a paucity of evidence in the health economics literature on the hypothesis that proximity to death is an important driver of prescription expenditures. Specifically it provides evidence of the proximity to death effect for prescribing expenditures in both Ireland and New Zealand. It reports that decedents expenditure approximately double that of similar survivors in the last year of life. Estimates of future medication expenditure are shown to be over stated if proximity to death is not taken into account. The implications of these findings do not apply to just policies to control future expenditures. Cost effectiveness analysis relies on future projections which often do not take into account PTD leading to an over estimation of the cost effectiveness ratio (Gandjour and Lauterbach, 2005, Gandjour, 2009).

1.5 Study design and analysis

The main expenditure variable used throughout this thesis is the ingredient cost payable by the public health service for medications dispensed to individuals by their community pharmacy, not including any dispensing fee or discounts from manufacturers. Pharmacy dispensing data are automatically collected at the point of care to facilitate reimbursement of pharmacists. It provides a population cohort for each country that is free from patient's recall or social biases[7]. To ensure appropriate identification of decedents, the pharmacy dispensing datasets were linked to death records. A nested case control study was used to

[7] Recall bias is introduced when researchers are relying on the participant to remember details of their past behaviour. Social bias occurs when the participant may not want to report socially undesirable facts.

analyse the expenditures of decedents (cases), matched to those of similar survivors (controls). Chapter 3 sets out a detailed analysis of the literature on expenditure analysis, health care expenditure and proximity to death. Based on this literature the hypothesis was tested on both datasets using a two part model, consisting of a Probit regression to identify the probability of expenditure in any given month and a Generalised Linear Model (GLM) to regress the positive expenditures.

1.6 Thesis structure

This chapter has given an overview of the main aims and scope of this thesis. The first part of the thesis consists of this introduction (chapter 1) and two further chapters: Chapter 2 introduces the main literature and chapter 3 provides a detailed analysis of the general and methodological literature.

The second part of the thesis presents the country specific background information and data analysis, across three chapters: Chapter 4 introduces the Irish setting for the study set out in chapter 5, using data from the Irish Longitudinal Study on Ageing (TILDA) to profile the study population. A comparator study is undertaken on New Zealand and is described in chapter 6. The final part of the thesis contains the discussion of the findings in chapter 7 and the main conclusions in chapter 8. This final chapter presents the overall conclusions of this thesis, identifies areas for future research, highlights how this work has contributed to the body of research and the potential policy recommendations.

The appendices contain more supplementary information on the literature review (A), the weighting process used on TILDA data (B), further data analysis of the prescribing data sets (C), information on the population projections (D), ethics approval and data agreements (E) and publications (F).

2 Literature Review

The aim of this chapter is to provide a narrative overview and summary conclusion of the evidence available. The chapter begins with a brief description of the literature search strategy undertaken and continues with a critical appraisal of the literature before concluding with a summary of the relevant evidence.

2.1 Search strategy

2.1.1 Electronic academic databases

The main focus of the database search is on studies published in academic journals and the pertinent evidence they present. Given that the themes overlap the broad areas of economics, social science, medicine and pharmacy the databases were chosen to be inclusive of these different potential strands of information. The Pubmed, Embase and Econlit databases were searched using a number of search terms which along with the search results are detailed in Appendix A. The initial searches were conducted on 5th, 6th, 7th and 8th September 2011 and last updated on the 19th and 20th February 2013. A systematic approach was taken to screening the bibliographies of the studies discovered in the database searches to identify further relevant studies. In order to keep the review of literature as current as possible during the data collection and analysis phase a number of alerts were instigated for key databases.

2.1.2 Grey literature

In order to identify studies which may not have been published in academic journals a search strategy for grey literature was devised. This primarily included website searches and two online databases: Scirus and OpenSIGLE. Searches of the websites of key research agencies, non-governmental organisations (NGO's) and other organisations active in the various research fields were conducted. Further details of the searches and results can be found in Appendix section A2.

2.1.3 Other sources of literature

Other sources were obtained through networking with experts at conferences, workshops and meetings. In addition, following the twitter accounts of experts, research agencies, NGO's and other organisations active in the various fields.

2.2 Overview of the Relevant Literature

2.2.1 Demand for Healthcare

Grossman (1972b) sets out a theoretical framework for the demand for health care using the theory of human capital in which the patient is the sole decision maker in determining the demand as they seek to invest in their health as a means of increasing their earnings. A key proposition of his theory is that the demand for healthcare is derived from the demand for health. Based on Grossman's assertions the demand for pharmaceuticals is derived from the demand for health, the rational consumer only requires medicine to return to good health or improve future health. The subsequent theory of principal and agent views medical staff as the decision makers (agents), who act on behalf of the individual (principal). This theory arose from early work by Arrow (1963) and Akerlof (1970) who looked at asymmetric information in healthcare and the used car market respectively. For the present thesis it is the prescriber (agent) who makes the decision to issue a prescription not the individual (principal) although the individual makes the decision to fill the prescription. The extent to which an individual can influence the decision of a prescriber is outside the scope of this Thesis.

2.2.2 Determinants of Healthcare Expenditure

Studies only examining the effects of ageing or proximity to death (PTD) all include new evidence or refer to previous work on the overall determinants of healthcare expenditure. Therefore it would seem appropriate to begin with a synopsis of the literature on such determinants before focusing on the areas of ageing and proximity to death. The key papers are summarized in Appendix Table A6.

There is widespread agreement that income and health care expenditure (HCE) are closely linked, but the reliability of the precise mechanisms through which this relationship arises is far from clear (Newhouse, 1977, Culyer, 1988, Hansen and King, 1996, Martikainen et al., 2012). The main hypothesis in this body of literature is that

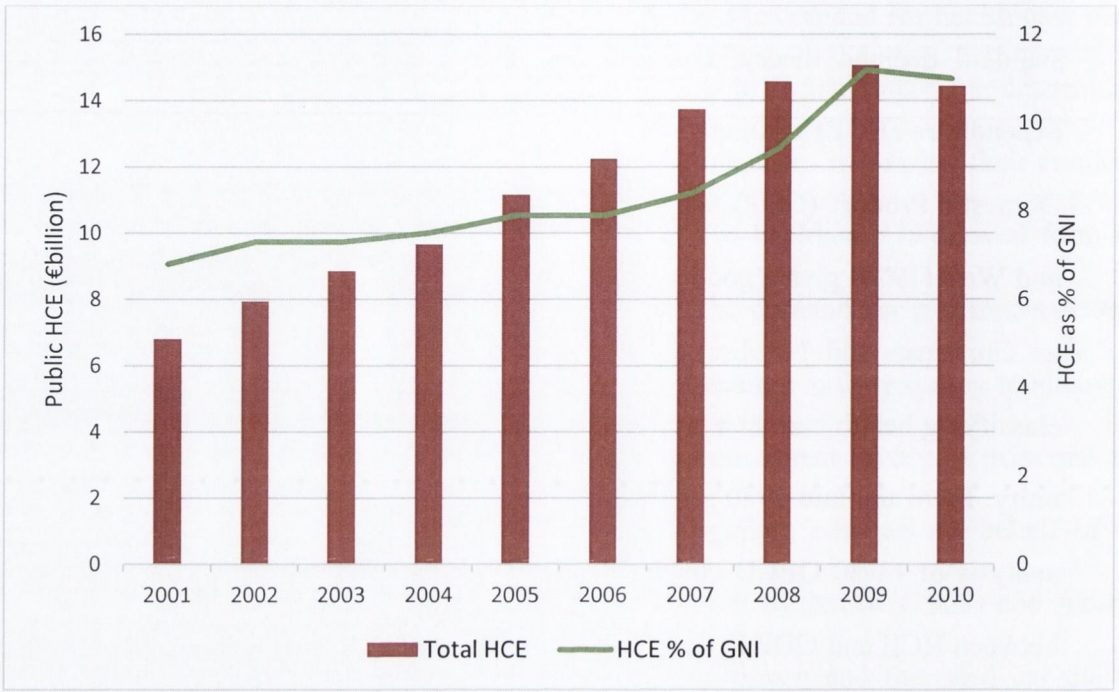
GDP[8] per capita is the single most important determinant of the level of health care expenditure (Kanavos and Mossialos, 1996). The analysis of HCE has been based on standard demand theory, typically focusing on the income elasticity[9] of health care expenditure (HCE) estimated in functions linking per capita HCE to per capita Gross Domestic Product (GDP) using cross sectional data from a number of countries. Cullis and West (1979) give a good synopsis of the early studies undertaken by economists such as Grossman and Newhouse looking at the relationship between income and HCE, classifying health care as a necessity based on an observed income elasticity of less than unity. From the late 1970's onwards research on this subject focused on cross sectional analysis of 13-20 OECD countries. These studies reported a strong positive correlation between HCE and GDP in developed countries, with income elasticity greater than one in the countries studied (Newhouse, 1977, Newhouse, 1987, Leu, 1986, Brown, 1987, Parkin et al., 1987). None of these studies included Ireland or New Zealand. The seminal article in this area Newhouse (1977) reported an income elasticity of 1.4. This implies that health care is a "luxury good" and the share of HCE in GDP will increase with per capita income. This is what has occurred in Ireland in the decade to 2011, while the real amount of HCE has risen, the proportion of Gross National Income (GNI)[10] spent on health has also increased, as seen in Figure 2.1. Subsequent studies such as Sen (2005), who included New Zealand, have reported elasticities as low as 0.21, making health care a necessity.

[8] GDP is the value of all output in the economy regardless of who owns the production inputs BEGG, D., FISCHER, S. & DORNBUSCH, R. 2003. *Economics,* Maidenhead, UK, McGrawHill..

[9] Income elasticity is the percentage change in the quantity demanded divided by the corresponding change in income.

[10] GNI is the total income earned by domestic citizens regardless of the country in which it is accrued OECD 2013. Healthdata. Organisation for Economic Co-operation and Development. It is equivalent to GDP plus net asset income from abroad BEGG, D., FISCHER, S. & DORNBUSCH, R. 2003. *Economics,* Maidenhead, UK, McGrawHill..

Figure 2.1 Real health care expenditure and real health care expenditure as a percentage of Gross National Income (GNI) for Ireland 2001-2010



The importance of whether or not health care is a luxury good is based on the behaviour of health care markets. If it is a luxury any income growth would create an increased demand for health care, driving up HCE at a faster rate, regardless of efforts to reduce HCE (Farag et al., 2012). Macro studies use data at a regional or country level whereas micro level studies report at the individual or firm level. Based on the macro results reported of high elasticities the view that income is the main non-demographic driver of future health expenditure has been used in numerous projection studies (Directorate-General for Economic and Financial Affairs of the European Commission, 2009). Häkkinen et al. (2008) highlight a concern about this income approach, they posit that the high positive income elasticities (>1) reported in macro studies may be a consequence of failing to control for other important factors such as prices and health status. They argue that high elasticities are also seen more at the aggregate level, whereas micro level studies such as Giannoni and Hitiris (2002) report much lower elasticity (0.33). So while a strong positive relationship between HCE and income has been a consistent finding in the literature, there remains discord on the magnitude of the income elasticity. A number of

methodological issues have been raised about the HCE and income relationship studies which are discussed in section 3.2.

The literature on the determinants of healthcare expenditure (HCE) has evolved from focusing on income to a more broad cohort of explanatory variables such as ageing, proximity to death, new technologies, types of healthcare systems and methods of reimbursement (Martin et al., 2011). For example Okunde and Murphy (2002) examine the importance of technology change to HCE. They use research and development spend as a proxy and find evidence to support Newhouse's (1992) conjecture that technology is the main driver of HCE over the period 1960-1997 in the USA. Of interest to this thesis are those studies that have reported a positive association between age and health care expenditures and have used age based per capita HCE to predict future expenditures (Newhouse, 1992, Dormont et al., 2006, Roberts, 2000, Giannoni and Hitiris, 2002). The next section discusses age and its relationship with HCE in more depth.

2.2.3 Ageing

Studies frequently associate ageing with higher health care expenditures relative to the younger population (Miller, 2001, Westerhout, 2006, Reinhardt, 2000, Anderson and Hussey, 2000). The elderly population is estimated to expenditure between 30% and 50% of total health care expenditure in OECD countries (Jacobzone, 2002). Anderson and Hussey (2000) examined health care expenditure and income across eight industrial countries (Australia, Canada, France, Germany, Japan, New Zealand, the United Kingdom, and the United States). They estimated that the average person aged 65 years or more expenditures between 2.7 and 4.8 times more than the average person aged 0 to 64 years. Spijker and MacInnes (2013) argue that current measures of population ageing are misleading and provide only a very rough estimate of future burden. They take the example of the old age dependency ratio and highlight that it neither identifies those who

are dependent or those who are required to care. Instead it takes a ratio of those over 65 years of age to those under.

Numerous macro and microeconomic studies have sought to explain the consequences of ageing. Micro level data are used in a large body of studies which report a reduced effect of age when proximity to death (PTD) is taken into account, albeit not without detractors, this is discussed at length in section 2.2.4. At the macro level the evidence is more conclusive with the vast majority of studies having found that age has a small or negligible effect on HCE in contrast to income or GDP which has a significantly sizeable effect (Gerdtham et al., 1992, Hitiris and Posnett, 1992). Di Matteo and Di Matteo (1998) examining Canadian provincial data from 1965-1990 found the population over 65 years of age, income (GDP per capita) and transfer funds from the federal government[11] to be the main determinants of HCE. Dormont et al (2006) conclude their review of the ageing and HCE literature by commenting that "...identifying the factors that influence the age profile of health care expenditures is a difficult undertaking.". They findings based on a French sample from 1990 and 2000 suggest that ageing will only cause a minor increase in HCE which will be cancelled out by gains from a reduction in morbidity. This finding is very sensitive to changes in the innovation pattern observed, morbidity may not decrease into the future.

The literature proposes four main possibilities on ageing and health, all assume increasing longevity, Gruenberg's (1977) "Failure of Success" theory envisages the proportion of life spent in ill health increasing as longevity increases, an expansion of morbidity. In contrast to this Fries (1980) "compression of morbidity" theory proposes that people will live longer healthier lives with a limited period of illness at the end of life. A third possibility is put forward by Manton (1982), who found the other two theories inadequate to explain mortality trends in the USA. His hypothesis is of a "dynamic equilibrium"

[11] The federal Canadian government provides funds to each of its provincial health services to ensure an appropriate level of service is provided across the country.

where morbidity increases due to rising levels of chronic conditions and disabilities amongst the older population while serious disability would decrease. Murphy (2012) argues that while the older population in western countries is predicted to treble by 2050, it is unclear how health status and the expenditure of treatment will fluctuate. He does however comment on Manton's (1982) "dynamic equilibrium" as being "the most plausible scenario"(Murphy, 2012). A fourth possibility is discussed by Payne et al (2007), postponement of morbidity, in which the period of morbidity at the end of life remains the same in duration but just occurs later in the individuals life due to expanding life expectancy building on Fries theory of "compression of morbidity". Evidence shows that the extra years gained due to increases in longevity are healthy years (Crimmins et al., 1997, Waidmann and Liu, 2000, Gheorghe et al., 2014), this lends support to the theories of ageing expounded by Fries (1980) and Payne et al (2007).

Fuchs (1984) described the major social and economic trends affecting the older population in the USA of the mid-eighties. He identified six areas and discussed them in light of the funding crisis which was affecting the Medicare[12] scheme at the time. The six areas were: "the number of elderly: their health status; use of medical care; labour force participation; income; and their living arrangements"(Fuchs, 1984). Despite the intervening 30 years these areas are still pertinent today.

Mortality statistics show that people are living longer but are they living longer in poorer health? Fuchs (1984) asserts that disability and morbidity statistics lack the objectivity to assess if people who are living longer are doing so with a good quality of life. There remains no consensus in the literature on how to measure morbidity, potential measures include the prevalence of chronic diseases, self-reported health status and disability measures such as the ability to complete activities of daily living, ADL or instrumental

[12] Medicare is an American national social insurance scheme predominately for those aged 65 or more.

activities of daily living, IADL (Robine and Michel, 2004, Payne et al., 2007). The use of these different measures may complicate the identification of time trends in population morbidity.

In terms of age as a driver of expenditure, some cross-sectional studies of aggregated national HCE have found that the proportion of the population 65 years or over is a poor predictor of expenditures if at all (Gerdtham, 1992, Reinhardt et al., 2002). This evidence suggests that age is not strongly linked to HCE. Getzen (1992) examined a time series of HCE from 1966-1988 across 20 OECD countries, he concludes that while ageing may increase the demand for healthcare it is the constraints of government budgets that will prevent a requisite rise in HCE. In contrast Payne et al (2007) report that the average per capita HCE for those aged 65 years or more are two to eight times more than those aged 18-64 years, and increase with age. A similar finding is reported in Di Matteo and Di Matteo (1998). These studies did not take into account the fact that a large number of people die in the 65 years or more age groups.

Within the "elderly" distinct age groups many also have varying relationships with HCE. Cutler and Meara (1997) and Fuchs(1998) both showed steep increasing gradients in HCE in older age groups with the oldest old expenditureing 3 times as much as the youngest old.

Different components of HCE may have a different relationship with age, studies have shown an increase in nursing home expenditure for decedents which increases with age (Spillman and Lubitz, 2000, McGrail et al., 2000). In contrast studies examining acute hospital care have reported age as having no effect once proximity to death is considered (Zweifel et al., 1999, Seshamani and Gray, 2004b), this is discussed further in the next section.

2.2.4 Proximity to Death

While age may be important to an extent, Fuchs (1984) proposed the idea of proximity to death (PTD) having an important positive effect on health care expenditures. The premise being the closer someone is to death, possibly the more health care resources they use resulting in higher health care expenditure. Table 2.1 summarizes the relevant literature on health care expenditures and proximity to death discussed in this section.

A higher rate of mortality in older age groups could be a confounder in the age – expenditure relationship. Van Baal and Wong (2012) suggest that PTD may be a better predictor of expenditure than age as it includes both age and mortality risk. Studies conducted in this area have mostly used individual level data and broadly address two clinical services: acute hospital care and long-term care (LTC).

More than three decades ago Ginzberg (1980) questioned the spending of large sums on terminal ill patients and highlighted the high expenditures associated with death by disclosing the health care expenditures of his mother's last year. The substantial expenditure incurred towards the end of life remains a fact (Simoens et al., 2013, Polder et al., 2006). Studies on publically provided health care from the US and UK report that annually 26-30% of expenditures are incurred by the 5% who are in their last year of life (Lubitz and Riley, 1993, Gray, 2004).

Scitovsky (2005) draws attention to a distinction between retrospectively and prospectively identifying patients who are in their last year of life. She argues that while studies looking at the 'expenditure of dying' can examine expenditures retrospectively, it is difficult to prospectively estimate when a patient is going to die[13]. Hence any policies targeted at reducing patient expenditures at the end of life are difficult if impossible to

[13] The exception being cancer patients, for whom Scitovsky (2004) points out it is easier to predict their death based on disease progression.

implement as clinicians are at a lost to identify death 3, 6 or 12 months prior. Scitovsky (2005) sets out to ascertain if expenditure containment efforts amongst the terminally ill is the best measure to tackle rising health care expenditures. She provides a detailed analysis of the literature on studies from the 1960's and 1970's examining the medical expenditures of those who die. She highlighted the omission of drug expenses from all of the studies done using Medicare data. In conclusion she states that there is no evidence to suggest that the use of 'high technology interventions" for terminally ill patients is driving high health care expenditures in fact she cites a small amount of evidence to the contrary. This may have changed in the intervening years as technology has played an increasing role in healthcare since the 1980's (Fuchs, 2012). However, there were at the time of publication, 1984, limited studies and Scitovsky's conclusions acknowledge that fact.

While authors such as Fuchs (1984) and Getzen (1992) had identified proximity to death as a determinant of high healthcare expenditure Zweifel et al (1999) provided more extensive empirical evidence and introduced the phrase "red herring" for the hypothesis that age does not have a significant effect on HCE but is instead a proxy for proximity to death (PTD). Using longitudinal data from Switzerland they challenged the widespread belief that ageing populations would lead to higher HCE by testing two potential hypotheses, firstly that age was a driver of HCE and secondly that proximity or closeness to death was a driver of HCE. They concluded that PTD was a predictor of HCE but age was not. Their methodology is critiqued in section 3.4. Subsequent studies (Zweifel et al., 2004, Seshamani and Gray, 2004a, Stearns and Norton, 2004, Werblow et al., 2007, Di Matteo, 2005) showed that older survivors did not demonstrate higher HCE, with age not being a significant predictor once PTD was controlled for. This built on previous work by Lubitz et al (1995) who showed that the expenditure of the last year of life decreased with age, that is the average annual Medicare payments in the USA for individuals decreased

as their age at death increased. Subsequent studies also showed that hospital expenditure for decedents declined with age (Spillman and Lubitz, 2000, McGrail et al., 2000).

The majority of the literature on PTD has focused on micro level data, using individuals expenditure records, this is in contrast to the income focused studies discussed in section 2.2.2, which used marco data and sometimes included a variable for the population over 65 as a proxy for ageing (Newhouse, 1977, Brown, 1987, Leu, 1986). The exception to this is van Baal and Wong (2012) who uses macro level data from the Netherlands consisting of mortality rates and per capita health expenditures stratified by age and gender for the years 1981–2007 (discussed further in section 2.2.7).

O'Neill et al. (2000) uniquely examined PTD and GP expenditures for nursing home patients in the Nottingham area of the UK, while the study found PTD to have a significant positive effect on expenditures and age to be neutral, it is limited by its small sample size (n=52) and time period (12 months).

Felder et al (2000) take into account the 8 quarters prior to death, they use OLS estimation to find that HCE decreases as an individual ages but increases with PTD. But age is only significant when considering the whole population, for those 65 years or older age has a negative coefficient close to zero, a strong positive coefficient (1.3) is reported for females over 65 years. A coefficient of 1.9 is reported for the last 3 months prior to death, the further from death the lower the monthly coefficient becomes. They also found that those on a low income incur lower HCE in the last months of life than those on higher incomes.

The Wanless report (2002) in the UK looked at the effect of PTD in the last year of life and incorporated it into future HCE projections from 2002 to 2023. The report used Scottish hospital and mortality data and projected an increase in HCE as a proportion of GDP, which would have been overestimated had PTD not been taken into account. Other studies have shown that the PTD effect extends far beyond just the last 12 months of life,

a British study found a significant effect up to 6 years prior to death (Seshamani and Gray, 2004c, Himsworth and Goldacre, 1999).

Despite the numerous studies supporting the Zweifel et al. (1999) seminal paper numerous researchers subsequently raised methodological concerns and these are discussed in more detail in section 3.4. Even though Seshamani and Gray (2004a) highlighted several econometric weaknesses in the methodology of Zweifel et al (1999) they still had similar findings. Their extended two step model and random effects model showed time to death had a significant effect on quarterly hospital expenditures, which increased up to 15 years prior to death. And while age has an effect on expenditure predictions it is relatively small compared to the tripling of quarterly expenditures in last year of life. In terms of expenditure Seshamani and Gray (2004c) estimated for a UK population aged 65 or more in 2002 the 5% of people in their last year of life accounted for 50% of the hospital expenditures for that age group. They hold the view that time to death is a major driver of healthcare expenditure and deduce that in combination with lower mortality rates and increasing longevity real per capita HCE in each age group will decline, holding all other things constant.

Layte (2007) took a similar approach to Seshamani and Gray but without a two step model (see section 3.3). He used an Irish national panel survey of 15,000 individuals to provide evidence to support the hypothesis that HCE is a function of PTD rather than age for expenditure on GP and hospital services.

Breyer and Felder (2006) present evidence that suggests PTD has a small effect on underestimating future expenditure on healthcare but their study applies Swiss age expenditure profiles to a German population which may not be appropriate. In contrast to the aforementioned studies in this section Westerhout (2006) has argued that ageing is still a more important driver of healthcare expenditures rather than PTD, with taking the latter into account only reducing expenditures by a small amount. More recently

Colombier and Weber (2011) present evidence that ageing is still the most important driver of healthcare expenditure. Their study uses 2004 population statistics to project HCE to 2050, while the methodologies are widely used, the results of the study are based on one year only, in contrast to previous studies which used a time series of results before any predictions were made.

Studies typically report mean HCE per annum as rising in the 60 year old age group with a bell curve peak in the 80 year old age group and a decline there after (Bjørner and Arnberg, 2012). A simple graph, reproduced in figure 2.2, of mean HCE per person for the year 2000 by time to death presented in Bjørner and Arnberg (2012), clearly shows the higher expenditures incurred by all decedents, the rise of these expenditures with proximity to death and the decline of expenditure with age of death.

Wouterse et al (2013) set out to combine data from the Netherlands on the health and expenditures (long-term care and hospital) of individuals over their remaining life span. Firstly they created a latent health state for each individual based on health indicators and expenditure, they then analysed dynamics in health and expenditure using a Markov framework. They did not include PTD as an explanatory variable as they felt it was a proxy for health. The study reports evidence that supports the compression of morbidity theory discussed in section 2.2.3.

Figure 2.2 Mean public HCE per person in the year 2000, with different periods to death, based on a Danish 10% population sample.

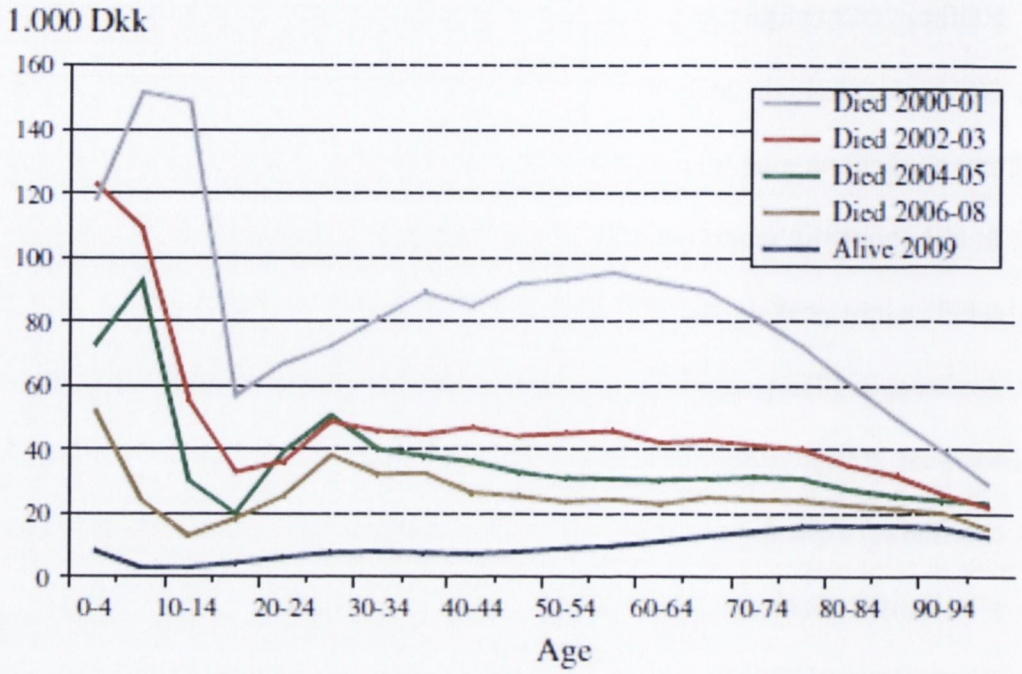


Figure 2 from (Bjørner and Arnberg, 2012) Average public health expenditure per person in 2000 for individuals with different distances to death. © Springer Science + Business Media. Reproduced with kind permission of Springer Science + Business Media.

The investigation of proximity to death and ageing is not confined to individual level data, a number of studies have also looked at aggregate data and found evidence of the same effect. Bech et al (2011) examine HCE with social, economic, demographic, mortality and life expectancy explanatory variables, reporting only short term effects of ageing on HCE instead citing increasing longevity as a long term driver of HCE. They also suggest that past rather than future mortality rates predict HCE which they posit is the result of a political lag. Karlsson and Klohn (2014) use Swedish municipality data to address the question of time to death (PTD) and ageing for LTC, concluding that age is the main determinant but PTD is still relevant. In terms of whether macro or micro data is best suited to this analysis Getzen (2000) in the context of income elasticities for HCE, advocates that the unit of analysis is of key importance, as health care is found to be a

necessity at the individual level and a luxury at the macro level. Furthermore he argues that differences within groups are averaged out at the aggregate level with between group difference being more important hence the original link between individual determinants and HCE may no longer exist.

All these aforementioned studies have focused on demand side factors such as individual age gender etc., a recent paper has started to look more at the supply side characteristics, in this case the hospital (Chang et al., 2013). They followed hospital expenditures for patients over the last 24 months of life and concluded that private hospitals are associated with greater expenditures than public ones, with no statistically significant difference in length of stay. At the aggregate level a study of 15 EU countries reported an effect of several supply side variables on health care expenditure (Bech et al., 2011). In particular they found evidence of the influence of health care system structure and capacity on HCE. The prevalence of morbidity and disability has been shown to increase with age and also to have an impact on the risk of mortality (Majer et al., 2011). In terms of drivers for individual health care, van Baal and Wong (2012) suggest that age and PTD are proxies for morbidity and disability. Two recent studies present evidence that suggests once morbidity and disability are controlled for PTD loses its explanatory ability (Goldman and Shang, 2008, de Meijer et al., 2011). Within prescribing data there is no information on disability and limited information on morbidity. The identification of chronic conditions from the types of medication dispensed could be used to mitigate this short coming for morbidity information.

Several studies agree that PTD rather than age predicts HCE for acute care but both are important for long-term care (Scitovsky, 1994, Comas-Herrera et al., 2007, Werblow et al., 2007). What is not discussed in this literature is how important these factors are for prescribing expenditures. Layte concludes a report on the impact of demographic change in Ireland by observing that *"One particular dimension which should receive attention is*

the relative roles of ageing and proximity to death in structuring the demand for health care and how population health among older age groups may influence this relationship." (Barry et al., 2009) The subsequent section discusses the literature which has in some part examined the prescription medication component of HCE.

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Table 2.1 Studies with findings relevant to the proximity to death effect on health care expenditure (HCE)

Study Authors	Time period, location, age group, sample size	Healthcare expenditure (HCE)	Methods & model for HCE	Relevant findings
(Lubitz et al., 1995)	1974-1990 USA ≥ 65 n= 129,166 Medicare	Total Medicare expenditures	Decedents form 1989 and 1990 were followed back 17 years before death.	HCE in the last 2 years of life declines with age. Annual payments decrease each year as age of death increases.
(Zweifel et al., 1999)	1983-1992 1983-1994 Switzerland	HCE quarterly	Probit, log OLS, two stage Heckman. Independent variables: age, gender, quarter, year, insurance status. The inverse of Mills ratio (λ) was calculated from the Probit model using maximum likelihood estimation the results of which were used in the OLS model to account for bias of removing zero expenditure individuals.	Age is insignificant in determining HCE once PTD included. (Weakly significant variable with a regression coefficient of 0.062 for all individuals. Negative coefficient close to 0 for those ≥65yrs of age)

Study Authors	Time period, location, age group, sample size	Healthcare expenditure (HCE)	Methods & model for HCE	Relevant findings
(Felder et al., 2000)	1987-1992 Switzerland ≥ 65 years n = 415	HCE quarterly	Log OLS time-series, two stage Heckman. Independent variables: age, age squared, gender, age and gender, dummy for over 65 years of age, insurance, time to death, year, λ (inverse of Millis ratio)	Evidence suggests HCE increase with PTD, HCE decreases with age for retired individuals and those on a low income incur lower HCE in the last months of life than those with higher incomes.
(Spillman and Lubitz, 2000)	1996 USA Medicare, National Mortality Followback Survey, National Medical Expenditure Survey.	Mean cumulative HCE	Followed decedents in 1996 back to age 65. Used Social Security Administration's mortality and pop projections to predict future expenditures.	Mean cumulative HCE for decedents increased with age, mostly attributed to Nursing home expenditures.

Study Authors	Time period, location, age group, sample size	Healthcare expenditure (HCE)	Methods & model for HCE	Relevant findings
(Salas and Raftery, 2001)	Critique of Zweifel et al (1999) methodology.			Claim that PTD presents problems of endogeneity[14] in the estimations and sample selectivity. Suggest an amended model to overcome the endogenity by including lagged variables of the dependent variable and re-specifying age and age squared in the model to limit multicollinearity.
(Busse et al., 2002)	1989-1995 Germany n = 73,933 (4,086 decedents)	n/a	Cohort study using a random 10% sample. Examination of hospital days.	Number of days spent in hospital were lowest for <25 and ≥85 age groups, and greatest for the 55-64 year olds. Hospital days for those who die at ≥ 50 years is directly proportional to the years lived.
(Yang et al., 2003)	1992-1998 USA Medicare n = 25,994	Average monthly HCE	Descriptive analysis.	HCE starts increasing 24 months before death. PTD is driver of higher inpatient expenditures, Age is a driver of LTC expenditures.

[1414] see section 3.3 for a description of endogeneity and its implications

Study Authors	Time period, location, age group, sample size	Healthcare expenditure (HCE)	Methods & model for HCE	Relevant findings
(Seshamani and Gray, 2004a)	1970-1999 Oxfordshire, England Oxford Record Linkage Study (ORLS) ≥65 n= 90,952	HCE quarterly, time to death	Replicated Zweifel (1999) et al model and also extended the model, the first part a regular Probit with independent variables for age, gender, time to death, cause of death and social class. The second part used a GLM with the Probit variables and diagnosis, source of admission, place of discharge, and marital status.	Attempt to address methodological criticisms of Zweifel et al study (1999). Replica model showed an insignificant relationship between both PTD and age with HCE. Extended model showed time to death had a significant effect on quarterly hospital expenditures. The rise in average quarterly expenditures with PTD were largely influenced by the probability of being in hospital. While age has an effect on expenditure predictions its relatively small compared to tripling of quarterly expenditures in last year of life.
(Stearns and Norton, 2004)	1992-1998 England	HCE	Logit	Increased power of model by including PTD (adjusted coefficient of determination)
(Di Matteo, 2005)	1975-2000 Canada 1980-1998 USA	HCE per capita per province	Independent variables: Per capita GDP, federal funds per capita (USA), percentage of population over 65, province, age.	Percentage of population over 65 closely related to HCE (coefficient = 1.07)
(Breyer and Felder, 2006)	1999 Switzerland Germany	HCE per capita	Cross – sectional Independent variables: age, gender, decedent, time to death.	Taking PTD into account decreases the expenditure impact of an ageing population.

Study Authors	Time period, location, age group, sample size	Healthcare expenditure (HCE)	Methods & model for HCE	Relevant findings
(Dormont et al., 2006)	1992-2006 France	HCE	Independent variables: age, morbidity, disability, risk of death, co-morbidities, self-perceived health, income, employment class, educational attainment, heathcare cover, gender, size of household, marital status.	Attributes a small growth in HCE due to population ageing. Morbidity has an important effect and the risk of death maybe a better indicator of HCE than PTD due to the endogeneity (see section 3.3) of the latter.
(Johnson and Yong, 2006)	1994-2001 Australia Medicare	Budget share of HCE on total consumption	Calculates an exact aggregation health demand model. Independent variables: year, Medicare health price index, price index of non-health goods, per capita Gross State Product, pop <65, pop ≥ 65, pop 60-69, pop 70-79, pop ≥ 80, deaths 60-69, deaths 70-79, deaths ≥ 80	Taking PTD into account Age has a negligible or negative effect on health care demand.
(Polder et al., 2006)	1998-1999 The Netherland 13% of population	HCE	Descriptive analysis of decedents and survivors.	Higher expenditures in last year of life and an inverse relationship between age and expenditure of dying. Overestimation of excluding PTD of 9.3% to 25.8% depending on component of HCE and demographics.

Study Authors	Time period, location, age group, sample size	Healthcare expenditure (HCE)	Methods & model for HCE	Relevant findings
(Layte, 2007)	1994-2001 Ireland Living in Ireland survey n=15, 483 (444 decedents)	GP & hospital expenditures	Random effects panel model. Independent variables: Age, gender, years before death, marital status, highest education, calendar year.	PTD more important predictor of expenditures than age, gradient in expenditures increasing with PTD. Controlling for PTD showed no expenditure increase with age.
(Palangkaraya and Yong, 2009)	1990-1996 22 OECD countries (incl. IRE)	HCE share of consumption	Independent variables: proportion of population over 65, mortality rate (proxy for PTD), size of public sector.	PTD is more empirically important than Age in accounting for the share of HCE in total consumption. Once PTD accounted for Age and HCE are negatively correlated.
(Felder et al., 2010)	1997-2006 Switzerland (Zurich & Geneva)	HCE	Two- part model, instrumental variables (IV) to examine endogeneity	Set out to examine endogeneity in models that look at PTD in relation to HCE. While some endogeneity remains the evidence suggests relationship holds.
(Colombier and Weber, 2011)	2004 Switzerland Private Health Insurer $\geq$ 65 years	HCE (subsets HC & LTC) per capita	Projected HCE for HC and LTC base on 1 year of observed microdata.	Age is still the most important age-related expenditure-driver. Other important drivers are non-demographics like medical progress and morbidity which are more important than mortality as a factor of HCE.

Study Authors	Time period, location, age group, sample size	Healthcare expenditure (HCE)	Methods & model for HCE	Relevant findings
(van Baal and Wong, 2012)	1981-2007 The Netherlands Macro data	HCE	OLS regression on logged variables.	Ageing is a proxy for PTD (effect declines with age) but including PTD in projection models may lead to an underestimation due to increases in unidentified HCE drivers.

2.2.5 Prescribing expenditures and proximity to death

There is a relatively large body of literature which has examined the price elasticity of demand[15] for prescription medications, in which the consistent finding is a low negative elasticity, typically in the range -0.08 to -0.25 (Newhouse and the Insurance Experiment Group, 1993, Pilote 2002, Contoyannis et al., 2005, Kiil and Houlberg, 2014) signifying that prescription medication is a necessity with individuals continuing to buy regardless of price increase. It is worth noting that in the case of the consumer not being the purchaser, demand is likely to be more inelastic (Png, 2012).

Despite the increasing expenditures on drugs in most developed countries there have been few studies examining the predictability of drug expenditures (Hanley et al., 2010). The focus of the previously described studies is very much on total HCE or inpatient expenditures. Even though some studies (McGrail et al., 2000, Spillman and Lubitz, 2000, Bjørner and Arnberg, 2012) include pharmaceutical expenditures they do not examine them individually and any reported effect of an increase in HCE with age is attributed, in the main, to the hospital expenditures as opposed to pharmaceuticals. Seshamani and Gray (2004b) suggest examining pharmaceutical use as one possible area for further research.

Spillman and Lubitz (2000) examine the effects of longevity on HCE, they report the mean cumulative expenditure on prescription drugs from the age of 65 to death as rising with age of death, with a 17.6 time increase from age 65 to age >101. When they examine HCE in the last two years of life they see a sharp increase in nursing home care expenditures with age, and a decrease in general Medicare services. Unfortunately they do not separate out prescription drug expenditures in the last two years of life.

A study in the Manitoba region of Canada shows that the percentage of drug expenditures at the end of life relative to other expenditures such as hospital expenditures or primary care expenditures decreases with age, from 9.2% for the 19-44 year olds to 3.2% for the over 85 year

[15] Price elasticity of demand gives the percentage change in quantity demanded in response to a one percent change in price, holding other factors constant.

olds (Menec et al., 2004). Seshamani and Gray (2004a) highlighted that they intuitively would expect prescription expenditures to be less associated to proximity to death than hospital expenditures as acute hospital services are more associated with end of life.

The addition of detail on drugs in the form of indices of use has been shown to improve the predictive power of models (Zhao et al., 2005, García-Goñi and Ibern, 2008). However these studies (Zhao et al., 2005, Wrobel et al., 2003) used linear regression despite the expenditure data not being normally distributed, with a large right sided tail, the issues of which are discussed further in chapter 3.

A Spanish cross-sectional study examined health expenditure using population microdata and reported age, Spanish nationality and retirement as all positively influencing pharmaceutical expenditure (Angulo et al., 2011). They also discovered important differences between doctors treating the same type of patients which would account for differing expenditures. The Spanish study is based on 2004 data only and did not examine proximity to death.

Of the HCE studies that do include prescribing expenditures they are often not analysed separately but are used to calculate total expenditures per individual (McGrail et al., 2000, Spillman and Lubitz, 2000, van Baal and Wong, 2012, Bjørner and Arnberg, 2012). Table 2.2 sets out a summary of the studies which attempt to examine prescribing data and proximity to death in some way.

O'Neil et al. (2000) reported no effect of PTD or age on prescribing expenditures for a small cohort of nursing home patients (n=52) and cautioned about the different effects on individual components of HCE. Given the small sample size of this study it is not appropriate to make population inferences.

Previous attempts to project future pharmaceutical expenditures in Ireland have not accounted for PTD(Bennett et al., 2009, Conway et al., 2014). One of the few studies to specifically examine prescribing expenditures and PTD, Kildemoes et al (2006), demonstrated that the effect of ageing on future drug expenditures will be overestimated when not accounting for proximity to death.

They examined prescribing records for 471,614 individuals in the Funen region of Denmark on a survivor/decedent basis for 2001. While they concede that ageing will increase future drug expenditures they conclude that the increase will be relatively small.

Werblow et al. (2007) divide HCE into seven components one of which is pharmaceuticals. They use a two-part model (probit and GLM) to examine HCE on medications and report evidence to support the red herring hypothesis proposed by Zweifel et al. (1999).

Table 2.2 Studies with findings relevant to the proximity to death effect on prescribing expenditure

Study Authors	Time period, location, age group, sample size	Healthcare expenditure (HCE)	Methods & model for HCE	Relevant findings
(O'Neill et al., 2000)	1996-1997 Nottingham (UK) ≥ 65 years n = 52	GP care expenditures including prescription medications expenditures	Log OLS. Dependent variables: age, PTD, gender, age gender interactions, health condition dummies	No statistically significant difference in prescribing expenditures between decedents and survivors. PTD associated with an increase in expenditures. No effect of age on expenditures.
(McGrail, Green, Barer, Evans, Hertzman, and Normand 2000)	1987-1988 1994-1995 British Columbia, Canada ≥ 65 years	HCE	Cross-sectional analysis of HCE in the last 6 months of life for survivors / decedents.	Hospital care expenditures increase with age but PTD more important determinant of expenditure. The hospital expenditures for the dying declines with age. Nursing & social care increases with age, and the expenditures associated with decedents also increase with age. Calculated prescribing expenditure but did not analyse separately.

Study Authors	Time period, location, age group, sample size	Healthcare expenditure (HCE)	Methods & model for HCE	Relevant findings
(Spillman and Lubitz, 2000)	1996 USA Medicare, National Mortality Followback Survey, National Medical Expenditure Survey. n=73,280	Mean cumulative HCE	Followed decedents in 1996 back to age 65. Used Social Security Administration's mortality and pop projections to predict future expenditures.	Mean cumulative HCE for decedents increased with age, mostly attributed to Nursing home expenditures. Prescribing expenditures increase with age at death but subsequent analysis is on total HCE.
(Kildemoes et al., 2006)	2001 Funen, Denmark n=471,614	Drug expenditure	Comparison of survivors / decedents expenditure. Developed a "generalised projection model" for prescription expenditure 2003-2030 based on 2001 observations.	Ageing of population is likely to increase pharmaceutical expenditure. Slight increases with PTD therefore high drug expenditure amongst older pop not attributable to PTD.

Study Authors	Time period, location, age group, sample size	Healthcare expenditure (HCE)	Methods & model for HCE	Relevant findings
(Werblow et al., 2007)	1999 Switzerland n = 65,000	HCE	Two part models, with first pat probit and OLS and GLM in second part	No or weak age effects on HCE, once PTD controlled for. Exemption being LTC, were age is still important.
(Häkkinen et al., 2008)	1997-2002 Finland 40% sample of ≥ 65 n = 281,119	HCE	Two step models, logit (to determine likelihood of use) & OLS linear functional form, Box-cox test rejected linear but alternative GLM did yield different results. Independent variables: age, gender, time to death, death, region	Evidence of total HCE increasing with Age, attributed to LTC, which alone has a strong Age relationship. Prescription drug expenditure declined with age amongst decedents.

Study Authors	Time period, location, age group, sample size	Healthcare expenditure (HCE)	Methods & model for HCE	Relevant findings
(Bjørner and Arnberg, 2012)	2000-2009 Statistics Denmark, Danish National Board of Health, Danish Cause of Death Registry n≈0.5m/year (10% of population)	HCE/year	GLM. Independent variables: age, gender, interaction terms, PTD.	PTD has a significant impact on HCE due to high "terminal expenditures". Age also impacts HCE. All out of hospital prescribing expenditure are included in HCE calculations but not analysed separately.

2.2.6 Longevity

Most of the research studies discussed in this chapter have been a response to worries about increasing longevity and its expenditure implications for national health care systems. The early decades of the 20th Century saw increases in life expectancy due to a reduction in child mortality, in the more recent decades longevity increases are due to a reduction in old age mortality (Gheorghe et al., 2014). In the period 1960 to 2009 OECD countries saw an increase of 11.2 years in life expectancy, New Zealand 9.7 years and Ireland 10 years (OECD, 2011a). Most developed countries are expecting substantial increases in their older populations in the medium (10-30 years) to long term (30 years or more, this is partly due to historically high birth rates but also due to increasing longevity. Life expectancies are increasing in general and evidence suggests that these additional years are being lived in good health (Crimmins et al., 1997, Waidmann and Liu, 2000, Gheorghe et al., 2014).

Spillman and Lubitz (2000) report a rise in the mean cumulative expenditures from the age of 65 year until death, showing the effects of increased longevity. They show the rise across all categories of expenditure except Medicare covered services. The results don't show the effect of PTD and fail to compare decedents to similar survivors.

Murphy (2012) suggests that if age is a main driver of HCE then increasing longevity will result in an increase of living years spent in the older more expensive years. Oliveira and de la Maisonneuve (2006) point out that increases in longevity need to be accompanied by increases in the years of good health to ensure that proximity to death remains an important determinant of HCE. They posit that extra years in bad health would increase HCE.

There is a body of literature which questions whether longevity is going to increase into the future. A seminal paper on longevity documented that higher levels of income per

capita were associated with greater life expectancy in a cross-section of countries (Preston, 1975) implying that longevity is subject to income cycles. More recently an American study (Ezzati et al., 2008) suggests that within countries there may in fact be a decline in longevity for poorer sectors of society; when examining county level mortality rates they reported a stagnation or increase in mortality rates in poorer counties which they attributed to a rise in cardiovascular disease, lung cancer, chronic lung disease, diabetes, HIV/AIDS and homicide (Ezzati et al., 2008). The interpretation of the income/longevity curve proposed by Preston (1975) is the subject of debate around whether income is a proxy for other factors that correlate with it such as efficiency differences in health care (Dalgaard and Strulik, 2010). The shape of the curve determines to what extent income is protective for longevity and the effectiveness of income redistribution to improve population health (Deaton, 2003). Dalgaard and Strulik (2010) developed a model that accounted for 80% of the Preston curve, they attributed the remaining 20% to omitted factors that are correlated with both income and longevity. They also reported that changes in health efficiency had a larger impact on longevity than changes in prices or income. Therefore improvements to health outcomes might be better achieved via efficiencies in health service delivery and health technology.

Grossman's (1972a) model for the demand of health views longevity as an indirect outcome of investments in "health capital". Ehrlich and Chuma (1990) critique Grossman's approach to longevity and develop their own model of the demand for longevity which links individual longevity with the economic incentives coming from wealth, health, education, medical expenditures, age and time preference. A major limitation to their model is the assumption of certainty and the assumption of death as a distant conclusion rather than a possible hazard throughout the life cycle.

Studies have reported factors other than biology that have extended human lifespan, changes in lifestyles, diet and sanitation (Philipson and Becker, 1998). Fogel (1994)

attributes increasing longevity to variables such as weight and height that are determined by economic well-being. From 2000-2009 he estimated that pharmaceutical innovation increased mean age at death by 0.29 years in France, 20% of the total increase in longevity over the period. For Germany there was an increase in life expectancy at birth of 0.44 years and the USA an increase of 0.44 years in the mean time to death (Lichtenberg, 2013).

Longevity and health care expenditures intuitively would seem to be related, investing in the latter should increase life expectancy. Zweifel and Ferrari (1992) described the relationship between HCE and longevity as a dynamic feedback advocating that not only does HCE increase longevity but it also ultimately increases the demand for health care. They called this the "Sisyphus syndrome", but failed to find any evidence supporting it. A subsequent study provided some supporting evidence at the aggregate level (Zweifel et al., 2005).

Yang et al (2003) argue that based on their descriptive analysis of health care expenditures in the last 2 years of life, it is PTD that is a main driver of inpatient expenditures, but end of life expenditures decline with age therefore increasing longevity will not increase HCE as much as expected. This idea relies on a postponement of morbidity assumption (discussed in section 2.2.2) rather than an expansion.

2.2.7 Predicting healthcare expenditures

If proximity to death is a more important driver of expenditure than age then this needs to be included in future projections. According to the "Red Herring" hypothesis traditional projection methods will overestimate the influence of ageing as improvements in longevity will postpone rather than increase health expenditure (Zweifel et al., 1999). If mortality rates continue to decline the exclusion of PTD has been shown to lead to an

overestimation of the future HCE in a number of studies with varying magnitude (Stearns and Norton, 2004, Madsen et al., 2002, Breyer and Felder, 2006). Van Baal and Wong (2012) have argued that the inclusion of PTD in macro level forecasting models does not lead to lower forecasted expenditure and they cite increasing health expenditures due to unidentifiable sources and decreasing mortality rates as an explanation for this. The key studies which have investigated the effect of PTD on future HCE are outlined in table 2.3. There is considerable variation in the periods covered by the projections making it difficult to draw comparisons. Van Baal and Wong (2014) is the only study to provide evidence of an underestimation when PTD is accounted for. They attribute this to a rise in "unidentifiable causes" over the projection period, but offer no information on what theses causes may be.

Table 2.3 Magnitude of effect of exclusion of proximity to death (PTD) in projections

Study	Country	Prediction Period	Outcome	Magnitude of effect overestimation / (underestimation)
Madsen, Serup-Hansen and Kristiansen (2002)	Denmark	1995-2020	Total HCE	3.4%
Stearns and Norton (2004)	USA	2004-2020	Total HCE	9% -15%
Polder (2006)	The Netherlands	1999-2020	Total HCE	9.3% to 25.8%[a]
Breyer and Felder (2006)		2050	Total HCE	18.5%
Kildemoes et al (2006)	Denmark	2003-2030	Community prescribing expenditure	1%
Van Baal and Wong (2012)	The Netherlands	1981-2007	Total HCE	(0.1%) to (1.1%)[b]

a Depending on component of HCE and demographics.
b Depending on timeframe

O'Neill et al (2013) attempt to model future drug expenditures in the UK using a bottom up approach based on an individual medicine analysis (ATC level 4) to account for the changes in prescribing practice in the medium term. They do not directly include the potential effects of complements, substitutes or income demand elasticity.

2.3 Summary of the literature review

There is general consensus that most countries will experience a demographic shift towards an aging population in the next few decades. What is in contention is the effect this shift will have on health care expenditures. Central to the debate is whether or not ageing is a key driver of expenditure.

While all the studies discussed in this chapter have reported an effect of proximity to death (PTD) what is still debatable is the extent of this effect and its magnitude relative to other factors such as new medical technology (Breyer and Felder, 2006, Westerhout, 2006, Colombier and Weber, 2011). In addition examining the constitute services of total health care expenditure is important to fully understand the effect of ageing (McGrail et al., 2000). Age and proximity to death may have a varying importance depending on the component of health care expenditure being examine – for example: Acute hospital care; long term care; primary care or prescribing. To date most of the studies have focused on overall health care expenditure (HCE) or one of its two main expenditure components: acute hospital expenditure and long term care expenditures. Despite prescribing being the main medical intervention there is limited separate analysis of the effect of age and proximity to death on prescribing expenditure. This may be due to the difficulty of separating these expenditures from other medical expenditure. This thesis aims to address the paucity of evidence on the relationship between ageing, proximity to death and prescribing expenditures.

Some of the studies discussed in this chapter used potentially non-representative samples such as those taken from private health insurance or hospital datasets or failed to deal with econometric issues such as heterogeneity or endogeneity. The following chapter examines the methodologies employed in previous studies with a view to identifying an appropriate methods for this thesis.

"Essentially, all models are wrong, but some are useful."

George Box (Box and Draper, 1987)

3 Review of approaches to modeling prescribing expenditures

The aim of this chapter is to provide a narrative overview and summary conclusion of the methodologies used to model expenditure data, in particular health care and prescribing expenditures. The search strategy to identify appropriate literature is outlined in detailed in Appendix A. A recent systematic review of the literature on the determinants of healthcare expenditure highlighted the lack of empirical evidence to support ageing as a main determinant but also emphasized the methodological weaknesses in studies on proximity to death as a determinant (Martin et al., 2011). This chapter begins with a critical appraisal of the literature on expenditure data modelling, continues with the literature on health care and prescribing expenditures before concluding with a summary of the relevant evidence.

3.1 Introduction to expenditure data and potential challenges

Expenditure is composed of two interrelated parts: price and quantity. Quantity represents the consumption of resources which in this thesis is dispensed prescription medication. Price is the monetary value of the resources used and depends on the dosage and the perspective taken, for example that of patient, insurer or public healthcare system. In this thesis the price is the ingredient cost of the medication from the perspective of the public health system and the dosage is determined by the prescriber who in turn is guided by clinical guidelines and professional experience. The ingredient cost is the amount of money paid by the public health care system for the medication, excluding mark-up, pharmacy fees or any other pay back or other manufacturer reimbursement scheme. This is a widely used measure of medication expenditure and removes other issues such as pharmacist remuneration.

The search for unbiased, efficient estimators that can deal with the challenging characteristics of expenditure distributions is well documented in the literature. Expenditure data is often characterised by a highly skewed distribution, a large number of zero values, no negative values and heteroskedasticity (Jones, 2010, Briggs and Gray, 1998). Hetroskedasticity means that the variances across the variable are not the same (See section 3.1.4). An important assumption of many econometric methods is no heteroskedasticity (i.e. homoskedascticity). These are characteristics that are also common to other types of health care data such as length of stay (Xie et al., 2004) or alcohol consumption (Liu et al., 2012). Four pertinent questions arise in the literature examining expenditure data (Jones, 2011, Mihaylova et al., 2011, Wijeysundera et al., 2012):

- How to deal with missing expenditure data?
- How to account for those who have zero expenditure?
- How to deal with heavy right skewed data?
- How to overcome heteroskedasticity?

The relevant literature referring to these four issues will be discussed in this following subsections.

3.2.1 Missing data

Missing data can occur because of nonresponse. For example, some variables about private health coverage or income are more sensitive to nonresponse than others. It is often difficult to obtain all medical expenditures especially in surveys, a number of imputation methods can be used to deal with missing data, including multiple imputation. An introduction to imputation methods such as single and multiple imputation is provided by Cameron and Trevedi (Cameron and Trivedi, 2005). The methods often require assumptions that missing values are unrelated to the true observation and occur at

random(Cameron and Trivedi, 2005). Missing data can lead to selection bias that is difficult to eliminate even with imputation methods (Machlin and Dougherty, 2007). There is a vast literature on dealing with missing data building on Rubin's (1976) seminal paper on inference and missing data. It is unlikely that missing data will be an issue in this thesis as the datasets being used are based on administrative dispensing data collected at the point of care (pharmacy) to facilitate reimbursement. Therefore it is reasonable to expect that there would be no response or recall biases but data may be subject to coding errors (Jones, 2010).

3.2.2 Dealing with a high number of zero values

A starting point in the examination of data with a high level of zeros would be to determine the cause of such zeros. There are three possible scenarios: zero expenditure is the result of missing data; zeros are the result of a decision over which the individuals had no control; zeros represent a genuine choice by the individual. In the case of prescription expenditures it is the latter case which is relevant as there are months when individuals have genuinely no need for prescription medication. The datasets used in this thesis do not contain missing value zeros, the zeros encountered are "true zeros", therefore, there is no selection problem to address (Dow and Norton, 2003), but there is an issue for statistical analysis of how to deal with zeros. The Heckman sample selection model (also know as Heckit model)(Heckman, 1979) would be more appropriate for modeling situations in which the zero values are not "true zeros" but the result of missing data. Dow and Norton (2003) elaborate extensively on this point and provide a thorough explanation with examples. Population health expenditure data will by its nature contain a high number of zero expenditures as not all individuals will use the services in every time period. Jones (2000) highlights two typical ways of dealing with this challenge by using

two part models or a generalized Tobit model. These are discussed in sections 3.2 and 3.3 respectively.

3.2.3 Skewness

The standard approach to skewed data in clinical evaluation would be to use a summary measure of the distribution, for example the median. Drummond et al (2005) argue that this is inappropriate in an economic study as only the mean can provide a link between the expenditure per patient and the budget impact. The traditional approach in economics for dealing with skewed outcomes like expenditure is a transformation, such as logarithmic or a square root. An excess number of zeros is problematic for the log transformation for two reasons: the log of zero cannot be computed and the model fails to deal with the excess number of zeros. The addition of a small number to the expenditure data to facilitate transformation is not appropriate as the resulting log transformed regression can be sensitive to changes in the left-hand tail of the expenditure distribution (Buntin and Zaslavsky, 2004, Mihaylova et al., 2011). A number of researchers have pointed out that if ordinary least squares (OLS) is used to estimate a regression model on skewed expenditure data with a log transformation the analysis would not be based on the population means but rather the mean on an alternative scale (Duan, 1983, Manning, 1998, Briggs and Gray, 1998, Barber and Thompson, 2000, Liu et al., 2010). This scale would measure geometric means and require a system of back transformation for interpretation (Duan, 1983, Barber and Thompson, 1998, Barber and Thompson, 2000, Liu et al., 2010). A process of retransforming the data unless suitably sophisticated introduces transformation bias mainly due to the presence of heteroskedasticity (Manning, 1998). Duan (1983) advocates the use of a smearing or retransformation factor for logged data to overcome any potential bias in cases where the residuals of the logged variable are not normally distributed but are homoskedasctic. The smearing or retransformation factor

attenuates the loss of precision when transferring from the transformed scale back to the original scale. While the smearing methodology has been applied in numerous large studies of medical expenditures (Lohr et al., 1986, Manning et al., 1987) questions have been raised. A number of authors warn against the use of log transformations when there is heteroskedasticity in the transformed scale as this leads to problems with retransformation (Manning, 1998, Manning and Mullahy, 2001, Mullahy, 1998). The transformation problem has been extensively discussed in the literature (Jones, 2000, Manning, 2006, Mullahy, 2009, Mullahy, 1998, Jones, 2010, Manning and Mullahy, 2001).

3.2.4 Heteroskedasticity

Individual level expenditure data is typically heteroskedastic (Jones, 2010) which means that the variance is not constant over the entire distribution. For example if we consider the income and consumption of a population, those on low income will have limited flexibility on what they spend their money on so there will be little difference between each individuals consumption and the average consumption. In contrast high income earners will have a broader range of options and more flexibility in their consumption patterns, some may consume a lot others may save or invest as a consequence there may be a large difference between the average consumption and each individual. Variance is a measure of spread and in this example we can imagine that the spread of consumption amongst the high and low earners is quite different. Hence there is heteroskedasticity in the total consumption. It is usually accounted for in linear models using robust standard errors for inference (White, 1980). There are numerous diagnostic tests which can be used to identify heteroskedasticity (Breusch and Pagan, 1979, Godfrey, 1978, White, 1980). The relative importance of heteroskedasticity depends on the econometric methods being used therefore it will be discussed further in the context of each individual method.

The statistical literature shows six typical ways of modeling expenditure data these are outlined in table 3.1.

Table 3.1 Statistical methods for modelling skewed expenditure data

Method	Advantages	Disadvantages
The standard linear regression model with ordinary least squares (OLS) without any transformation	• Simple to interpret • Easy to implement	• Assumption of normality and homoskedasticity. • Can predict negative expenditure. • Biased estimators sensitive to outliers in tail of distribution
Transformation model (For example: taking the log expenditure and independent variables)	• Allows transformed expenditures to have a particular type of distribution, e.g. normal. Over comes skewness. • Allows additive effects in the log-scale • Reduces possible issues with heteroscedasticity and kurtosis	• Difficult to interpret coefficients. • Retransformation problem. • Models geometric mean not arithmetic mean. • Scale of estimation is a log scale i.e. log euros. • Can't log zeros. • Doesn't account for large number of zeros.
The Cox proportional hazards model (Dudley, 1993)	• Not reliant on normality assumption Allows transformed expenditures to have a particular type of distribution, e.g. normal.	• Regression coefficients are hazard ratios which are difficult to interpret for expenditure data. • Proportionality assumption must hold
Two part model	• Takes account of the different mechanisms that drive use and expenditure	• Interdependence between parts for prediction
Tobit	• Deals with positive only values	• Assumes both the decision to consume and the level of expenditure come from the same stochastic process
Generalized linear models	• Models the shape of the distribution • Predictions on raw expenditure scale	• May loose precision with highly skewed data

Numerous comparative studies have been undertaken to examine the different methods and how they perform with particular datasets, these are summarized in table 3.2. Manning and Mullahy (2001) examine alternatives to the traditional approach of using a

log model when confronted with a skewed distribution. They provide evidence on the econometric behaviour of the resulting estimators from five Ordinary Least Squares (OLS) and Generalized Linear Models (GLM) previously identified in the literature as alternatives to simple log models. They comment that the choice of estimator *"...can have major implications for the empirical results if the estimator is not designed to deal with the specific data generating mechanism."*(Manning and Mullahy, 2001) and no one model provides both unbiased and efficient estimates in all the relevant cases. They conclude by recommending an algorithm for choosing the best possible model.

Table 3.2 Comparative studies on methods

Study	Comparison
Manning & Mullahy (2001)	OLS on log (y), GLM
Basu, Manning & Mullahy (2004)	OLS on log (y), GLM, Weibull, Cox proportional hazard
Basu, Arondeker & Rathouz (2006)	OLS on y , OLS on log (y) GLM and extended estimating equations (EEE)
Deb & Burgess (2007)	OLS on y , OLS on log (y) GLM , Finite Mixture Method FMM gamma
Hill & Miller (2010)	OLS on y, OLS on log (y) GLM, generalized gamma and Extended estimating Equations(EEE)
Jones (2010)	OLS on y, OLS on log (y) GLM, generalized gamma and Extended estimating Equations(EEE), Finite Mixture Method (FMM) gamma.

y being the dependent variable expenditure

Basu at al. (2004) also found no one model was the best across all metrics but they report the GLM gamma model with a log link as performing the best in their comparison. Basu et al. (2006) built on the previous comparison studies (Basu et al., 2004, Manning and Mullahy, 2001) by including Extended Estimating Equations (EEE) as a comparator examining expenditure data for heart attack patients. Similar to the other comparison studies they conclude that the choice of estimator should depend on the attributes of the dependent variable.

Hill and Miller (2010) used models of two populations (elderly, privately insured adults) on total HCE and prescription expenditure. They report that OLS on log(y) with a homoskedasctic smearing factor was always the worst fit in each of its models. Hill and Miller (2010) didn't explore the introduction of continuous dependent variables into any of their models. Of interest to this thesis are their findings on prescribing expenditures. Based on Hosmer-Lemeshow and Pregibon tests they report GLM with a poisson distribution, a linear OLS or an EEE being the most suitable.

Mihaylova et al. (2011) conduct a systematic review of the statistical methods used in the literature on healthcare resource use and expenditures. They divide the field of expenditure analysis into two: 'randomized evaluation' which is the expenditureing for randomised control trials and 'health econometrics' which is the use of large observational datasets to examine the influence of the individual's characteristics (health status, income etc) on expenditure. It is the latter field which is of interest to this thesis, where the authors undertook a systematic review of methods for analysing healthcare resources and expenditures and provide a comprehensive comparison of methods. They concluded by providing guidance to analysts which consisted of discussing methods in three categories, green, amber and red, based on level of difficulty. The green group being the easiest and appropriate for large sample sizes, assuming normality, the amber group being of medium difficulty included transformations, Generalizied Linear Models (GLMs) and Two-Part models (TPMs), the red group or most difficult are those methods which have been largely untried in applied work. The majority of studies conducted thus far on expenditure data have utilized estimators from the green and amber groups. The red group are the emerging methods. Basu and Manning (2009) looked at future issues for health care expenditure analysis and also concluded that "No current method is optimal or dominant for all expenditure applications. Many of the diagnostics used in choosing among alternatives have limitations that need more careful study." Further to this they

provided some possible future directions for modeling expenditures. Mullahy (2009) surmises the analytical issues associated with expenditure data, he touches on the four questions described at the start of this section and argues for improved presentation of results using confidence intervals instead of p-values and point estimates. Mullahy concludes with:

> "Social scientists and policymakers alike seem driven to draw sharp conclusions, even when these can be generated only by imposing much stronger assumptions than can be defended. We need to develop a greater tolerance for ambiguity." (Mullahy, 2009: S108)

The literature on methods to analysis expenditure variables provides no one pathway or gold standard methodology instead it posits cautious exploration of data using several models and paying attention to assumptions before drawing any conclusions. The following section examines literature that has focused on healthcare expenditure.

3.3 Modelling Healthcare Expenditure

The literature modelling the determinants of health care expenditure (HCE) described in section 2.2.1 has typically focused on the macroeconomic variables of income and total health care expenditure in cross country analysis. A summary of the main research papers on the determinants of health care expenditure can be found in Appendix A Table A6. A consistent finding in the literature through simulations and applied research is that there is no one consistent estimator for all health care expenditures (Duan, 1983, Manning and Mullahy, 2001, Basu et al., 2006, Buntin and Zaslavsky, 2004, Hill and Miller, 2010). There is limited guiding theory, with difficulty predicting the signs of covariates and the functional form.

Despite the finding of a strong positive correlation between HCE and GDP (Hansen and King, 1996) discussed in chapter 2, two main methodological issues have been raised:

stationarity and structural breaks. Hansen and King (1996) and Roberts (2000) drew attention to the methodological robustness of the time series analysis undertaken on income and HCE, specifically the difficulties that arise when unit roots[16] are present in time series. Hansen and King (1996) take umbrage with studies conducted by Culyer (1990) and Hitiris and Posnett (1992). Roberts (2000) focuses on Hitiris (1997) in which panel data for ten EU countries is used to analyse the determinants of aggregate health care expenditure. Both critics highlight the failure of the previous studies (Culyer, 1990, Hitiris and Posnett, 1992, Hitiris, 1997) to deal with the time series properties of the data in particular the difficulties that arise when variables are non-stationary. One of the assumptions underlying traditional regression methods such as ordinary least squares is that of stationarity. A time series is said to be stationary when the data generating process is the same over time. Stationarity can be detected using various unit root tests such as the Augmented Dickey-Fuller (Dicky and Fuller, 1979) or Philips Peron (Phillips and Perron, 1988) tests. Both of these tests use the existence of a unit root (i.e.nonstationarity) as the null hypothesis. To estimate a regression containing non-stationary variables would omit important information about the underlying statistical and economic processes generating the data, if not lead to an entirely spurious regression. Roberts (2000) employs techniques for detecting unit roots in panel data devised by Im et al. (1996) to show the possible errors involved in Hitris's (1997) exposition.

Clemente et al. (2004) question the feasibility of income and HCE relationships across 22 OECD countries, they cite the presence of structural breaks in the various time series as a problem. When trying to explain differences between studies the OECD (2003) cautioned that due to the diverse nature of health expenditure measurement from country to country, vast inconsistencies exist in the data which may make such cross country comparisons inappropriate. The aforementioned studies (Giannoni and Hitiris, 2002, Clemente et al.,

[16] An autoregressive process $a(L)y_t=e_t$ has a unit root if $a(1)=0$

2004, Roberts, 2000) would seem to provide the proof for Hansen and King's (1998) earlier assertion that "a deeper understanding of what drives HCE is more likely to be gained through careful country-by-country analysis".

To control for other factors apart from income that may be driving HCE some studies have used methods such as a two-way fixed effects model, which controls for country-specific and year-specific unobservable determinants of HCE and first order serial correlation (Sen, 2005, Farag et al., 2012). Diagnostic tests have been used in the literature to ensure the appropriate model is selected for example the Hausman test (Hausman, 1978) has been used to determine whether a random or fixed effects model is more appropriate, the Pesaran's test for cross-sectional dependence (Pesaran, 2004) and a Lagrange-Multiplier test (Breusch and Pagan, 1979) for serial correlation. This thesis is focused on two individual countries with separate analysis and therefore does not encounter the difficulties of multiple country analysis.

3.4 Modelling healthcare expenditure in relation to Proximity to Death

The literature introduced in section 2.2.4 discusses the studies which have begun to explore the effect of proximity to death on various types of healthcare expenditure. In this section the various methods applied are reviewed in more detail.

Researchers have highlighted potential methodological issues with the seminal paper on proximity to death (Zweifel et al., 1999), namely: the short time frame; the direction of causality and collinearity of Mills Ratio (λ)[17]. Salas and Raftery (2001) first raised questions on the robustness of the findings, principally the endogenous nature of a time to death variable in a model of health care expenditures and sample selectivity. They argue that individuals close to death or having a terminal illness may incur additional

[17] The inverse of Mills Ratio is calculated from the Probit model and is the change in the population when there is a change in x, conditional on y>0.

expenditures from treatment but this treatment itself may prolong the individual's life, this may lead to an endogeneity bias. A variable is endogenous when correlation exists between the variable and the error term, usually as the result of a loop of causality between an independent variable and the dependent variable (Wooldridge, 2009). They suggest an amended model to overcome the endogeneity by including lagged variables of the dependent variable and re-specifying age and age squared in the model to limit multicollinearity. Multicollinearity occurs when two or more of the independent variables in a regression are correlated. Felder et al (2010) explored the potential endogeneity bias using instrumental variables estimation and concluded that despite no evidence to formally reject endogeneity the size of the possible bias is small. The endogeneity issue was again revisited by two recent studies (Bjørner and Arnberg, 2012, Karlsson and Klohn, 2014) neither of which found a solution. Karlsson and Klohn (2014) suggest the effect may be minor as the emphasis of long term care (LTC) is mostly on the treatment of chronic conditions.

Seshmani and Gray (2004a) demonstrate several problems with the methodology employed by Zweifel et al. (1999) by replicating the original model and comparing it to their own two part model using a Probit for the probability of hospitalization and an OLS regression on the positive expenditures. Zweifel et al. (1999) use a Heckman Sample Selection model (Heckman, 1979) with a Probit and OLS regression on the positive expenditures. They calculated the inverse of Mills Ratio (λ) from the Probit model and include it as a regressor in the OLS estimation to account for the possible selection bias of excluding observations with zero expenditure (Zweifel et al., 1999). After overcoming the collinearity of mills ratio (λ) Seshmani and Gray (2004a) report similar results to Zweifel et al. (1999) but address the methodological concerns.

A starting point to model the prescribing data used in this study would be to use a cross sectional framework. The original studies looking at HCE and income were all based on

cross sectional data (Newhouse, 1987, Parkin et al., 1987, Gerdtham et al., 1992). Progression was made to studies such as Di Matteo and Di Matteo (1998) which used pooled cross sectional data to examine the determinants of HCE from 1965 -1990 from Quebec and Newfoundland in Canada. This macro level data used population aged 65 or more as a crude measure of ageing and reported positive coefficients for this age variable and income. The following subsections will explore in detail several methods which have been used in the literature to model healthcare expenditure and which have been summarized in table 3.1.

3.4.1 The Tobit model

The Tobit model is suggested by several authors for dealing with health care expenditure data (Jones, 2000). The Tobit model, first proposed by Tobin (1958) assumes the individual chooses the healthcare expenditure that maximizes his utility (welfare) therefore positive expenditures are desired. When preferences for health are so low zero spending on healthcare can be the best option for an individual. The Tobit accounts for situations with censoring but not those where a zero is a natural product (Sigelman and Zeng, 1999). In the case of prescription expenditures the zero total monthly expenditures are a natural phenomena of the model – some months individuals don't consume any medication. In addition a Tobit would appear inappropriate as it assumes both the decision to consume prescription medication and the level of expenditure come from the same stochastic process (Cameron and Trivedi, 2005). In the present case these are two different processes: factors influencing the demand for a prescription drug and factors determining the level of expenditure.

3.4.2 The two part model (TPM)

An alternative to Ordinary least squares (OLS) estimation for dealing with skewed data combined with a high level of zeros is a two part model (Blough et al., 1999). Two part

models have been used since the 1970's, firstly as an extension of the Tobit model (described in section 3.2.1) (Cragg, 1971) and became widely adopted in the mid-eighties after its use to model healthcare expenditures in the RAND Health Insurance Experiment (Belotti et al., 2012, Duan et al., 1984). Their use is not just limited to Economics, two part models are used in other fields including actuary where they are called frequency and severity models (Bowers et al., 1997). First the probability of the individual using the service is assessed, then a regression, typically OLS, is applied to the non-zero expenditure data to estimate correlates of the positive level of expenditure. This type of model has been employed to show the effect of proximity to death on total health care expenditures (Seshamani and Gray, 2004b, Werblow et al., 2007). An alternative to the two part model could be a Heckman sample selection (Heckman, 1979) which was used in early paper on PTD(Zweifel et al., 1999, Felder et al., 2000). Such a model may be inappropriate for prescribing expenditures due to the zero expenditures being observed rather than missing or censored data (Jones, 2000, Duan et al., 1983) and the need for exclusion regressors, these are regressors that are significant in the first part (selection model) but not in the subsequent part (Puhani, 2000). Mullahy (1998) provides a good example of the application of a two part model to a case of genuine zeros. The two part models are discussed at length by Duan et al (1984), Jones (2000) and Mihaylova et el (2011). A major difference between the Heckit and the TPM is the inability of the latter to appropriately deal with potential outcomes (Dow and Norton, 2003) in this thesis it is actual expenditure that is used rather than potential expenditure. A major critique of Zweifel et al (1999) is their use of the Heckit model with mills ratio when they were dealing with actual expenditure and "true zeros" (Salas and Raftery, 2001, Seshamani and Gray, 2004a). Salas and Raftery (2001) highlighted the problem of collinearity of the Heckit mills ratio with age, leading to potentially incorrect signs and inflated standard errors for age coefficients. This was subsequently addressed in a critique conducted by

Seshamani and Gray (2004a) who attempted to replicate the earlier study using more appropriate methodology. Monte Carlo simulations comparing the Heckit and the TPM have shown that when Heckit is the true model any bias in the TPM is more often than not outweighed by the greater relative efficiency of the TPM (Hay et al., 1987, Manning et al., 1987, Leung and Yu, 1996). For simplicity all the aforementioned comparison studies have used linear models.

Some researchers have argued that the two-step approach to modeling healthcare utilization is the most suitable method to analyse the process which underlies the expenditure (Buchmueller et al., 2002, Häkkinen et al., 2008). The first part of the model is generally confined to a Probit or Logit, the logistic distribution has heavier tails than the normal but both models produce similar results over a large range of values (Greene, 2012). The Probit model uses the cumulative normal probability distribution whereas the Logit is based on log odds. There are a number of options to specify the second part of the model, the most common will be discussed in the following paragraphs.

An OLS model and an OLS model with a log transformation, to allow for the large right skew, are typical specifications that have been widely used (Seshamani and Gray, 2004b, Jones, 2000). An OLS estimation runs the risk of misspecification with highly skewed data. A major criticism of the log transformed models is that the analysis would not be based on the population means but rather the mean on an alternative scale as previously discussed in section 3.1. The Generalized Linear Model (GLM) has also been used as a the second part of a TPM, most relevant to this thesis is its use in HCE studies like Seshamani and Gray (2004b). Liu et al. (2012) used a two part model with a GLM, gamma and a log link, in the second part to examine medical expenditures, they compared the GLM with a log-skew-normal and Box-Cox-transformed two-part models and found that the generalized gamma model provided superior fit in their analysis. The advantages and disadvantages of the GLM are discussed at length in section 3.2.3.

The two part model can estimate the mean expenditure for the given covariates and be used to examine specific effects on the mean of one covariate while controlling for the other covariates (Tian and Huang, 2007). Jones (2000) and Duan et al (1983) provide further discussion of the merits of the two part model. The two part model assumes that the zero values and the positive values are generated by different independent mechanisms, in contrast a simple Tobit would assume both positive and zero values are generated from the same mechanism.

3.4.3 Generalized linear model (GLM)

An alternative to OLS estimation is the generalized linear model (GLM) which emerged in the health economics literature in the late 1990's (Mullahy, 1998, Blough et al., 1999, Blough and Ramsey, 2000, Manning and Mullahy, 2001) but was first presented over four decades ago (Nelder and Wedderburn, 1972). The use of generalized linear models (GLM) has been the most popular approach to modelling health care expenditures in recent literature (Jones, 2010). The GLM is composed of two parts: the first is a link function that relates the conditional mean to the covariates; the second is a distribution function that specifies the relationship between the variance and the mean (McCullagh and Nelder, 1989). Buntin and Zaslavsky (2004) summarized one of its most attractive features "... the link function directly characterizes how the expectation on the original scale is related to the predictors." The GLM also allows for heteroskedasticity through the choice of distribution function although it is within the confines of the conditional variance which are pre-specified functions of the mean (Jones, 2010).

Buntin and Zaslaxsky (2004) point out that the GLM model can be used as the second part of a TPM or on the entire sample as "... zeros in the data pose no problem for fitting such models". A comparison of a two part, consisting of a GLM in the second part, with a standard GLM to model highly skewed expenditure data with a high number of zeros

reported only a slight difference between the models with the two part model a marginally better fit (Buntin and Zaslavsky, 2004). A disadvantage of the GLM is that it can be less precise for a given sample than OLS, Manning and Mullahy (2001) warn of imprecise GLM estimates if the distribution function is mis-specified or if the log residuals have a high kurtosis. Fox (2008) highlights a major advantage of the GLM as being its flexibility around choice of distribution and link functions. Manning and Mullahy's (2001) simulation results demonstrate that the estimates of the mean function are robust to misspecifications of the distribution function.

There are key assumptions that must be met when using the GLM model the violation of which may compromise the interpretation of model results by producing biased standard errors and thus unreliable p-values. Assumptions of homogeneity and independence of residuals must be met (Dobson and Barnett, 2008, Cameron and Triverdi, 1998, Hoffman, 2004) but independence may be stretched (McCullagh and Nelder, 1989). There is a lack of consensus on the importance of normality of residuals in GLMs with some authors (Dobson and Barnett, 2008, Hoffman, 2004) viewing it as a key assumption to be met while others do not (Gill, 2001).

Hanley et al (2010) attempted to address the methodological issues of analysing expenditure data by using a GLM to explain prescription drug expenditures. They reported that adjusted clinical groups (ACG) case-mix adjusters[18] have a more powerful predictive ability for pharmaceutical use and expenditure than age, sex and the Charleson index of co-morbidity.

A typical specification of the GLM for healthcare expenditures is a gamma distribution function with a log link (Blough et al., 1999, Manning and Mullahy, 2001, Manning,

[18] Case mix adjusters measure the morbidity burden of patient populations based on disease patterns, age and gender. It relies on the diagnostic and/or pharmaceutical code information found in insurance claims or other electronic medical records.

2006, Jones et al., 2010). Using a log link function is not the same as a log OLS model, in the GLM we get the log of the mean expected values (E)

Equation 3.1

$$\ln E(y|x) = X\beta$$

Equation 3.1 does not equate to the mean of the log expenditures which are calculated in log OLS and shown in equation 3.2.

Equation 3.2

$$E(\ln(y|x)) = X\beta$$

The GLM model needs to be adapted to appropriately deal with panel data where there is correlation within individuals, as is the case with prescribing data. Individuals often take the same medication for prolonged periods, therefore their monthly prescriptions would not be independent. Statistical analysis needs to allow for the clustered nature of the data, with repeat observations for individuals over time, the methods need to allow for correlation within individuals and independence between individuals. The scaling of standard errors was an initial attempt to account for the impact of correlation effects, this requires that each standard error is multiplied by the square root of the Pearson χ^2 dispersion statistic, this was a post regression analysis that had no effect on the regression coefficients (Hardin and Hilbe, 2013). The use of fixed and random effects to account for the repeat nature of observations is discussed in section 3.5.2

A modified Parks test is the proposed method for testing the fit of a GLM (Manning and Mullahy, 2001). While there is no one test for assessing an appropriate link function the following tests can be used as a guide: Pearson correlation test, Pregibon link test and a Modified Hosmer and Lemeshow test. The Pearson correlation test checks for systematic bias in fit on the original scale. The Pregibon link test assesses the linearity of response on the scale of estimation. The Modified Hosmer and Lemeshow test checks for systematic bias in fit on the original scale.

3.4.4 Modified Parks test

Manning and Mullahy's (2001) suggest the use of a modified Parks test to assist in identifying the appropriate family for a GLM based on the Parks test (Park, 1966) which is used to test for heteroscedasticity of a particular variable. The Parks test attempts to estimate the true variance function a fact which can be used to reverse engineer a suitable GLM via the modified test. The test can be broken down into five steps:

1. Estimate a GLM on data assuming any distribution function and link function
2. Predict the value of the expenditure (monthly medication expenditure) on the untransformed scale and log transform it.
3. Generate residuals on the untransformed scale and square them.
4. Regress the square residuals on the log of predicted values of expenditure (y) using a GLM with a log link and gamma distribution.
5. Interpret the resulting coefficients to identify the appropriate functions (Glick et al., 2007).

The interpretation of the modified Parks test depends on the coefficient of the log of predicted values, if this is a 0 its Gaussian, 1 Poisson, 2 Gamma, 3 Inverse Gaussian (Manning and Mullahy, 2001). While there is guidance on the selection of an appropriate distribution function there is an absence of a similar definitive test for the link function. The log link is the most commonly used in health economics literature (Jones, 2011). Use of an inappropriate link function can introduce bias into the results (Glick et al., 2007). Several tests can be used for guidance on the appropriate link: Pearson correlation test; Pregibon link test; a modified Hosmer and Lemeshow test. These are discussed in the following sections.

3.5 Panel data methodology

Within prescribing datasets each individual has repeated observations over time as they receive more prescription medications. Thus the resulting dataset is akin to repeated cross sections giving it a longitudinal element. Such panel data require methods to account for the heterogeneity of the individuals over time. Panel data models allow the examination of individual specific effects, time effects or both in order to account for heterogeneity that is observable or not. The two key issues for devising a panel data model concern the relationships that exist between the independent variables and both the individuals and time. (This is discussed at length in section 3.4.2)

3.5.1 Ordinary Least Squares estimation

The original studies looking at HCE and income were all based on cross sectional data (Newhouse, 1987, Parkin et al., 1987, Gerdtham et al., 1992). Progression was made to studies such as Di Matteo and Di Matteo (1998) which used pooled cross sectional data to examine the determinants of HCE from 1965 -1990 from Quebec and Newfoundland in Canada. This macro level data used population aged 65 or more as a crude measure of ageing and reported positive coefficients for this age variable and income.

A traditional starting point in regression analysis would be an Ordinary Least Square (OLS) estimation. If an individual effect does not exist, u_{it} =0, then Ordinary Least Square (OLS) will produce efficient and consistent estimates, using the specification (Baltagi, 2010):

Equation 3.3

$$y_{it} = X_{it}\beta + \propto_i + \epsilon_{it}$$

This is an error components model meaning the error term has been split into two components: an individual (i) specific unobservable effect α_i and a random error term ε_{it}.at time (t) Jones (2007) views the critical question for panel data models as whether or not the individual effects α_i are correlated with the independent variables X if such

correlation is not accounted for, then panel data regression will produce inconsistent estimators of ß, the slope coefficients. The six core assumptions of OLS are outlined in various textbooks (Gujarati, 1995, Greene, 2012):

1. Linear in the parameters – dependent variable is a linear function of the independent variables and the error term.
2. Exogeneity – expected value of error term given all explanatory variables is zero.
3. Homoskedasticity – disturbances have the same variance.
4. No autocorrelation – given any value of X the correlation between the error disturbances is zero.
5. Nonstochastic – X values are fixed in repeated sampling.
6. No multicollinearity – there is no perfect linear relationship amongst the independent variables.

A violation of any of these assumptions would potentially make the OLS no longer the best linear unbiased estimator (BLUE). For example if there is an individual effect (i.e. $u_i \neq 0$) disturbances may be heteroskedastic, that is they may vary across individuals and/or are related to one another (autocorrelation). Panel data allows for individual heterogeneity, meaning it can control for variables that cannot be observed directly in the model such as policy changes or cultural factors (Wooldridge, 2010).

3.5.2 Fixed and Random Effects

Equation 3.4 sets out a basic model for panel data:

Equation 3.4

$$Y_{it} = \beta_0 + \beta X_{it} + Z_i\gamma + \alpha_{it} + \epsilon_{it} *$$

where Y_{it} is the expenditure variable per individual at time t and βX_{it} are the observed time variant factors which can be estimated by both fixed and random effect models. Z_i are the observed variables (such as gender) which are time invariant, they cannot be

estimated directly by the fixed effects model. The two unobservable effects are α_{it} and ε_{it}, the former is the individual specific effect, a fixed value for each individual across repeated measures and ε_{it} is the random error term (residual). The relationships that exist between the independent variables and both the individuals and time should influence the choice of model to use. Fixed effect models are designed to observe causes of the changes within individuals, they cannot look at time invariant variables (e.g. gender, ethnic group) as these remain constant over the time period for each individual (Kohler and Kreuter, 2009). The main difference between fixed effects and random effects models is that the latter assumes the variation across individuals is random and uncorrelated with the dependent or independent variables. "... the crucial distinction between fixed and random effects is whether the unobserved individual effect embodies elements that are correlated with the regressors in the model, not whether these effects are stochastic or not" (Greene, 2008) this opinion is also echoed by Wooldridge (2009).

As it is the differences across individuals or groups that is of interest in this thesis, a random effects model would seem appropriate. To further support such a choice the use of a fixed effects model would mean the loss of coefficients for time-invariant variables such as gender and ethnic group and the exclusion of individuals with all zero or all positive monthly expenditures resulting in a severely limited analysis.

Least squares dummy variables (LSDV) estimator is used to estimate the fixed effect model, this is a pooled Ordinary Least Squares (OLS) estimation including a set of dummy variables for each individual. Any time invariant explanatory variables are dropped because they are perfectly collinear with the individual dummy variables (Baltagi, 2010).

Table 3.3 Comparison of Fixed Effect and Random Effect models

	Fixed Effect	Random Effect
Specification:	$Y_{it} = \beta_0 + \beta X_{it} + (Z_i\gamma + \alpha_{it}) + \epsilon_{it}$ *	$Y_{it} = \beta_0 + \beta X_{it} + Z_i\gamma + \alpha_{it} + \epsilon_{it}$ *
Existence Test:	F test	Breusch-Pagan LM test
Intercept:	Varying across individuals and/or time	Constant
Error variances:	Fixed	Randomly distributed across individuals and/or time with zero mean and no correlation with ε_i
Estimated by:	Least squares dummy variable(LSDV)	Estimated generalized least squares (EGLS)

*Where u_{it} is the between individuals error and ε_{it} is the within individuals error

The random effects model is as follows:

Equation 3.5

$$Y_{it} = \beta X_{it} + \alpha + u_{it} + \epsilon_{it}$$

Where u_{it} is the between individuals error and ε_{it} is the within individuals error. An assumption of the random effects model is that the individual's error term is not correlated with that of the independent variables, which allows for the explanatory role of time-invariant variables.

A fixed effect model examines the differences in intercepts for individuals. Creating dummy variables for each individual is not possible given the size of prescribing datasets. Instead a within effects model can be employed which uses the difference between the mean for each individual and the actual expenditure observed. However given the limited number of variables in the prescribing datasets coupled with the time invariant nature of most of these a fixed effects model would not be appropriate as it would not provide coefficients for these variables and furthermore it would eliminate those individuals with all zero or all positive monthly expenditures. Greene (2012) questions the justification for treating the individual effects as uncorrelated with the other regressors, as is assumed in the random effects model. The datasets used in this thesis contain near total populations,

therefore we are not concerned with population sizes and the use of the fixed effects model would lead to a large loss of degrees of freedom (Baltagi, 2010).

3.5.3 Testing Panel Data Models

A Hausman test can be used to confirm the choice of fixed or random effects. The null hypothesis is that the unique errors u_i are not correlated with the regressors (i.e. preferred model is a random effects) while the alternative hypothesis is correlation of unique errors and regressors, a fixed effect model (Hausman, 1978).

A Breusch-Pagan Lagrange Multiplier (LM) test with a null hypothesis of variances across individuals being zero, would suggest whether or not a random effects model which takes account of the panel effect is more appropriate over an OLS model. The test statistic is stated as follows:

Equation 3.6

$$\mathrm{LM} = \frac{nT}{2(T-1)}\left[\frac{\sum_{i=1}^{n}(T\bar{e}_i)^2}{\sum_{i=1}^{n}\sum_{t=1}^{T}e_{it}^2} - 1\right]^2$$

If the null hypothesis is true, the limiting distribution of the lagrange multiplier is chi-squared with one degree of freedom (Greene, 2012).

Given the shortness of the panel and the large number of individuals cross-sectional dependence should not be problematic (Baltagi, 2010). A Breusch-Pagan Lagrangian Multiplier test of independence can be used to identify any cross sectional independence. The null hypothesis is that the residuals across individuals are not correlated. The Ramsey Regression Equation Specification Error Test (RESET) (Ramsey, 1969) would test for omitted variable bias in the models which is possibly due to the use of a cross-sectional framework which fails to control for individual-specific effects (Baltagi, 2010).

3.6 Morbidity index

Health data is often coded to facilitate analysis, and the most frequently used coding methods are the Diagnostic related groups (DRG) and the International classification of disease (ICD). Even if this coded information is available it is often provided with a considerable time lag. Pharmacy dispensing data in contrast typically lacks information on diagnosis, but in the absence of easily linkable health information combinations of pharmaceutical therapies have been used as proxies for broad medical conditions. Such datasets may be more timely, accurate, accessible and complete (Sloan et al., 2003). An index based on medications dispensed provides some information on the conditions individuals may have. While this methodology lacks specificity for certain conditions, as some medications may have a broad application across a number of conditions or even off label use, the methodology has been validated in several settings (Fishman et al., 2003, Gray et al., 2000, Maio et al., 2005, Silwer and Lundborg, 2005, Sloan et al., 2003) and previously used on Irish data (Naughton et al., 2006, O'Shea et al., 2013).

The Chronic Disease Score (CDS) was developed in the USA by a health management organisation with the aim of creating a score which would reflect the number of chronic diseases each individual was being treated for, the complexity of the treatment regime and the probability of morbidity or mortality (Von Korff et al., 1992). Malone et al (1999) developed a chronic disease index using a medication database to approximate the number of chronic diseases a patient has. The index predicted the presence of six common diseases with a specificity of $\geq$ 75%. Lamers (1999) replicated and extended the CDS using automated dispensing data from a Dutch sickness fund. He used 28 chronic conditions in seven Pharmacy Expenditure Groups (PCGs) clustered, which explained 10% of differences between patients in the following year's expenditures and improved the R^2 to almost double that of a model containing only demographic variables. Lamer conducted further studies which confirmed the predictive accuracy and validity of PCG

for the Dutch health system (Lamers and Vliet, 2003, Lamers, 2001, Lamers and van Vliet, 2004). The CDS has since evolved into the RxRisk model which has been further enhanced by the Veterans Health Administration (VHA) to become the RxRisk-V which is a pharmaceutical based comorbidity index, calculated from the sum of 45 potential disease groups derived from dispensing data using ATC codes (Sloan et al., 2003). Individuals were classified as having one of the conditions listed if they had been dispensed at least one prescription for a disease class during a given study period (Sloan et al., 2003).

The addition of detail on types of medication dispensed in the form of indices has been shown to improve the predictive power of models (Lamers and van Vliet, 2004, Zhao et al., 2005, García-Goñi and Ibern, 2008). However these studies (Lamers and van Vliet, 2004, Zhao et al., 2005, Wrobel et al., 2003) used linear regression despite the expenditure data not being normally distributed, with a large right sided tail, the issues of which are discussed at length in section 3.1.

Some studies have shown the efficacy of combining pharmaceutical data with diagnoses, Diagnostic Expenditure Groups, DCG/Rx (Stam et al., 2010) and Adjusted Clinical Groups ACG/Rx (Hanley et al., 2010, Kuo and Lai, 2010). However it is not always possible to combine such information in the absence of individual health identifiers.

Including a chronic conditions score, or dummy variables for specific chronic conditions would help to control for the effects of specific conditions in any model of prescribing expenditures.

3.7 Projecting future expenditures

The main aim of this thesis is to elucidate the importance of proximity to death and age on prescription medication expenditures. An extension of this is how important proximity to death is when projecting future expenditures on prescription medication. Traditional

projections of future expenditures have used the current age/gender distribution of service use multiplied by the projected future population (Bennett et al., 2009, Smith et al., 1999, Dang et al., 2001). Recently Conway et al (2014) used a Monte Carlo simulation to project future expenditure on prescription medication, while they included varying population scenarios they did not account for proximity to death.

Predicted expenditures based on regression analysis have also been used to project future expenditure (Seshamani and Gray, 2004b, Kildemoes et al., 2006). In the case of two part models regression based predictions can be calculated using the sum of the two part model outlined earlier in section 3.3.2, holding other variables at their mean values. Predicted expenditure in the two-part model:

Equation 3.7

$$E(Y|X) = P(Y>0|X)*E(Y|Y>0, X)$$

Where $P(Y>0|X)$ is the probability of any expenditure being incurred (Part 1) and $E(Y|Y>0, X)$ is the predicted expenditure conditional on incurring any expenditure (Part 2).

3.8 Conclusions

This chapter has built on the previous literature presented in chapter 2 by specifically examining the methodologies used in previous studies of health care expenditures. It also provides the methodological background for the subsequent chapters 5 and 7.

The field of expenditure analysis has evolved in an attempt to overcome the limitations of the previous method but there still are limitations of each new method (Basu and Manning, 2009). To accommodate skewness, transformed models were previously widely adopted. But this raised the issue of retransformation due to estimation on a different scale (Duan, 1983) and concern about bias from ignoring non-constant variability across covariates (Mullahy, 1998, Manning, 1998). GLM's facilitated modelling mean functions

directly avoiding the previous methodological issues but led to a loss of precision for some extremely skewed data (Basu and Manning, 2009).

The literature does not identify one clear path for the analysis of expenditure data, but stresses the importance of acknowledging the strengths and weaknesses of each method and finding the best fit for the data under study (Jones, 2000, Basu et al., 2004, Basu et al., 2006, Manning and Mullahy, 2001, Manning, 2006).

4 Health, Health Policy and Demographics

This chapter outlines the context of the thesis and provides an introduction to orientate the reader on the healthcare systems in the countries studied. The following sub-sections will briefly discuss the healthcare system, health policy, demographics, general health status and prescription expenditure in Ireland.

4.1 Data

Four main data sources are used in this thesis, the Irish Longitudinal Studying on Ageing (TILDA), Irish dispensing data, New Zealand dispensing data, mortality and population data from national statistics. The first of these sources is documented in this section and the results are used throughout the thesis.

4.1.1 The Irish Longitudinal Study of Ageing (TILDA)

A major disadvantage of using dispensing records for research is the lack of information on the health status of the population under study. To address this issue data from the Irish Longitudinal Study of Ageing (TILDA) was chosen to provide more detailed information regarding the health and social circumstances of the community dwelling population aged 70 or more. TILDA provides a longitudinal nationally representative data on the health, social and economic circumstances of the Irish population aged 50 years or more in 2009/2010. The data is collect every two years and this thesis used the first wave which had 8,174 participants aged 50 years or more, 2,307 of which were aged 70 or more in 2009/2010.

A number of subjective and objective measures were used from the TILDA data set. The data was collected through personal interviews, self-completed questionnaires and a nurse led health assessment. All prevalence results from TILDA were weighted using age, sex and educational attainment to be representative of the total population aged 70 or more. Details of the weighting calculation are set out in Appendix B. Most of the analysis used throughout the thesis based on TILDA data is limited to the population of interest: participants aged 70 years or more unless stated. Confidence intervals are reported at the 95% level for any estimates based on TILDA data.

4.2 Demographics

In 2011 census Ireland had a predominantly urban population of approximately 4.6 million of which 0.36 million (7.9%) were aged 70 years or older. Table 4.1 sets out the age and gender profile of the total population and those aged 70 or more from the 2006 and 2011 census.

Table 4.1 Age and gender census profile of the Irish population aged 70 years or more, 2006 and 2011

	2006			2011		
	All	Male (%)	Female (%)	All	Male (%)	Female (%)
70 - 74 years	119,152	56,540 (47.5)	62,612 (52.5)	131,190	63,476 (48.4)	67,714 (51.6)
75 - 79 years	92,466	40,121 (43.4)	52,345 (56.6)	102,036	46,631 (45.7)	55,405 (54.3)
80 - 84 years	64,884	24,694 (38.1)	40,190 (61.9)	70,113	28,423 (40.5)	41,690 (59.5)
85 years and over	48,028	14,845 (30.9)	33,183 (69.1)	58,416	18,486 (31.6)	39,930 (68.4)
Total 70+	324,530	136,200 (42.0)	188,330 (58.0)	361,755	157,016 (43.4)	204,739 (56.6)
All ages	4,239,848	2,121,171 (50.0)	2,118,677 (50.0)	4,588,252	2,272,699 (49.5)	2,315,553 (50.5)

Source: Central Statistics Office (CSO) 2006 & 2011 Census data

In 2009 Ireland had the highest number of young people and the lowest number of older people in the European Union (EU) (2013a). This is predicted to dramatically change in the coming decades with the population aged 65 years and over projected to rise from 532,000 in 2010 to between 850,000 and 860,700 by 2026, and to 1.4 million by 2046, almost trebling (Central Statistics Office, 2013). An even more marked increase is predicted for those aged 80 years of age and over going from 128,000 in 2011 to 484,000 by 2046 (Central Statistics Office, 2013). The Central Statistics Office estimated that in 2009, 9.6% of the population over 65 years of age were at risk of poverty and the deprivation rate was 9.5% (CSO, 2013b). Table 4.3 shows the projected population changes for those aged 70 years or more from 2011 to 2031, based on CSO projections this age group will double in size, variations depend on differing migration patterns (M1, M2, M3). Further details of the CSO projections are provided in Appendix C.

Table 4.2 Projected population aged 70 or more 2011-2031 (Ireland)

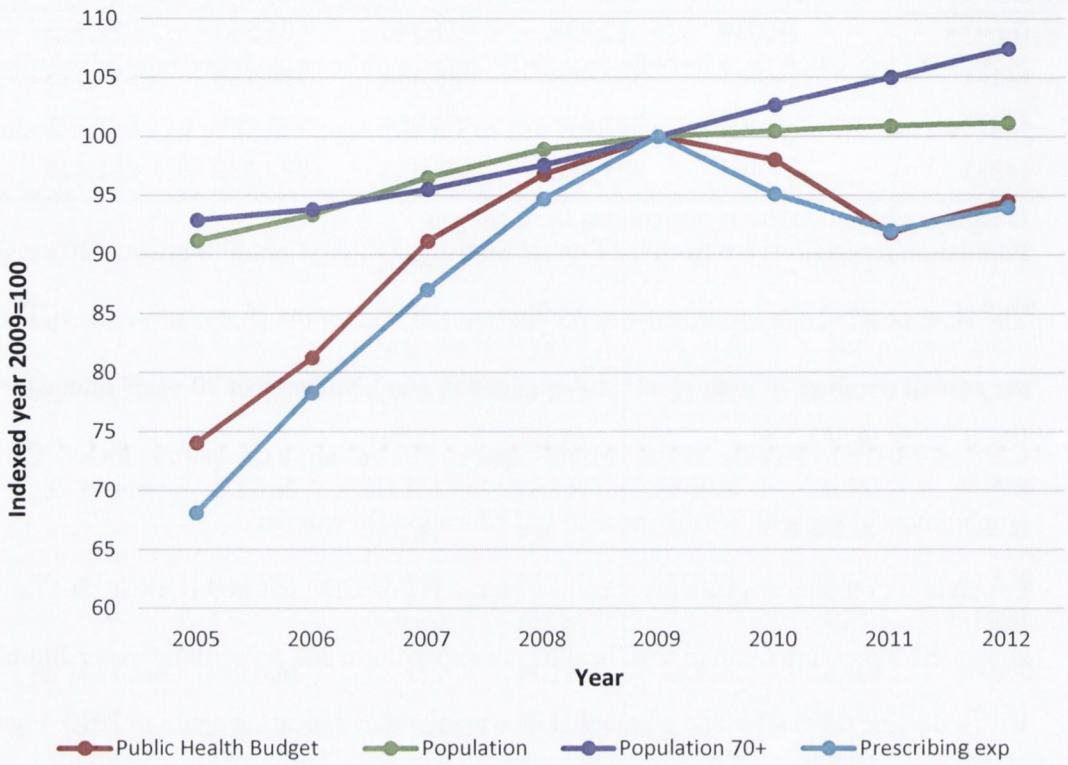
	2011	2016	2021	2026	2031	change 2011-2031
Deaths	20,039	20,732	21,346	21,961	22,575	1.13
M1F1	339,461	397,968	486,454	584,739	694,225	2.05
M2F1	339,461	397,668	484,854	581,039	687,225	2.02
M3F1	339,461	397,568	483,254	577,239	681,425	2.01

Deaths are based on thesis projections from chapter 5
Population projections are from the Central Statistics Office (Central Statistics Office, 2013)

The state pension age in Ireland was 65 years at the time of the study, as a consequence there are very small numbers of individuals still engaged in employment post 70 years of age (n=141, 5.6% CI95 4.7-6.6%). Health status would appear to be an explanatory factor for continued employment along with wealth for men and education for women.

Expenditure on pharmaceuticals accounted for 1.7% of GDP in 2009 (OECD, 2011a). Figure 4.1 shows the increasing trend in total health care expenditure and prescribing expenditure up to 2009 with a decline there after and a potential increasing trend appearing again in 2012. Figure 4.1 also highlights that the population aged 70 years or more has a steeper slope than total population meaning the older population group is expanding at a higher rate than the general population which is becoming more static.

Figure 4.1 Total health care expenditure, prescribing expenditure and the population aged 70 years or more 2005-2012



Source: Department of Expenditure and Reform, Primary Care Reimbursement Service

4.3 Health

Table 4.3 provides the insurance coverage for individuals aged 70 years or more in 2009/2010, based on the TILDA data. The wave 2 data from TILDA which was collected in 2011/2012 shows that the introduction of means testing for medical cards for those aged 70 or more has had a minor reduction in coverage with 89.1% (95%CI 87.8-91.7) reported having a medical card.

Table 4.3 Insurance coverage in those age 70 years or more in 2009/2010

Coverage	%	95% Confidence Interval
No Cover	0.9	0.6 - 1.3
Medical Card only	57.0	54.8 – 59.2
Private Health Insurance only	6.6	5.7 - 7.7
Both Medical Card & Private Health Insurance	35.5	33.4 – 37.6

Source: TILDA

The majority (75%, 95%CI 74.0-75.8%) of older adults report self-rated health of good, very good or excellent. This increases with age with 82.9% (95%CI 81.2-84.4%) of the over 70's reporting that their health was good or better. There has been a consistent pattern of mortality for the last two decades with cardiovascular disease as the number one cause of death accounting for over a third of all deaths, with cancer in second place and respiratory diseases in third place (CSO, 2013a). Cardiovascular risk factors of high cholesterol, high blood pressure, abnormal heart rhythm, smoking and alcohol use generally increase with age with the exception of cholesterol and smoking. There are high prevalence rates for chronic conditions such as chronic obstructive pulmonary disease (COPD), heart failure, and type two diabetes. Multimorbidity, the co-occurance of two or more chronic conditions, is now the norm among the older population with over two thirds (66.2% (95% CI: 64.5–67.8)) of those aged 50 or more reporting two or more conditions, this rises to 82.4% (95% CI: 81.5–87.0) in those aged 70 or more (Glynn et al., 2011). Given the high levels of multimorbidity in this age group it is not surprising that levels of polypharmacy, taking five or more medications regularly, are high. In the over 50s one in five report polypharmacy, this rises to one in three in those aged 70 or more, see Table 4.4. Polypharmacy is associated with increased risk of drug interactions, falls, delirium, disability, mortality and a reduction in adherence to treatment (Moore et al., 2012).

Table 4.4 Five or more medications regularly, by age group

Age group	Five or more medications (95% Confidence Interval)
70+	34.2% (32.2-36.3)
70-74	29.1% (26.2-32.1)
75-79	35.9% (32.4-39.6)
80-84	35.0% (30.3-40.0)
85+	42.9% (36.2-49.8)

Source: TILDA

The risk of falls increases with age, independent of other factors. Disability as measured by declines in Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL) increases with age.

4.4 Prescription expenditure

Pharmaceutical expenditure in Ireland has rapidly increased over the last two decades, in 2000 Ireland ranked 20th out of 27 countries for expenditure per capita, in 2010 the country was 3rd out of 25 (Brick et al., 2013). The average annual growth rate of pharmaceutical expenditure was 8.7% in Ireland in the decade to 2009, compared to an OECD average of 3.5% CITE (OECD, 2011a). This is also above the group rate for total HCE for the period which was 6.1% (OECD, 2011a). TILDA reports that in 2009 91.6% (95%CI 90.5-92.7%) of individuals aged 70 years or more have a medical card.

In Ireland prescription drugs can be prescribed by a doctor, advanced nurse practitioner or a dentist. Prescribing by international nonproprietary name (INN) is considered international best practice and even though it is not a legal requirement it is taught as part of medical education in Ireland. Older healthcare professionals or those educated abroad may not have had this educational experience. Previous studies report generic prescribing rates of around 20% or less (Moore et al., 2012, Usher et al., 2012) in stark contrast to an OECD average of 41%, Germany 76%, the United Kingdom 75% and New Zealand 73%, in 2011 (OECD, 2013). At the time of this study it was not possible for a pharmacist to substitute generically without the permission for the prescriber, this has subsequently changed in 2013 and is discussed at the end of this section. Article 5(1) of the Medicinal Products (Prescription and Control of Supply) Regulations (2003) implies that a pharmacist can only supply what is written on the prescription if it is a prescription only product. The Pharmacy regulator, the Pharmaceutical Society of Ireland (PSI) have a "dispense as written" provision in their guidance to pharmacists

> "...where a prescriber specifies a particular branded product on the prescription, the pharmacist is required to dispense the product specified. The pharmacist cannot supply a different equivalent brand without consulting the prescriber concerned....."
>
> (The Pharmacuetical Society of Ireland, 2008)

Table 4.5 sets out the eligibility for subsidised medications for the Irish population, for the period in this study of 2006-2009 those aged 70 years or more were entitled to free medication regardless of income or health.

Table 4.5 Eligibility for subsidised medications in Ireland

Scheme	Eligibility criteria	Eligible for	Co-payment
General medical service (GMS) (Medical card)	Low income and individuals in financial hardship due to medical expenses. Income limits for those under 70 years of age and those 70 or more. From 1st January 2009, the gross income limits for people 70 years or older was €700 per week for single people and to €1,400 per week for couple. From 1st January 2012 it reduced to €600 and €1,200 respectively and from 1st January 2014 €500 and €900 respectively. Lower income limits apply to those under 70 years of age.	All medications	January 2010 50cent January 2013 €1.50 December 2013 €2.50
Long term illness (LTI)	Individuals who have a specific illness from a schedule. (2010 – Mental Handicap, Hydrocephalus, Cerebral Palsy, Muscular Dystrophy, Haemophilia, Diabetes Mellitus, Diabetes Insipidus, Epilepsy, Multiple Sclerosis, Parkinsonism, Cystic Fibrosis, Phenylketonuria, Acute Leukaemia, Mental illness (under 16years of age), Spina Bifida.)	Medications pertaining to specific illness only	0
High Tech Drugs (HTD)	High expenditure drugs which would cause undue financial burden. This scheme is available for all citizens and covers a range of medications used to treat conditions such as cancer and rheumatoid arthritis.	A specific list of medications.	Monthly limit ŧ (same as DP)
Drugs Payment (DP)	Any individuals/families who don't have a medical card and who spend over a threshold amount in a calendar month on prescription medications.	All medication expenditure in excess of a monthly limit.	Monthly limitŧ
Health Amendment Act 1996 (HAA)	Individuals who have contracted Hepatitis C, directly or indirectly from the use of Human Immunoglobulin-Anti-D, any other blood product or transfusion within Ireland.	All medications	0

*Only medications approved by the HSE are covered by any of the schemes, although they may be available privately at full expenditure to the patient.

ŧThe monthly limit was €90 in 2007, €120 in 2009, €132 in 2012 and €144 in 2014.

A number of measures have been implemented to control expenditures. These include the use of cost effectiveness analysis for new medications, a preferred medications programme and price negotiations with the manufacturers (Department of Health (IRE), 2014). Further proposed measures such as e-prescribing are still in the planning stages (Department of Health (IRE), 2014).

An important recent development in prescription expenditures in Ireland is the Health (Pricing and Supply of Medical Goods) Act (2013b) which introduces generic substitution and drug group reference pricing. Implementation of both aspects of the Act significantly alter dispensing practice and should lead to substantial expenditure savings for the state, helping to stem the exponential increase in prescription expenditures that Ireland has seen in the last two decades. Given the high price of generic medications relative to their branded equivalents evidence shows that savings from generic substitution are limited whereas drug group reference pricing will provide more substantial savings based on 2010 prices (Moore et al., 2012).

4.5 Conclusions

This chapter has broadly described the variations in demography, health care system and health policy relevant to this thesis for Ireland. In addition the cross sectional, disease prevalence and health behaviors for the over 70's based on the first wave of the Irish Longitudinal Study on Ageing were reported to provide context on the population examined in the study. In Ireland health care for those aged 70 years or more is mostly publically funded with some patient co-payments. Medications were provided to the population aged 70 or more, free of charge, for the period 2001-2009. The high prevalence of chronic conditions, multimorbidity and associated problems are major concern in this age group, which is predicted to more than double in size over the next 20 years. The impact of the recession on health care provision in Ireland has been considerable with large reductions in the overall budget, As a consequence there has been cuts to the benefits and services provided as well as the introduction of co-payments for medications for the older population and those on low incomes. This chapter has provided the background and context for the subsequent study of dispensing data, proximity to death and ageing presented in chapter 5.

5 Age, proximity to death and prescribing expenditures in an older Irish population

This chapter is an examination of the importance of proximity to death (PTD) and ageing for prescription expenditures in the Irish population aged 70 years or more. A brief background is set out, followed by methodology, results, discussion and conclusion. The aim of this study is to examine the importance of proximity to death and ageing for public expenditure on prescription medication and report the implications for expenditure projections in Ireland.

5.1 Introduction and background

An individuals health care needs are higher as they approach death, with more than a quarter of all acute health care expenditures incurred in the last year of life (Wanless, 2002). However individuals in their last year of life may not necessarily be the oldest. As discussed in section 2.2.4 there appears to be general consensus that PTD has an effect on healthcare expenditures in acute and long term health care but what is less known is the extent of the effect. Previous studies have focused on hospital or long term care expenditures with little separate analysis of medication expenditures. Wanless (2002) highlighted the need to consider all healthcare utilisation in relation to age, proximity to death and other factors.

While attempts have been made to predict future expenditure on prescriptions (Bennett et al., 2009) in Ireland there currently appears to be no Irish studies and limited international studies on the impact of ageing on future drug expenditure taking proximity to death into account (As discussed in section 2.2.5). Given the rising volume and expenditures of prescribing experienced in developed countries, gaining an understanding of what effects health care expenditure in this area will assist policy makers to more accurately predict and develop new policies to control future spending on prescription drugs.

5.2 Data and Methods

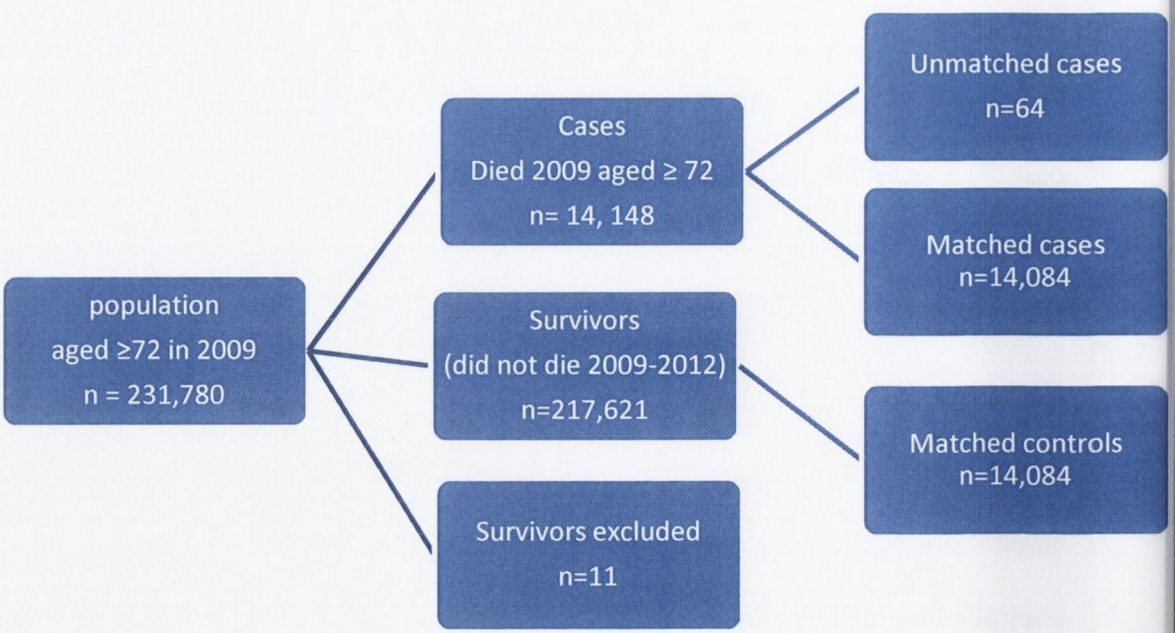
5.2.1 Data

Ethical approval was obtained from the Health Policy and Management Ethics Committee, Trinity College Dublin, details are provided in Appendix D. A data agreement was entered into with the Health Service Executive Primary Care Reimbursement Service (HSE-PCRS) to provide prescribing and mortality data (see Appendix D). Community prescribing for 2006-2009 inclusive and mortality data from 2009 – 2012 for individuals aged 70 years or more were used to ensure a full 36 months of observations for decedents and to ensure survivors are not in their last three years of life. Community prescribing does not include any medications taken during a hospital visit and the database has no record of such visits. Medications covered by the High Tech drugs scheme (detailed in section 4.5) are also not included. The omission of such data introduces a bias as it precludes certain types of medication which may be used by the sickest and those closer to the end of life. The over 70s were chosen as this is the age group with the largest number of deaths and they are also entitled to publically funded medication based on age dissimilar to the rest of the population. To be included individuals must have been dispensed at least one prescription medication in the period 2006-2009. The prescription dispensing data contain a unique person identifier, date of birth, region, gender, age, date of claim, details of medication dispensed and ingredient cost. The expenditure amount is based on the ingredient cost not including any mark-up fee, dispensing fee or corporate discounts/pay backs. All medications are coded using the WHO Anatomical Therapeutic Chemical (ATC) code. The ATC classification system was introduced in 1981 by the WHO Regional Office for Europe and is co-ordinated by the WHO Collaborating Centre for Drug Statistics Methodology in Oslo. Mortality records come from the Death Events Publication Service (DEPS). DEPS is an electronic database controlled by the Department of Public Expenditure and Reform, which was developed to

notify public sector agencies immediately and electronically of registered deaths to facilitate the efficient termination of services, benefits and pensions to deceased individuals. The data include a unique person identifier and the date of death. Unlike previous studies examining Health Care Expenditure (HCE) which employed samples, the time period of this study has been selected to facilitate the use of a national cohort.

In order to gain an insight into the differences between decedents and survivors a matched case-control study methodology was used. Decedents aged at least 72 years at the start of 2009 were selected to ensure they had access to free medication for the duration of the study 2006-2009, and were matched 1:1 based on age, gender and region to survivors (controls). Table C1 in the appendix contains details of the counties covered by each region which was used in the matching, previous research has suggested that there may be regional variances in health service use (Wren, 2011, Conway et al., 2014). Controls are those individuals who were in receipt of medication in 2009 and who did not die in the subsequent three years (2010-2012). A descriptive analysis of the monthly expenditures of both cases and controls was undertaken and the mean monthly expenditures and medication usage of survivors and decedents were compared. The study population is

Figure 5.1 Participant Flowchart



detailed in figure 5.1, 11 survivors were excluded due to errors in their data collection in the dispensing database.

To provide more detailed information regarding the health and social circumstances of the community dwelling population aged 70 or more which was not available from prescribing records data from the Irish Longitudinal Study of Ageing (TILDA) was used. TILDA is described in more detail in chapter 4.

A number of population scenarios from the Central Statistics Office (CSO) online database Statbank (Central Statistics Office, 2013) were used, based on the 2011 Census population figures, to estimate future population taking births, deaths and migration into account (see Appendix D for a brief description). All analysis were conducted using Stata version 12 (Stata Corp., College Station, Texas).

5.2.2 Model specification

The primary outcome was monthly individual expenditure on community prescription medication for a 36 month period ending in 2009 (month of death in 2009 or matched month for survivors), which is highly skewed with non-constant variance and a large number of zeros. These are the typical attributes of expenditure data discussed in chapter 3. Methods employed must account for the skewed distribution of the data and the large numbers of zeros (zero-inflation). Based on the literature examining expenditure data a two part model (TPM) using a Probit and generalized linear model (GLM) was considered appropriate. The Probit was used to identify those who had any expenditure and the GLM to model those positive expenditures.

The following Probit model was run to examine the effects of age, gender, proximity to death and region on the probability of using medication in a given month.

Equation 5.1

$$\Pr(Expend. > 0) = \propto + \beta_1 A + \beta_2 A^2 + \beta_3 AG + \beta_4 G + \beta_5 D + \sum_{t=1}^{35} m_t M_t + \sum_{e=1}^{7} \epsilon_e R + \sum_{t=1}^{35} \gamma_t M_t D$$

Where A: individual age; A^2: Age squared; AG: Age gender interaction; G: Male gender (1), Female (0); D: decedent (1); M: months until death or censor; R: Region; M_t D: decedent-month interaction term; β, m, ε, γ: regression coefficients. To account for the nonlinearity of age an age squared variable was added.

The second part of the model is a random effects GLM which facilitates the analysis of mean expenditures while allowing for the non-normal distribution of the data and the longitudinal observations for each individual. The model consists of a distribution function for expenditures and a link function which describes the nature of the relationship of the covariates with the expenditure. The various GLMs were assessed using the modified Parks test following Manning and Mullahy, Akaike Information Criteria (AIC) and normal probability plots of deviance residuals to ascertain a suitable distribution function. While there is no one test for assessing an appropriate link function the following three tests were run for guidance: Pearson correlation test; Pregibon link test; a modified Hosmer and Lemeshow test. The consistent result from these tests was gamma distribution function and a log link. This is similar to other studies which have found a GLM gamma with a log link to be a good fit for HCE data (Basu et al., 2004).

Equation 5.2

$$\text{GLM(expend)} = \propto + \beta_1 A + \beta_2 A^2 + \beta_3 AG + \beta_4 G + \beta_5 D + \sum_{t=1}^{35} m_t M_t + \sum_{e=1}^{7} \epsilon_e R + \sum_{t=1}^{35} \gamma_t M_t D$$

Where A: individual age; A^2: Age squared; AG: Age gender interaction; G: Male gender (1), Female (0); D: decedent (1); M: months until death or censor; R: Region; M_t D: decedent-month interaction term;

The use of a log link function in the GLM means the coefficients act multiplicatively on the mean, by taking the exponential they can be expressed as the percentage increase in the mean monthly medication expenditure per unit increase in the covariate (Barber and Thompson, 2004).

Other studies have shown a decline in "the expenditure of dying" with age (Seshamani and Gray, 2004, McGrail et al 2000, Garattini et al, 2013, Bjørner et al, 2012) however the regression model may not take this into account in its' current form. Including an interaction variable between age and month to death may give unrealistic results in any forecasting as increase or decreasing life expectancies may change this relationship. For example if we assume an increasing longevity an average 70 year in 2009 would be closer to death than a 70 year old in 2029. To overcome this issue Bjorner and Arnberg (2012) focused on the remaining life expectancies of individuals and included this in the model as dummy variables and in interactions with PTD. This approach raises the question of whether the decrease in the expenditure of dying is in fact a function of age or remaining expected life years. While it may make little difference to the regression model it will alter any predictions especially in the longer term (Bjørner and Arnberg, 2012). To ascertain which is correct would require a much larger period of time than the data in this study allow.

5.2.3 Chronic disease score

The pharmacy claims database lacks information on diagnosis, thus combinations of pharmaceutical therapies are used as proxies for broad medical conditions. The aim of using these conditions is to control for the effect they may have on expenditures. This methodology lacks specificity for certain conditions as some medications may have a broad application across a number of conditions or even off label use. Despite this limitation the methodology has been validated in several settings (Gray, 2000, Schneeweiss et al., 2001, Fishman, 2003, Maio, 2005, Silwer, 2005) and previously used

on Irish data (Naughton et al., 2006, O'Shea et al., 2013). The score was calculated following the methodology first employed by Von Korff et al (1992). The index used is a pharmaceutical based comorbidity index, calculated from the sum of 20 potential chronic disease groups derived from dispensing data using Anatomical Therapeutic Chemical (ATC) codes, presented in table 5.1. Individuals were assumed to have one of the diseases if they received at least three consecutive prescriptions of a medication representing a specific disease class in a 12 month period, using the ATC codes in table 5.1.

Table 5.1 Chronic disease score – disease group composition

code	Chronic disease	Medications	ATC codes*
1	Acid related disorders	Drugs for acid related disorders	A02
2	Cancer	Antineoplastic agents	L01
3	Cardiovascular disease	Digitalis glycosides, Antiarrhythmics, Organic nitrates	C01
		Antihypertensives	C02
		Diuretics	C03
		Beta blockers	C07
		Calcium channel blockers	C08
		Agents acting on the renin-angiotensin system - ACE inhibitors,	C09
		Lipid lowering agents	C10
		Vitamin K antagonists	B01AA
		Platelet aggregation inhibitors (excluding Heparin)	B01AC
4	Dementia	Antidementia drugs	N06D
5	Diabetes mellitus	Insulins and analogs, Blood glucose lowering drugs,Other drugs used in diabetes	A10
6	Epilepsy	Antiepileptics	N03
7	Glaucoma	Anti-Glaucoma and miotics	S01E
8	Gout and hyperuricemia	Antigout preparations	M04A
9	Human Immunodeficiency Virus (HIV) $^{\Psi}$	Protease inhibitors	J05AE
		Non-nucleoside reverse transcriptase inhibitors	J05AG
		Antivirals for HIV	J05AR
10	Hyperlipedemia	Lipid lowering agents	C10

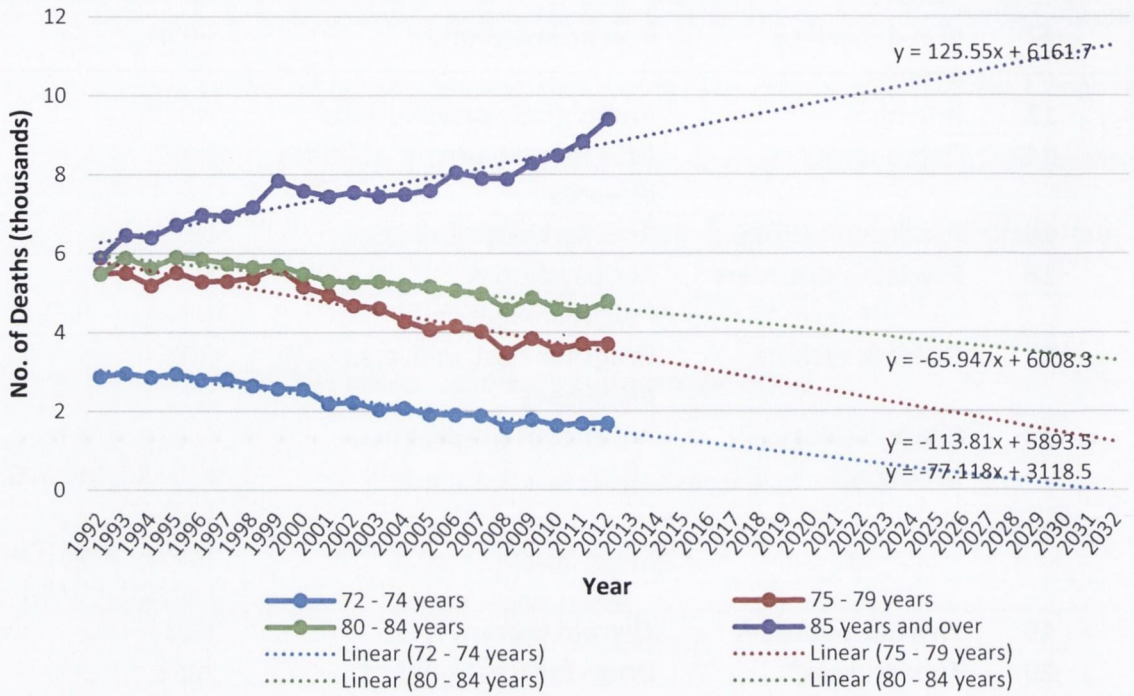
code	Chronic disease	Medications	ATC codes*
11	Intestinal inflammatory disease	Intestinal inflammatory agents	A07E
12	Iron deficiency anemia	Iron preparations	B03A
13	Migranes	Antimigrane preparations	N02C
14	Osteoporisis	Drugs for treatment of bone diseases	M05
15	Parkinson's disease	Anti-Parkinson's drugs	N04
16	Psyciatric disorders	Antipsychotics	N05A
		Psychoanaleptics	N06A
17	COPD & Asthma	Drugs for obstructive airways diseaseses	R03
18	Rheumatological conditions	Antirheumatic products	M01AB, M01AC, M01AE, M01AG, M01AH, M01AX, M01CB, M01CC, P01BA
19	Thyroid disorders	Thyroid therapy	H03
20	Tuberculosis$^{\Psi}$	Drugs for treatment of Tuberculosis	J04A

$^{\Psi}$Medications for these illnesses were not covered by the dataset but are part of the High Tech Drugs (HTD) scheme summarised in table 4.5.

5.2.4 Projection models

Two projection methods were used: firstly traditional multiplicative models and secondly regression based projections, both of which are discussed in the following sections. Past mortality rates were used to project possible future trends. (See Figure 5.2) Declining mortality rates are projected for each age group except the 85 years or more group. This corresponds with increasing longevity trends (Central Statistics Office, 2013). Detailed mortality tables are in Appendix D.

Figure 5.2 Past mortality rates and future projections



Historical deaths based on Eurostat mortality data for Ireland (Eurostat, 2013)

5.2.5 Traditional models

Two traditional projection models of prescription expenditure estimation were used based on the current level of drug use continuing. Model 1, pure population growth, was calculated by assuming the rate of medication use remains constant at the 2009 level and applying age-sex specific prescribing rates and expenditures/individual to the total population.

Model two includes proximity to death assuming the decreasing mortality trend observed over the last decade will continue. These mortality projections were used with age-sex specific prescribing rates and expenditures/individual in 2009 for survivors and decedents.

Regression based predictions are calculated using the sum of the two part model outlined earlier, holding other variables at their mean values. Predicted expenditure in the two-part model:

Equation 5.3

$$E(Y|X) = P(Y>0|X)*E(Y|Y>0, X)$$

Where $P(Y>0|X)$ is the probability of any expenditure being incurred (Part 1) and $E(Y|Y>0, X)$ is the predicted expenditure conditional on incurring any expenditure (Part 2). The last twelve months (1-12) were used in conjunction with population projections outlined in the previous section to calculate the projected expenditures.

5.3 Results

5.3.1 Descriptive statistics

The contextual data from TILDA shows that 92.2% (95% CI 91-93.3%) of those aged 70 or more had a medical card entitling them to free medications. The vast majority had only a primary education or none, 60.7% (95% CI 58.6-62.8%) and more than a third (34% 95% CI 36-40.5%) regularly take 5 or more medications.

The total population aged 70 years or more in 2006 that was used in the prescribing study and the population characteristics are set out in table 5.2. A total of 14,084 decedents or cases were matched to 14,084 survivors or controls with 65 cases not matched, due to the very small numbers of older people in certain regions. Those unmatched cases had a mean age of 99.3 years (Standard error (SE) 0.33yrs), a last year of life mean expenditure of €1,715.9 (SE €172.2) and a median expenditure of €1,361.6 (SE €168.2).

Table 5.2 Population characteristics 2009

	Total cohort population		2009 matched decedents	
	N	%	N	%
Total	231,710	100.0	14,084	6.1
Female	136,215	58.8	7,539	53.5
Mean Age	79.1 years		84.1 years	
(SD)	(5.5 years)		(6.5 years)	
Male	95,495	41.2	6,545	46.5
Mean Age	77.9 years		81.6 years	
(SD)	(5.3 years)		(5.9 years)	
Age Groups				
72-74	63,120	27.2	1,432	10.2
75-79	82,158	35.5	3,172	22.5
80-84	51,973	22.4	3,802	27.0
85-89	25,120	10.8	3,348	23.8
90+	9,339	4.0	2,330	16.6
Region				
Midlands	13,717	5.9	953	6.7
Mid-west	19,960	8.6	1,433	10.2
Northeast	19,851	8.6	1,298	9.2
Northwest	15,341	6.6	909	6.5
Southeast	28,324	12.2	1,797	12.8
South	36,936	15.9	2,233	15.9
West	27,033	11.7	1,547	11.0
East	70,548	30.5	3,914	27.8

In all time periods examined, 12, 24 or 36 months before death, decedents consistently show higher expenditures on medications than their counterparts who survived. (see Figure 5.3) The pattern changes in the last 12 months of life, during which decedents have a sustained month on month increase until death.

Figure 5.3 Total monthly expenditures for matched cohort

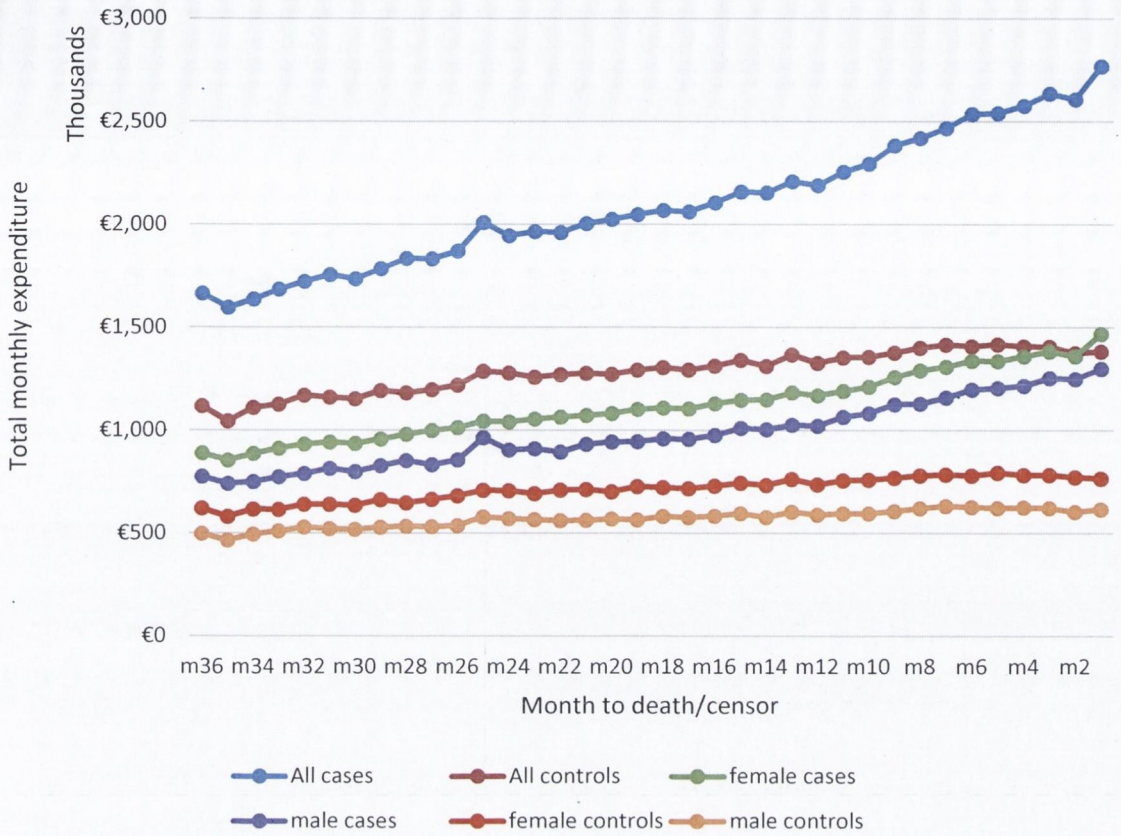


Table 5.3 shows the expenditures and item use for survivors and decedents by age group. Table 5.4 shows the decedent to survivor ratio for mean monthly expenditure in the last 12 months of life by gender and age group. The decedent to survivor ratios for the average number of items used shows a similar pattern 1.5 overall, 1.5 for females, 1.6 for males. (details of the expenditure amounts and means are contained in the Appendix, Tables C1 and C3) There is a declining ratio in number of items with age in females while males have a U shaped trend, bottoming in the 80-84 year old age group. The higher expenditures of decedents are more evident in younger age groups and also persist as far out as three years before death. (Results for the full 36 months are shown in Appendix Tables C4 and C6)

Table 5.3 Ingredient costs for 12 months prior to death or censored (1:1 exact matching on age (as at 1st Jan 2009), gender, region), decedents from 2009 by age group and gender (Ireland)

	Age group	Nr of individuals	Total expenditure (Std.dev) (€)	Mean expenditure per individual (SE) (€)	Median expenditure per individual (€)	Mean nr of items per individual (95%CI)	Average expenditure per prescription (€)
Decedents female	70-74	576	1,328,240 (980)	2,306.0 (24.9)	1,760.0	107.7 (105.6-108.1)	21.4
	75-79	1,415	3,329,458 (889)	2,353.0 (22.1)	1,940.6	112.5 (110.8-113.1)	20.9
	80-84	1,944	4,260,201 (1,067)	2,191.5 (20.4)	1,797.8	114.1 (112.6-115.3)	19.2
	85-89	1,953	3,956,046 (997)	2,025.6 (19.7)	1,687.5	110.0 (109.6-111.1)	18.4
	90+	1651	2,797,325 (1,456)	1,694.3 (14.8)	1,366.4	98.9 (97.4-100.1)	17.1
Decedents male	70-74	856	2,011,561 (970)	2,350.0 (22.5))	1,913.5	106.9 (105.6-107.9)	22.0
	75-79	1,757	3,909,137 (1,450)	2,224.9 (20.7)	1,788.8	106.7 (105.1-107.5)	20.9
	80-84	1,858	3,938,596 (1,523)	2,119.8 (21.2)	1,807.5	106.2 (105.7-107.2)	20.0
	85-89	1,395	2,954,777 (1,590)	2,118.1 (23.5)	1,765.7	107.7 (107.0-108.3)	19.7
	90+	679	1,182,377 (1,789)	1,741.4 (26.5)	1,430.4	96.9 (90.1-98.8)	18.0

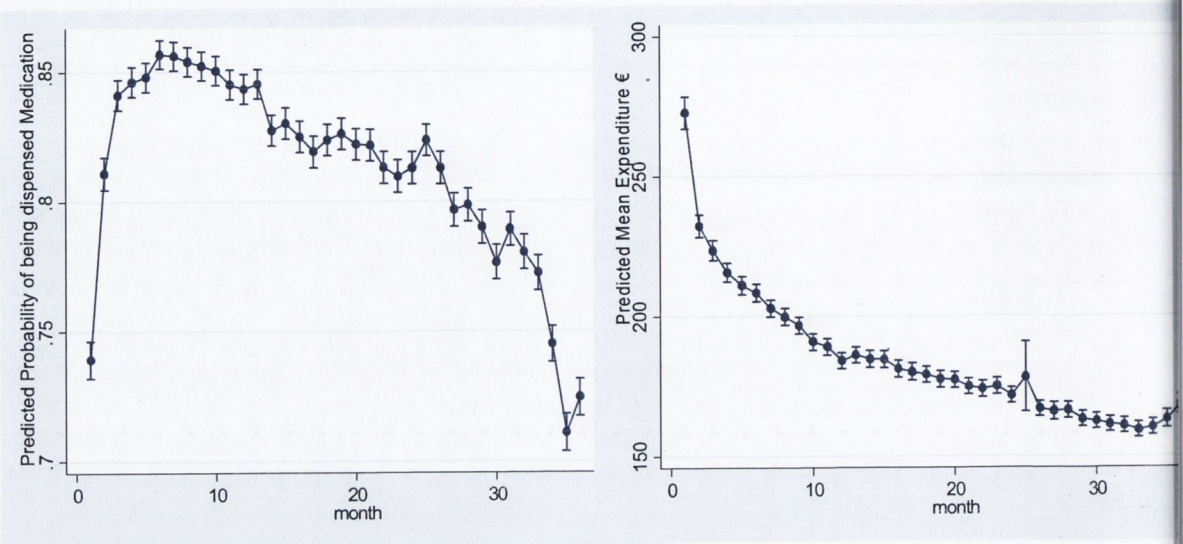
Table 5.4 Mean monthly expenditure ratio (decedents/ survivors) by age group and gender.

Gender	Age group	Mean expenditure ratio (Decedents /Survivors)
Both	All	1.8
female	All ages	1.7
	72-74	2.0
	75-79	1.9
	80-84	1.7
	85-89	1.5
	90+	1.6
male	All ages	1.9
	72-74	2.2
	75-79	1.9
	80-84	1.7
	85-89	1.9
	90+	2.0

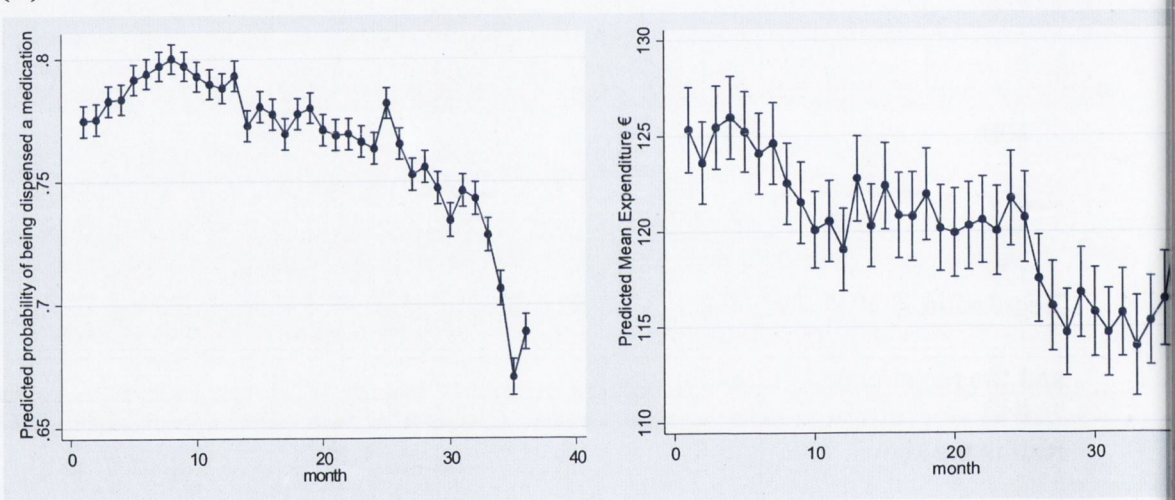
Regression analysis was used to predict the probability of being dispensed a medication and the mean expenditures for any given month for decedents and matched survivors, the results are shown in Figure 5.4 on the next page.

Figure 5.4 Predicted probability of medication use and expenditure for decedents (A) and matched survivors (B) by month to death (95% confidence intervals)

(A)



(B)



Controlling for age, age squared, gender, region, chronic conditions.

5.3.2 Medication use

The median number of items per month was 4, mean of 5.6 (SE 0.002) and a range of 0 to 181. Table 5.5 shows the prevalence of chronic conditions, based on the chronic disease score with 52.6% of the study population reporting 3 or more chronic diseases, rising to 72.2% for decedents.

Table 5.5 Chronic conditions 2009, based on chronic conditions score derived from medications dispensed

No. of chronic conditions	Total cohort population		2009 matched decedents		2009 matched survivors	
	N	%	N	%	N	%
0	26,284	11.3	744	5.3	1,690	12.0
1	34,434	14.9	1,114	7.9	2,058	14.6
2	49,143	21.2	2,065	14.7	3,008	21.4
≥3	121,849	52.6	10,161	72.2	7,328	52.0

Table 5.6 presents the detailed regression results for each disease in the chronic disease score based on the specification outlined in equation 5.2 with the addition of a dummy variable for each condition. As expected chronic conditions is a significant driver of prescription expenditures, resulting in an average increase of 24% in expenditure per month for each additional condition. Dementia is responsible for the largest average increase in expenditure (78%). Acid related conditions, diabetes, epilepsy, hyperlipidemia, COPD and asthma are all associated with a 40% or more increase in average expenditures compared to those who don't have the conditions, see table 5.6 (Full regression results are available in Appendix C, table C5.)

Table 5.6 GLM regression results for Chronic Conditions

Conditions	exp(b)	Standard Error	95% Confidence Interval	
Acid related disorders	***1.491	0.004	1.483	1.499
Cancer	***1.082	0.024	1.035	1.131
Cardiovascular disease	***1.117	0.004	1.109	1.126
Dementia	***1.787	0.011	1.766	1.808
Diabetes mellitus	***1.456	0.006	1.445	1.468
Epilepsy	***1.437	0.008	1.421	1.453
Glaucoma	***1.243	0.006	1.232	1.254
Gout and hyperuricemia	***1.119	0.007	1.106	1.133
Human Immunodeficiency Virus (HIV) $^{\Psi}$	1.000			
Hyperlipidemia	***1.427	0.004	1.419	1.435
Intestinal inflammatory disease	***1.389	0.018	1.355	1.425
Iron deficiency anemia	***1.121	0.005	1.111	1.131
Migraines	***1.160	0.041	1.082	1.243
Osteoporosis	***1.344	0.004	1.336	1.353
Parkinson's disease	***1.582	0.017	1.549	1.615
Psychiatric disorders	***1.356	0.005	1.346	1.365
COPD & Asthma	***1.575	0.005	1.564	1.585
Rheumatological conditions	***1.079	0.003	1.072	1.085
Thyroid disorders	0.997	0.004	0.989	1.005
Tuberculosis $^{\Psi}$	1.000			

Controlling for age, gender, region, mortality and month

*, **, *** indicates significance at the 90%, 95%, and 99% level, respectively

$^{\Psi}$ Medications for these illnesses were not covered by the dataset but are part of the High Tech Drugs (HTD) scheme summarised in table 4.5.

5.3.3 Regression analysis

Table 5.7 sets out the summary results for the two part model specified in section 5.2.2, using the full 3 year period, with the Probit showing the probability of expenditure on prescription medication and the GLM regression the effect on monthly expenditure per individual with the listed explanatory variables. (full results in Appendix Table C5) An interaction term with decedent was included for each month to capture the proximity to death effect. Looking at the basic model in table 5.7, age appears to have a neutral effect on expenditures, while decedents have on average 23.1% larger expenditures. An additional chronic condition increases monthly expenditures an average of 32.2%, taking

the other variables contribution into account. Applying the regression model on only the last year before death shows both effects of being a decedent and having an additional chronic condition increase to 39.1% and 39.8% respectively (Results shown in appendix). Monthly expenditures for individuals who are dispensed a medication (part 2 of the model) show that decedents have consistently higher expenditure than survivors in the last 12 months of life. There is a marked increasing trend in the last 6 months of life, culminating in the last month with decedents having an expenditure that is 1.58 times more than survivors.

Table 5.7 Two part model using a Probit followed by a Generalized linear model (GLM) of monthly prescribing expenditures assuming a Gamma distribution with a log link

	Probit				GLM on positive expenditures			
	Basic model[a]		Interactions model[b]		Basic model[a]		Interactions model[b]	
Covariates	Coeff.	Std. error	β	Std. error	Coeff.	Std. error	β	Std. error
Age	0.132ϕ	0.008	0.132ϕ	0.008	1.007	0.007	1.007	0.007
Age square	-0.001ϕ	$4.7x10^{-4}$	-0.001ϕ	0.000	1.000	$4.7x10^{-5}$	1.000	0.000
Male	1		1		1		1	
Female	0.023ϕ	0.003	0.023ϕ	0.003	0.916ϕ	0.003	0.916ϕ	0.003
No. Chronic conditions	-0.181ϕ	0.007	-0.471ϕ	0.013	1.231ϕ	0.008	1.152ϕ	0.014
Decedents	0.277ϕ	0.001	0.278ϕ	0.001	1.322ϕ	0.001	1.322ϕ	0.001
AIC					11.385		11.384	
Loglikelihood					-37,628,213		-37,625,078	

a Basic model includes dummy variables for 35 months prior to death/censor with month 36 as baseline and eight geographical regions with the Midlands as the baseline.

b The interactions model in addition to the basic model includes interactions between decedent and each month as specified in equations 5.1 and 5.2 ($\sum_{t=1}^{35} \gamma_t M_t D$). Age and gender interactions where not significant univariately and not included in model.

ϕ Indicates significance at the 99% level, respectively based on Z statistic.
Table A7 in Appendix reports the full detail of interactions and covariates used.

5.3.4 Expenditure projection

The traditional multiplier models detailed in section 5.2.5 are set out in the appendix for various population growth scenarios. Table 5.8 shows the ratio of the model including PTD (model 1) to the model excluding (model 2). Part A of table 5.8 shows the effect of including or excluding PTD using a traditional multiplier model, part B shows the same effect but using predicted values from a two part model. Full expenditures for each year and model are listed in Appendix table D3. In all cases not accounting for proximity to death in the models leads to significant overestimation of expenditures, ranging from 1.22 times to 1.73 times overestimated expenditures depending on the age group and demographics. In general there is less overestimation for older age groups.

Taking the ratio of excluding PTD to including PTD shows an overestimation of between 1.27 and 1.58 times depending on the age group and year, see table 5.7 (Appendix table D4 contains ratios for more population scenarios). The models based on the predicted values display a similar pattern as the traditional models albeit with a slightly larger effect. The predicted expenditures for each year are displayed in the Appendix table D5 for decedents and survivors.

Table 5.8 Ratio of Non PTD/ PTD (model 1 /model 2) expenditures

(A) Traditional multiplier model using M3 migration pattern, ratio of include PTD to excluding PTD

Age (years)	2011	2016	2021	2026	2031
70 - 74	1.52	1.53	1.53	1.54	1.54
75 - 79	1.41	1.41	1.42	1.43	1.44
80 - 84	1.29	1.30	1.31	1.32	1.33
85 and over	1.22	1.22	1.23	1.24	1.25

(B) Two part model using M3 migration pattern, ratio of include PTD to excluding PTD

70 - 74	1.56	1.57	1.58	1.58	1.58
75 - 79	1.46	1.47	1.48	1.49	1.50
80 - 84	1.38	1.39	1.40	1.42	1.43
85 and over	1.27	1.28	1.29	1.30	1.32

5.4 Discussion

This study investigated the effect of PTD on historical community prescription expenditures and used this data to project future expenditures examining the effect of excluding PTD in their calculation. TILDA data confirms that 92% of the population over 70 years had access to publically funded medications in 2009/2010. The results of this study show that decedents, on average, use more prescription medication and generate higher expenditures than survivors as distant as three years before death. The effect of PTD on prescription expenditures follows a similar trend to that of acute hospital expenditures only, but with a lower magnitude. Similar to acute hospital studies but in contrast to long term care (LTC) studies age has minimal effect on expenditures. Projection analysis shows the importance of taking decedents into account when projecting future expenditures, failure to do so will lead to an overestimation of expenditures, regardless of demographic or projection model chosen. Overestimation of expenditure was previously reported in a Danish study but with a smaller effect (Kildemoes et al., 2006).

Similar to other studies the results show a decline in the expenditure of dying with age (Seshamani and Gray, 2004c, McGrail et al 2000, Garattini et al, 2013, Bjørner et al, 2012) with those in the oldest group (≥90 years) expenditureing on average 1.3 times less than those in the youngest (72-74 years in 2009).

The reason to focus on the last year of life in projection models follows from evidence in this study and others that suggests this is when the PTD effect is the strongest (van Baal and Wong, 2012, Smyth A et al., 2013). The projection is an over simplification of prescribing expenditures by assuming current usage patterns continue and aside from population factors nothing else alters. It does however serve to show the potential importance of PTD and ceritus paribus the effect it could have on future projections when not accounted for.

The step like increases in expenditures for survivors correspond broadly with changes in pricing contracts between the state and the pharmaceutical industry. However Felder et al (2010) posit that increasing medical technology may be responsible for increasing healthcare expenditure (HCE). This is also a plausible explanation for increasing pharmaceutical expenditures with high percentages of individuals on relatively expensive preventative medications introduced in the last decade and would explain the upward trend in survivor expenditures evidenced in the data. For example we know from TILDA data that 30.2% (95% CI: 29.1-31.2%) of the population over 50 regularly take a statin[19] which rises to 41.6% (95% CI: 39.4-43.9%) of the population over 70 years and remains high in the over 80s at 38.8% (95% CI: 34.4-43.1%).

While the dispensing database covers the majority of the target population there is still the potential for individuals who have been dispensed a medication in the period 2006-2009 or individuals who are not in possession of a medical card, to be omitted. TILDA data shows that 94.6% (95%CI 93.4-95.6%) of those aged 72 or more in 2009/2010 had a medical card. While using a chronic disease score was to try and control for the effect of chronic conditions on medication use there is the possibility of confounding between mortality and chronic conditions even when using the reduced count of conditions. A full discussion of the strengths and limitations of the thesis is included in chapter 8.

5.5 Conclusion

The PTD effect is not just relevant for acute and long term care settings but is also evident in community prescribing expenditures. While the magnitude of the effect is lower than found in other settings it still has an important impact on future expenditure projections even accounting for chronic conditions. Failure to account for the large number of individuals who die in any year leads to an over estimation of the true expenditure and

[19] Statins are a group of medications used to lower cholesterol in the prevention of cardiovascular disease and at the time of this study were relatively expensive.

perpetuates the theory of ageing alone driving expenditures. Further evidence of this effect using New Zealand data is presented in chapter 6 and a detailed discussion is contained in chapter 7.

6. The Importance of Proximity to Death in Modelling Community Medication Expenditures for Older People: Evidence From New Zealand

In order to provide additional validation of the results and findings from Irish data presented in chapter 5, data from New Zealand is used to examine the relationship between ageing, proximity to death and prescribing expenditures. While geographically distant the countries are quite similar in demographics and health service provision. These similarities coupled with the availability of dispensing and mortality data made for a suitable comparator. The literature outlined in chapter 2 highlighted the need for a country by country analysis rather than attempting a comparison with a large number of countries. A number of countries were considered as potential comparators and are summarized in Appendix section A3.

This chapter presents the background, context, study data, methods, results and a brief discussion of the findings from the New Zealand cohort. Some of the common discussion themes between findings from the Irish study and New Zealand study are presented in chapter 7.

6.1 Introduction to the study

Concerns about the long term sustainability of increasing healthcare expenditure has become an important policy issue in New Zealand. Such growth is increasing pressure on government budgets, healthcare providers and individuals. Understanding drivers of this growth should enable us to more accurately forecast future expenditures and inform appropriate policies.

The literature outlined in chapter 2 introduced the literature on ageing, health care expenditures and the studies which have presented evidence of increased healthcare expenditures for those close to death (Scitovsky, 1994, Comas-Herrera et al., 2007, Werblow et al., 2007, Zweifel et al., 1999, Seshamani and Gray, 2004b). The aim of this

study is to examine the association between age, proximity to death and medication expenditure by examining the expenditures of decedents and survivors.

6.2 The New Zealand Healthcare System

In common with most developed countries the health system in New Zealand has experienced significant transformations in the decades since the first labour government introduced free health care for all under the Social Security Act 1938, which included access to free medication. It has moved from an entirely public system to the current mixture of public and private provision. Gauld (2009) provides an indepth analysis of health system reform in New Zealand from 1840 to 2009. From 1st January 2001 District Health Boards (DHBs)[20] were responsible for ensuring the provision of health and disability services to populations within 21 defined geographical areas (Governement of New Zealand, 2000). The DHBs receive public funding from the Ministry of Health, based on a formula which takes into account the size, age, socioeconomic status and ethnic mix of their population. Primary healthcare, including GP services, are contracted by DHBs to approximately 80 primary healthcare organisations (PHOs) who either directly provide the services or indirectly through member providers. Recent changes to the Ministry of Health structure include the creation of a National Health Board (NHB) to improve coordination between the 21 DHBs and supervise expenditure of public health funding. New Zealanders are enrolled by PHO's to ensure continuity of care with the same general practice, this is incentivized through lower co-payments resulting in a high level of population coverage (Hefford et al., 2005).

In 2009 New Zealand spent 10.3% of its GDP on health care (OECD, 2014a). The annual average growth rate in health expenditure per capita in real terms for the decade to 2009 was 4.8%, the OECD average rate was 4.0% (OECD, 2011a).

[20] Southland and Otago DHBs were subsequently merged to create one Southern DHB on 1st May 2010.

The Ministry of Health has overall responsibility for health and disability services and provides advice to the Minister of Health and the government of New Zealand on policy issues.

6.3 Funding of prescription medication

The Social Security Act 1938 introduced a free at the point of care Health system for New Zealanders under the control of the Department of Health which included access to free medication. It was a progressive move towards improving the health of its citizens. A major difference in the Act to previous attempts at social welfare was the inclusion of citizens based on residency rather than paid social contributions, this remains in the current system but free medication is now limited.

In 1993 the government were proactive and progressive in tackling medication expenditure, they set up the Pharmaceutical Management Agency of New Zealand (PHARMAC) to manage the list of reimbursable items and bring economies of scale to community pharmaceutical purchasing (Gauld, 2009). Hospital dispensing remains within the remit of hospitals and their budgets. In 2009 there were approximately 2,000 drugs listed on the national medicines schedule that are either fully or partially subsidized (Pharmac, 2009). Full economic evaluation has been a requirement for all new medications in the drug formulary since 1993 (Sullivan et al., 2001).

The Ministry of Health currently subsidises prescription drugs, in the case of eligible patients a co-payment of NZ$3[21] is required up to a maximum of NZ$60 (20 prescriptions) in any year, after which there is no co-payment. The over 65s are more likely to have been issued with numerous prescriptions in the previous 12 months than younger age groups (NZIER, 2004).

The success of PHARMAC is evident in OECD expenditure figures, relative to other OECD countries public expenditure on prescription drugs in New Zealand has not risen

[21] This has increased to NZ$5 since 2012.

dramatically in the last two decades(OECD, 2011b). In 2009 the country had one of the lowest expenditures on pharmaceuticals as a share of GDP amongst OECD countries at 0.9% well below the average 3.5% (OECD, 2011a). Pharmaceutical expenditure accounted for 11% of the total health care budget in 2009 (OECD, 2011a). So while New Zealand has witnessed modest yearly rises in prescription medication expenditure it has not seen the dramatic increases evident in Ireland (see chapter 4).

While there has been an increase in the use of preventative medication, such as cholesterol lowering agents, the increase in expenditure may be offset by a decrease in other medical expenditures. For example the rise in statin use has coincided with a decrease in cardiovascular events such as myocardial infraction and stroke (Moodie, 2008, OECD, 2013).

A key equity measure of the New Zealand Healthcare system is the Community Services Card, similar to the Irish Medical card it is assessed on income and provides access to a number of medical services. The High Use Health Card and the Pharmaceutical Subsidy Card both provide greater subsidisation of medicines for those with poorer health. A High Use Health Card is not assessed on income grounds but use, it is given to those who attend the doctor 12 times or more in the last 12 months. It provides the same subsidies on doctors' visits and prescriptions as a Community Services Card. The Pharmaceutical Subsidy Card is for those who are high users of medications, it is issued to an individual once they have collected 20 prescriptions in a year, and ensures all subsequent prescriptions are free.

6.4 Demographics and Ethnic groups

In 2009 New Zealand had a predominantly urban population of approximately 4.32 million of which 0.38 million (12%) were 70 years or older (Statistics New Zealand, 2009). The New Zealand population over 70 years of age is predicted to more than double in the next two decades similar to the majority of other developed countries (Statistics

New Zealand, 2009, OECD, 2011c). In addition, the working population (15-64) will only marginally increase (Statistics New Zealand, 2009, OECD, 2011c) or even decline (OECD, 2011c) leading to an increase in the old age dependency ratio of those aged 70 years or more to those aged 15-64 years (Department of Economic and Social Affairs Population Division, 2013, OECD, 2011c). As a result of this demographic shift a reduced proportion of the population will be supporting an increased older population. Policy makers in New Zealand and other developed countries with similar ageing populations are concerned about a significant health care expenditure increase associated with the anticipated population shift.

The population is predominately of European descent with 67% identifying as so in the 2006 census (Statistics New Zealand). The largest minority groups are Māori 14.6%, Asian 9.2% and Pacific peoples 6.9% (Statistics New Zealand). When the participants in this study were born in the mid 20th century New Zealand only had a population of approximately 1 million, the vast majority being European with 4.5% Māori (Statistics New Zealand, 2011c). Māori and Pacific peoples across all age groups are more likely to have poorer health outcomes coupled with shorter life expectancies than other ethnic groups in New Zealand (Blakely et al., 2005, Ministry of Health, 2011). A self reported study found that Māori and Pacific peoples are more likely to defer buying medications because of expenditure than those of European descent (Jatrana et al., 2011).

6.5 Data and Methods

Ethical approval was obtained for the Health Policy and Management Ethics Committee, Trinity College Dublin, details are provided in Appendix D. A data agreement was entered into with the New Zealand Ministry of Health under which prescribing and mortality data for individuals 70 years of age and older was provided from the Pharmacy Claims Data warehouse for 2007-2010. Data was received in text files and Stata version 12 (STATA Corp., Texas) was used for all data management and analysis. Due to the size

of the data files initial analysis was done using the facilities of the Trinity Centre for High Performance Computing (TCHPC)[22]. Each prescription record contains a unique person identifier, date of birth, ethnic group, gender, age, date of dispensing and ingredient cost. Ingredient cost is the amount of New Zealand dollars the state has paid the pharmacist for the medication at 2008/2009 prices and does not include dispensing fees or co-payments made by individuals. Mortality records include a unique person identifier, the date of death, age at death and place of death. Further details on how mortality data is compiled and coded in New Zealand are available in the Mortality and Demographic data report (Health, 2012). Unlike previous studies examining Health Care Expenditure (HCE) which used samples, this study uses a national cohort.

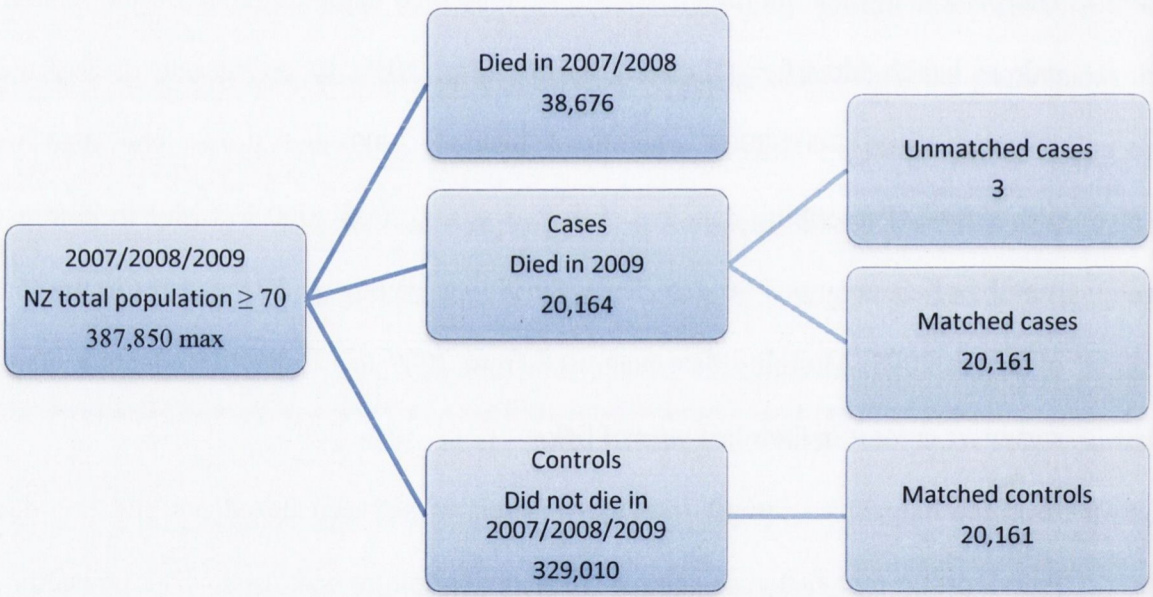
The prescribing and mortality records were merged using an anonymised version of the unique health identifier (National health index NHI) to create one dataset including survivors from 2008/2009 who lived beyond 2009 and those who died in 2009 (decedents). Prescribing data are over two years, 2008-2009 in order to gain a full 12 months of observations for decedents. Survivors are those who were not in their last year of life in 2008. Mortality data was used from 2009 to identify decedents and to ensure survivors are not in their last year of life.

In order to gain an insight into the differences between decedents and non-decedents (survivors) a matched case-control study methodology was used. The mortality dataset was utilized to identify decedents in 2009 as cases, and match them 1:1 based on age, gender and ethnic group to controls (survivors) from 2008. Data for survivors was calculated for the year January to December 2008. Coarsened exact matching (CEM) was used, this involved three steps: First the matching variables were coarsened into broader groups (similar to creating a histogram by putting the variables into categories or bins) e.g. Age into 5 year bands; Secondly data were exactly matched using the matching

[22] TCHPC provide supercomputing and visualisation facilities to researchers and is funded by Science Foundation Ireland. Further details are available at http://www.tchpc.tcd.ie/

variables, which involves sorting the observations into strata, each with unique values of the matching variables; Thirdly Strata containing only control units were discarded; strata with case and control units were retained. A detailed description of CEM and its merits over other matching methods is given by Iacus et al (2011). The total population over 70 years of age considered in the study can be broken down into three groups as shown in Figure 6.1. A total number of 20,161 decedents or cases matched to 20,161 survivors or controls with only 3 cases not matched, this was due to the very small numbers of older people in certain ethnic groups.

Figure 6.1 Participant Flowchart



6.5.1 Econometric specification

Exploratory data analysis was conducted followed by an econometric data analysis which included: two part model (TPM) was estimated using a Probit and GLM; TPM was tested for cross-sectional dependence; TPM was tested for suitability for panel data framework (Likelihood ratio test and F-test).

Monthly expenditure on prescription medicines has a spike at zero and for those individuals who do incur expenditure the distribution is right skewed with non-constant

variance. This distribution is typical of health care expenditure data therefore any regression methods must take account of the skewed data and focus on the population means (Blough et al., 1999, Manning and Mullahy, 2001). If an Ordinary Least Squares (OLS) regression methodology were used with a log transformation to account for the skewness the analysis would not be based on the population means but rather the mean on the log scale. This scale would measure geometric means and require a system of back transformation for interpretation (Duan, 1983, Barber and Thompson, 1998, Barber and Thompson, 2000, Manning and Mullahy, 2001).

In the study population of 4.2 million monthly expenditure observations 1.6 million (38.7%) have a zero value. The total monthly expenditure variable is heavily skewed (skewness=35), if zero values are ignored the skewness is only slightly reduced (skewness=30)[23]. The distribution also has considerable non-normal kurtosis (kurtosis=2,371), while kurtosis shows a relatively larger reduction (kurtosis=1,651)[24] it still implies a heavy tailed distribution (leptokurtic). After careful consideration of the data using a modelling strategy the best fitting was a two part model with a Probit model to first identify the likelihood of monthly expenditure by modelling a dictonomous dependent variable for whether or not there was an expenditure in a given month and then a generalized linear model (GLM) was run conditional on the presence of non-zero prescribing expenditure to estimate the monthly medication expenditure of individuals. The two part model assumes that the zero values and the positive values are generated by different independent mechanisms. Duan et al (1983) and Jones (2000) provide more in-depth discussion of the merits of the two part model.

Given the nature of the panel dataset, a large number of observations over a short 12 month period, I have not tested for stationarity. Two tests were conducted to ascertain if

[23] Normal values: skewness=0

[24] Normal values: kurtosis=3, STATA calculates kurtosis based on Bock BOCK, R. D. 1975. *Multivariate Statistical Methods in Behavioral Research,* New York, McGraw-Hill.

panel data methods were appropriate for the two part model as follows. A likelihood ratio test was conducted on the first part of the model to test for panel-level variance equal to zero and concluded that there was no evidence of zero variance. An F-test was conducted on the second part of the model to test if all individual specific effects were equal to zero, this hypothesis was rejected. The following Probit model was run to examine the effects of age, gender, proximity to death and ethnic group on the probability of using medication in a given month.

Equation 6.1

$$\Pr(Expend. > 0) = \propto + \beta_1 A + \beta_2 A^2 + \beta_3 G + \beta_4 D + \sum_{t=1}^{23} m_t M_t + \sum_{e=1}^{5} \epsilon_e E_e + \sum_{t=1}^{23} \gamma_t M_t D$$

Where A: individual age; G: Male gender; D: decedent; M: months until death or censor; E: Ethnic group; MD: decedent-month interaction term; β, m, ε, γ: regression coefficients.

The second part of the model is a random effects GLM which facilitates the analysis of mean expenditures while allowing for the non-normal distribution of the data. A major advantage of the GLM is that it models the mean and link (variance) functions on the original scale of expenditure. The model consists of a distribution function for expenditures and a link function which describes the scale of the relationship of the covariates with the expenditure. The various GLMs were assessed using the Modified Parks Test following Manning and Mullahy (2001), Akaike Information Criteria (AIC) (Akaike, 1973) and normal probability plots of deviance residuals to ascertain a suitable distribution function. While there is no one test for assessing an appropriate link function the following three tests were run for guidance: Pearson correlation test; Pregibon Link Test; a modified Hosmer and Lemeshow Test. The consistent result from these tests was an inverse gaussian distribution function and a log link. The key difference between this and the model used for Irish data in chapter 5 is the choice of distribution function.

Equation 6.2

$$\text{GLM}(Expend) = \propto + \beta_1 A + \beta_2 A^2 + \beta_3 G + \beta_4 D + \sum_{t=1}^{23} m_t M_t + \sum_{e=1}^{5} \epsilon_e E_e + \sum_{t=1}^{23} \gamma_t M_t D$$

Where A: individual age; G: Male gender; D: decedent; M: months until death or censor; E: Ethnic group; MD: decedent-month interaction term; β, m, ε, γ: regression coefficients. The use of a log link function in the GLM means the coefficients act multiplicatively on the mean, by taking the exponential they can be expressed as the percentage increase in the mean monthly medication expenditure per unit increase in the covariate (Barber and Thompson, 2004). A random effects model is more appropriate for the dataset over a fixed effects model for a number of reasons, principally the loss of coefficients for time-invariant variables such as gender and ethnic group and the exclusion of individuals with all zero or all positive monthly expenditures. A Breusch-Pagan LM will test for the appropriateness of a random effect model.

As presented in section 6.4 there are considerable differences in health status based on ethinic origin in New Zealand, to account for this ethnicity was included in the models. The original 26 codes for ethnic groups presented in Table 6.1 were condensed into six, starting with the largest: European, not stated, Māori, Asian, Pacific Islands and other. Age was split into four five year bands and a 90+ category for exploratory analysis and maintained as a continuous variable for regression analysis. The number of items variable is a count of medicines dispensed in each month, it has a monthly median of 2, a monthly mean of 4 (std dev. 7.12) and a range of 0 to 460.

Table 6.1 Condensed Ethnic groups

Original Ethnic group	Original code	Condensed ethnic group
European not further defined	10	European
New Zealand European	11	
Other European	12	
New Zealand Maori	21	Maori
Cook Island Maori	32	
Pacific Island not further defined	30	Pacific Islands
Samoan	31	
Tongan	33	
Niuean	34	
Tokelauan	45	
Fijian	36	
Other Pacific Island (not listed)	37	
Asian not further defined	40	Asian
South east Asian	41	
Chinese	42	
Indian	43	
Other Asian	44	
Middle Eastern	51	Other
Latin American/Hispanic	52	
African	53	
Other	54/61	
Not known/not stated	94/99	Not stated/known
Refuse to answer	95	
Response unidentifiable	97	

6.6 Results

6.6.1 Descriptive statistics

Table 6.2 outlines in more detail the three characteristics - gender, age and ethnic group - that were used to match the decedents (case group) to survivors (control group).

Table 6.2 Characteristics of total population and decedents

	Characteristic	Total population	Decedents
Gender	Male (%)	141,365 (43%)	9,306 (46%)
	Female (%)	187,632 (57%)	10,855 (54%)
Age	Mean (SD)	76.5 (5.9)	81.9 (7.1)
	Median (range)	75 (70-111)	82 (70-107)
Ethnicity	European (%)	267,594 (81.3%)	17,503 (86.8%)
	Māori (%)	12,673 (3.9%)	1,112 (5.5%)
	Pacific peoples (%)	5,893 (1.8%)	364 (1.8%)
	Asian (%)	10,076 (3.1%)	312 (1.6%)
	Other (%)	880 (0.3%)	30 (0.2%)
	Not stated (%)	31,894 (9.7%)	843 (4.2%)

Separating the population into survivors and decedents shows the difference in number of items used and ingredient costs of those in their last 12 months of life. Figure 7.2 shows the mean 12 month expenditure by age group for male and female decedents and survivors. The mean expenditures for decedents decreases with age, from NZ$2,259 in the 70-75 age group to NZ$864 in the 100+ group, a 62% decrease in expenditure. The mean expenditure for survivors increases to a peak of NZ$933 in the 85-89 age group and decreases thereafter. Figure 7.3 plots the mean number of items used in the 12 month period.

The patterns in Figures 6.2 and 6.3 show that while mean expenditure for decedents decreases with age group, mean items dispensed peaks in the 80-84 age group and declines thereafter. This would suggest that older decedents use more items and cheaper items on average than younger decedents. In contrast the mean expenditure of survivors increases with age in line with the number of items, but again there is a change in the 85+ age groups where the expenditure remains level but the number of items continues to

increase. While at every age decedents use more items and have a higher mean expenditure than survivors, the additional "expenditure of dying" decreases with age as demonstrated in Figure 6.4 which shows the decedent / survivor ratio narrowing as age group increases.

Figure 6.2 Mean expenditure per individual by age group 2008/2009

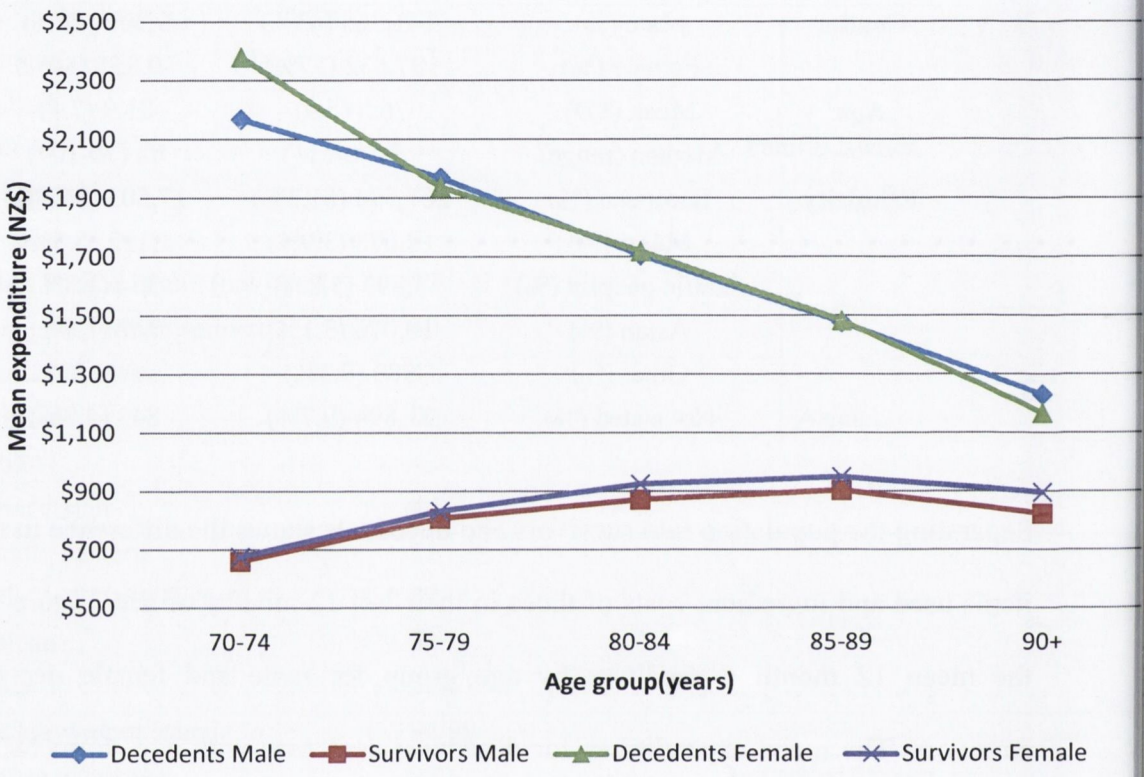


Figure 6.3 Mean number of items per individual by age group 2008/2009

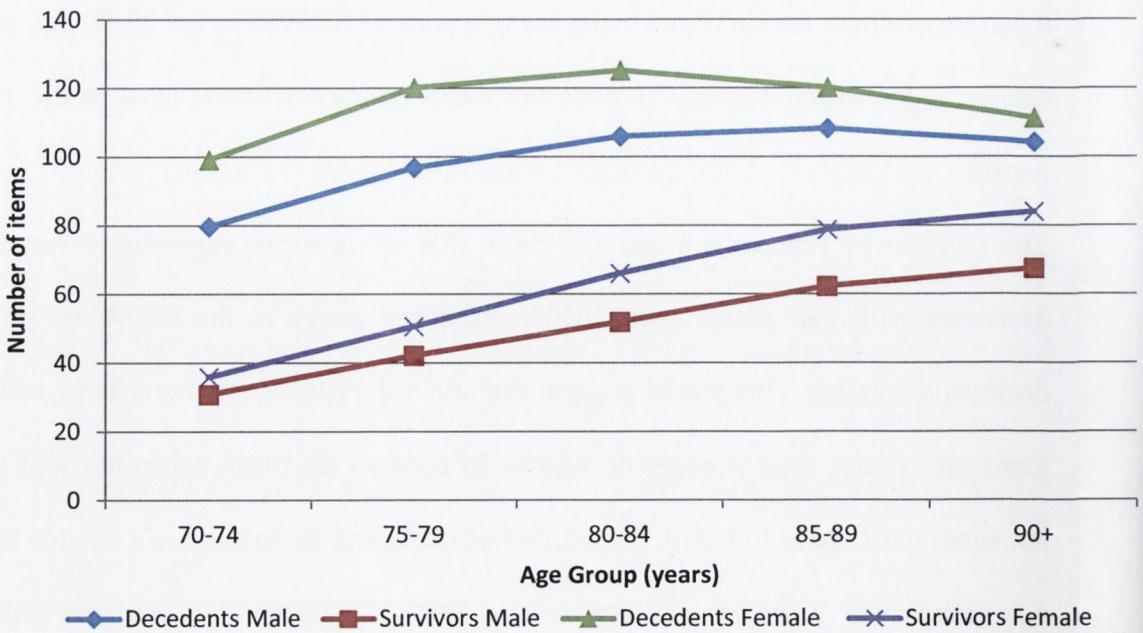
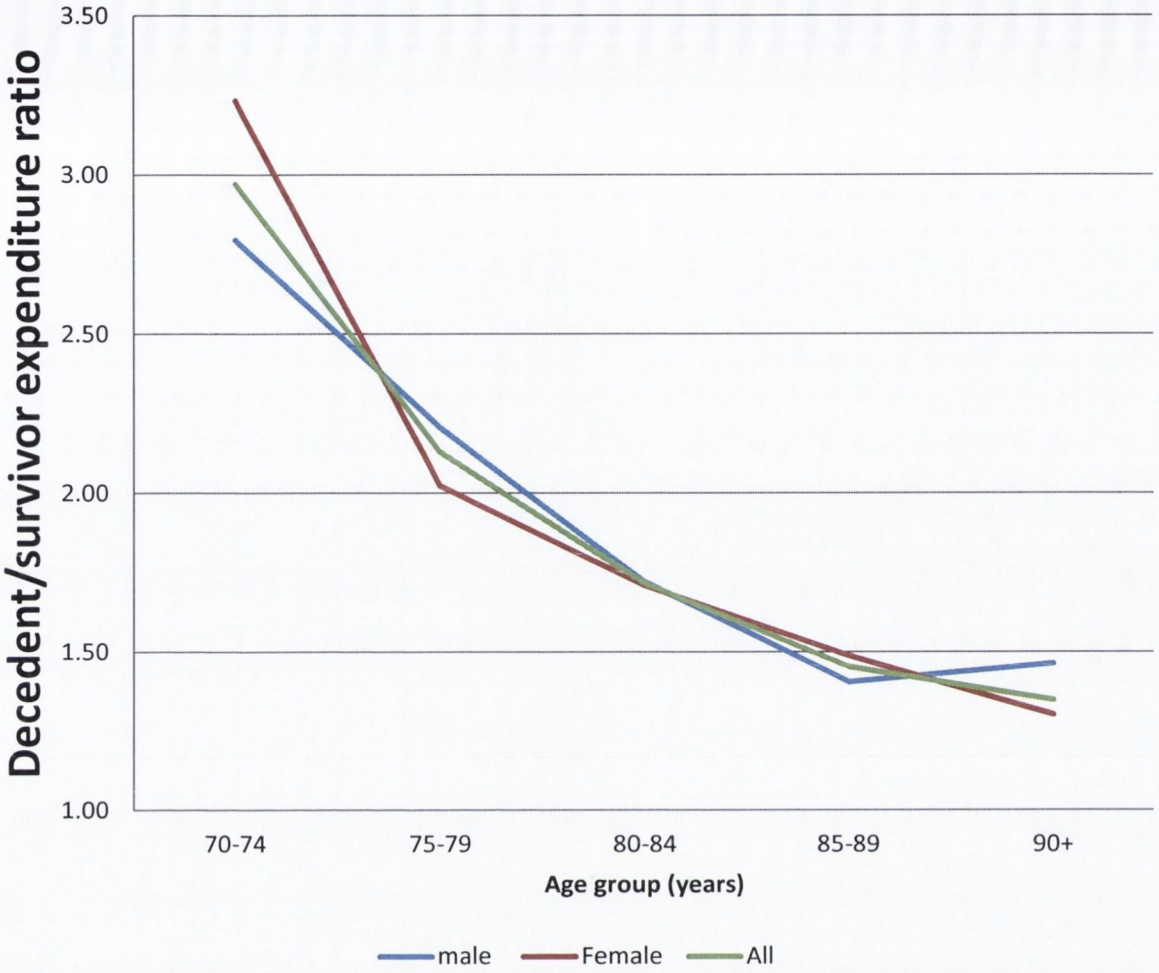


Figure 6.4 Decedent / survivor expenditure ratio by age group



Results given in Table 6.3 show the matching of the case group of decedents taken from 2009 and followed back to 2008 with a matched control group from 2008. The mean expenditure ratio (decedents/ survivors) in Table 6.3 shows that decedents are on average 1.95 times more expenditurely than survivors, which ranges from 2.09 for males to 1.82 for females. This ratio declines with age as seen in Figure 6.4. The all age mean expenditure per item is similar for both groups while the number of items per individual is 1.95 times more for decedents.

Table 6.3 Ingredient costs for 12 months prior to death or censored (1:1 coarsened exact matching on age, gender, ethnic group)

	Nr of individuals	Total annual expenditure (standard deviation) (NZ$)	Mean expenditure per individual (standard error) (NZ$)	Median expenditure per individual (NZ$)	Mean nr of items per individual (95%CI)	Average expenditure per prescription (NZ$)	Mean expenditure ratio (Decedents /Survivors)
Cases	20,161	20,749,092 (2,030)	1,029.17 (14.30)	614.41	109 [108-110]	9.47	1.95
Female	10,855	10,284,171 (1,973)	947.41 (18.94)	601.11	115 [113-117]	8.23	1.82
Male	9,306	10,464,921 (2,091)	1,124.53 (21.67)	633.96	102 [100-104]	11.19	2.09
Controls	20,161	10,642,978 (928)	527.90 (6.54)	352.45	57 [56-58]	9.35	
Female	10,855	5,644,264 (885)	519.97 (8.50)	370.50	66 [64-67]	8.06	
Male	9,306	4,998,714 (976)	537.15 (10.12)	334.67	47 [46-49]	11.48	

6.6.2 Medication use

A comparison of the medications dispensed to decedents in the 12th month from death and in the last month before death shows, as expected, a significant increase in medications over the 12 month period. In the last month of life over double the number of items were dispensed to the decedents in comparison to the matched survivors. In the last month of life there is a significant increase in use across most therapeutic groups compared to the 12th month. The largest being the Nervous System (N)[25] with an overall 3.8 times rise driven by large absolute increases in analgesics (N02) (4.6 times), anti-nausea & vertigo agents (N07C and A04) (12.9 times), antipsychotic (N05A) (5.4 times), sedative (N05C) (3.2 times), anti-epilepsy (N03) (4 times) and antidepressant (N06A) (4 times) medications. While medication use increases on average in the last month before death it does not show a dramatic rise or pattern in the preceding months.

[25] Medications are reported using the WHO Anatomical Therapeutic Chemical (ATC) system

6.6.3 Regression analysis

A Breusch-Pagan LM test rejected a null hypothesis of variances across individuals being zero, this would suggest that a random effects model, which takes account of the panel effect, is more appropriate than using an Ordinary Least Squares (OLS) method. Table 6.4 sets out the results of a two part model, with the Probit showing the probability of expenditure on prescription medication and the GLM regression the effect on monthly expenditure per individual with the listed explanatory variables. The reference groups being female, of European ethnicity and the 12^{th} month before death or censor. An interaction term with decedent was included for each month and all were found to be significant.

An increase in one year of age has a decreasing effect on mean monthly expenditures, 2.2% on average, adjusting for the contributions of the other explanatory variables. Decedents have a higher monthly expenditure in every month leading up to death. In terms of ethnic groups, those of Asian origin had considerably higher monthly expenditures, while Māori and Pacific islanders had lower expenditures. Only Māori had an increased likelihood of medication use, as seen in part 1 of the model.

Part 1 of the model shows that with 12 months prior to death as the baseline there is a constant upward trend in the likelihood of medication use in months 11 to 1. The proximity effect extends at least 12 months prior to death.

Monthly expenditures for individuals who are dispensed a medication show no consistent increasing trend prior to death other than those who die being consistently 1.3 to 1.4 times greater than survivors with a more noted increase in the last month of life to 1.6 times greater. Even when the decedent time span is expanded to 24 months there is no convergence or surge in use towards the end of life, apart from the last month (data not shown here). But decedents do on average use twice as many items as survivors over the whole period, and are more likely than survivors to have used medication in any given month.

Table 6.4 Probit and Generalized linear model (GLM) of monthly prescribing expenditures assuming an inverse Gaussian distribution with a log link.

Covariates	Part 1 - Probit		Part 2 - GLM	
	Coefficient	Standard. error	Coefficient	Standard. error
Age	***0.0470	0.0003	***0.9783	1.0002
Age^2	***-.0.001	$4.2x10^{-4}$	1.000	0.000
(ref group female) Male	***-0.2342	0.0039	***1.1259	1.0027
(ref group European) Māori	***0.0481	0.0101	***0.9576	1.0070
Pacific Islands	***-0.4024	0.0146	***0.9220	1.0109
Asian	***-0.5673	0.0113	***1.1618	1.0101
Other	***-0.2762	0.0376	***1.0949	1.0300
Not stated	***-0.4657	0.0066	***0.7838	1.0045
(ref group 12^{th} month) 1 month	***0.2490	0.0037	***1.0418	1.0066
2 months	***0.2383	0.0037	***1.0341	1.0065
3 months	***0.1077	0.0036	**0.9848	1.0065
4 months	***0.1402	0.0036	1.0017	1.0066
5 months	0.1187	0.0036	1.0098	1.0066
6 months	***0.0097	0.0036	***0.9754	1.0066
7 months	***0.0644	0.0036	***0.9693	1.0065
8 months	***0.0272	0.0036	***0.9787	1.0066
9 months	*0.0065	0.0036	***0.9715	1.0066
10 months	***-0.0641	0.0036	***0.9345	1.0066
11 months	0.0142	0.0036	**0.9836	1.0066
Decedent*1 month	***0.8849	0.0168	***1.6260	1.0200
Decedent* 2 month	***0.8467	0.0167	***1.3774	1.0185
Decedent*3month	***0.8269	0.0161	***1.4068	1.0185
Decedent*4 month	***0.7046	0.0158	***1.3481	1.0184
Decedent*5month	***0.6400	0.0155	***1.3205	1.0184
Decedent*6month	***0.7008	0.0153	***1.4282	1.0189
Decedent*7month	***0.5749	0.0150	***1.4185	1.0188
Decedent*8 month	***0.5739	0.0149	***1.3882	1.0188
Decedent*9month	***0.5478	0.0148	***1.3856	1.0188
Decedent*10month	***0.5708	0.0146	***1.4300	1.0188
Decedent*11month	***0.4561	0.0145	***1.3586	1.0189
Constant	***-3.0798	0.0263	***391.4	1.0181
Nr of observations	4,190,088		2,568,273	
		Log likelihood	-16,255,102	
		AIC	12.6584	

*significant at the 90% level, **significant at the 95% level, ***significant at the 99% level

6.7 Discussion

This study provides evidence of the importance of accounting for proximity to death rather than ageing alone for expenditure on prescription drugs in an older community based population. In fact the regression results show that ageing has a negative effect on prescription expenditure. By comparing prescription expenditures for decedents in the last 12 months of life to a similar group of survivors we can see that decedents expenditure on average between 1.82 and 2.09 times more. Similar to other studies mean HCE per annum is rising after 70 years of age with a peak in the 80 to 84 year age group and a decline there after in the total population and the survivors control group (Bjørner and Arnberg, 2012, Seshamani and Gray, 2004b). The mean number of items used in the 12 month period by survivors increases linearly with age but at a greater rate than expenditure which suggests that while survivors are using more items in these older groups they are relatively cheaper medications. The increases in mean items and expenditure of survivors with age may be due to increasing rates of chronic illness, as the number of people over 70 years of age reporting one or more chronic illness increases with age (Aspin et al., 2010). In contrast descendants demonstrate a dramatic decrease in expenditure which is combined with a more staid increase in mean number of items, this is in line with other HCE studies which have reported a decrease in the "expenditure of dying" with age (McGrail et al., 2000, Lubitz et al., 1995).

The study adds to the existing literature on proximity to death by providing evidence on patterns of prescribing expenditures. This study reports a similar magnitude for the PTD effect as a Danish study (2006) which reported a mean expenditure ratio of 1.7 for those aged 75 years or more. The Danish study also reports that ageing will increase future drug expenditures but taking PTD into account they conclude that the increase will be relatively small (Kildemoes et al., 2006). In contrast a Dutch study examining macro level data suggests that accounting for PTD may not simply reduce future projections of HCE

due to growth from other unidentified causes which were not included in previous modelling attempts (van Baal and Wong, 2012).

Similar to a Spanish study (Angulo et al., 2011) age was found to have a positive influence on the probability of pharmaceutical expenditure, in contrast the Spanish study additionally found a positive association between age and the amount of expenditure but was focused on individual doctors prescribing and excluded PTD. Studies looking at total health care expenditures have reported increasing expenditures with age (Yang et al., 2003, Colombier and Weber, 2011) with some attributing it to proximity to death (Zweifel et al., 1999, McGrail et al., 2000, Felder et al., 2010). This study has focused on prescribing expenditures and found that they do not steadily increase with age for the older population even before accounting for PTD. Instead they show a bell curve peaking in the early 80 years of age and declining thereafter. The effect of proximity to death on prescription expenditures is less than the PTD effect reported in studies looking at total HCE and long term care (LTC) this may in part be due to the high uptake of hospital and long term care services at the end of life and the high volume of preventative medication in use by survivors.

The fact that decedents on average have a higher use and expenditure in the 12^{th} month and even as far out as the 24^{th} month before death suggests that increased medication use may be a sign of a health crisis and subsequent mortality. Previous studies have suggested a distance of up to 6 years for the PTD effect on total HCE (Seshamani and Gray, 2004b). While this study reports mean expenditure for decedents to be double that of survivors, regression models show a smaller increase between the groups for each of the 12 months before death. This result does not demonstrate a clear pattern of increasing expenditure with proximity to death but that expenditure for decedents is consistently higher with a peak in the last month prior to death. The data suggest that there are other factors driving the higher drug expenditures amongst the older population in addition to proximity to

death. More complex country specific issues such as the agreements and bargaining power of the public health system and patent expiry dates should be considered in addition to PTD.

In terms of differences in expenditures by ethnic minorities, it could be hypothesized that Māori and Pacific Islanders who are in the older age groups are the healthiest of their respective groups, based on evidence that suggests members of these ethnic groups are more likely to have poorer health and lower life expectancies (Blakely et al., 2005, Ministry of Health, 2011). An alternative hypothesis for these lower expenditures could be reduced up take of medications or impaired access by these ethnic groups (McNaughton et al., 2002, Scott et al., 2003).

6.8 Strengths and Limitations

This study focuses on a key expenditure component of total health care expenditures, examining the services that make up total health care expenditures is important to fully understand the effect of ageing (McGrail et al., 2000). Some of the studies discussed in this paper used potentially non-representative samples such as those taken from private health insurance or hospital datasets. The strength of this study lies in its use of population data which is automatically collected by the health care system every time a prescription is dispensed, therefore there is no recall bias or prestige bias involved and no sampling issues.

A limitation of the study is the possible confounding from the large numbers of older people who die in hospitals or long term care, with those living in the community at older age cohorts the potentially healthier of their age group. Estimates suggest that New Zealand has a higher proportion of its older population in LTC than most OECD countries, with estimates of up to 9.2% (Broad et al., 2013). Further evidence for this hypothesis is also present in the decline of medication use with age in the older groups. Based on previous hospital based studies (McGrail et al., 2000, Spillman and Lubitz, 2000, Bjørner and Arnberg, 2012) which included pharmaceuticals as part of total health care expenditure the inclusion of such medications would be expected to increase the expenditure gap between decedents and survivors.

According to population estimates the over 70 population was 371,950 for 2008 (Statistics New Zealand, 2011b), therefore the prescribing dataset used in this study is potentially missing 3.5% of the total population in this age group. This potential 3.5% would comprise of people over 70 who did not die or did not receive any prescription medicines in 2008/2009. In addition the dataset lacks information on potential confounders such as medical history for both decedent and survivor groups, e.g. diagnoses, severity of any illness, disability, smoking, alcohol etc. The study does not contain any information on the use of over the counter (OTC) medicines which may or may not have an impact on the expenditure of public prescribing. It's likely that the future burden of morbidity and patterns of medication use will be altered by new and improved preventative and curative treatments which may be developed or price reductions, patent expiries and the lifestyle changes of individuals. A full discussion of the strengths and limitations of the thesis is included in chapter 8.

6.9 Conclusion

New Zealand has a predominantly public health care system with access based on residency. Under this system medication is provided in the community subject to a co-payment. Since the 1990s New Zealand has implemented a number of expenditure control measures on pharmaceutical expenditures and as a result has seen more modest expenditure increases than most of the other OECD countries (OECD, 2011a). The older population are more likely to use medication and forecast predict a doubling of their numbers in the coming decades. Health inequalities exist across ethnic groups with Māori and Pacific peoples more likely to have poorer health outcomes coupled with shorter life expectancies than other ethnic groups in New Zealand (Blakely et al., 2005, Ministry of Health, 2011).

This study primarily investigated the relationship between expenditure on prescription medication, proximity to death and age, using a population of 349,174 individuals, 70 years of age or more, over a 12 month period. The analysis found that the additional "expenditure of dying" is on average twice that of a similar group of survivors. There is a notable increase in decedent prescribing during the last month of life; while all other months are consistently higher they do not demonstrate an increasing pattern towards death. Regression analysis suggests that while age

has a positive influence on the probability of expenditure, it has a negative effect on monthly expenditures in line with exploratory analysis which shows lower monthly expenditures for the oldest age groups. The results show a positive effect of PTD on prescription expenditure in line with some previous evidence. Compared to studies examining long-term care and acute care expenditures the magnitude of the effect of PTD is considerably lower. The results in this chapter are similar to those found using Irish data in chapter 5, the similarities and differences are discussed in chapter 7.

7 Discussion

This penultimate chapter briefly summarises the research undertaken, the main findings and the limitations of the data and analysis. The final chapter of the thesis presents the conclusions, implications for research, reflections on the research process and some possible future directions for further research.

7.1 The hypothesis

This thesis set out to test the hypothesis that proximity to death (PTD) is an important driver of prescribing expenditures and more important than ageing. The period used for the Irish study, 2006 – 2009, provides a unique experiment in Ireland when individuals aged 70 years or more were entitled to free health care and medications paid for by the state regardless of income, illness or socioeconomic status[26]. This is compared to a similar population from New Zealand who also had access to free medication. Given this eligibility it was possible to use dispensing data automatically collected at pharmacies for reimbursement purposes as a national cohort. A case control methodology was used to compare the expenditures of decedents (cases) and similar matched survivors (controls). The hypothesis was tested using a two part model, consisting of a Probit regression model to identify the probability of expenditure in any given month and a Generalised Linear Model (GLM) to regress the positive expenditures. New Zealand was used as a comparator country given the similarities in demographics and socioeconomic circumstances. As a nation it is much further down the path of aggressive expenditure control of state pharmaceutical expenditures than Ireland, which provides an interesting comparison.

[26] The data in this thesis covers the period 2006-2009, but free healthcare was available to all those aged 70 years or more from 2001 until 2009 when a means test was introduced.

7.2 Main findings

Chapters 1 and 2 of this thesis provides a review of the literature and methods used to analyse health care expenditure and in particular prescribing expenditures. The following conclusions were drawn:

- A large body of evidence suggests that proximity to death is a more important driver of total health care expenditure (HCE) than age.
- While consensus exists on a proximity to death effect for total health care expenditures, what is in contention is the magnitude of this effect.
- Studies have provided some evidence on a school of "Red Herrings", meaning that the proximity to death effect is evident in the various components of total health care expenditure and plays a differing role in each component e.g. in acute hospital studies age is a proxy for proximity to death and in long term care studies PTD is important but age also shows an independent effect.
- The literature review identifies a deficit of evidence on the effect of proximity to death on prescribing expenditures.
- There is no preferred methodology for modelling expenditure data for health care or prescribing.. Numerous methodological comparative studies exist which posit a careful analysis of data and an appreciation of the limitations of each method rather than any preferred method.

In chapters 4, 5, and 6 of this thesis the descriptive and econometric panel data analysis of dispensing data from two countries, New Zealand and Ireland, demonstrates that:

- Expenditure on decedents exceeds that for similar age and gender matched survivors even up to three years before death, rising from 1.3 times of a difference 3 years before death to double in the last year of life.

- The average expenditure of dying decreases with age, older decedents (age ≥90 years of age) expenditure almost half of their younger counterparts (aged 70-74 years in the last year of life.
- The additional expenditure of dying, that is the difference between decedents and matched survivors, declines with age but begins to increase again in the oldest old (age ≥90 years).
- Proximity to death is an upward driver of medication expenditure for the community based population aged 70 years or more, in Ireland and New Zealand.
- Age is not an important driver of prescribing expenditure once proximity to death and chronic conditions are taken into account, using prescribing as a proxy for each chronic condition.
- There is a considerable difference in the types and volume of medication dispensed to decedents and survivors. As decedents get closer to the end of life they increase their use of analgesics (N02), anti-nausea & vertigo agents (N07C and A04), antipsychotics (N05A), sedatives (N05C) (3.2 times), anti-epilepsy (N03) (4 times) and antidepressants (N06A) medications.

7.3 Ageing, proximity to death and prescribing expenditures

For decades researchers have been concerned about the increasing proportion of older people in society and its potential expenditure implications for healthcare. While a number of studies have added empirical evidence to the area a debate has emerged on the power of age to determine Health Care Expenditure (HCE). Expenditure on prescription medications is a substantial component of HCE, accounting for approximately 18.7% on average of total healthcare spending in OECD countries, 13% in Ireland and 12% in New Zealand (OECD, 2013). The year on year growth rates have been substantial with an average of 3.5% in the OECD for the decade to 2009, 8.7% in Ireland and 2.1% in New Zealand (OECD, 2011).

To date the studies that have examined health care expenditure and its drivers have largely over looked prescribing expenditures in favour of acute hospital or long term care. Of those that have included prescribing expenditures the vast majority have not analysed them separately. The fact that proximity to death is a driver of healthcare expenditure is not novel, and the literature discussing this was presented in chapter 2. What is novel is the evidence of this effect and its magnitude in prescribing expenditures. That is the major contribution of this thesis.

Grossman's model (1972b)(presented in section 2.2.1) may help explain some of the differences observed between decedents and survivors. His model suggests that age increases the depreciation rate of an individual's health stock, increasing the need for prescription medications. However while there is no financial expenditure for an individuals investment in medications provided by the state there may be a health expenditure in terms of side effects of medications. Also given the biological changes caused by ageing, which effect the pharmacokinetic and pharmacodynamic properties of medications, older individuals are more at risk of adverse drug events (ADE), and clinicians may be reluctant to prescribe medications to these individuals. Gender may also be an important factor as men and women vary in the prevalence of specific conditions at different ages, for example women typically experience cardiovascular disease at an older age than their male counterparts. Returning to Grossman's model (1972b), women may also be more risk averse and therefore invest more in health.

Some of the same issue debates that have arisen in the HCE literature can also apply to prescribing expenditure:

- Is age still important even after accounting for PTD?
- Is the magnitude of the effect minor compared to other drivers?
- Is proximity to death in fact a proxy for morbidity or disability?
- Does the expenditure of dying change with age?

- How will longevity affect proximity to death?

These questions are discussed in the following subsections.

7.3.1 Age

The literature set out in chapters 2 and 3 on the drivers of HCE presents mixed evidence on the importance of age. A number of studies suggest that proximity to death is a more important driver than age (O'Neill et al., 2000, Zweifel et al., 1999, Felder et al., 2000). Later studies addressed methodological issues in the earlier studies and still found a PTD effect for HCE (Seshamani and Gray, 2004b, Seshamani and Gray, 2004a). In contrast to these findings studies have reported that ageing is more important (Breyer and Felder, 2006, Westerhout, 2006, Karlsson and Klohn, 2014) and that PTD is minor in magnitude (Colombier and Weber, 2011, Westerhout, 2006).

7.3.2 The magnitude of the effect

A number of studies on long term care (LTC) have found that age remains an important driver of HCE (Werblow et al., 2007, Karlsson and Klohn, 2014). This provides evidence for the hypothesis presented by Werblow et al. (2007) that there is a 'school of red herrings', with the proximity to death effect evident across numerous components of HCE to varying degrees. By examining each component of HCE we will gain a better understanding of the combination of factors that drive total expenditures which should inform targeted policies to help control expenditures. The important aspects of health vary between components of health care, for example, acute hospital utilization and medication use is associated with disease whereas long term care use is more associated with disability. This thesis has found evidence from two countries of a strong statistically significant effect on prescribing expenditures of proximity to death, with average expenditure on decedents double that of survivors and an independent weak or negative effect of ageing. This magnitude is less than that reported in studies examining total HCE or LTC, reported in section 2.2.4 and might explain the difference of effect shown in

expenditure estimates in table 2.3, where there is a lower effect on prescribing expenditures than total HCE.

7.3.3 Is proximity to death a proxy?

De Meijer et al (2011) using an individual level Dutch dataset on LTC, found that once morbidity and disability were controlled for PTD becomes insignificant while age remains a driver of HCE. TILDA shows a prevalence of disability measured by Activities of Daily Living (ADL) or Instrumental Activities of Daily Living (IADL) impairment of 23% (95% CI 21.1-25%). A recent study of disability rates in the older Irish population reported a declining prevalence over the period 2002-2006 (Wren, 2011). In this thesis disability was not controlled for, due to its absence from the prescribing datasets. However, it is hard to argue that disability has a major impact on medication expenditures, it would seem more intuitive that morbidity is a more important factor and this has been examined though the inclusion of variables derived from pharmacy claims data, as proxies for 20 chronic conditions, with a chronic conditions count.

7.3.4 Does the expenditure of dying change with age?

The pattern of decreasing expenditure ratio of decedents to that of survivors shown in chapters 5 and 7 is similar to other HCE studies (Yang et al., 2003, McGrail et al., 2000). This suggests that, in terms of medication, the expenditure of dying relative to surviving actually decreases with age. Two other explanatory factors worth considering: firstly the numbers of individuals who die in hospitals or long term care facilities in these age groups and are not captured in the datasets employed in the thesis; secondly the fact that those who do remain living in the community are potentially healthier. Throughout the 20th century both Ireland and New Zealand witnessed a shift in place of death from predominantly home based to hospital or institutional death. In recent years only a quarter of all deaths occur at home in Ireland (McKeown et al., 2010, Joint Committee on

Health and Children, 2014), with only 20% in New Zealand (Statistics New Zealand, 2012).

This decline in expenditure of dying may also be due to a difference in the cause of death in the oldest old population. The top three causes of death are similar across the age groups, however, there is a difference in the order. Cardiovascular and respiratory illnesses are dominant in the oldest age groups (≥85 years), while cancer is the most prevalent in the younger groups (70-74 years) (CSO, 2013a, Health, 2012).

7.3.5 How will longevity effect proximity to death?

Life expectancies are increasing in general and evidence suggests that these additional years are being lived in good health (Crimmins et al., 1997, Waidmann and Liu, 2000, Gheorghe et al., 2014). In order to use the results in this thesis to more accurately model future data consideration must be given to increases and convergences in life expectancies. The cross-sectional age and spending relationship will not remain constant over time if life expectancies continue to increase. If current trends in life expectancy continue the average 80 year old in 2029 will be further from death than an 80 year old in 2009. As proximity to death results in increased prescribing expenditures compared to similar survivors in all age groups it is important to account for the shift in mortality rates in each age group which increasing life expectancies will bring. Separating the survivors and decedents allows a more realistic estimation of future expenditure, but it potentially underestimates the effect of increasing longevity because the implicit assumption is one of diminishing end of life expenditures when people live longer. However, if individuals are living longer healthier lives as a result of using more (expensive) medicines, then the expenditure of such advances may counterbalance the effect of less people in each age group at the end of life. The constant age expenditure relationship is a common problem of projection models.

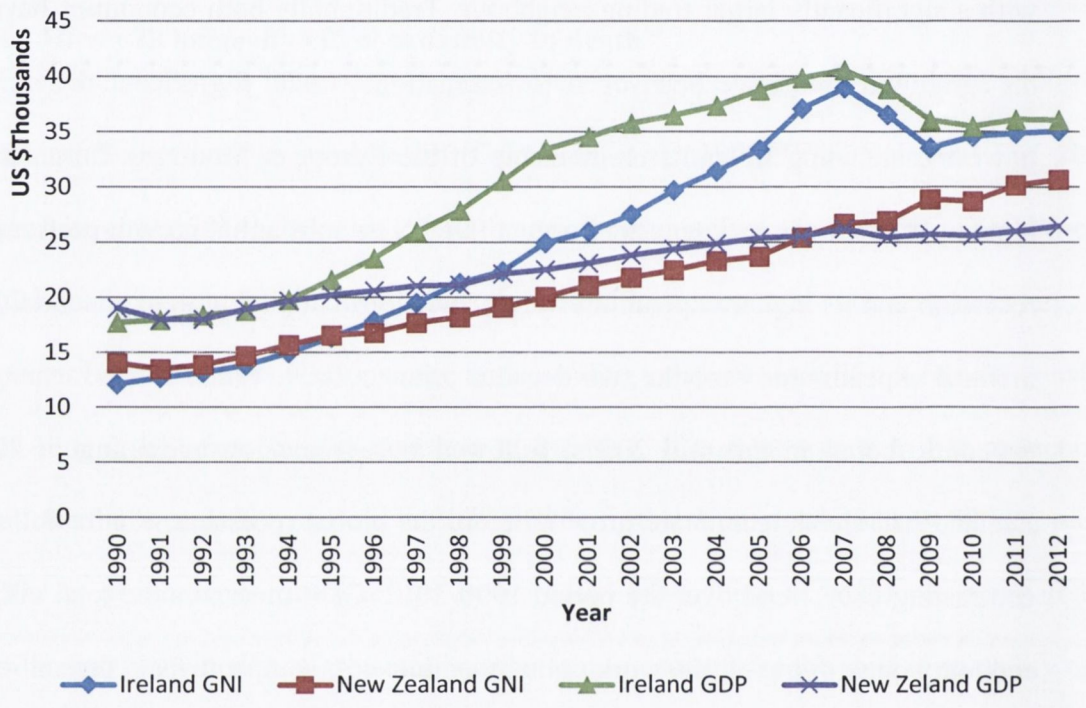
The effect of increasing longevity depends on which theory of ageing, outlined in chapter 2, accurately reflects the population. There is mixed evidence on whether longevity will continue to increase adding healthy years (Crimmins et al., 1997, Waidmann and Liu, 2000, Gheorghe et al., 2014) or in fact decline due to a rise in unhealthy lifestyles (Ezzati et al., 2008).

7.4 Comparing Ireland and New Zealand

New Zealand and Ireland are both small island nations of a similar demographic profile with a significantly larger trading neighbour. Traditionally both economies have focused on agriculture and have been open to international trade. Significant differences exist however, including Ireland's membership of the European Monetary Union (EMU), its higher per capita Gross Domestic Product (GDP), its substantial growth performance pre-recession and its higher expenditures on medications coupled with exponential growth in medical expenditures over the two decades prior to 2009. While Ireland experienced an economic boom in the mid 2000s, followed by a recession beginning in 2008, New Zealand had steady economic growth before the global recession. Figure 8.1 shows the contrasting GDP trend over the period 1990-2012. GDP measures the total output of the economy quantifying all the work done by employees, companies and the self-employed. Gross National Income (GNI) measures the income generated by Irish residents and includes income generated in other jurisdictions by Irish residents. Economists have argued that Gross National Income (GNI) is a more appropriate measure of income for the population(FitzGerald, 2013). The premise being that GDP is over stated due to the large numbers of foreign companies reporting profit in Ireland. Figure 7.1 shows that GDP and GNI were more closely in line during the period of this study although still overstated it is similar to New Zealand in relative terms. Income inequality in both countries is similar with estimates of the highest 20% exceeding income of the lowest 20% by between 6 and 7 times (Wilkinson and Pickett 2009). An additional measure of

income inequality, the Gini coefficient[27], is estimated to be 0.303 for Ireland and 0.330 for New Zealand in 2008 changing to 0.302 and 0.323 respectively in 2011 (OECD, 2014b). Public expenditures account for close to 80% of all health care expenditures in both countries (OECD, 2013).

Figure 7.1 Gross Domestic Product (GDP) per capita and Gross National Income (GNI) per capita for Ireland and New Zealand 1990-2012



Source: OECD database (OECD, 2014b)

Having established their broader demographic and economic similarities the question of value to this thesis is how similar are they in terms of prescribing expenditures. The health systems of both countries and methods of payments for medications are outlined in chapters 4 and 6. A key difference in terms of overall expenditures on medications is the earlier implementation of expenditure controls policies in New Zealand which has resulted in lower overall expenditures and lower year on year increases in expenditures.

[27] The Gini Coefficient is a measure of income dispersion on a scale of 0 being complete equality and 1 complete inequality GINI, C. 1997. Concentration and dependency ratios (English translation). *Rivista di Politica Economica*, 769-789..

These policies include appointing one agency to manage the formulary, economic evaluations of new medications, the use of generics and single supplier contracts.

The findings in this thesis on proximity to death, age and expenditure on prescription medications illustrate the importance of proximity to death over age when considering these expenditures. Data from both countries report decedents consistently spending more than similar survivors and up to two times as much on average. Interestingly there is a difference in the effect of age on expenditures with the Irish data reporting a neutral effect and the New Zealand data reporting a slight decline. The Irish data used do not include data on the high tech drugs scheme (HTD) outlined in chapter 4. These medications are primarily high expenditure, initiated in hospital, and used for specific purposes such as anti-retro viral treatment, anti-rejection post transplant or in conjunction with hospital led chemotherapy. Their omission may account for the difference in the age effect. Also as suggested in chapter 6 this may be due to the high numbers of older New Zealanders who are resident in nursing homes.

Any reduction in community medication expenditure gained through lifestyle changes, price reductions or other factors may be counter balanced by the increase care of individuals in the community and new medications. Both Ireland and New Zealand have followed an explicit policy of reducing resources in acute care and encouraging more care in the community. In the case of Ireland this policy is informed by a detailed report commissioned by the HSE on the potential for reducing acute care (PA Consulting Group, 2007) and has continued to the present day. Rising community expenditures reported in chapter 4 (Figure 4.1) may in fact be attributable, in part, to an increased number of individuals living in the community.

Ireland has only recently introduced demand-side co-payments as a means to reduce dispensing and shift some of the expenditure to patients (see section 4.5). This is a common feature of both public and private health insurance schemes in other countries

including New Zealand (Costa-i-Font and Gemmill-Toyama, 2010). Co-payments of this manner have been shown to reduce the overall expenditure on prescription medications (Gemmill et al., 2008, Gibson et al., 2005) and inappropriate use of medications (Costa-i-Font and Gemmill-Toyama, 2010). There is evidence that such measures also reduce adherence, particularly to medications which have no immediate visible effect (Atella et al., 2006, Sinnott et al., 2013, Kiil and Houlberg, 2014) and vulnerable groups such as those on low incomes and with poor health are more likely to reduce their use than the general population (Kiil and Houlberg, 2014). This potentially leads to poorer health outcomes and higher expenditures for the health care system in hospitalisations and other services.

The gaps between the countries in terms of total medication expenditure have narrowed since the data analysed in this thesis was collected. Ireland, in particular, has experienced a period of intense economic reform since 2009. As a consequence the market for prescription medications has evolved and changed considerably. A number of measures were taken to reduce expenditure on prescription medications which, combined with other market forces such as patent expiries of high volume medications, have resulted in a recent stagnation in expenditure growth (See section 4.7). The introduction of drug group reference pricing and generic substitution (2013b) brings Ireland closer to New Zealand's policies.

The data used on Ireland included a regional variable to try and account for regional variations in health service use across the country as described in section 5.2.1. Similarly other research has identified low health service use by ethnic groups in New Zealand as referred to in section 6.4.

The findings from the New Zealand Study provide a validation of the results obtained using Irish data. Suggesting that PTD is an important factor in determining prescription expenditures and more important than ageing.

7.5 Strengths

This thesis addresses a gap in the evidence on the relationship between age, proximity to death and prescribing expenditures, identified in the literature review undertaken in chapter 2. Some of the studies undertaken on total HCE discussed in the review used potentially non-representative samples such as those taken from private health insurance or hospital datasets. The analysis conducted in this thesis used individual patient-level data from two countries. The main strength of this thesis lies in its use of national population-based cohorts. The dispensing data used from both countries are based on administrative data automatically collected at the point of dispensing. This method of data collection avoids any recall or interview bias on behalf of the patient and avoids sampling bias in the study design. In addition the linking of these prescribing datasets to death certification data allows for the accurate identification of end of life expenditures.

7.6 Limitations

A major limitation is the absence of linked morbidity and other health care expenditure data. Despite legislating for the introduction of unique health identifiers for individuals in Ireland (Governement of Ireland, 2014) the absence of these identifiers in use is a major impediment to health research and makes it difficult to link prescribing data to diagnostic, outcome or disability data. A chronic conditions index based on medications was used to overcome the limitation on absence of morbidity data and, for Irish study, the general characteristics of the population based on data from a large cross-sectional study (TILDA) were used. The availability of cause of death data would facilitate a more robust analysis than using a chronic disease score as there is the possibility of confounding between mortality and chronic conditions. The availability of a unique health identifier in New Zealand made the data easier to link and provided the possibility to link to hospital and GP data in the future. Within the time frame of this thesis it was not feasible to link this additional data.

The findings could be further enhanced by the inclusion of cause of death data, this would allow the exploration of conditions which are associated with higher expenditues. At present the mortality database used does not include this information even though death certificates have a primary cause of death and up to five secondary causes of death. The inclusion of secondary causes would be important given the high level of multi-morbidity in the older population the primary cause of death may only be a part of the individual's illness.

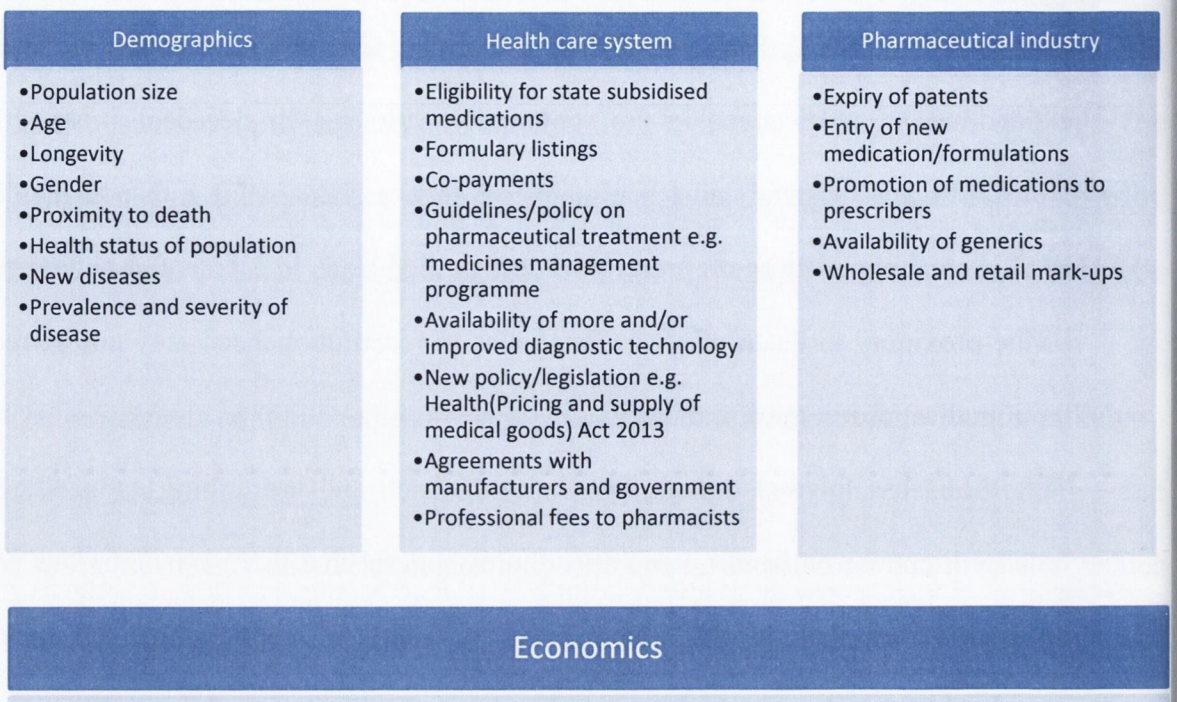
The projections of future expenditure are based on observed patterns which are likely to change due to alterations in a number of factors. New and improved preventative and curative treatments and technologies may increase medication use but may also reduce future expenditures. For example the use of preventative medication like statins to lower cholesterol may avoid the development of cardiovascular disease and the increased medication and healthcare service use associated with such an illness. New pricing policies such as Drug Group Reference Pricing, introduced in late 2013 under the Health (Pricing and Supply of Medical Goods) Act (2013b) may have a substantial effect on reducing public expenditure on medications. The number and type of medications coming off patent protection in any given year is likely to have a downward effect on expenditures. At the individual level, lifestyle changes such as increased exercise and improved social connectedness could impact health, medication use and ultimately expenditures. The main purpose of including the projections was to demonstrate the effect of not accounting for proximity to death rather than providing estimates of future use.

While the dispensing datasets used contain all the data for individuals who were dispensed a medication at least once in the time period it does not include those individuals who used no medications. This limitation introduces a selection bias into the study. Given the numbers recorded in each study and the estimated population sizes at the time there is only a small number of individuals who are not included.

In both countries there is possible confounding from the large numbers of older people who die in hospitals or long term care, with those living in the community at older age cohorts the potentially healthier of their age group. Similarly a reduction in the use and expenditure of medications in the community with age for decedents may reflect an increased use of hospital and other healthcare services later in life rather than a decrease in the actual expenditure on prescription drugs This leads to a potential underestimation of the proximity to death effect as those who are institutionalised may not be receiving their medications in the community.

This thesis has focused on age, proximity to death and prescribing expenditures. The broader literature on health care expenditures suggest that there are numerous potential drivers of prescribing expenditure beyond proximity to death that are not specifically examined in this thesis, which may influence medication use and expenditure, these are summarised in Figure 7.2. What is still under investigation is how important each factor may be. The evidence presented in this thesis from two countries has demonstrated the effect of proximity to death on prescribing expenditures and the importance of including proximity to death in future projections. The final chapter draws conclusion based on the thesis, summarises the implications for policy and suggests some possible directions for future research to build on the contribution of the thesis.

Figure 7.2 Factors which influence medication use and expenditure



Since the data used in this thesis was collected Ireland in particular has experienced a period of intense economic turmoil since 2009 as a result of the Great Recession and the European Union – International Monetary Fund (EU-IMF) financial support programme which loaned the country €85 billion. The recessionary period occurred largely since the collection of data for this thesis. The Irish economy entered recession in 2008, its worst since the second world war (Barrett et al., 2008). Interest rates have decreased to lows of 1%, this may disproportionately effect the older population who may be reliant on income from savings (Nolan et al., 2014). Jenkins et al.(2013) examined the effect of the early years of the Great Recession on 21 OECD countries, as well as six detailed country studies (including Ireland) which provided evidence on the decreases in income and wealth revealing that the lowest quintile was the hardest hit in terms of income and wealth. They also found evidence that elderly populations and those on social welfare were protected from decreasing income. Callan et al (2013) demonstrated that the taxation and social welfare regime in Ireland effectively redistributed income, reducing income inequality during the recession. These studies suggest that the initial impact of the recession on those aged 70 or more

is minor. However the impact of health budget reductions experienced since the period studied in this thesis may be substantial and is a limitation of the work. While direct incomes for older people remained largely unaffected, with the state pension remaining at the same rate since 2009, a number of taxation measures and social benefit cuts have been introduced[28]. The age entitlement to free healthcare for those aged 70 or more was removed in 2009 albeit with a high income means test of €700 per individual per week[29]. A co-payment was introduced in 2010 on prescription items of €0.50, which has subsequently risen to €2.50 in 2013. Hospital charges for non-medical card holder have risen several times and the threshold for medication reimbursement has risen to €144 in 2014. We have yet to see the medium to long term impact of the recession on the health status of the citizens.

[28] For example the reduction of the tax threshold for pension lump sums, the reduction of the household benefits package, abolishment of the bereavement grant.

[29] The means test has been reduced to €500 a week for a single person and €900 for a couple from the 1st January 2014. This is substantially higher than the means test applied to younger age groups which ranges from €164 to €201.50 per week.

8 Conclusion

This final chapter of the thesis presents the conclusions, reflections on the research process, implications for policy and some possible future directions for further research.

8.1 Conclusions

A central motivation of the thesis has been to improve the accuracy of pharmaceutical expenditure projections by investigate the impact of ageing and proximity to death on prescription expenditures using available national datasets. The resulting information is of use to policy makers who are attempting to control budgets given a forecasted expansion in the older aged population.

This thesis has contributed to the evidence in support of the proximity to death hypothesis and provides further information on the magnitude of this effect for prescribing expenditures in two distinct countries. It is the first study of age, proximity to death and prescription expenditures in Ireland and New Zealand.

Most developed countries are facing large increase in the number of older people and the proportion of the overall population they represent. As we move towards a model of more community based care in the developed world prescription medication will become even more prevalent. Proximity to death matters because it is often much more expenditurely to treat end-of-life patients, e.g. cancer or end-stage renal disease patients, than less patients with milder illnesses, e.g. seasonal influenza patients. Yet end-of-life patients are not necessarily old patients, and less ill patients are not always young patients either. In other words, while there is an association, proximity to death is not a deterministic function of age.

Over the two decades to 2009 prescribing expenditure in Ireland was rising markedly each year, data presented in chapter 4 shows a subsequent decline to 2013 despite the increase in the eligible population. This is primarily in response to negotiated price decreases with manufacturers and the patent expiry of a number of high volume and

relatively high expenditure medications. While the introduction of reference pricing limits the expenditure of off patent medications there is nothing to prevent the expansion of expenditure again with the introduction of new medications. This means it remains imperative to understand what drives prescribing expenditure in order to develop appropriate policies. A key concept of economics is that of scarcity, which leads to the study of the efficient allocation of finite resources. Based on this theory the opportunity expenditure of higher expenditures on medications will be felt in other areas of health or public spending. Therefore controlling of medication expenditures has implications beyond medication use. Even outside of recession a return to high expenditure growth would not be an efficient use of the limited health budget.

The expansion of older age groups currently underway in most developed nations will affect expenditures on medication, but projection models which multiply current expenditures by population projections overestimate the contribution of age. Separating the survivors and decedents allows a more realistic estimation of future expenditure. The analysis of medication use in sections 5.3.2. and 6.6.2 show that there is a shift to certain medication use at the end of life and not just an increase in the use of medications. Polices aimed at controlling the expenditure of this medications would help to control the expenditure of dying. This thesis suggests that rather than focusing on ageing, policies aimed at more cost-effective prescribing especially at the end of life will yield greater expenditure savings. However, even accounting for PTD there will be a rise in the demand for medications in an ageing population, driven primarily by other factors (see Figure 8.2) such as new products and the increasing prevalence of chronic conditions.

This thesis doesn't attempt to definitively forecast future prescribing expenditures but rather demonstrate the importance of proximity to death in such projections holding other factors constant.

Irish policy makers have more recently begun to take action on achieving greater expenditure efficiency from public expenditure on medication. A number of measures have been implemented including the use of cost effectiveness analysis for new medications, a preferred medications programme, generic substitution at the pharmacy level and drug group reference pricing. These measures have already had some impact on prescription expenditures however it remains to be seen if Ireland can reduce its expenditures to be more in line with New Zealand who are providing a similar service at a lower level of expenditure.

This thesis highlights the benefits of linking large data sets to test research hypothesis. However, conducting research on secondary data has unique challenges. The data are collected for an entirely different purpose and it is often difficult to gain access to these data. In the case of this thesis while gaining access to some of the Irish data took a long time it was rewarded in having a population cohort. The limitations of the data and the analysis are discussed in more detail chapter 8.

8.2 Implications for policy

- Not accounting for proximity to death in models of prescribing expenditure will lead to an over estimate of expenditure all other things being equal.
- A more comprehensive model of prescribing expenditures is required, that includes proximity to death and other factors that influence expenditure, to make more reliable future projections and to compare possible future strategies.
- Policies aimed at more cost effective prescribing, especially at the end of life may reduce expenditures from current levels.

8.3 Future directions

There is vast scope for further research on the supply side, with policy changes in pricing structures and the introduction of generic substitution at the pharmacy level(2013b).

Examining end of life prescribing by illness and place of care (Hospice, hospital, long-term care, home) could inform policies on end of life care.

On the demand side expanding the cohort to younger age groups would facilitate the examination of the proximity to death effect across different age cohorts and between cohorts. The introduction of co-payments for each dispensed item would also be an interesting demand side factor to examine as it may have affected decedents and survivors differently.

This thesis examines Irish data on the population aged 70 years or more for a unique period when they were provided with free health care and medications paid for by the state regardless of income, illness or socioeconomic status and compares it to similar data from New Zealand. The ultimate policy question regarding any government's decision to provide free health care for those over 70 years is whether or not this provision improved the health status of the eligible population whilst reducing government spending in the long term. Given the global driver towards universal health care (Boerma et al., 2014) and in particular the Irish government's plans to introduce universal healthcare (or some variant of it)(Department of Health (IRE), 2013b) following this cohort would be an interesting area of research and would help address this important policy question.

In 2010 women outlived men by some 3.7 years in New Zealand (Statistics New Zealand, 2013) and 4.8 years in Ireland (Central Statistics Office, 2013), this gap would appear to be closing. Converging life expectancies between men and woman would mean couples will be potentially living together for longer time periods which should have a positive effect on health outcomes and ultimately a negative effect on health care expenditures. The data used herein does not contain information on co-habitation status however future linking of the prescribing data to the TILDA biennial survey would provide this information as well as some diagnostic and socioeconomic variables.

The data used in this thesis was individual (micro) level prescribing data, it would be interesting to explore if the proximity to death hypothesis is also evident in macro level data looking at the total population, prescribing expenditures and a measure of mortality. The question is to what extend will an increase in years lived extend morbidity at the end of life? Will life expectancies continue to increase, stay the same or will they in fact begin to decline again? Will the additional years be healthy? Evidence from the USA suggests that within countries there may in fact be a decline in longevity for poorer sectors of society. When looking within American states, at county level mortality rates they reported a stagnation or increase in mortality rates in poorer counties which they attributed to a rise in cardiovascular disease, lung cancer, chronic lung disease, diabetes, HIV/AIDS and homicide (Ezzati et al., 2008). Healthy Ireland, the national framework for health and wellbeing, identifies major risks to health from a continuation of the increases in adverse population trends such as obesity, diabetes and physical inactivity (Department of Health (IRE), 2013a). These risks have the potential to reverse the significant gains in life years discussed in chapter 2 and reported in chapter 4, as well as place an increased burden on the health system. While evidence suggests that life years gained are healthy ones (Crimmins et al., 1997, Waidmann and Liu, 2000, Gheorghe et al., 2014) a more definitive answer to these questions will be found in longitudinally following a cohort.

This thesis has addressed a gap in the literature on prescribing expenditures, ageing and proximity to death. It has found evidence in support of the hypothesis that ageing is a proxy for proximity to death for prescribing expenditures in two countries using micro-level data for community dwelling individuals aged 70 years or more. When projecting future expenditures it has shown the potential impact of failing to account for proximity to death. Counting the years left would seem to be more important than the years lived.

"The others . . . tallied their age not in relation to

the number of years they had lived, but in relation

to the time left to them before they died."

Gabriel Garcia Marquez (1989), Love in the Time of Cholera

APPENDIX

Appendix A – Literature Search Strategies and Results

A1 Academic Databases

A substantial amount of literature had been collected via informal searches and bibliography searches of key papers prior to commencement of the formal literature searches outlined below. For this reason there are often a large number of "previously recorded" documents from the formal searches.

Table A1 Keyword searches

Search Number	Keywords/MESH	Pubmed Results	Econlit Results	Embase Results
#1	Proximity to death OR time to death	2,386	228	1,133
#2	Expenditures OR expenditure OR expenses OR Economic	340,981	319,745	444,341
#3	dying OR death OR decedent	551,398	4,117	246,153
#4	Prescription drugs OR Pharmaceuticals OR Medications	115,867	3,211	116,998
#5	Prediction OR forecast OR projection	223,754	29,918	150,861
#6	Ageing OR aging OR aged OR older OR elderly (filter 65yrs+ for Pubmed)	2,155,043	12,203	1,453,356

A1.1 Pubmed

Pubmed provides online access to the US National Library of Medicine's MEDLINE bibliographic database which contains over 19 million references to journal articles in life sciences. Access was gained via TCD library.

Target: Studies undertaken on:

1. proximity to death and healthcare expenditure
2. proximity to death and prescribing expenditure
3. proximity to death and prescribing expenditure and ageing

Aim: To identify possible relevant literature in the area published in academic journals.

Inclusion criteria: Studies or meta-analysis relating to HCE and PTD and/or prescribing. Studies or meta-analysis relating to ageing expenditures, or expenditures at the end of life.

Exclusion criteria: Studies relating to animals, economic evaluations of specific clinical procedures/treatments, no English translation available.

Last updated 19th February 2013

No limiting factors were used in searches, except #6 restricted to 65 or more years of age.

Table A2 Literature Search Results for Pubmed

	Keywords	Searches	Results	Relevant Papers	Previously recorded	Recorded papers
#7	Proximity to death OR time to death AND Expenditures OR expenditure OR expenses OR Economic	#1 AND #2	37	23	16	7
#8	Proximity to death OR time to death AND Prescription drugs OR Pharmaceuticals	#1 AND #4	23	0	0	0
#9	Proximity to death OR time to death AND Ageing OR aging OR aged OR older OR elderly	#1 AND #6	728	11	0	11
#10	Expenditures OR expenditure OR expenses OR Economic AND Prediction OR forecast OR	#2 AND #5	1,328	80	15	65

	projection					
#11	Expenditures OR expenditure OR expenses OR Economic AND Prescription drugs OR Pharmaceuticals OR Medications	#2 AND #4	2,076	36	2	34
		Totals from Pubmed:	**4,192**	**150**	**33**	**117**

A1.2 EconLit

Last updated 20th February 2013

Search abstract or title.

Target- Studies undertaken on:

1. proximity to death and healthcare expenditure
2. proximity to death and prescribing expenditure
3. proximity to death and prescribing expenditure and ageing

Aim: To identify possible relevant general literature in the area.

Inclusion criteria: Studies or meta-analysis relating to HCE and PTD and/or prescribing. Studies or meta-analysis relating to ageing expenditures, or expenditures at the end of life, studies using expenditureing methodologies for end of life or econometrics for modelling expenditure data.

Exclusion criteria: Studies relating to animals, economic evaluations of specific clinical procedures/treatments, no English translation available.

Table A3 Literature Search Results for Econlit

	Keywords	Searches	Results	Relevant Papers	Previously recorded	Recorded papers
#12	Proximity to death OR time to death AND Expenditures OR expenditure OR expenses OR Economic	#1 AND #2	91	29	11	18

	Keywords	Searches	Results	Relevant Papers	Previously recorded	Recorded papers
#13	Expenditures OR expenditure OR expenses OR Economic AND dying OR death OR decedent	#2 AND #3	1,410	46	35	11
#14	Proximity to death OR time to death AND Prescription drugs OR Pharmaceuticals	#1 AND #4	4	4	2	2
#15	Proximity to death OR time to death AND Ageing OR aging OR aged OR older OR elderly	#1 AND #6	42	29	24	5
#16	Expenditures OR expenditure OR expenses OR Economic AND Prescription drugs OR Pharmaceuticals OR Medications	#2 AND #4	1,247	49	14	35
#17	Expenditures OR expenditure OR expenses OR Economic AND Prescription drugs OR Pharmaceuticals OR Medications AND Prediction OR forecast OR projection	#2 AND #4 AND #5	44	4	4	0
		Totals from EconLit:	**2,838**	**161**	**90**	**71**

Proximity to death OR time to death AND Expenditures OR expenditure OR expenses OR Economic AND dying OR death OR decedent AND Prescription drugs OR Pharmaceuticals OR Medications AND Prediction OR forecast OR projection AND Ageing OR aging OR aged OR older OR elderly

A1.3 EMBASE

Last updated 20th February 2013

Search abstract or title.

Target- Studies undertaken on:

1. proximity to death and healthcare expenditure
2. proximity to death and prescribing expenditure
3. proximity to death and prescribing expenditure and ageing

Aim: To identify possible relevant general literature in the area.

Inclusion criteria: Studies or meta-analysis relating to HCE and PTD and/or prescribing. Studies or meta-analysis relating to ageing expenditures, or expenditures at the end of life, studies using expenditureing methodologies for end of life or econometrics for modelling expenditure data.

Exclusion criteria: Studies relating to animals, economic evaluations of specific clinical procedures/treatments, no English translation available.

Table A4 Literature Search Results for Embase

	Keywords	Searches	Results	Relevant Papers	Previously recorded	Recorded papers
#18	Proximity to death OR time to death AND Expenditures OR expenditure OR expenses OR Economic AND dying OR death OR decedent AND Prescription drugs OR Pharmaceuticals OR Medications AND Prediction OR forecast OR projection AND Ageing OR aging OR aged OR older OR elderly	#1 AND #2 AND #3 AND #4 AND #5 AND #6	1	1	1	0

	Keywords	Searches	Results	Relevant Papers	Previously recorded	Recorded papers
#19	Proximity to death OR time to death AND Expenditures OR expenditure OR expenses OR Economic	#1 AND #2	95	30	20	10
#20	Proximity to death OR time to death AND Prescription drugs OR Pharmaceuticals	#1 AND #4	45	3	2	1
#21	Proximity to death OR time to death AND Ageing OR aging OR aged OR older OR elderly	#1 AND #6	562	30	28	2
#22	Expenditures OR expenditure OR expenses OR Economic AND Prescription drugs OR Pharmaceuticals OR Medications AND Prediction OR forecast OR projection	#2 AND #4 AND #5	379	10	3	7
		Totals from EMBASE:	**1,082**	**74**	**54**	**20**

A2 Grey Literature

The Fourth International Conference on Grey Literature (GL '99) in Washington, DC, in October 1999 defined grey literature as follows: "That which is produced on all levels of government, academics, business and industry in print and electronic formats, but which is not controlled by commercial publishers." While it is easy to access traditional

academic publications via various databases grey literature is more difficult to collectively search. Three sources were searched to try and identify sources of grey literature relevant to this thesis:

Scirus: an online database of grey literature and traditional publications

OpenSIGLE: A European repository and bibliographic database of multidisciplinary grey literature.

These database searches were supplemented with searches of the publications listings on the following websites:

Table A5 Websites of Grey Literature Sources

Agency	Country	Website
National Bureau of Economic Research	USA	www.nber.org
Economic and Social Research Institute	Ireland	www.esri.ie
Ministry of Health (NZ)	New Zealand	www.health.govt.nz
Motu Economic and Public Policy Research	New Zealand	www.motu.org.nz
National Institute of Demographic and Economic Analysis	New Zealand	www.waikato.ac.nz
Department of Health (IRE)	Ireland	www.dohc.ie
World Health Organisation (WHO)	Global	www.who.org
Organisation for Economic Co-operation and Development (OECD)	Global	www.OECD.org

Table A6 Studies looking at the determinants of healthcare expenditure (HCE)

Study Authors	Time period & location	Healthcare expenditure (HCE)	Model for HCE	Relevant Findings
Newhouse (1977)	1970 13 OECD countries (excl. IRE & NZ)	HCE per capita	Linear, logarithmic, cross – sectional income	Healthcare is a luxury.
Leu (1986)	1974 19 OECD countries	HCE per capita	Linear, Logarithmic, cross – sectional	Healthcare is a luxury.
Culyer (1982)	1980 20 OECD countries (Incl. IRE & NZ?)	HCE per capita	Linear, Logarithmic, cross – sectional	Healthcare is a luxury.
Gerdtham & Jonssön (1985)	1984 22 OECD (Incl. IRE & NZ?)	HCE per capita	Logarithmic, cross sectional	Healthcare is a luxury
Parkin, McGuire and Yule (1987)	1980 OECD countries	HCE per capita	Logarithmic, cross sectional	Healthcare is a luxury.

Study Authors	Time period & location	Healthcare expenditure (HCE)	Model for HCE	Relevant Findings
Gerdtham et al (1988)	1987 19 OECD countries (Incl. IRE & NZ)	HCE per capita	Logarithmic, Cross – sectional	Healthcare is a luxury.
Hitiris & Posnett (1992)	1960 -1987 OECD (Incl. IRE)	HCE per capita	Log-linear, Panel data.	Healthcare is a luxury.
Hitiris (1997)	1960 -1991 EU (Incl. IRE)	HCE per capita	Logarithmic, panel data.	Healthcare is a luxury. Methodology later critiqued by Roberts(2000) and found to be erroneous.
Barros (1998)	1960-1990 24 OECD countries (Incl. IRE & NZ)	Increase per capita of HCE	Linear time-series, Independent variables: health system type, decades, state funding, pop over 65, primary care gatekeeping, mean growth of GDP per capita.	Income elasticity varies between 0.62 and 0.92, suggesting that health care is not a luxury. Coefficients on population over 65 show the ageing does not increase HCE.

Study Authors	Time period & location	Healthcare expenditure (HCE)	Model for HCE	Relevant Findings
Di Matteo and Di Matteo (1998)	1965-1991 Canada provinces (Quebec, Newfoundland)	HCE per capita	Pooled time series cross sectional data. Independent variables: per capita GDP, population aged 65 or more, transfer funds from federal government.	Significant positive effects of Income, Population over 65, and federal transfer funds on HCE. Health care not a luxury income elasticity 0.7.
Roberts (2000)	1960-1990 10 EU countries (Incl. IRE)	HCE per capita & growth	Critic of methods employed by Hititis (1997)	Both HCE and GDP series found to be non-stationary and no evidence of cointegration. Neither fixed effects model or a pooled OLS are appropriate.
Gerdtham and Löthgren (2000)	1960-1997 21 OECD countries (Incl. IRE & NZ)	HCE per capita	Log linear, panel data.	Both HCE and GDP series found to be non-stationary and cointegrated.

Study Authors	Time period & location	Healthcare expenditure (HCE)	Model for HCE	Relevant Findings
Karatzas (2000)	1962-1989 USA	HCE per capita	Log- log, time series. Independent variables: Health care price index, income distribution ratio, nr of beds per capita, nr of physicians per capita, nr of cities with a population over 100,000, percentage over 65 years of age, GDP per capita, real insurance premiums per capita, ratio of specialists to GPs, nr of nurses per capita	No evidence to support the ageing hypothesis for HCE. Specific analysis of pharmaceutical expenditure reports overall expenditure and private expenditure to be price elastic but private expenditures are price inelastic.
Salas and Raftery (2001)			Re-examining work of Zweifel et al (1999)	PTD presents problems of exogeneity in the estimations
Okunade, Karakus and Okeke (2004)	1960-1997 25 OECD countries	HCE per capita	Logarithmic maximum likelihood	Age is a main driver of HCE along with economic and institutional factors.
Sen (2005)	1990-1998 15 OECD countries	HCE per capita	Two-way fixed effects model, confirmed similar results using WLS, GLS and IV models.	Income elasticites of between 0.21 and 0.51 making healthcare a necessity.

Study Authors	Time period & location	Healthcare expenditure (HCE)	Model for HCE	Relevant Findings
Mosca (2007)	1990-2000 20 OECD Countries (Incl. IRE & NZ)	Per capita HCE	Log- log model, time series. Independent variables: GDP, nr of physicians per 1,000 inhabitants, nr of acute beds per 1,000 inhabitants, percentage of population aged over 19 and percentage aged over 80, unemployment rate, dummy variables for categories of health system.	All variables are statistically significant and all but population over 19 have a positive effect on HCE. Healthcare is found to be a normal good. Decentralised health care systems spend more.
Colombier and Weber (2011)	2004 Switzerland Private Health Insurer	Per capita HCE	Projected HCE for HC and LTC base on 1 year of observed microdata.	Age is still the most important age-related expenditure-driver. Other important drivers are non-demographics like medical progress and morbidity which are more important than mortality as a factor of HCE.
Farag et al. (2012)	1995-2006 173 countries WHO-NHA	Per capita HCE	Time series, log-log. two-way fixed effects model with AR (1) correction. Independent variables: Per capita GDP,	Healthcare is a necessity. HCE is least responsive to changes in low income countries.

Study Authors	Time period & location	Healthcare expenditure (HCE)	Model for HCE	Relevant Findings
Wouterse et al. (2013)	1995-2007 Holland Longitudinal Ageing study Amsterdam(LASA) Dutch Municipal register (GBA)	LTC & Hospital expenditures	Latent Markov model, GLM. Independent variables: gender, age, age^2, education, year.	Combined health information with expenditures. Compared expenditures for 2 groups: those with good current health and low current expenditures and those with poor current health and high current expenditures. For first group expenditures are postponed till later.

A3 General Literature Review on prescribing databases

In order to validate the findings from the study presented in chapter 5 a search was undertaken to identify other countries which would have accessible data and be a suitable comparator.

Target: Studies undertaken on national prescribing databases relating to older people.

Aim: To identify possible countries and sources of data for a comparator study.

Table A7 Searches for studies using prescribing databases

Search Portal	Search Number	Keywords/MESH	Limits	Results	Papers recorded
Pubmed	#1	Prescribing OR prescription	Humans, English, Aged: 65+ years, published in the last 5 years	4,981	0
Pubmed	#2	Older OR elderly OR aged	Humans, English, Aged: 65+ years, published in the last 5 years	374,974	0
Pubmed	#3	#1 AND #2	Humans, English, Aged: 65+ years, published in the last 5 years	4,981	0
Pubmed	#4	Database AND (#1 AND #2)	Humans, English, Aged: 65+ years, published in the last 3 years	372	85
Scirus	#5	prescribing AND database	Elderly patient, aged	1,119	0

Scirus	#6	prescribing AND database	Humans, aged, elderly, between 2009 & 2012	238	*98

Exclusion criteria: Studies using questionnaires , surveys or medical records only, studies using the UK General Practice Research Database (GPRD), studies restricted to small local databases.

*98 Scirus downloaded including 48 duplicates with Pubmed.

Table A8 Country prescribing databases

Country of Study	Nr of studies	Nr of databases	Databases	Link	UI
Australia	1	1	Department of Veterans' Affairs administrative claims database	Yes	No
Canada	5	6	• British Columbia Linked Health Database, • Administrative databases of the Regie de l'assurance maladie du Quebec, • Ontario Drug Benefits Database and Registry of the Canadian Stroke Network • Hospital discharge summary database and provincial database of physicians' services and medication claims	Yes	Yes
China	1	1	Regional clinical database	No	Yes
Denmark	4	4	• Danish national hospital/outpatient database, the population register and the Danish National Drug Prescription Database (Combinations) • Danish Hip Arthroplasty Registry, the Danish National Registry of Patients and the Danish National Drug Prescription Database.	Yes	Yes
Finland	1	1	National prescription database	No	Yes

Country of Study	Nr of studies	Nr of databases	Databases	Link	UI
France	1	2	National hospital discharge database and the outpatient medications reimbursement database	Yes	Yes
Germany	1	1	National Database of the German Collaborative Arthritis Centres	No	Yes
Ireland	2	1	Primary Care Reimbursement Services (PCRS) database	No	No
Italy	8	13	• Regional prescribing databases • Health Search/CSD Patient database • Italian Interregional Group of Pharmacovigilance (IGP) • Health Search/Thales Database	Yes	Yes
Korea	1	1	Health Insurance Review & Assessment Service (HIRA) claims database	No	Yes
New Zealand	3	3	National pharmaceutical and laboratory investigations databases and national hospital admissions database	Yes	Yes
Norway	8	1	Norwegian Prescription Database (NorPD)	No	Yes

Country of Study	Nr of studies	Nr of databases	Databases	Link	UI
South Africa	1	1	Private pharmacy group database	No	No
Spain	1	1	Catalan regional prescription database	No	Yes
Taiwan	3	1	National Health Insurance Database reimbursement database	No	Yes
The Netherlands	3	2	• Regional health insurance database • Dutch Integrated Primary Care Information database	No	Yes
UK	7	7	• The Health Improvement Network (THIN) primary care database • PGRx database • Scottish Programme for Improving Clinical Effectiveness - Primary Care (SPICE-PC) • QRESEARCH database • Health Informatics Centre-dispensed prescribing database for the population of Tayside, Scotland and the Diabetes Audit and Research in Tayside Scotland • hospital inpatient admission records, death certificates and prescribing data Tayside Scotland.	Yes	Yes

Country of Study	Nr of studies	Nr of databases	Databases	Link	UI
USA	73	74	Medicare Medicaid Veterans Health Administration Private managed health care schemes	Yes	No

Link = 'Yes' if prescribing databases were linked to other databases such as mortality records or hospital records.

UI = unique patient identifier, 'Yes' if country has an individual identification number which would facilitate linking of databases

Based on the findings presented in table A8 three possible comparator countries were identified: New Zealand, Norway and Ontario, Canada. These are all countries with accessible data on prescribing which is already linked or could be linked to mortality records. New Zealand was chosen as the comparator country based on the similar population size, proportion of the population over 70 and health care provision.

Table A9 Comparison of four possibilities

Demographics (2006)	Ireland	New Zealand	Norway	Ontario Canada
Total Population	4,239,848	4,143,279	4,858,199	12,793,572
Population 70 +	324,510	356,808	510,612	1,200,339
% of population 70+	7.65%	8.61%	10.51%	9.38%
GDP per capita (US$)	41,218	25,830	52,041	36,820
Public Exp. (% GDP)	5.5%	7.2%	7.2%	7%
Life expectancy at birth (yrs)	79.8	80.1	80.5	80.7

Source: national statistics agencies, GDP & Life exp from OECD, GNP per capita for Ireland $35 873

Appendix B – The Irish Longitudinal Study of Ageing (TILDA)

TILDA is a longitudinal study of ageing which began collecting data on the Irish population age 50 years or more in 2009/2010, and every two years since. Information is gathered on economic, health and social aspects of individuals' lives to create a valuable resource for research. The first wave of TILDA provides a cross section of nationally representative health, social and economic data on the Irish population aged 50 years or more (n=8,174) with 2,307 participants aged 70 or more in 2009/2010.

Participants were recruited on a household basis using a stratified clustered sample of Irish residential addresses. Those who agreed to participate were given an indepth face to face interview, provided with a brief self-completion questionnaire to be completed in private and posted back and invited to a health assessment center. Participants were also offered a home assessment if they were unable to attend one of the health assessment centres. The study is longitudinal returning to respondents every two years, with every second wave containing a health assessment. The data used in this thesis comes from wave 1 which was collected in 2009 and 2010. An overall response rate of 62% was achieved. More details on the sampling process, questionnaires and descriptive findings have been published elsewhere (Barrett et al., 2011, Kenny et al., 2010, Cronin et al., 2013). The following paragraphs briefly describe the data collection.

The face to face interview is conducted by trained interviewers in the respondents home using a computer-assisted personal interview (CAPI). The CAPI collects key data on all aspects of the respondents' lives, including their economic circumstances (income, employment, living standards), health (physical, mental, service needs and usage) and their social situation (contact with friends and kin, formal and informal care, social participation).

A self completion questionnaire was left with each respondent to complete in their own time. The questionnaire was designed to collect data on areas that were considered particularly sensitive for respondents to answer directly to an interviewer (e.g. relationship quality, loneliness, stressful life events, anxiety, worry and alcohol intake). 1,902 (82.4%) of the 2,307 participants aged 70 or more completed a questionnaire.

The final data collection instrument at wave 1 was a health assessment. Participants were invited to attend a health assessment centre where a number of tests were carried out by research nurses. These tests took measurements of cognition, cardiovascular health, vision, balance and gait. Those who were unable to attend an assessment centre were given a partial assessment in their own home by a research nurse. 1,473 (63.9%) of the 2,307 participants aged 70 or more availed of a health assessment. Of those who had an assessment, 1,010 (68.6%) attended an assessment centre and 463 (31.4%) had a home assessment.

The TILDA dataset is weighted to be representative of the population aged 50 years or more. In order to use the data for the population aged 70 or more new weights were calculated these followed the weighting procedure that is used in the main survey and is set out in Barrett et al (2011). Population data was used from the 2011 Census available at www.cso.ie/census. Each TILDA participant age 70 years or more represents approximately 150 individuals in the population. The census records a high number of individuals who do no state their highest educational attainment, the numbers of these individuals are recorded in table B1. To calculate the weight the non stated category was reallocated across the primary / secondary / tertiary categories based on the percentage already in those groups. Table B2 sets out the weights used to calculate all reported prevalence figures.

Age group	Non stated			Primary			Secondary			Tertiary		
	All	Male	Female	All	Male	Female	All	Male	Female	All	Male	Female
70-74	53420	26118	25254	4916	2294	2500	4277	1696	2689	1690	887	817
Percentage				45.2%	47.0%	41.6%	39.3%	34.8%	44.8%	15.5%	18.2%	13.6%
75-79	45274	20693	22875	4607	2013	2492	3448	1272	2267	1238	637	612
Percentage				49.6%	51.3%	46.4%	37.1%	32.4%	42.2%	13.3%	16.2%	11.4%
80-84	33163	14706	18457	3865	1567	2279	2519	757	1791	839	374	455
Percentage				53.5%	58.1%	50.4%	34.9%	28.1%	39.6%	11.6%	13.9%	10.1%
≥ 85	28094	9602	17200	4171	1252	2807	2474	575	2000	807	275	543
Percentage				56.0%	59.6%	52.5%	33.2%	27.4%	37.4%	10.8%	13.1%	10.2%

Table B2 Population age, sex and educational attainment from 2011 Census and TILDA weights for population aged 70 years or more

Age group		Primary			Secondary			Tertiary		
		All	Male	Female	All	Male	Female	All	Male	Female
70-74	Population	58336	28412	27754	50754	21006	29856	20049	10989	9074
	Sample	407	209	198	312	138	174	245	129	116
	Weight	143	136	140	163	152	172	82	85	78
75-79	Population	49881	22706	25367	37334	14346	23079	13409	7186	6234
	Sample	333	163	170	236	91	145	146	75	71
	Weight	150	139	149	158	158	159	92	96	88
80-84	Population	37028	16273	20736	24134	7864	16299	8039	3887	4142
	Sample	202	96	106	116	40	76	77	38	39
	Weight	183	170	196	208	197	214	104	102	106
≥ 85	Population	32265	10854	20007	19142	4988	14255	6243	2382	3872
	Sample	146	63	83	63	19	44	20	12	8
	Weight	221	172	241	304	263	324	312	198	484

*population figures and weights have been rounded

Appendix C – Additional Data Analysis

This Appendix sets out more detailed data analysis for chapter 5, over varying time periods – last 12months of life or the last 36 months.

Table C1 Region and counties used in matching

code	Region	Counties				
9,10, 11	East	Dublin	Kildare	Wicklow		
2	Midlands	Laois	Offaly	Longford	West Meath	
3	Mid West	Clare	Limerick	North Tipperary		
4	North East	Cavan	Louth	Meath	Monaghan	
5	North West	Donegal	Leitrim	Sligo		
6	South East	Carlow	Kilkenny	South Tipperary	Waterford	Wexford
7	South West	Cork	Kerry			
8	West	Galway	Mayo	Roscommon		

Table C2 Ingredient costs for 12 months prior to death or censored (1:1 matching on age, gender, region) for 2008/2009, decedents from 2009 (Ireland)

		No. of individuals	Total annual expenditure (Std dev) (€)	Mean expenditure per individual (SE) (€)	Median expenditure per individual (€)	Mean no. of items per individual (95% CI)	Average expenditure per prescription (€) (total no. Items)
Decedents	All	14,084	29,667,717 (2,920)	2,106.5 (27.2)	1,722.0	107.5 (107.0-107.9)	19.6
	female	7,539	15,671,269 (1,456)	2,078.7 (21.6)	1,688.9	108.9 (108.0 -109.2)	19.1
	male	6,545	13,996,448 (1,149)	2,138.5 (19.8)	1,761.0	105.8 (105.8-106.1)	20.2
Survivors	All	14,084	16,622,139 (2,010)	1,180.2 (15.3)	888.7	70.3 (69.2-71.9)	16.8
	female	7,539	9,262,681 (1,878)	1,228.6 (16.1)	935.0	74.6 (72.2-76.1)	16.5
	male	6,545	7,359,458 (1,563)	1,124.4 (10.5)	838.8	65.3 (63.9-66.0)	17.2

Standard error (SE), Confidence Interval (CI), Standard deviation (Std.dev)

Table C3 Ingredient costs for 36 months prior to death or censored (1:1 exact matching on age (as at 1st Jan 2009), gender, region) for 2006-2009, decedents from 2009 (Ireland)

		No. of individuals	Total expenditure (Std. dev) (€)	Mean expenditure per individual (SE) (€)	Median expenditure per individual (€)	Mean no. of items per individual (SE)	Average expenditure per prescription (€)
Decedents	All	14,084	75,495,253 (6,584)	5,360.4 (91.12)	4,419.2	278.6 (273.1-280.2)	19.2
	female	7,539	40,262,621 (6,320)	5,340.6 (87.4)	4,417.8	285.0 (280.5-287.1)	18.7
	male	6,545	35,232,632 (6,125)	5,383.1 (82.6)	4,422.4	271.2 (269.2-272.7)	19.9
Survivors	All	14,084	46,152,395 (5,678)	3,276.9 (33.6)	2,513.2	195.1 (193.8-196.5)	16.8
	female	7,539	25,632,571 (2,965)	3,400.0 (30.0)	2,635.2	206.6 (204.2-207.1)	16.5
	male	6,545	20,519,823 (2,134)	3,135.2 (30.8)	2,385.3	181.8 (180.2-183.2)	17.2

Standard error (SE), Confidence Interval (CI), Standard deviation (Std.dev)

Table C4 Ingredient costs for 12 months prior to death or censored (1:1 exact matching on age (as at 1st Jan 2009), gender, region), decedents from 2009 by age group and gender (Ireland)

	Age group	Nr of individuals	Total expenditure (Std.dev) (€)	Mean expenditure per individual (SE) (€)	Median expenditure per individual (€)	Mean nr of items per individual (95%CI)	Average expenditure per prescription (€)
Decedents female	70-74	576	1,328,240 (980)	2,306.0 (24.9)	1,760.0	107.7 (105.6-108.1)	21.4
	75-79	1,415	3,329,458 (889)	2,353.0 (22.1)	1,940.6	112.5 (110.8-113.1)	20.9
	80-84	1,944	4,260,201 (1,067)	2,191.5 (20.4)	1,797.8	114.1 (112.6-115.3)	19.2
	85-89	1,953	3,956,046 (997)	2,025.6 (19.7)	1,687.5	110.0 (109.6-111.1)	18.4
	90+	1651	2,797,325 (1,456)	1,694.3 (14.8)	1,366.4	98.9 (97.4-100.1)	17.1
Decedents male	70-74	856	2,011,561 (970)	2,350.0 (22.5))	1,913.5	106.9 (105.6-107.9)	22.0
	75-79	1,757	3,909,137 (1,450)	2,224.9 (20.7)	1,788.8	106.7 (105.1-107.5)	20.9
	80-84	1,858	3,938,596 (1,523)	2,119.8 (21.2)	1,807.5	106.2 (105.7-107.2)	20.0
	85-89	1,395	2,954,777 (1,590)	2,118.1 (23.5)	1,765.7	107.7 (107.0-108.3)	19.7
	90+	679	1,182,377 (1,789)	1,741.4 (26.5)	1,430.4	96.9 (90.1-98.8)	18.0

	Age group	Nr of individuals	Total expenditure (Std.dev) (€)	Mean expenditure per individual (SE) (€)	Median expenditure per individual (€)	Mean nr of items per individual (95%CI)	Average expenditure per prescription (€)
Survivors female	70-74	576	651,539 (451)	1,131.1 (10.2)	808.2	63.6 (60.5-64.9)	17.8
	75-79	1,415	1,749,202 (580)	1,236.2 (11.6)	947.7	73.0 (72.1-73.9)	16.9
	80-84	1,944	2,556,039 (689)	1,314.8 (12.1)	1,001.5	78.4 (77.2-79.2)	16.8
	85-89	1,953	2,558,169 (788)	1,309.9 (14.3)	995.5	79.6 (78.1-80.5)	16.4
	90+	1651	1,747,731 (578)	1,058.6 (12.5)	771.1	69.3 (68.5-70.8)	15.3
Survivors male	70-74	856	933,319 (734)	1,090.3 (10.2)	747.4	58.9 (57.2-60.0)	18.5
	75-79	1,757	2,044,152 (886)	1,163.4 (11.6)	880.9	64.7 (63.2-65.1)	18.0
	80-84	1,858	2,261,722 (962)	1,217.3 (12.9)	944.6	71.8 (70.1-72.9)	16.9
	85-89	1,395	1,519,312 (756)	1,089.1 (10.7)	827.9	65.9 (64.2-66.8)	16.5
	90+	679	600,952 (521)	885.1 (9.2)	603.9	55.8 (50.2-59.7)	15.8

Standard error (SE), Confidence Interval (CI), Standard deviation (Std.dev)

Table C5 Ingredient costs for 36 months prior to death or censored (1:1 exact matching on age (as at 1st Jan 2009), gender, region), decedents from 2009 by age group and gender (Ireland)

	Age group	No. of individuals	Total expenditure (Std.dev) (€)	Mean expenditure per individual (SE) (€)	Median expenditure per individual (€)	Mean no. of items per individual (95% CI)	Average expenditure per prescription (€)
Decedents female	70-74	576	3,252,414 (1,256)	5,646.6 (41.2)	4,386.7	270.8 (268.1-271.8)	20.8
	75-79	1,415	8,351,330 (2,521)	5,902.0 (40.5)	4,993.6	288.7 (286.1-289.8)	20.4
	80-84	1,944	11,026,979 (2,321)	5,672.3 (39.8)	4,661.2	298.9 (297.0-300.8)	19.0
	85-89	1,953	10,382,634 (2,154)	5,316.2 (40.1)	4,557.5	292.2 (290.4-293.8)	18.2
	90+	1,651	7,249,264 (1,980)	4,390.8 (38.7)	3,666.6	261.9 (260.1-262.8)	16.8
Decedents male	70-74	856	4,783,902 (1,369)	5,588.7 (42.6)	4,526.6	259.2 (258.0-261.2)	21.6
	75-79	1,757	9,826,965 (1,856)	5,593.0 (40.2)	4,556.1	270.9 (268.5-271.2)	20.6
	80-84	1,858	10,080,810 (1,897)	5,425.6 (42.3)	4,598.9	278.3 (276.5-279.1	19.5
	85-89	1,395	7,568,999 (1,963)	5,425.8 (44.5)	4,447.0	280.8 (278.5-281.5)	19.3
	90+	680	2,971,955 (2,569)	4,377.0 (46.9)	3,618.3	247.8 (246.1-248.0)	17.7

	Age group	No. of individuals	Total expenditure (Std.dev) (€)	Mean expenditure per individual (SE) (€)	Median expenditure per individual (€)	Mean no. of items per individual (95% CI)	Average expenditure per prescription (€)
Survivors female	70-74	576	1,796,448 (1,800)	3,118.8 (35.1)	2,196.9	175.1 (174.1-176.9)	17.8
	75-79	1,415	4,808,147 (1,967)	3,398.0 (34.2)	2,595.8	201.1 (199.8-202.6)	16.9
	80-84	1,944	6,971,411 (1,892)	3,586.1 (36.1)	2,795.5	215.0 (214.5-216.5)	16.7
	85-89	1,953	7,125,596 (2,145)	3,648.5 (35.6)	2,880.3	220.8 (219.4-222.1)	16.5
	90+	1,651	4,930,970 (1,987)	2,986.7 (35.1)	2,222.8	195.5 (194.5-196.8)	15.3
Survivors male	70-74	856	2,561,955 (1,638)	2,992.9 (29.2)	2,103.6	161.0 (159.6-162.3)	18.6
	75-79	1,757	5,603,537 (1,532)	3,189.3 (29.6)	2,477.0	177.3 (175.6-179.0)	18.0
	80-84	1,858	6,383,478 (1,652)	3,435.7 (30.6)	2,644.8	201.4 (199.5-202.9)	17.1
	85-89	1,395	4,259,936 (1,896)	3,053.7 (29.9)	2,364.4	184.5 (183.9 - 186.2)	16.6
	90+	680	1,710,917 (2,056)	2,519.8 (32.1)	1,850.3	160.5 (159.1-161.3)	15.7

Standard error (SE), Confidence Interval (CI), Standard deviation (Std.dev)

Table C6 Generalized linear model (GLM) of monthly prescribing expenditures with chronic conditions assuming a Gamma distribution with a log link, for 36 months

Covariates	exp(b)	Standard Error	95% Confidence Interval	
age	***1.006	0.000	1.005	1.006
female	***0.945	0.003	0.939	0.951
reg2	***0.963	0.007	0.949	0.977
reg3	1.004	0.008	0.989	1.019
reg4	***0.957	0.008	0.942	0.972
reg5	***0.948	0.006	0.936	0.961
reg6	***0.966	0.006	0.954	0.978
reg7	***0.976	0.007	0.963	0.989
reg8	***1.046	0.006	1.033	1.058
case	***1.190	0.007	1.176	1.205
cc1	***1.491	0.004	1.483	1.499
cc2	***1.082	0.024	1.035	1.131
cc3	***1.117	0.004	1.109	1.126
cc4	***1.787	0.011	1.766	1.808
cc5	***1.456	0.006	1.445	1.468
cc6	***1.437	0.008	1.421	1.453
cc7	***1.243	0.006	1.232	1.254
cc8	***1.119	0.007	1.106	1.133
cc9	1.000			
cc10	***1.427	0.004	1.419	1.435
cc11	***1.389	0.018	1.355	1.425
cc12	***1.121	0.005	1.111	1.131
cc13	***1.160	0.041	1.082	1.243
cc14	***1.344	0.004	1.336	1.353
cc15	***1.582	0.017	1.549	1.615
cc16	***1.356	0.005	1.346	1.365
cc17	***1.575	0.005	1.564	1.585
cc18	***1.079	0.003	1.072	1.085
cc19	0.997	0.004	0.989	1.005
cc20	1.000			
month				
1	***1.072	0.003	1.066	1.078
2	***1.036	0.003	1.031	1.041
3	***0.980	0.002	0.975	0.985

Covariates	exp(b)	Standard Error	95% Confidence Interval	
4	***1.023	0.003	1.018	1.027
5	***0.985	0.003	0.980	0.990
6	***1.059	0.003	1.054	1.064
7	***1.069	0.003	1.064	1.074
8	***1.075	0.003	1.069	1.080
9	***1.052	0.003	1.047	1.057
10	***1.020	0.002	1.015	1.024
11	***1.102	0.003	1.097	1.107
12	***1.053	0.003	1.048	1.059
13	***1.053	0.003	1.048	1.058
14	***1.119	0.003	1.114	1.125
15	***1.109	0.003	1.104	1.115
16	***1.049	0.003	1.044	1.054
17	***0.985	0.002	0.980	0.990
18	***1.009	0.002	1.004	1.013
19	***1.010	0.002	1.006	1.015
20	***0.973	0.002	0.969	0.978
21	***1.007	0.002	1.003	1.012
22	***0.970	0.002	0.966	0.975
23	***1.048	0.002	1.043	1.052
24	***0.903	0.003	0.898	0.908
25	***1.289	0.004	1.281	1.297
26	***1.061	0.002	1.056	1.066
27	1.001	0.002	0.997	1.005
28	***1.012	0.002	1.007	1.016
29	***1.006	0.002	1.002	1.010
30	1.001	0.002	0.996	1.005
31	***0.962	0.002	0.958	0.967
32	***0.989	0.002	0.985	0.993
33	***0.983	0.002	0.979	0.987
34	***0.959	0.002	0.955	0.963
35	***1.007	0.002	1.003	1.012
constant	31.778	0.809	30.230	33.405

exponential (exp)

*, **, *** indicates significance at the 90%, 95%, and 99% level, respectively

Chronic conditions cc1 – cc20 are described in Table 5.2

Table C7 Two part model using a Probit followed by a Generalized linear model (GLM) of monthly prescribing expenditures assuming a Gamma distribution with a log link, for 36 months

	Probit				GLM on positive expenditures			
	Basic model		Interactions model		Basic model		Interactions model	
Covariates	Coeff.	SE	Coeff.	SE	Exp(Coeff.)	SE	Exp(Coeff.)	SE
Age	***0.132	0.008	***0.132	0.008	1.007	0.007	1.007	0.007
Age squared	***-0.001	4.7x10-4	***-0.001	0.000	1.000	4.7x10-5	1.000	0.000
Male	1		1		1		1	
Female	***0.023	0.003	***0.023	0.003	***0.916	0.003	***0.916	0.003
No. Chronic conditions	***-0.181	0.007	***-0.471	0.013	***1.231	0.008	***1.152	0.014
Decedents	***0.277	0.001	***0.278	0.001	***1.322	0.001	***1.322	0.001
Midlands	1		1		1		1	
Mid-west	***0.093	0.009	***0.093	0.009	***0.942	0.007	***0.942	0.007
Northeast	***0.042	0.009	***0.041	0.009	0.994	0.008	0.994	0.008
Northwest	0.013	0.010	0.012	0.010	***0.946	0.008	***0.946	0.008
Southeast	***0.051	0.009	***0.051	0.009	***0.930	0.007	***0.930	0.007
South	***0.076	0.008	***0.076	0.008	***0.943	0.006	***0.944	0.006
West	***0.076	0.008	***-0.063	0.008	***0.966	0.007	***0.966	0.007
East	***-0.060	0.008	***-0.060	0.008	***1.042	0.007	***1.042	0.007
1 month	***-0.662	0.004	***-0.708	0.004	***1.077	0.003	***1.034	0.003
2 months	***0.146	0.004	***0.133	0.004	***1.041	0.003	***1.020	0.003
3 months	***0.089	0.004	***0.064	0.004	***0.984	0.003	***0.963	0.003
4 months	***0.164	0.004	***0.142	0.004	***1.027	0.003	***1.011	0.003
5 months	***-0.027	0.004	***-0.059	0.004	***0.991	0.003	***0.974	0.003

6 months	***0.220	0.004	***0.199	0.004	***1.064	0.003	***1.053	0.003
7 months	***0.200	0.004	***0.178	0.004	***1.073	0.003	***1.066	0.003
8 months	***0.189	0.004	***0.167	0.004	***1.079	0.003	***1.073	0.003
9 months	***0.170	0.004	***0.147	0.004	***1.057	0.003	***1.050	0.003
10 months	***0.143	0.004	***0.119	0.004	***1.024	0.003	***1.017	0.003
11 months	***0.314	0.004	***0.302	0.004	***1.110	0.003	***1.110	0.003
12 months	***-0.407	0.004	***-0.457	0.004	***1.061	0.003	***1.060	0.003
13 months	***0.076	0.004	***0.050	0.004	***1.059	0.003	***1.057	0.003
14 months	***0.248	0.004	***0.238	0.004	***1.126	0.003	***1.128	0.003
15 months	***0.255	0.004	***0.244	0.004	***1.115	0.003	***1.116	0.003
16 months	***0.237	0.004	***0.226	0.004	***1.054	0.003	***1.053	0.003
17 months	***0.148	0.004	***0.133	0.004	***0.990	0.002	***0.985	0.002
18 months	***0.195	0.004	***0.182	0.004	***1.013	0.002	***1.010	0.003
19 months	***0.196	0.004	***0.183	0.004	***1.015	0.002	***1.013	0.002
20 months	***0.108	0.004	***0.089	0.004	***0.977	0.002	***0.973	0.002
21 months	***0.197	0.004	***0.185	0.004	***1.011	0.002	***1.009	0.002
22 months	***0.133	0.004	***0.119	0.004	***0.974	0.002	***0.970	0.002
23 months	***0.184	0.003	***0.174	0.004	***1.051	0.002	***1.052	0.003
24 months	***-0.761	0.004	***-0.824	0.004	***0.906	0.003	***0.898	0.003
25 months	***0.070	0.004	***0.049	0.004	***1.292	0.004	***1.307	0.003
26 months	***0.153	0.003	***0.141	0.003	***1.064	0.002	***1.068	0.003
27 months	***0.091	0.003	***0.078	0.003	1.003	0.002	*1.004	0.002
28 months	***0.099	0.003	***0.087	0.003	***1.014	0.002	***1.016	0.002
29 months	***0.079	0.003	***0.068	0.003	***1.007	0.002	***1.010	0.002
30 months	***0.071	0.003	***0.063	0.003	1.002	0.002	*1.004	0.002
31 months	***0.017	0.003	0.002	0.003	***0.964	0.002	***0.965	0.002
32 months	***0.060	0.003	***0.050	0.003	***0.990	0.002	***0.992	0.002

33 months	***0.056	0.003	***0.048	0.003	***0.983	0.002	***0.986	0.002
34 months	***-0.012	0.003	***-0.018	0.003	***0.959	0.002	***0.960	0.002
35 months	***0.018	0.003	***0.023	0.003	***1.007	0.002	***1.009	0.002
36 months	1		1		1		1	
Decedent*1 month			***0.761	0.018			***1.579	0.025
Decedent* 2 months			***0.190	0.018			***1.355	0.020
Decedent*3months			***0.392	0.018			***1.379	0.019
Decedent*4 months			***0.337	0.018			***1.266	0.017
Decedent*5months			***0.548	0.018			***1.286	0.018
Decedent*6months			***0.334	0.018			***1.172	0.016
Decedent*7months			***0.351	0.018			***1.126	0.015
Decedent*8 months			***0.352	0.018			***1.101	0.015
Decedent*9months			***0.362	0.018			***1.111	0.015
Decedent*10months			***0.382	0.018			***1.112	0.015
Decedent*11months			***0.173	0.017			1.007	0.013
Decedent*12			***0.924	0.017			**1.029	0.013

month				
Decedent*13months	***0.424	0.017	***1.044	0.014
Decedent*14months	***0.155	0.017	**0.973	0.013
Decedent*15months	***0.161	0.016	0.981	0.012
Decedent*16months	***0.156	0.017	*1.024	0.013
Decedent*17months	***0.223	0.017	***1.090	0.014
Decedent*18months	***0.194	0.016	***1.052	0.013
Decedent*19months	***0.203	0.016	***1.043	0.013
Decedent*20months	***0.279	0.016	***1.080	0.013
Decedent*21months	***0.183	0.016	**1.030	0.013
Decedent*22months	***0.211	0.016	***1.064	0.013
Decedent*23months	***0.142	0.015	0.987	0.012
Decedent*24months	***1.154	0.016	***1.133	0.014
Decedent*25months	***0.326	0.015	***0.811	0.034

Decedent*26months		***0.189	0.015			***0.927	0.011
Decedent*27months		***0.185	0.015			*0.978	0.013
Decedent*28months		***0.184	0.014			**0.970	0.012
Decedent*29months		***0.169	0.015			***0.959	0.011
Decedent*30months		***0.122	0.015			***0.960	0.011
Decedent*31months		***0.231	0.015			0.991	0.012
Decedent*32months		***0.149	0.014			***0.961	0.011
Decedent*33months		***0.121	0.014			***0.957	0.011
Decedent*34months		***0.088	0.014			0.987	0.011
Decedent*35months		***-0.067	0.015			***0.950	0.012
Decedent*36months		1				1	
Constant		0.132	0.008	1.007	0.007	1.007	0.007
Akaike Information Criteria (AIC)				11.385		11.384	
Loglikelihood				-37,628,213		-37,625,078	

n	8,341,380	8,341,380	6,609,899	6,609,899

Coefficient (Coeff.), exponential (exp), Standard error (SE),

*, **, *** indicates significance at the 90%, 95%, and 99% level, respectively.

Appendix D – Population Projections

Table D1 Annual deaths in Ireland for those aged ≥72 years

Total Population Mortality	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
72 - 74 years	2,879	2,960	2,865	2,955	2,799	2,825	2,651	2,572	2,552	2,191	2,219
75 - 79 years	5,498	5,500	5,188	5,511	5,286	5,289	5,373	5,635	5,156	4,943	4,681
80 - 84 years	5,482	5,891	5,633	5,907	5,859	5,735	5,649	5,701	5,478	5,296	5,266
85 years and over	5,903	6,470	6,403	6,729	6,980	6,945	7,171	7,848	7,584	7,442	7,543
Female											
72 - 74 years	1,167	1,215	1,186	1,200	1,200	1,180	1,143	1,073	1,053	889	938
75 - 79 years	2,503	2,500	2,331	2,483	2,446	2,390	2,453	2,572	2,352	2,334	2,135
80 - 84 years	2,777	3,066	2,899	3,042	3,050	3,037	2,944	3,011	2,895	2,824	2,756
85 years and over	3,790	4,186	4,199	4,330	4,462	4,465	4,634	5,050	4,952	4,723	4,907
Male											
72 - 74 years	1,712	1,745	1,679	1,755	1,599	1,645	1,508	1,499	1,499	1,302	1,281
75 - 79 years	2,995	3,000	2,857	3,028	2,840	2,899	2,920	3,063	2,804	2,609	2,546
80 - 84 years	2,705	2,825	2,734	2,865	2,809	2,698	2,705	2,690	2,583	2,472	2,510
85 years and over	2,113	2,284	2,204	2,399	2,518	2,480	2,537	2,798	2,632	2,719	2,636

Source: Central Statistics Office (CSO), Ireland

Table D1 Annual deaths in Ireland for those aged ≥72 years (condt)

Total Population Mortality	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
72 - 74 years	2,038	2,080	1,912	1,904	1,888	1,587	1,781	1,637	1,687	1,693
75 - 79 years	4,604	4,269	4,072	4,155	4,017	3,479	3,846	3,563	3,702	3,706
80 - 84 years	5,288	5,195	5,166	5,054	4,974	4,582	4,880	4,587	4,527	4,790
85 years and over	7,437	7,494	7,597	8,051	7,899	7,889	8,285	8,484	8,842	9,401
Female										
72 - 74 years	840	854	774	700	780	616	723	657	681	659
75 - 79 years	2,147	1,937	1,845	1,849	1,821	1,550	1,696	1,563	1,604	1,585
80 - 84 years	2,779	2,658	2,722	2,643	2,587	2,378	2,435	2,254	2,271	2,360
85 years and over	4,826	4,871	4,902	5,202	5,078	5,173	5,261	5,465	5,700	5,933
Male										
72 - 74 years	1,198	1,226	1,138	1,204	1,108	971	1,058	980	1,006	1,034
75 - 79 years	2,457	2,332	2,227	2,306	2,196	1,929	2,150	2,000	2,098	2,121
80 - 84 years	2,509	2,537	2,444	2,411	2,387	2,204	2,445	2,333	2,256	2,430
85 years and over	2,611	2,623	2,695	2,849	2,821	2,716	3,024	3,019	3,142	3,468

Table D2 Projected annual mortality (based on table D1)

	Age group	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total population	72 - 74 years	1,421.9	1,344.8	1,267.7	1,190.6	1,113.4	1,036.3	959.2	882.1	805.0	727.8	650.7
	75 - 79 years	3,389.7	3,275.9	3,162.1	3,048.3	2,934.4	2,820.6	2,706.8	2,593.0	2,479.2	2,365.4	2,251.6
	80 - 84 years	4,557.5	4,491.5	4,425.6	4,359.6	4,293.7	4,227.7	4,161.8	4,095.8	4,029.9	3,963.9	3,898.0
	85 years and over	8,857.8	8,980.4	9,102.9	9,225.5	9,348.0	9,470.6	9,593.1	9,715.7	9,838.2	9,960.8	10,083.3
Female	72 - 74 years	557.3	523.5	489.6	455.8	421.9	388.0	354.2	320.3	286.4	252.6	218.7
	75 - 79 years	1,490.0	1,434.5	1,379.0	1,323.5	1,268.0	1,212.5	1,157.0	1,101.5	1,046.0	990.5	935.0
	80 - 84 years	2,309.8	2,271.4	2,232.9	2,194.5	2,156.0	2,117.6	2,079.1	2,040.7	2,002.2	1,963.8	1,925.3
	85 years and over	5,730.9	5,809.8	5,888.8	5,967.8	6,046.7	6,125.7	6,204.6	6,283.6	6,362.6	6,441.5	6,520.5
Male	72 - 74 years	864.6	821.3	778.1	734.8	691.5	648.3	605.0	561.8	518.5	475.3	432.0
	75 - 79 years	1,900.3	1,842.0	1,783.7	1,725.4	1,667.1	1,608.7	1,550.4	1,492.1	1,433.8	1,375.5	1,317.2
	80 - 84 years	2,247.7	2,220.2	2,192.7	2,165.2	2,137.7	2,110.2	2,082.7	2,055.2	2,027.7	2,000.2	1,972.7
	85 years and over	3,192.8	3,239.4	3,286.0	3,332.6	3,379.2	3,425.8	3,472.4	3,519.0	3,565.5	3,612.1	3,658.7

Table D2 Projected annual mortality (based on table D1) continued

	Age group	2024	2025	2026	2027	2028	2029	2030	2031	2032
Total population	72 - 74 years	573.6	496.5	419.4	342.3	265.1	188.0	110.9	33.8	-43.3
	75 - 79 years	2,137.8	2,024.0	1,910.2	1,796.3	1,682.5	1,568.7	1,454.9	1,341.1	1,227.3
	80 - 84 years	3,832.0	3,766.1	3,700.2	3,634.2	3,568.3	3,502.3	3,436.4	3,370.4	3,304.5
	85 years and over	10,205.9	10,328.4	10,451.0	10,573.5	10,696.1	10,818.6	10,941.2	11,063.7	11,186.3
Female	72 - 74 years	184.8	151.0	117.1	83.2	49.4	15.5	-18.4	-52.2	-86.1
	75 - 79 years	879.5	824.0	768.5	713.0	657.5	602.1	546.6	491.1	435.6
	80 - 84 years	1,886.9	1,848.4	1,810.0	1,771.5	1,733.1	1,694.6	1,656.2	1,617.7	1,579.3
	85 years and over	6,599.4	6,678.4	6,757.4	6,836.3	6,915.3	6,994.3	7,073.2	7,152.2	7,231.1
Male	72 - 74 years	388.8	345.5	302.3	259.0	215.8	172.5	129.3	86.0	42.8
	75 - 79 years	1,258.9	1,200.6	1,142.2	1,083.9	1,025.6	967.3	909.0	850.7	792.4
	80 - 84 years	1,945.2	1,917.7	1,890.2	1,862.7	1,835.2	1,807.7	1,780.2	1,752.7	1,725.2
	85 years and over	3,705.3	3,751.9	3,798.5	3,845.1	3,891.7	3,938.2	3,984.8	4,031.4	4,078.0

Figure D1 Projected mortality 2013- 2032 based on actual mortality 1992 – 2012, males aged ≥ 72 years of age

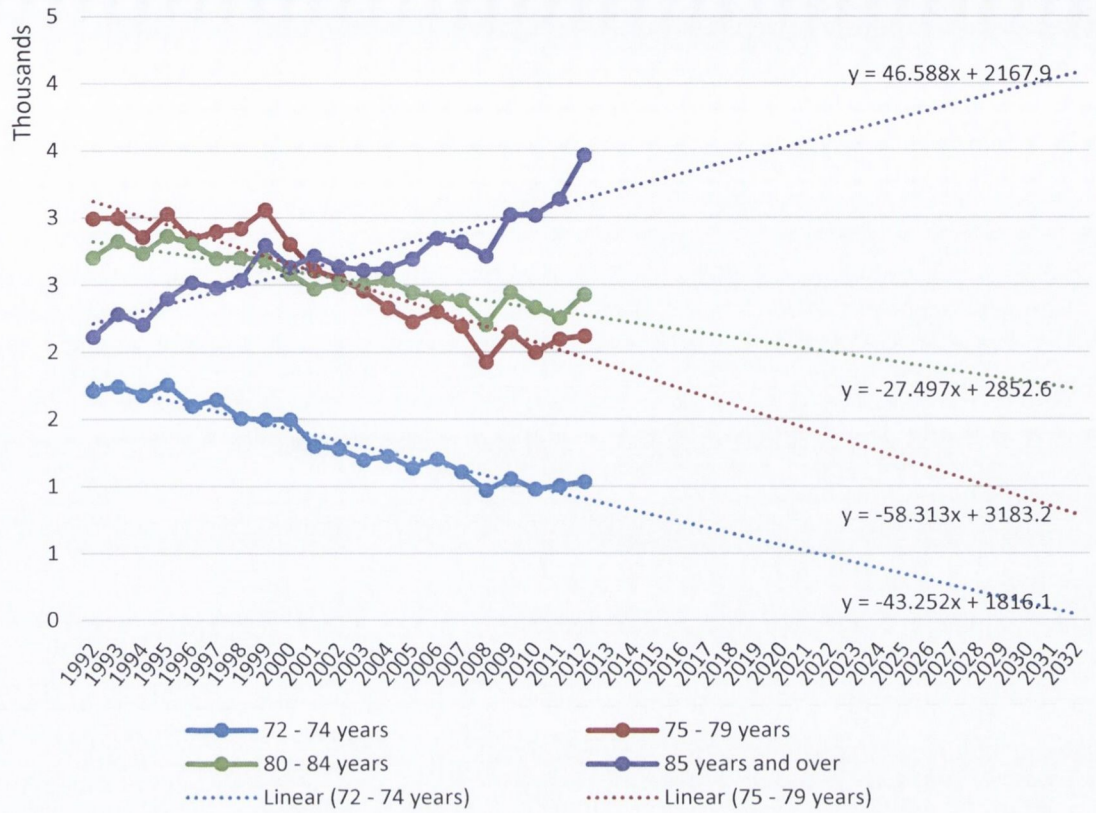


Figure D2 Projected mortality 2013- 2032 based on actual mortality 1992 – 2012, females aged ≥ 72 years of age

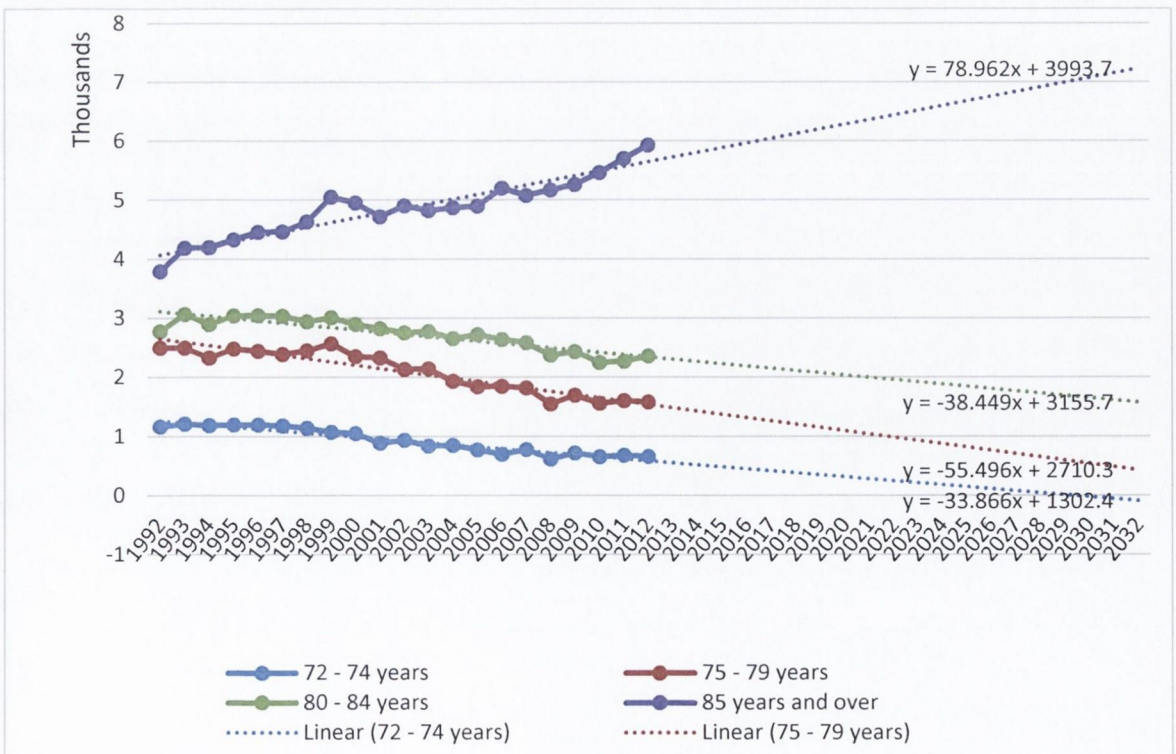


Table D3 Expenditure projections for traditional multipliers model 1(non PTD) and model 2 (PTD)

Model	Age (years)	2011 (€)	2016 (€)	2021 (€)	2026 (€)	2031 (€)
Model 1 no PTD Criteria: M1	70 - 74	223,707,467	271,337,727	330,660,614	367,286,049	414,228,508
	75 - 79	176,330,327	195,284,968	243,280,205	300,665,815	337,531,721
	80 - 84	119,483,924	134,718,980	154,747,088	197,884,550	248,553,951
	85 and over	88,748,795	106,590,048	129,920,917	159,503,849	208,300,437
Model 2 PTD Criteria: M1	70 - 74	147,312,355	177,605,682	215,455,759	238,696,807	240,125,827
	75 - 79	125,358,156	138,028,925	170,721,661	209,872,187	212,688,641
	80 - 84	92,537,419	103,652,134	118,216,253	149,887,099	154,161,204
	85 and over	72,893,843	87,322,146	105,788,877	128,895,847	146,781,021
Model 1 no PTD Criteria: M2	70 - 74	223,707,467	271,165,777	329,456,962	364,706,793	409,757,797
	75 - 79	176,330,327	195,111,072	242,584,622	298,752,961	334,053,806
	80 - 84	119,483,924	134,547,800	154,233,547	196,857,468	246,328,605
	85 and over	88,748,795	106,590,048	129,615,938	158,741,402	206,623,054
Model 2 PTD Criteria: M2	70 - 74	147,312,355	177,495,008	214,681,038	237,036,690	265,700,787
	75 - 79	125,358,156	137,909,337	170,243,306	208,556,711	232,519,470
	80 - 84	92,537,419	103,525,418	117,836,103	149,126,800	185,486,157
	85 and over	72,893,843	87,322,146	105,562,524	128,329,965	165,018,122
Model 1 No PTD Criteria: M3	70 - 74	223,707,467	270,993,826	328,253,309	362,127,537	405,974,889
	75 - 79	176,330,327	195,111,072	241,889,039	296,840,107	331,097,577
	80 - 84	119,483,924	134,547,800	153,720,005	195,659,205	244,445,621

	85 and over	88,748,795	106,590,048	129,310,959	157,978,955	205,403,140
Model 2 PTD	70 - 74	147,312,355	177,384,333	213,906,317	235,376,573	263,265,949
Criteria: M3	75 - 79	125,358,156	137,909,337	169,764,951	207,241,235	230,486,462
	80 - 84	92,537,419	103,525,418	117,455,954	148,239,785	184,092,275
	85 and over	72,893,843	87,322,146	105,336,171	127,764,082	164,112,710

Table D4 Expenditure projections using predicted expenditure from Two part regression model

Model	Age (years)	2011 (€)	2016 (€)	2021 (€)	2026 (€)	2031 (€)
Including PTD	70 - 74	137,330,391	165,285,371	199,245,203	219,198,014	245,124,408
Criteria: M3	75 - 79	117,455,398	129,126,491	158,809,267	193,734,306	215,386,383
	80 - 84	85,979,187	96,009,895	108,704,042	136,835,963	169,610,825
	85 and over	67,743,424	81,076,455	97,648,300	118,209,443	151,352,219
Excluding PTD	70 - 74	214,029,071	259,269,651	314,051,881	346,460,587	388,410,943
Criteria: M3	75 - 79	171,576,202	189,850,591	235,367,354	288,836,861	322,170,699
	80 - 84	118,633,336	133,589,975	152,625,696	194,266,337	242,705,450
	85 and over	86,235,173	103,571,110	125,648,499	153,504,534	199,585,529

Table D5 Ratio of Non PTD/ PTD (model 1 /model 2) expenditures

Model	Age (years)	2011	2016	2021	2026	2031
Model 1/2	70 - 74	1.52	1.53	1.53	1.54	1.73
Criteria: M1	75 - 79	1.41	1.41	1.43	1.43	1.59
Ratio: PTD/no PTD	80 - 84	1.29	1.30	1.31	1.32	1.61
	85 and over	1.22	1.22	1.23	1.24	1.42
Model 1/2	70 - 74	1.52	1.53	1.53	1.54	1.54
Criteria: M2	75 - 79	1.41	1.41	1.42	1.43	1.44
Ratio: PTD/no PTD	80 - 84	1.29	1.30	1.31	1.32	1.33
	85 and over	1.22	1.22	1.23	1.24	1.25
Model 1/2	70 - 74	1.52	1.53	1.53	1.54	1.54
Criteria: M3	75 - 79	1.41	1.41	1.42	1.43	1.44
Ratio: PTD/no PTD	80 - 84	1.29	1.30	1.31	1.32	1.33
	85 and over	1.22	1.22	1.23	1.24	1.25
Predicted values from Two-part regression model	70 - 74 years	1.56	1.57	1.58	1.58	1.58
	75 - 79 years	1.46	1.47	1.48	1.49	1.50
Criteria: M3	80 - 84 years	1.38	1.39	1.40	1.42	1.43
Ratio: PTD/no PTD	85 years and over	1.27	1.28	1.29	1.30	1.32

Table D6 Central Statistics Office (CSO) Population Projection Model Criteria

Model criteria	Description	Details
M1	Immigration continuing to decline but returning at a high level.	-19,100 per annum in 2011/2016 +18,200 per annum in 2016/2021 +30,000 per annum in 2021/2026 +30,000 per annum in 2026/2031 +30,000 per annum in 2031/2036
M2	Immigration decreasing but returning at more moderate levels.	- 21,600 per annum in 2011/2016 + 4,700 per annum in 2016/2021 + 10,000 per annum in 2021/2026 + 10,000 per annum in 2026/2031 + 10,000 per annum in 2031/2036
M3	Immigration, remaining negative but improving.	- 25,100 per annum in 2011/2016 - 10,000 per annum in 2016/2021 - 5,000 per annum in 2021/2026 - 5,000 per annum in 2026/2031 - 5,000 per annum in 2031/2036

More detail available at www.cso.ie

Appendix E

E1 Ethics application

HEALTH POLICY & MANAGEMENT / CENTRE FOR GLOBAL HEALTH
RESEARCH ETHICS COMMITTEE
ETHICAL APPROVAL APPLICATION FORM

PLEASE NOTE THE FOLLOWING:

- **Incomplete and/or late applications will not be processed and will be returned to the applicants.**
- **Forms without the following signatures will not be processed: Applicant(s) signature, Research Supervisor signature (applicable in student application).**
- **Forms without the checklist completed will not be processed.**

Applicant Details

Name of Principal Investigator:	Patrick Moore
Status (delete as applicable)	Postgraduate Student
Staff / Student Number:	09128506
Email address:	moorepv@tcd.ie
Primary Supervisor's name and contact (if applicable):	Charles Normand normandc@tcd.ie
Contact address and telephone number:	Health Policy & Management, 3-4 Foster Place, Dublin 2 01 8962201
Project Title:	The Importance of Proximity to Death in Modelling Future Drug Expenditures for Older People.

For Which REC Meeting:	Meeting Date: January/2011 (Month / Year) Other (Emergency / Re-submission)	
Level of Submission (tick as appropriate):	New Application (Full Protocols) Amended Application (Full Protocols)	☒ ☐

Please complete the application form and return three signed hard copies to
Ms. Sheena Cleary
Secretary, HPM/CGH Research Ethics Committee
Please also email your application in full (application and appendices) to
hsmsec@tcd.ie
by 5pm of the Application Submission Deadline Date.

LATE SUBMISSIONS WILL NOT BE ACCEPTED.

To process your application form efficiently you are required to fill in the checklist below. Do not leave any blanks. If this checklist is not completed, your application will not be processed.

		Yes	No	N/A
1.	Is the rationale for the study clearly stated?	☒	☐	
2.	Is the project design fully explained?	☒	☐	
3.	Are the inclusion and exclusion criteria complete?	☒	☐	☐

		Yes	No	N/A
4.	Are members of a vulnerable population being studied?	☒	☐	☐

If yes, please tick the vulnerable population being studied (please refer to section 3.3):

☐ Children under 18 Years
☒ Elderly
☐ Persons in Restricted Environments (e.g. psychiatric facilities, nursing homes)
☐ Prisoners / Youth Offenders
☐ Members of the Travelling Community
☐ Refugees / Asylum Seekers
☐ Persons with Diminished Capacity (e.g. cognitive impairment, learning disability, communication difficulties, etc.)
☐ Others (Please Specify:)

	a. Is the justification for studying this vulnerable population adequate?	☒	☐	☐
	b. Have adequate provisions been made to ensure that the vulnerable population is not being exploited?	☒	☐	☐
5.	Have the risks vs. the benefits for the research participants been discussed in the research protocol?	☒	☐	☐
6.	When appropriate, do provisions exist in the protocol for counselling research participants during and after the research?	☐	☐	☒
7.	Have adequate provisions been made to ensure the confidentiality of data and its ongoing protection throughout the study?	☒	☐	

IF APPROPRIATE TO THE STUDY YOU SHOULD ATTACH THE FOLLOWING:	Attached	N/A
(a) the consent form you propose using		✓
(b) the letter(s) to prospective participants seeking their co-operation with the study		✓
(c) the participant information leaflet you propose using		✓
(d) for the purpose of your proposed study, if you require access to: (i) a site outside your home department/School, and/or (ii) the person who is responsible for the welfare of your proposed participants please attach the letter seeking access		✓
(e) If the study requires ethical approval by ethics committees of any other institutions, outside of the HPM/CGH committee, please attach a copy of the responses received from these committees		✓
(f) If the project involves the use of a questionnaire, phone survey, focus group discussion and interviews please attach a copy of the tool(s) of data collection you propose using (Questionnaire / interview schedule / observation schedule/other)		✓

DETAILS OF RESEARCH STUDY & PARTICIPANT SELECTION

2.1 Working title of proposed study

Understanding the importance of proximity to death in patterns of drug use for older people

2.2 Dates & Duration of Study

Proposed Start Date: 01/02/2011 Proposed End Date: 01/09/2013

2.3 What are the primary location(s) for data collection? (e.g. classroom, participant's home, hospital/clinic, laboratory, place of convenience for participant – specify likely locations)

Secondary data will be used from state databases.	

2.4 State concisely the research aim(s) and objective(s), research question or specific hypothesis to be tested (as appropriate)

Aim:
Given the ageing population understanding the impact of this demographic shift on prescribing expenditures is important for preparing accurate forecasts. The main aim of this study is to explore the possible effect/influence of proximity to death on pharmaceutical health care expenditures for the older Irish population to enable more accurate predictions of future cost and ultimately inform policy makers

Objectives:

- To retrospectively quantify the extent to which proximity to death has influenced prescription drug consumption in an older Irish population.
- To examine the difference between future predictions for drug expenditures including and excluding proximity to death.
- To develop an appropriate economic model for future drug expenditure for use in an Irish context.
- To relatively compare the proximity to death effect in Irish prescribing expenditures with other jurisdictions.

Null hypothesis:
Proximity to death has no effect on pharmaceutical expenditure, i.e. there will be no difference in pharmaceutical costs between patients who have died and those who have lived.

2.5 Provide brief outline of the project (maximum 500 words, must include background, research approach, design, data collection methods, sampling – size of target population and if applicable indicate the method of sampling you intend to use and the sample size, data analysis and expected research outputs)

Background:
It is vital for expenditure forecasts and ultimately health policy to fully understand the relationship between age, death and health care expenditure (HCE). Studies frequently associate ageing with higher health care costs. The Irish population over 65 years of age is predicted to almost treble by 2041. Thus policy makers in Ireland are concerned about a health care cost explosion to accompany the anticipated population shift. Given the traditionally younger demographic in Ireland compared to the rest of the EU, population ageing may be even more pronounced. While age may be important

to an extent, several studies have looked at other determinants of health care costs, notably proximity to death (PTD). Studies suggest that proximity to death is a more important driver of health care costs than age alone. But there are limited studies of prescription expenditures. This is particularly relevant to Ireland where expenditures on prescription drugs have risen significantly in the last two decades. Gaining an understanding of what effects health care expenditure in this area will help policy makers to more accurately predict and control future spending.

Study design:
Retrospective case and control study based on a national cohort of secondary data from state prescribing and mortality databases.

Research collection methods:
The general medical card scheme (GMS) administered by the HSE Primary Care Reimbursement service (PCRS) provided free prescriptions to the over 70's in Ireland from 1st July 2001 to 31st December 2008. In this period there were between 317,374-351,853 people eligible for a medical card over 70 years of age with an estimated population coverage of over 97%. Therefore the PCRS is a national database for this age group providing details on dispensed medications for each individual on a monthly basis however it is an administrative database which does not document diagnosis, outcomes or mortality. To obtain date and place of death PCRS data from 2004 -2008 will be linked to CSO mortality data by an independent third party, providing an anonymised data set for this study. The HRB Primary Care Research Centre based at RCSI are beginning a data linking project using the CSO as a data processor and anonymiser to link mortality data and prescribing data for the over 70s for 2001-2008.

For patients who die in the community or nursing homes a case control study methodology will be used to firstly identify decedents as cases, then follow those clients through the PCRS and match them to survivors (controls) for the period 2005 – 2008.

New Zealand was considered an appropriate comparison country due to similarities in health care provision to the target population, population size and demographic. The New Zealand Health Information Service (NZHIS) maintains a Pharmacy Claims Data warehouse containing details on all prescriptions subsidized by the state. Anonymised individual dispensing records will be used for the study. An anonymised version of the unique health identifier (National health index NHI) will be used to link this prescribing information to mortality data maintained by Ministry of Health Data and Statistics unit. The period 2005 – 2008 will be examined for the population over 70 to again look at the possibility of a proximity to death effect. The population will also be grouped based on place of death.

Data analysis:
Patients' consumption of prescription drugs will be examined based on a survivor/decedent basis to calculate the average cost of prescriptions for a 12 month period. Data will be provided by data processors in MS access and Excel formats. STATA version 11 will be used to analysis data.

Research outputs:
The resulting data will be used to develop an economic forecasting model for Irish and New Zealand prescription expenditures taking proximity to death into account. This model will be used to consider alternative health policies to manage drug expenditures amongst the older population in Ireland.

2.6 List your exclusion/inclusion criteria for participant selection:

Inclusion criteria:
Clients of at least 70 years of age between 1st January 2005 and 31st December 2007 on the PCRS database.
Clients of at least 70 years of age between 1st January 2007 and 31st December 2009 on the New Zealand Ministry of Health database (PHARMS).

Exclusion criteria:
Clients who died in a hospital or hospice on the PCRS database.
Clients who died in a hospital or hospice on the New Zealand Ministry of Health database (PHARMS).

2.7 State number of participants to be selected and reasons for choosing this number:

This study will use a national cohort from Ireland and from New Zealand therefore a sample will not be taken. In a 12 month period all persons dying in the target population will be followed up and matched 2:1 to members of the target population who haven't died in the period.

2.8 If appropriate please identify how participants will be recruited and what steps you will take to access the sample, specifying details of people who will be contacted during this process:

Participants will not be directly contacted as anonymised data is to be used. The Irish data will be obtained from the HRB Primary Care Research Centre at RCSI in anonymised format. The New Zealand Ministry of Health will provide the data on New Zealand also in anonymised format.

CONSENT, CONFIDENTIALITY (INCLUDING DATA PROTECTION)

3.1 Will informed consent be obtained from the research participants?

YES [ ] NO [✓] If No, please give reason: Anonymised data will be used in this study.

If yes, please give details of **who** will take consent and **how** it will be done.
(Please attach a copy of letter, consent form (if required) and information leaflet. See guidelines on how to prepare these documents in Guidelines and adapt examples accordingly to suit your study and participants)

N/A

3.2 What is the time interval between giving information and seeking consent?
(It is recommended that a period of seven days be provided for reflection. If less than this, please justify).

N/A

3.3 Is deception involved at any stage of the study? If so, what are the justifications, how will it be done and what safeguards are in place for research participants?

There is no deception involved in any stage of the research process.

3.4 Will the participants be from any of the following groups (tick as appropriate)

	INVOLVEMENT	
	YES	NO
Children under 18 years of age		✓
Elderly	✓	
Adults with learning disabilities	✓	
Adults with communication difficulties	✓	
Adults with cognitive impairment (e.g. dementia)	✓	
Adults who are unconscious or severely incapacitated (though not terminally ill)	✓	
Adults with a terminal illness	✓	
Adults with mental illness	✓	
Adults in restricted environments (e.g. psychiatric facilities, nursing homes, etc.)	✓	
Members of the travelling community	✓	
Refugees / Asylum seekers	✓	
Prisoners	✓	
Young Offenders		✓
Those who could have been considered to have a particularly dependent relationship with the investigator, e.g. those in care homes, students		✓
Other groups who may be considered vulnerable (Please specify below)		✓

3.5 If participants are to be recruited from any of the potentially vulnerable groups listed above, please give details of:

(a) The way(s) in which the participants are considered vulnerable for the purpose of research participation: Participants will be recruited from national datasets and therefore may be members of the above mentioned vulnerable groups. However the target population are persons of 70 years or more not specifically from any of the other vulnerable groups listed above. Furthermore given the anonymised nature of the data, that has already been collected for another purpose, the participants will not be identifiable or contactable in anyway by the principle investigator.

(b) The extra steps taken to ensure that participants from any of these vulnerable groups are as fully informed as possible about the nature of their involvement: Due to the anonymised nature of the data participants can not be identified or contacted by the research team therefore no extra steps will be taken.

(c) Who will give consent (and/or assent as appropriate): Consent has been obtained from the data keepers, who have collected the data for administrative purposes. (See Appendix letters from CSO and New Zealand Ministry of Health)

(d) How consent will be obtained (e.g. will it be verbal, written or visually indicated?): Although informed consent is required when processing/storing identifiable information about living people, the deputy data commissoner proposed a model for dataset linkage in the absence of informed consent. (see letter Appendix 1) He proposed that a separate entity be created between the HRB Centre for Primary Care Research and the data controllers (i.e. people who hold the various datasets of interest). This entitiy is a data processor. The processor will take identifiable data from one data controller (e.g. HSE-PCRS) and link to another dataset (e.g. Mortality Register). The linked datasets will be stripped of any identifiable data before they are provided for use in the study. The unanonymised dataset will then be destroyed. The Central Statistics Office (CSO) has agreed to act as the data processor and has signed a contract to that effect with the HRB Centre for Primary care Research (Appendix 2). Furthermore, the Data Commissioner has approved the CSO as the data processer (Appendix 1). In the case of New Zealand data the Ministry for health has agreed to the use of their prescribing data which they will link to mortality data before providing the study with an anonymised dataset. (Appendix 3)

(e) When consent will be obtained: Consent has been sought from the data keepers before commencement of research.

(f) The arrangements that have been made to inform those responsible for the care of the research participants of their involvement in research: Anonymised data does not allow for identification of participants or their carers.

3.6 During and after the study, what steps will you take to protect the confidentiality of:

(a) Participant identities?
All data used will be anonymised by a third party before being accessed by principle investigator. The process outlined in 3.5 ensures the provision of anonymised datasets.

(b) Data collected (in particular, patient/client records if these are accessed)?
No patient records of individually identifying data will be stored or even sought.

(c) Hardcopy records?
No hardcopies will be made of data. All the data used in this study is anonymised data and will be stored on a stand alone encrypted hard drive which will be stored in a locked cabinet when not in use. The data will be analysed using STATA version 11 and there will be no need to maintain any hardcopies.

3.7 If your data is to be held electronically at any stage of the study, how will it be protected?

Data is anonymised and therefore presents limited confidentiality risk but it will be stored on a stand alone encrypted hard drive with no internet or network access which will be password protected and stored in a locked cabinet when not in use.

3.8 Is there any potential confidentiality issue through identification of the study location?

No. While place of death is recorded date of death is anonymised to within 3 months of the actual date of death. Making it difficult to identify any individual.

3.9 What other person(s) other than the researcher/team as listed will have access to the data collected and what steps will be done to protect confidentiality?

Under this study no other people will have access to individual anonymised data.

3.10 How will information be retained and/or disposed at the end of the study?

In line with TCD guidelines anonymised data will be retained for 5 years.

3.11 If the study involves audio taping interviews, you must allow the participant access to the transcript, if they so wish. This must be included in the Informed Consent Form and Participant Information Leaflet (if these forms are being used). Will the participant be given access to a transcript of the audio tape interview?

YES	NO	N/A	IF NO, PLEASE EXPLAIN WHY
		✓	

RISK, BENEFIT AND HARM

4.1 Describe any foreseeable risks to the participants?

Data is anonymised therefore there is no risk to participants from their inclusion in the study or any accidental disclosures.

4.2 Will individual or group interviews/questionnaires discuss any topics or issues that might be sensitive, embarrassing or upsetting, or is it possible that criminal or other disclosures requiring action could take place during the study (e.g. during interviews/group discussions, or use of screening tests for drugs)?

If Yes, give details of procedures in place to deal with these issues

N/A

4.3 What is the potential for benefit for research participants?

Research participants will not benefit directly from the research. But the research should help to inform healthcare policy and control future health care costs.

FUNDING & PAYMENT

5.1 **Outline sources of funding for the study if applicable and how you will manage any possible conflict between the funders of the study and the aims and results of the study if applicable?**

Funding for the principle investigator and any payments to cover the costs of data extraction are provided by a HRB scholarship under the HRBs PhD programme in Health Services Research.

5.2 **Will payment be made to research participants?**

YES	NONE OTHER THAN MINIMAL EXPENSES TO COVER TRAVEL COSTS ETC	NO
		✓

5.3 **If you answered YES to question 5.2, please specify for what purpose the payment will be made, the estimated amount per participant and the funding source for such payments (including travel reimbursements).**

No payments will be made to individuals, payment will be made to the data keepers only to go towards the cost of data extraction. (See Appendix 3 for New Zealand costs)

5.4 **Please disclose any interests outside of research funding (financial or otherwise) that may give rise to potential concerns regarding research integrity. How will you manage such concerns?**

None.

ETHICAL APPROVAL FROM OTHER COMMITTEES

Ethical approval from the HPM-CGH Research Ethics Committee, if granted, does not supersede any requirements that outside bodies may have that similar applications be made to local ethical approval bodies in advance of the study commencing.

6.1 Has ethical approval been sought from any other organisation(s) in which the study will take place?

YES [✓] (If you answer YES go to question 6.2)
NO [ ] (If you answer NO go to question 6.3)
N/A [ ] (If N/A please explain why below)

6.2 If you have answered YES to question 6.1, where has approval been sought from and has ethical approval been given? (Please supply a copy of relevant protocols and approval / exemption letters to the HPM-CGH Committee Secretary)

Name(s) of external ethics committee(s): RCSI Ethics Committee				
Approved	**Exempted from Review**	**Awaiting Reply**	**Rejected**	**IF EXEMPTED FROM REVIEW OR REJECTED, PLEASE EXPLAIN WHY**
		✓		Ethical approval has been sought to link PCRS data to GRO mortality data by the HRB Primary Care Research Centre.

6.3 If you have answered NO to question 6.1, is it your intention to seek ethical approval from the organisation(s) in which the study will take place?

YES	NO	IF NO, PLEASE EXPLAIN WHY
	✓	New Zealand Ministry of Health have stated their agreement subject to ethical approval in Ireland.

DECLARATION OF APPROVAL AND SIGNATURES

LEAD INVESTIGATOR
The lead investigator must provide all data below and sign:

LEAD INVESTIGATOR DECLARATION:

I confirm that the information provided in this protocol is correct, that I am not aware of any other ethical issue not addressed within this form and that I understand the obligations to and the rights of participants (particularly concerning their safety and welfare, the obligation to provide information sufficient to give informed consent, the obligation to respect confidentiality and all the obligations as set out in the **Declaration of Helsinki** (appendix attached) governing the conduct of research involving human participants) and/or other relevant guidelines (please refer to your Head of Department/School)

NAME: (BLOCK CAPITALS)	PATRICK MOORE		
STAFF / STUDENT I.D. No.	09128506		
SCHOOL / DEPARTMENT:	Health Policy & Management		
COURSE OF STUDY: (if appropriate)	PhD	**YEAR**	2
SIGNATURE:		**DATE:**	

E2 Ethics approval

UNIVERSITY OF DUBLIN
TRINITY COLLEGE

Telephone: +353 1 896 2201
Fax: +353 1 677 4956
Email: hsmsec@tcd.ie

Health Policy and Management
3-4 Foster Place
Trinity College
Dublin 2
Ireland

Patrick Moore
14 Coolamber Crescent,
Cobh,
Co. Cork

3rd February 2011

Re: The Importance of Proximity to Death in Modelling Future Drug Expenditures for Older People.

Application 01/2011/06

Dear Patrick,

Thank you for your submission of the above proposal to the HPM/CGH REC.

The REC has given ethical approval to the proposed study.

Yours sincerely,

Larkan

Dr Fiona Larkan
Member of the HPM/CGH REC

E3 Data agreement with Health Service Executive (HSE) Primary Care Reimbursement Service (PCRS)

Feidhmeannacht na Seirbhíse Sláinte
Health Service Executive

Primary Care Reimbursement Service

Data Usage Agreement

Date: 18-02-2013

Feidhmeannacht na Seirbhíse Sláinte
Health Service Executive

Data Usage Agreement

Please Use Block Capitals.

TRINITY COLLEGE DUBLIN
COLÁISTE NA TRÍONÓIDE, BAILE ÁTHA CLIATH

Organisation Details

Organization Name	Centre for Health Policy and Management at Trinity College Dublin
Office Address	3-4 Foster Place, Trinity College, Dublin 2, Ireland
Contact Number	+353 (0)1 896 2201
Web Site	www.medicine.tcd.ie/health_policy_management

Contact Details

These must refer to the individual representing the organization making the agreement.

First Name	Professor Charles	Surname	Normand
Position	Head of the Centre for Health Policy Management		
Office Address (If different)	n/a		
Email Address	normandc@tcd.ie ; hsmsec@tcd.ie		

Details of Data Usage Agreement

The Centre for Health Policy and Management at Trinity College Dublin (TCD) has requested data held by the HSE Primary Care Reimbursement Service ("PCRS") for the purpose of research into modelling the expenditures of future drug expenditures for older people. The data will be used by TCD to augment data provided already by PCRS to the National Centre for Pharmacoeconomics Ireland (NCPE). NCPE is linked with the Department of Pharmacology and Therapeutics, Trinity College Dublin for research purposes.

The PCRS agrees to provide TCD with the requested data for the purpose of this research only. The requested data will be supplied in accordance with all applicable provisions of data protection law, as set out in the Data Protection Acts 1988 and 2003 (the "DP Acts").

The onus rests with TCD to ensure that appropriate controls are in place in TCD infrastructure and processes so that any data provided by PCRS is securely controlled and used solely for the purpose provided and in accordance with the usage agreement in this document.

Declaration

Please note that this declaration is to be signed by the CEO (or equivalent) of the organization.

I am the authorised person representing TCD and agree with this data usage agreement.			
Signature		Date	
Name			

E4 Data agreement with Ministry of Health, New Zealand

Patrick Moore
Department of Health Policy & Management
3-4 Foster Place
Trinity College
Dublin 2
IRELAND

16th December 2010

Dear Patrick
I have outlined our understanding of your requirements and below.

Our Understanding of your Requirements
Data required from our National Collections:
Part 1 - Pharmaceutical data (PHARMS)
We will extract and format all records where:

- The dispensed date is between 1st January 2007 and 31st December 2009

And

- Where the patient is aged 70 or over at the date of dispense

The following fields will be provided:
- Dispensing Date
- Reimbursement Expenditure
- Supplier Expenditure
- Dose
- Daily Dose
- Quantity
- Frequency
- Therapeutic Group 1, 2, 3
- Provider Type (Prescriber)
- Provider DHB (Prescriber)
- Claimant DHB (Pharmacy)
- Encrypted NHI number
- Date of birth
- Age at dispensing
- Prioritised ethnicity
- Gender

Part 2 – Mortality data
Using the cohort of encrypted NHI's identified in part 1, we will extract and format all events in the mortality collection, where any date of death is recorded, providing the following fields:

- Master Encrypted NHI number
- Event Encrypted NHI number
- Date of death
- BDM age at death
- Place of death

Both datasets will be provided in MS Access.

Estimated expenditure excluding GST: $300.00

Data Conditions

1. The above expenditure estimate is valid for 60 days from the date of this correspondence.
2. By signing the acceptance below you agree that any information provided to you is for your internal use only and will not be made available to any other party without the prior consent of Analytical Services, Ministry of Health. The only exceptions to this are your research documents and statistical publications.
3. If you have any problems with this data please advise Analytical Services, Ministry of Health within 30 days of receipt of this data. Any changes or re-runs received after this time period may incur an additional charge.

Your Agreement

If you accept the above specification and conditions, please sign the Acceptance below and post or fax to Rob Hipkiss on (04) 816 2898 quoting Job # 2010-1116. If you would like to make some modifications to the above specification please note these on a separate sheet. We estimate that this will take 3 weeks from receiving written confirmation (excluding the 2 week Christmas period).

ACCEPTANCE OF SPECIFICATION, AND CONDITIONS
FOR JOB NUMBER: 2010-1116

Signed by : _____

Date: _____

Please contact me on (04) 816 2850 if you have any queries or require further information.

Yours sincerely

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Appendix F – Publications

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ORIGINAL RESEARCH ARTICLE

The Importance of Proximity to Death in Modelling Community Medication Expenditures for Older People: Evidence From New Zealand

Patrick V. Moore · Kathleen Bennett · Charles Normand

Abstract

Background Concerns about the long-term sustainability of health care expenditures (HCEs), particularly prescribing expenditures, has become an important policy issue in most developed countries. Previous studies suggest that proximity to death (PTD) has a significant effect on total HCEs, with its exclusion leading to an overestimation of likely growth. There are limited studies of pharmaceutical expenditures in which PTD is taken into account.

Objective This study presents an empirical analysis of public medication expenditure on older individuals in New Zealand (NZ). The aim of the study was to examine the individual effects of age and PTD using individual-level data.

Methods This study uses individual-level dispensing data from 2008/2009 covering the whole population of medication users aged 70 years or older and resident in NZ. A case–control methodology was used to examine individual cost and medication use for a 12-month period for decedents (cases) and survivors (controls). A random effects two-part model, with a Probit and generalized linear model (GLM) was used to explore the effect of age and PTD on expenditures.

Results The impact of PTD on prescription expenditure is not as dramatic as studies reporting on acute and/or long-term care. The 12-month decedent-to-survivor mean expenditure ratio was 1.95; 2.09 for males and 1.82 for females. The additional cost of dying in terms of prescription drugs decreases with age, with those who die at 90 years of age or older consuming fewer drugs on average and having a lower mean expenditure than those who died in their 70s and 80s. The following variables were found to have a decreasing effect on the mean monthly prescription expenditures: a reduction of 2.2 % for each additional year of age, 4.2 % being in the Maori ethnic group, and 7.8 % for Pacific Islanders. Increases in monthly expenditure were associated with being a decedent 32.1–62.6 % (depending on month), being of Asian origin 16.2 %, or being a male 12.6 %.

Conclusions Given the variance reported between survivors and decedents, future projections should include PTD in their models to improve accuracy. Policies targeted at reducing expenditures should not focus on age but on ensuring appropriate and cost-effective prescribing, particularly towards the end of life.

Key Points for Decision Makers

Despite prescription medications being the most common medical intervention, there is limited evidence on how proximity to death (PTD) and ageing affect prescribing expenditures for older people.

In terms of expenditure on prescription medications, PTD would appear to be a more important driver than ageing and should therefore be considered in any future expenditure projections

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1 Introduction and Background

Concerns about the long-term sustainability of increasing healthcare expenditure has become an important policy issue in most developed countries. Such growth is increasing pressure on government budgets, healthcare providers and individuals. Understanding drivers of this growth should enable us to more accurately forecast future expenditures and inform appropriate policies. The New Zealand (NZ) population over 65 years of age is predicted to more than double in the next two decades, similar to the majority of other developed countries [1, 2]. In addition, the working population (15–64 years) will only increase marginally [1, 2], or even decline [2], leading to an increase in the old-age dependency ratio of those aged 70 years or more to those aged 15–64 years [2, 3]. As a result of this demographic shift, a reduced proportion of the population will be supporting an increased older population. Policy makers in NZ and other developed countries with similar ageing populations are concerned about a significant health care cost increase associated with the anticipated population shift.

Studies frequently associate ageing with higher health care costs relative to the younger population [4, 5]. While age may be important to an extent, Fuchs [6] proposed the idea of proximity to death (PTD) having an important positive effect on health care costs. The premise being, the closer someone is to death, the more health care resources they use, resulting in higher health care expenditure (HCE). A higher rate of mortality in older age groups could be a confounder in the age–expenditure relationship. Several studies have presented evidence of increased healthcare expenditures for those close to death [7–11], while other studies have reported that ageing is more important [12], that PTD is minor in magnitude [12], or indeed a proxy for disability [13]. Van Baal and Wong [14] suggest that PTD may be a better predictor of expenditure than age as it includes both age and mortality risk. There remains general consensus on a PTD effect; what is contentious is the magnitude.

All these previous studies have focused on hospital or long-term care (LTC) expenditures, with little separate analysis of medication expenditures. Public spending on prescription medications is a significant commitment, accounting for approximately 18.7 % on average of total healthcare spending in OECD countries (12 % in NZ) [15]. Traditional predictions of future expenditure using prescription drugs have not taken into account the effect of PTD on individual expenditures [16]. One Danish study has examined medication expenditure and reported that the effect of ageing on future drug expenditures will be overestimated when not accounting for PTD [17]. Given the rising volume and costs of prescribing experienced in developed countries [18], gaining an understanding of what effects HCE in this area will help policy makers to more accurately predict and develop new policies to control future spending on prescription drugs. The aim of this study was to examine the association between age, PTD and medication expenditure by examining the expenditures of decedents and survivors.

2 Data and Methods

Prescribing and mortality data for individuals 70 years of age and older were extracted from the New Zealand Ministry of Health Pharmacy Claims Data warehouse for 2007–2010. Each prescription record contains a unique person identifier, date of birth, ethnic group, sex, age, date of dispensing and ingredient cost. Ingredient cost is the amount of NZ dollars the state has paid the pharmacist for the medication at 2008/2009 prices and does not include dispensing fees or co-payments made by individuals. Mortality records include a unique person identifier, the date of death, age at death and place of death. Unlike previous studies examining HCE that used samples, this study uses a national cohort.

The prescribing and mortality records were merged using an anonymized version of the unique health identifier (National Health Index) to create one dataset including survivors from 2008/2009 who lived beyond 2009 and those who died in 2009 (decedents). Prescribing data are over 2 years (2008–2009) in order to gain a full 12 months of observations for decedents. Survivors are those who were not in their last year of life in 2008. Mortality data was used from 2009 to identify decedents and to ensure survivors were not in their last year of life.

In order to gain an insight into the differences between decedents and non-decedents (survivors), a matched case–control study methodology was used. The mortality dataset was utilized to identify decedents in 2009 as cases, and match them 1:1, based on age, sex and ethnic group, to controls (survivors) from 2008. Data for survivors were calculated for the year January to December 2008. Coarsened exact matching (CEM) was used and involved three steps: first the matching variables were coarsened into broader groups (similar to creating a histogram by putting the variables into categories or bins), e.g. age into 5-year bands; second, data were exactly matched using the matching variables, which involved sorting the observations into strata, each with unique values of the matching variables; and third, strata containing only control units were discarded—strata with case and control units were retained. A detailed description of CEM and its merits over other matching methods is given by Iacus et al. [19]. The total population over 70 years of age considered in the

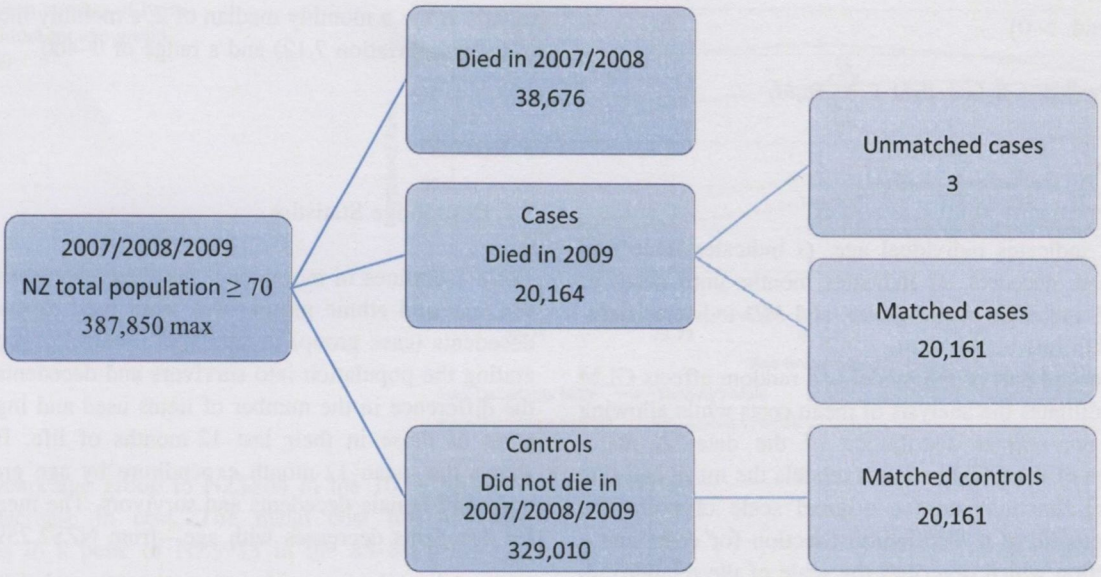

Fig. 1 Participant flowchart

study can be broken down into three groups, as shown in Fig. 1. A total of 20,161 decedents or cases were matched to 20,161 survivors or controls, with only three cases not matched, which was due to the very small numbers of older people in certain ethnic groups.

2.1 Econometric Specification

Exploratory data analysis was conducted, and was followed by an econometric data analysis that included a two-part model (TPM) which was estimated using a Probit and GLM; TPM was tested for cross-sectional dependence, and also for suitability for panel data framework (likelihood-ratio test and *F* test).

Monthly expenditure on prescription medicines has a spike at zero and, for those individuals who do incur expenditure, the distribution is right-skewed with a non-constant variance. This distribution is typical of health care cost data, therefore any regression methods must take account of the skewed data and focus on the population means [20, 21]. If an ordinary least squares (OLS) regression methodology was used with a log transformation to account for the skewness, the analysis would not be based on the population means but rather the mean on the log scale. This scale would measure geometric means and require a system of back-transformation for interpretation [21–24].

In the study population of 4.2 million, monthly expenditure observations of 1.6 million (38.7 %) have a zero value. The total monthly cost variable is heavily skewed (kurtosis = 2,371, skewness = 35) and has considerable non-normal kurtosis; if zero values are ignored the skewness is only slightly reduced, while kurtosis shows a relatively larger reduction (kurtosis = 1,651, skewness = 30)[1]. After careful consideration of the data using a modelling strategy, the best fitting was a TPM with a Probit model to first identify the likelihood of monthly expenditure by modelling a dictonomous dependent variable for whether or not there was an expenditure in a given month, and then a generalized linear model (GLM) was run conditional on the presence of non-zero prescribing expenditure to estimate the monthly medication expenditure of individuals. The TPM assumes that the zero values and the positive values are generated by different independent mechanisms. Duan et al. [25] and Jones [26] provide more in-depth discussion of the merits of the TPM.

Given the nature of the panel dataset, a large number of observations over a short 12-month period, we have not concerned ourselves with testing for stationarity. Two tests were conducted to ascertain if panel data methods were appropriate for the TPM as follows. A likelihood ratio test was conducted on the first part of the model to test for panel-level variance equal to zero, and concluded that there was no evidence of zero variance. An *F* test was conducted on the second part of the model to test if all individual specific effects were equal to zero; however, this hypothesis was rejected. The following Probit model was run to examine the effects of age, sex, PTD and ethnic group on the probability of using medication in a given month.

[1] Normal values: Kurtosis = 3, skewness = 0.

$$\Pr(\text{Expend.} > 0) = \propto + \beta_1 A + \beta_2 G + \beta_3 D + \sum_{t=1}^{23} m_t M_t + \sum_{e=1}^{5} \in_e E_e + \sum_{t=1}^{23} \gamma_t M_t D$$

where A indicates individual age, G indicates male sex, D indicates decedent, M indicates months until death or censor, E indicates ethnic group, and MD indicates decedent-month interaction term.

The second part of the model is a random effects GLM which facilitates the analysis of mean costs while allowing for the non-normal distribution of the data. A major advantage of the GLM is that it models the mean and link (variance) functions on the original scale of cost. The model consists of a distribution function for costs and a link function which describes the scale of the relationship of the covariates with the cost. The various GLMs were assessed using the modified Park's test following Manning and Mullahy [21], Akaike Information Criteria (AIC) [27], and normal probability plots of deviance residuals to ascertain a suitable distribution function. While there was no one test for assessing an appropriate link function, the following three tests were run for guidance: Pearson correlation test, Pregibon link test, and a modified Hosmer and Lemeshow test. The consistent result from these tests was an inverse gaussian distribution function and a log link.

$$\text{GLM(expenditure)} = \propto + \beta_1 + \beta_2 A + \beta_3 G + \beta_4 D + \sum_{t=1}^{11} m_t M_t + \sum_{e=1}^{5} \in_e E_e + \sum_{t=1}^{11} \gamma_t M_t * D$$

The use of a log-link function in the GLM means the coefficients act multiplicatively on the mean, and by taking the exponential they can be expressed as the percentage increase in the mean monthly medication expenditure per unit increase in the covariate [28]. A random effects model is more appropriate for the dataset over a fixed effects model for a number of reasons; principally, the loss of coefficients for time-invariant variables such as sex and ethnic group, and the exclusion of individuals with all zero or all positive monthly expenditures. A Breusch–Pagan lagrange multiplier (LM) will test for the appropriateness of a random effects model.

The original 26 codes for ethnic groups (see Appendix) were condensed into six, starting with the largest: European, not stated, Maori, Asian, Pacific Islander, and other. Age was split into four 5-year bands and a 90+ category for exploratory analysis, and maintained as a continuous variable for regression analysis. The variable for the number of items is a count of medicines dispensed in each month. It has a monthly median of 2, a monthly mean of 4 (standard deviation 7.12) and a range of 0–460.

3 Results

3.1 Descriptive Statistics

Table 1 outlines in more detail the three characteristics—sex, age and ethnic group—that were used to match the decedents (case group) to survivors (control group). Separating the population into survivors and decedents shows the difference in the number of items used and ingredient costs of those in their last 12 months of life. Figure 2 shows the mean 12-month expenditure by age group for male and female decedents and survivors. The mean costs for decedents decreases with age—from NZ$2,259 in the

Table 1 Characteristics of total population and decedents

Characteristic	Total population	Decedents
Sex [*n* (%)]		
Male	141,365 (43)	9,306 (46)
Female	187,632 (57)	10,855 (54)
Age, years		
Mean (SD)	76.5 (5.9)	81.9 (7.1)
Median (range)	75 (70–111)	82 (70–107)
Ethnicity [*n* (%)]		
European	267,594 (81.3)	17,503 (86.8)
Maori	12,673 (3.9)	1,112 (5.5)
Pacific Islanders	5,893 (1.8)	364 (1.8)
Asian	10,076 (3.1)	312 (1.6)
Other	880 (0.3)	30 (0.2)
Not stated	31,894 (9.7)	843 (4.2)

SD standard deviation

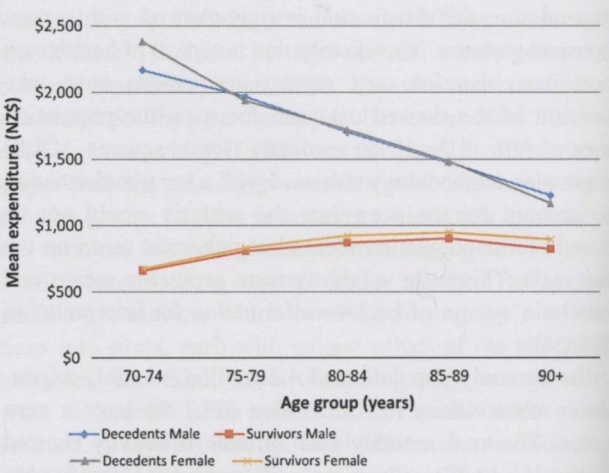

Fig. 2 Mean expenditure per individual by age group, 2008/2009

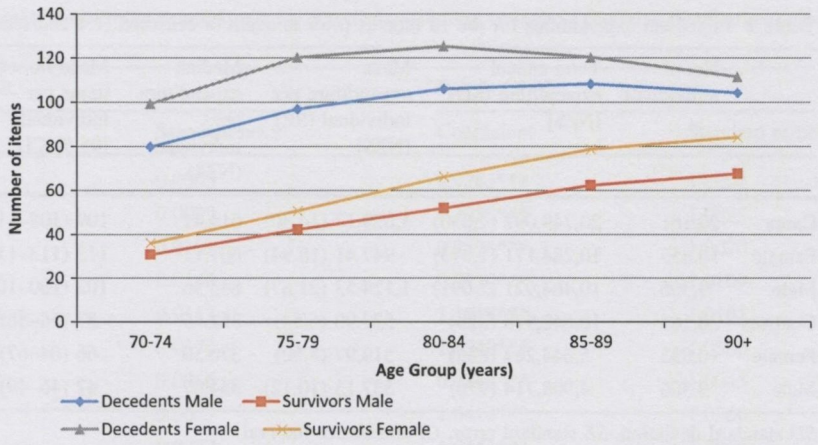

Fig. 3 Mean number of items per individual by age group, 2008/2009

70–75 years age group to NZ$864 in the 100+ group, a 62 % decrease in cost. The mean cost for survivors increases to a peak of NZ$933 in the 85–89 years age group and decreases thereafter. Figure 3 plots the mean number of items used in the 12-month period. The patterns in Figs. 2 and 3 show that while mean expenditure for decedents decreases with age group, mean items dispensed peaks in the 80–84 years age group and declines thereafter. This would suggest that older decedents use more and less expensive items on average than younger decedents. In contrast, the mean cost of survivors increases with age in line with the number of items, but again there is a change in the 85+ years age groups where the cost remains level but the number of items continues to increase. While at every age decedents use more items and have a higher mean expenditure than survivors, the additional 'cost of dying' decreases with age, as demonstrated in Fig. 4, which shows the decedent/survivor ratio narrowing as age group increases.

Results given in Table 2 show the matching of the case group of decedents taken from 2009 and followed back to 2008 with a matched control group from 2008. The mean expenditure ratio (decedents/survivors) in Table 2 shows that decedents are, on average, 1.95-fold more costly than survivors, which ranges from 2.09 for males to 1.82 for females. This ratio declines with age, as seen in Fig. 4. The all-age mean cost per item is similar for both groups, while the number of items per individual is 1.95-fold more for decedents.

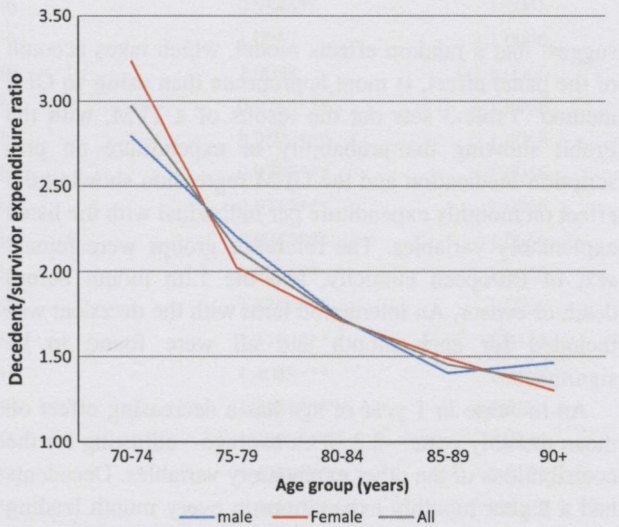

Fig. 4 Decedent/survivor cost ratio by age group

3.2 Medication Use

A comparison of the medications dispensed to decedents in the 12th month from death and in the last month before death shows, as expected, a significant increase in medications over the 12-month period. In the last month of life, over double the number of items were dispensed to the decedents in comparison to the matched survivors. In the last month of life there is a significant increase in use across most therapeutic groups compared with the 12th month, the largest being the nervous system (N)[2] with an overall 3.8-fold rise driven by large absolute increases in analgesics (N02) [4.6-fold], anti-nausea and vertigo agents (N07C and A04) [12.9-fold], and antipsychotic (N05A) [5.4-fold], sedative (N05C) [3.2-fold], antiepilepsy (N03) [4-fold] and antidepressant (N06A) [4-fold] medications. While medication use increases, on average, in the last month before death, it does not show a dramatic rise or pattern in the preceding months.

3.3 Regression Analysis

A Breusch–Pagan LM test rejected a null hypothesis of variances across individuals being zero. This would

[2] Medications are reported using the WHO Anatomical Therapeutic Chemical (ATC) system.

Table 2 Ingredient expenditures for the 12 months prior to death or censored (1:1 coarsened exact matching on age, sex, ethnic group)

	No. of individuals	Total annual expenditure (SD) [NZ$]	Mean expenditure per individual (SE) [NZ$]	Median expenditure per individual (NZ$)	Mean no. of items per individual (95 % CI)	Average expenditure per prescription (NZ$)	Mean expenditure ratio (decedents/ survivors)	Median expenditure ratio (decedents/ survivors)
Cases	20,161	20,749,092 (2,030)	1,029.17 (14.30)	614.41	109 (108–110)	9.47	1.95	1.74
Female	10,855	10,284,171 (1,973)	947.41 (18.94)	601.11	115 (113–117)	8.23	1.82	1.62
Male	9,306	10,464,921 (2,091)	1,124.53 (21.67)	633.96	102 (100–104)	11.19	2.09	1.89
Controls	20,161	10,642,978 (928)	527.90 (6.54)	352.45	57 (56–58)	9.35		
Female	10,855	5,644,264 (885)	519.97 (8.50)	370.50	66 (64–67)	8.06		
Male	9,306	4,998,714 (976)	537.15 (10.12)	334.67	47 (46–49)	11.48		

SD standard deviation, *SE* standard error, *CI* confidence interval

suggest that a random effects model, which takes account of the panel effect, is more appropriate than using an OLS method. Table 3 sets out the results of a TPM, with the Probit showing the probability of expenditure on prescription medication and the GLM regression showing the effect on monthly expenditure per individual with the listed explanatory variables. The reference groups were female sex, of European ethnicity, and the 12th month before death or censor. An interaction term with the decedent was included for each month and all were found to be significant.

An increase in 1 year of age has a decreasing effect on mean monthly costs—2.2 % on average—adjusting for the contributions of the other explanatory variables. Decedents had a higher monthly expenditure in every month leading up to death. In terms of ethnic groups, those of Asian origin had considerably higher monthly expenditures, while Maori and Pacific Islanders had lower expenditures. Only Maori had an increased likelihood of medication use, as seen in part 1 of the model.

Part 1 of the model shows that, with 12 months prior to death as the baseline, there is a constant upward trend in the likelihood of medication use in months 11 to 1. The proximity effect extends at least 12 months prior to death.

Monthly expenditures for individuals who are dispensed a medication show no consistent increasing trend prior to death, other than those who die being consistently 1.3- to 1.4-fold greater than survivors, with a more noted increase in the last month of life to 1.6-fold greater. Even when the decedent time span is expanded to 24 months, there is no convergence or surge in use towards the end of life, apart from the last month (data not shown). However, on average, decedents use twice as many items as survivors over the whole period, and are more likely than survivors to have used medication in any given month.

4 Discussion

This study provides evidence of the importance of accounting for PTD rather than ageing alone for expenditure on prescription drugs in an older community-based population. In fact, the regression results show that ageing has a negative effect on prescription expenditure. By comparing prescription expenditures for decedents in the last 12 months of life with a similar group of survivors, we can see that decedents cost, on average, between 1.82- and 2.09-fold more. Similar to other studies, mean HCE per annum rises after 70 years of age, with a peak in the 80–84 years age group and a decline thereafter in the total population and the survivors control group [11, 29]. The mean number of items used by survivors in the 12-month period increases linearly with age but at a greater rate than expenditure, which suggests that while survivors are using more items in these older groups, they are relatively cheaper medications. The increases in mean items and cost of survivors with age may be due to increasing rates of chronic illness as the number of people over 70 years of age reporting one or more chronic illness increases with age [30]. In contrast, descendants demonstrate a dramatic decrease in expenditure which is combined with a more staid increase in the mean number of items. This is in line with other HCE studies which have reported a decrease in the 'cost of dying' with age [31, 32].

The study adds to the existing literature on PTD by providing evidence on patterns of prescribing costs. This study reports a similar magnitude for the PTD effect as a Danish study [17] which reported a mean cost ratio of 1.7 for those aged 75 years or more. The Danish study also reports that ageing will increase future drug expenditures; however, taking PTD into account, they conclude that the increase will be relatively small [17]. In contrast, a Dutch study examining macro-level data suggests that accounting for PTD may not simply reduce future projections of HCE

Table 3 Probit and generalized linear model of monthly prescribing expenditures for decedents assuming an inverse Gaussian distribution with a log link

Covariates	Part 1: Probit		Part 2: GLM	
	Coefficient	Standard error	Coefficient	Standard error
Age	0.0470***	0.0003	0.9783***	1.0002
Male	−0.2342***	0.0039	1.1259***	1.0027
Maori	0.0481***	0.0101	0.9576***	1.0070
Pacific Islander	−0.4024***	0.0146	0.9220***	1.0109
Asian	−0.5673***	0.0113	1.1618***	1.0101
Other	−0.2762***	0.0376	1.0949***	1.0300
Not stated	−0.4657***	0.0066	0.7838***	1.0045
1 month	0.2490***	0.0037	1.0418***	1.0066
2 months	0.2383***	0.0037	1.0341***	1.0065
3 months	0.1077***	0.0036	0.9848**	1.0065
4 months	0.1402***	0.0036	1.0017	1.0066
5 months	0.1187	0.0036	1.0098	1.0066
6 months	0.0097***	0.0036	0.9754***	1.0066
7 months	0.0644***	0.0036	0.9693***	1.0065
8 months	0.0272***	0.0036	0.9787***	1.0066
9 months	0.0065*	0.0036	0.9715***	1.0066
10 months	−0.0641***	0.0036	0.9345***	1.0066
11 months	0.0142	0.0036	0.9836**	1.0066
Decedent* 1 month	0.8849***	0.0168	1.6260***	1.0200
Decedent* 2 months	0.8467***	0.0167	1.3774***	1.0185
Decedent* 3 months	0.8269***	0.0161	1.4068***	1.0185
Decedent* 4 months	0.7046***	0.0158	1.3481***	1.0184
Decedent* 5 months	0.6400***	0.0155	1.3205***	1.0184
Decedent* 6 months	0.7008***	0.0153	1.4282***	1.0189
Decedent* 7 months	0.5749***	0.0150	1.4185***	1.0188
Decedent* 8 months	0.5739***	0.0149	1.3882***	1.0188
Decedent* 9 months	0.5478***	0.0148	1.3856***	1.0188
Decedent* 10 months	0.5708***	0.0146	1.4300***	1.0188
Decedent* 11 months	0.4561***	0.0145	1.3586***	1.0189
Constant	−3.0798***	0.0263	391.4***	1.0181
No. of observations	4,190,088		2,568,273	
	Log likelihood		−16,255,102	
	AIC		12.6584	

GLM generalized linear model, *AIC* Akaike Information Criteria, * indicates significance at the 90 % level, ** indicates significance at the 95 % level, *** indicates significance at the 99 % level

due to growth from other unidentified causes which were not included in previous modelling attempts [14].

Similar to a Spanish study [33], we found age to have a positive influence on the probability of pharmaceutical expenditure. In contrast, the Spanish study additionally found a positive association between age and the amount of expenditure, but was focused on the prescribing of individual doctors and excluded PTD. Studies looking at total HCEs have reported increasing expenditures with age [12, 34], with some attributing it to PTD [10, 31, 35]. This study has focused on prescribing expenditures and found that they do not steadily increase with age for the older population, even before accounting for PTD. Instead, they show a bell curve peaking at 80–85 years of age and declining thereafter. The effect of PTD on prescription expenditures is less than the PTD effect reported in studies looking at total HCE and LTC. This may, in part, be due to the high uptake of hospital and LTC services at the end of life, as well as the high volume of preventative medication used by survivors.

The pattern of decreasing cost ratio of decedents to survivors shown in Fig. 4 is similar to other studies [31, 34]. This suggests that, in terms of medication, the cost of dying relative to surviving actually decreases with age. Two other explanatory factors worth considering are the numbers of individuals in these age groups who die in hospitals or LTC facilities, and the fact that those who do remain living in the community are potentially healthier.

The fact that, on average, decedents have higher use and expenditure in the 12th month, and even as far out as the 24th month, before death suggests that increased medication use may be a sign of a health crisis and subsequent mortality.

While this study reports mean expenditure for decedents to be double that of survivors, regression models show a smaller increase between the groups for each of the 12 months before death. This result does not demonstrate a clear pattern of increasing cost with PTD but that expenditure for decedents is consistently higher, with a peak in the last month prior to death. The data suggest that there are other factors driving the higher drug expenditures amongst the older population in addition to PTD. More complex, country-specific issues such as the agreements and bargaining power of the public health system and patent expiry dates should be considered in addition to PTD. The data demonstrate that the proximity of death effect persists beyond the 12-month period studied herein. Previous studies have suggested a distance of up to 6 years for the PTD effect [11].

A previous study looking at the effect of PTD, age and disability on LTC expenditures reported that PTD was acting as a proxy for disability [13]. While this current study lacks outcome or disability data, it is difficult to argue that disability increases prescription expenditure more than PTD in community prescribing.

In terms of differences in expenditures by ethnic minorities, it could be hypothesized that Maori and Pacific Islanders who are in the older age groups are the healthiest of their respective groups, based on evidence that suggests members of these ethnic groups are more likely to have poorer health and lower life expectancies [36, 37]. An alternative hypothesis for these lower expenditures could be reduced uptake of medications or impaired access by these ethnic groups [38, 39].

Life expectancies are increasing in general and evidence suggests that these additional years are being lived in good health [40, 41]. In order to use these results to more accurately model future data, we need to consider increases and convergences in life expectancies. If current trends in life expectancy continue, the average 70-year-old in 2059 will be further from death than a 70-year-old in 2008. As PTD results in increased prescribing costs in all age groups, it is important to account for the shift in mortality rates in each age group which increasing life expectancies will bring. Converging life expectancies between men and woman (woman outlived men by some 3.7 years in 2010 [42]) would mean couples will be potentially living together longer, which should have a positive effect on health outcomes and ultimately a negative effect on HCEs.

The implications of these findings do not just apply to policies to control future expenditures. Cost-effectiveness analysis relies on future projections which often do not take into account PTD, leading to an overestimation of the cost-effectiveness ratio [43, 44].

4.1 Strengths and Limitations

This study focuses on a key expenditure component of total health care costs—examining the services that make up total health care costs is important to fully understand the effect of ageing [31]. Some of the studies discussed in this article used potentially non-representative samples, such as those taken from private health insurance or hospital datasets. The strength of this study lies in its use of population data which is automatically collected by the health care system every time a prescription is dispensed, therefore there is no recall or prestige biases involved and no sampling issues.

A limitation of the study is the possible confounding from the large numbers of older people who die in hospitals or LTC facilities, with those living in the community at older age cohorts the potentially healthier of their age group. Estimates suggest that NZ has a higher proportion of its older population in LTC than most OECD countries, with estimates of up to 9.2 % [45]. Further evidence for this hypothesis is also present in the decline of medication use with increasing age in the older groups. Based on previous hospital-based studies [29, 31, 46] which included pharmaceuticals as part of total HCE, we would expect the inclusion of such medications to increase the expenditure gap between decedents and survivors.

According to population estimates, the population over 70 years of age was 371,950 for 2008 [47], therefore the prescribing dataset used in this study is potentially missing 3.5 % of the total population in this age group. This potential 3.5 % would comprise of people over 70 years of age who did not die or did not receive any prescription medicines in 2008/2009. In addition, the dataset lacks information on potential confounders, such as medical history for both decedent and survivor groups, e.g. diagnoses, severity of any illness, disability, smoking, alcohol, etc. The study does not contain any information on the use of over-the-counter (OTC) medicines, which may or may not have an impact on the cost of public prescribing. It is likely that the future burden of morbidity and patterns of medication use will be altered by new and improved

preventative and curative treatments which may be developed, or price reductions, patent expiries and the lifestyle changes of individuals.

5 Conclusions

This study primarily investigated the relationship between expenditure on prescription medication, PTD and age, using a population of 349,174 individuals aged 70 years or older, over a 12-month period. The analysis found that the additional 'cost of dying' is, on average, twice that of a similar group of survivors. There is a notable increase in decedent prescribing during the last month of life; while all other months are consistently higher, they do not demonstrate an increasing pattern towards death. Regression analysis suggests that while age has a positive influence on the probability of expenditure, it has a negative effect on monthly expenditures in line with exploratory analysis which shows lower monthly expenditures for the oldest age groups. The results show a positive effect of PTD on prescription expenditure in line with previous evidence. Compared with studies examining LTC and acute care costs, the magnitude of the effect of PTD is considerably lower. Given the variance between survivors and decedents, future projections should include PTD in their models. Policies aimed at reducing expenditures should not focus on age but on ensuring appropriate and cost-effective prescribing, especially towards the end of life.

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Author contributions Patrick V. Moore designed the study, conducted the data analysis and prepared the manuscript. Kathleen Bennett was involved in the study design and preparation of the manuscript. Charles Normand was involved in the study design and review of the manuscript. All authors performed a critical review of the manuscript content and approved its final version. Patrick V. Moore acts as guarantor of the overall content of this article.

Appendix

See Table 4.

Table 4 Condensed ethnic groups

Original ethnic group	Original code	Condensed ethnic group
European not further defined	10	European
New Zealand European	11	
Other European	12	
New Zealand Maori	21	Maori
Cook Island Maori	32	
Pacific Islander not further defined	30	Pacific Islander
Samoan	31	
Tongan	33	
Niuean	34	
Tokelauan	45	
Fijian	36	
Other Pacific Islander (not listed)	37	
Asian not further defined	40	Asian
South-east Asian	41	
Chinese	42	
Indian	43	
Other Asian	44	
Middle Eastern	51	Other
Latin American/Hispanic	52	
African	53	
Other	54/61	
Not known/not stated	94/99	Not stated/known
Refused to answer	95	
Response unidentifiable	97	

References

1. Statistics New Zealand. National population projections: 2009 (base)–2061. Wellington: Statistics New Zealand. 2009. Available from: http://www.stats.govt.nz/browse_for_stats/population/estimates_and_projections/NationalPopulationProjections_HOTP09base-61.aspx. Accessed 27 Oct 2012.
2. Labour force statistics: population projections, OECD employment and labour market statistics (database). 2011. Available from: http://www.oecd-ilibrary.org/employment/data/labour-force-statistics/historical-population-data-and-projections_data-00538-en;jsessionid=ba3jrdodrsu7f.delta?isPartOf=/content/datacollection/lfs-lfs-data-en. Accessed 21 May 2013.
3. World population prospects: the 2012 revision. United Nations. 2013. Available from: http://esa.un.org/unpd/wpp/index.htm. Accessed 1 Oct 2013.
4. Miller T. Increasing longevity and medicare expenditures. Demography. 2001;38(2):215–26.
5. Dormont B, Grignon M, Huber H. Health expenditure growth: reassessing the threat of ageing. Health Econ. 2006;15(9):947–63.
6. Fuchs VR. "Though much is taken": reflections on ageing, health and medical care. Milbank Mem Fund Q Health Soc. 1984;61(1):143–66.
7. Scitovsky AA. "The high cost of dying" revisited. Milbank Q. 1994;72(4):561–91.
8. Comas-Herrera A, Wittenberg R, Pickard L, Knapp M. Cognitive impairment in older people: future demand for long-term care services and the associated costs. Int J Geriatr Psychiatry. 2007;22:1037–45.
9. Werblow A, Felder S, Zweifel P. Population ageing and health care expenditure: a school of 'red herrings'? Health Econ. 2007;16(10):1109–26.
10. Zweifel P, Felder S, Meiers M. Ageing of population and health care expenditure: a red herring? Health Econ. 1999;8(6):485–96.
11. Seshamani M, Gray AM. A longitudinal study of the effects of age and time to death on hospital costs. J Health Econ. 2004;23(2):217–35.
12. Colombier C, Weber W. Projecting health-care expenditure for Switzerland: further evidence against the 'red-herring' hypothesis. Int J Health Plan Manage. 2011;26(3):246–63. doi:10.1002/hpm.1068.
13. de Meijer C, Koopmanschap M, d' Uva TB, van Doorslaer E. Determinants of long-term care spending: age, time to death or disability? J Health Econ. 2011;30(2):425–38.
14. van Baal PH, Wong A. Time to death and the forecasting of macro-level health care expenditures: some further considerations. J Health Econ. 2012;31(6):876–87.
15. Healthdata. Organisation for Economic Co-operation and Development. 2013. Accessed 30 Sep 2013.
16. Seshamani M, Gray AM. Time to death and health expenditure: an improved model for the impact of demographic change on health care costs. Age Ageing. 2004;33(6):556–61.
17. Kildemoes H, Christiansen T, Gyrd-Hansen D. The impact of population ageing on future Danish drug expenditure. Health Policy. 2006;75:298–311.
18. OECD. Health at a glance 2011: OECD indicators. 2011. Available from: http://www.oecd.org/els/health-systems/health-at-a-glance.htm.
19. Iacus SM, King G, Porro G. Multivariate matching methods that are monotonic imbalance bounding. J Am Stat Assoc. 2011;106(493):345–61.
20. Blough DK, Madden CW, Hornbrook MC. Modeling risk using generalized linear models. J Health Econ. 1999;18(2):153–71.
21. Manning W, Mullahy J. Estimating log models: to transform or not to transform? J Health Econ. 2001;20(4):461–94.
22. Duan N. Smearing estimate: a non-parametric retransformation method. J Am Stat Assoc. 1983;78:605–10.
23. Barber J, Thompson S. Analysis and interpretation of cost data in randomised controlled trials: review of published studies. BMJ. 1998;317:1195–200.
24. Barber J, Thompson S. Analysis of cost data in randomised controlled trials: an application of the non-parametric bootstrap. Med Stat. 2000;19(23):3219–36.
25. Duan N, Manning WG, Morris CN, Newhouse JP. A comparison of alternative models of the demand for medical care. J Bus Econ Stat. 1983;1(2):115–26.
26. Jones AM. Health econometrics. In: Culyer A, Newhouse J, editors. Handbook of health economics. Amsterdam: Elsevier; 2000.
27. Akaike H. Information theory and an extension of the maximum likelihood principle. In: Petrov BN, Csaki F, editors. Second international symposium on information theory. Budapest: Akademiai Kiado; 1973: pp. 267–281.
28. Barber J, Thompson S. Multiple regression of cost data: use of generalised linear models. J Health Serv Res Policy. 2004;9(4):197–204. doi:10.1258/1355819042250249.
29. Bjørner TB, Arnberg S. Terminal costs, improved life expectancy and future public health expenditure. Int J Health Care Finance Econ. 2012;12:129–43.
30. Aspin C, Jowsey T, Glasgow N, Dugdale P, Nolte E, O'Hallahan J, et al. Health policy responses to rising rates of multi-morbid chronic illness in Australia and New Zealand. Aust NZ J Public Health. 2010;34(4):386–93.
31. McGrail K, Green B, Barer ML, Evans RG, Hertzman C, Normand C. Age, costs of acute and long-term care and proximity to death: evidence for 1987–88 and 1994–95 in British Columbia. Age Ageing. 2000;29(3):249–53.
32. Lubitz J, Beebe J, Baker C. Longevity and medicare expenditures. N Engl J Med. 1995;332(15):999–1002.
33. Angulo AM, Barberán R, Egea P, Mur J. An analysis of health expenditure on a microdata population basis. Econ Model. 2011;28:169–80.
34. Yang Z, Norton EC, Stearns SC. Longevity and health care expenditures: the real reasons older people spend more. J Gerontol B Psychol Sci Soc Sci. 2003;58(1):S2–10.
35. Felder S, Werblow A, Zweifel P. Do red herrings swim in circles? Controlling for the endogeneity of time to death. J Health Econ. 2010;29(2):205–12.
36. Blakely T, Fawcett J, Atkinson J, Tobias M, Cheung J. Decades of disparity II: socioeconomic mortality trends in New Zealand, 1981–1999. Wellington: Ministry of Health; 2005.
37. Ministry of health. Tatau Kura Tangata: Health of Older Maori Chart Book 2011 Wellington: Ministry of Health (NZ); 2011.
38. McNaughton H, Weatherall M, McPherson K, Taylor W, Harwood M. The comparability of resource utilisation for Europeans and non-Europeans following stroke in New Zealand. NZ Med J. 2002;115(1149):101–3.
39. Scott K, Marwick J, Crampton P. Utilization of general practitioner services in New Zealand and its relationship with income, ethnicity and government subsidy. Health Serv Manage Res. 2003;16(1):45–55.
40. Crimmins EM, Saito Y, Ingegnenri D. Trends in disability-free life expectancy in the United States. Popul Dev Rev. 1997;23:555–72.
41. Waidmann TA, Liu K. Disability trends among elderly persons and implications for the future. J Gerontol. 2000;55:S298–307.
42. Statistics New Zealand. New Zealand period life tables: 2010–12. Wellington: Statistics New Zealand; 2013. Available from: http://www.stats.govt.nz/browse_for_stats/health/life_expectancy/NZLifeTables_HOTP10-12.aspx. Accessed 20 Apr 2013.

43. Gandjour A, Lauterbach KW. Does prevention save costs? Considering deferral of the expensive last year of life. J Health Econ. 2005;24(4):715–24.
44. Gandjour A. Aging diseases: do they prevent preventive health care from saving costs? Health Econ. 2009;18(3):355–62.
45. Broad JB, Ashton T, Lumley T, Connolly MJ. Reports of the proportion of older people living in long-term care: a cautionary tale from New Zealand. Aust NZ J Public Health. 2013;27(3):264–71.
46. Spillman BC, Lubitz J. The effect of longevity on spending for acute and long-term care. N Engl J Med. 2000;342(19):1409–15.
47. Statistics New Zealand. National population estimates 2008. Wellington: Statistics New Zealand; 2011. Available from: http://www.stats.govt.nz/browse_for_stats/population/estimates_and_projections/national-pop-estimates.aspx. Accessed 21 Jun 2011.

Bibliography

2003. Medicinal Products (Prescription and Control of Supply) Regulations.

2013a. Eurostat (database). European Commission (Eurostat).

2013b. Health (Pricing and Supply of Medical Goods) Act.

AKAIKE, H. 1973. Information theory and an extension of the maximum likelihood principle. *In:* PETROV, B. N. & CSAKI, F. (eds.) *Second International Symposium on Information Theory.* Budapest: Akademiai Kiado.

AKERLOF, G. 1970. The market for 'Lemons':Qualitative uncertainty and the market mechanism. *Quarterly Journal of Economics,* 84, 488-500.

ANDERSON, G. F. & HUSSEY, P. S. 2000. Population aging: a comparison among industrialized countries. *Health Aff (Millwood),* 19, 191-203.

ANGULO, A. M., BARBERÁN, R., EGEA, P. & MUR, J. 2011. An analysis of health expenditure on a microdata population basis. *Economic Modelling,* 28, 169-180.

ARROW, K. J. 1963. Uncertainty and the welfare economics of medical care. *American Economic Review,* 53, 941-973.

ASPIN, C., JOWSEY, T., GLASGOW, N., DUGDALE, P., NOLTE, E., O'HALLAHAN, J. & LEEDER, S. 2010. Health policy responses to rsing rates of multi-morbid chronic illness in Australia and New Zealand. *Australian and New Zealand Journal of Public Health,* 34, 386-393.

ATELLA, V., PERACCHI, F., DEPALO, D. & ROSSETTI, C. 2006. Drug compliance, co-payment and health outcomes: evidence from a panel of Italian patients. *Health Econ,* 15, 875-92.

BALTAGI, B. 2010. *Econometric Analysis of Panel Data,* Chichester, John Wiley & Sons Ltd.

BARBER, J. & THOMPSON, S. 1998. Analysis and interpretation of cost data in randomised controlled trials: review of published studies. *BMJ,* 1195–1200.

BARBER, J. & THOMPSON, S. 2000. Analysis of cost data in randomised controlled trials: an application of the non-parametric bootstrap. *Medical Statistics,* 19, 3219–3236.

BARBER, J. & THOMPSON, S. 2004. Multiple regression of cost data: use of generalised linear models. *J Health Serv Res Policy,* 9, 197-204.

BARRETT, A., BURKE, H., CRONIN, H., HICKEY, A., KAMIYA, Y., KENNY, R. A., LAYTE, R., MATY, S., MCGEE, H., MORGAN, K., MOSCA, I., NORMAND, C., O'REGAN, C., O' SULLIVAN, V., SAVVA, G., SOFRONIOU, N., TIMONEN, V. & WHELAN, B. (eds.) 2011. *Fifty Plus in Ireland 2011: First results from the Irish Longitudinal Study on Ageing (TILDA).*

BARRETT, A., KEARNEY, I. & O'BRIEN, M. 2008. Quarterly Economic Commentary, Summer 2008. Dublin: Economic and Social Research Institute (ESRI).

BARROS, P. 1998. The black box of health care expenditure growth determinants. *Health Economics,* 7, 533-44.

BARRY, M., BENNETT, K., BRICK, A., MORGENROTH, E., NORMAND, C., O'REILLY, J., THOMAS, S., TILSON, L., WILEY, M. & WREN, M.-A. 2009. Projecting the Impact of Demographic Change on the Demand for and Delivery of Health Care in Ireland. *In:* LAYTE, R. (ed.). Dublin: ESRI.

BASU, A., ARONDEKAR, B. V. & RATHOUZ, P. J. 2006. Scale of interest versus scale of estimation :comparing alternative estimators for the incremental costs of comorbidity. *Health Economics,* 15, 1091 - 1107.

BASU, A. & MANNING, W. G. 2009. Issues for the next generation of health care cost analyses. *Med Care,* 47, S109-14.

BASU, A., MANNING, W. G. & MULLAHY, J. 2004. Comparing alternative models: log vs Cox proportional hazard? *Health Econ,* 13, 749-65.

BECH, M., CHRISTIANSEN, T., KHOMAN, E., LAURIDSEN, J. & WEALE, M. 2011. Ageing and health care expenditure in EU-15. *Eur J Health Econ,* 12, 469-78.

BEGG, D., FISCHER, S. & DORNBUSCH, R. 2003. *Economics,* Maidenhead, UK, McGrawHill.

BELOTTI, F., DEB, P., MANNING, W. G. & NORTON, E. C. 2012. tpm: Estimating two-part models. *The Stata Journal,* 44.

BENNETT, K., BARRY, M. & TILSON, L. 2009. Pharmaceuticals. *In:* LAYTE, R. (ed.) *Projecting the Impact of Demographic Change on the Demand for and Delivery of Health Care in Ireland.* Dublin: ESRI.

BJØRNER, T. B. & ARNBERG, S. 2012. Terminal costs, improved life expectancy and future public health expenditure. *International Journal of Health Care Finance and Economics,* 12, 129-143.

BLAKELY, T., FAWCETT J, ATKINSON, J., TOBIAS, M. & CHEUNG, J. 2005. Decades of disparity II: Socioeconomic mortality trends in New Zealand, 1981-1999. Wellington: Ministry of Health

BLOUGH, D. & RAMSEY, S. 2000. Using generalized linear models to assess medical care costs. *Health services and Outcomes Research Methodology,* 1, 185-202.

BLOUGH, D. K., MADDEN, C. W. & HORNBROOK, M. C. 1999. Modeling risk using generalized linear models. *Journal of Health Economics,* 18, 153-171.

BOCK, R. D. 1975. *Multivariate Statistical Methods in Behavioral Research,* New York, McGraw-Hill.

BOERMA, T., EOZENOU, P., EVANS, D., EVANS, T., KIENY, M. P. & WAGSTAFF, A. 2014. Monitoring Progress towards Universal Health Coverage at Country and Global Levels. *PLoS Med,* 11, e1001731.

BOWERS, N. L., GERBER, H., U., HICKMAN, J. C., JONES, D. A. & NESBITT, C. J. 1997. *Actuarial Mathematics,* Schaumburg, IL., Society of Actuaries.

BOX, G. E. P. & DRAPER, N. R. 1987. *Empirical Model Building and Response Surfaces,* New York, John Wiley & Sons.

BREUSCH, T. S. & PAGAN, A. R. 1979. Simple test for heteroscedasticity and random coefficient variation. *Econometrica,* 47, 1287-1294.

BREYER, F. & FELDER, S. 2006. Life expectancy and health care expenditures: a new calculation for Germany using the costs of dying. *Health Policy,* 75, 178-86.

BRICK, A., GORECKI, P. K. & NOLAN, A. 2013. Ireland:Prescribing Prices, Prescribing Practices and Usage of Generics in a comparative context. Dublin: ESRI.

BRIGGS, A. & GRAY, A. 1998. The distribution of health care costs and their statistical analysis for economic evaluation. *J Health Serv Res Policy,* 3, 233-45.

BROAD, J. B., ASHTON, T., LUMLEY, T. & CONNOLLY, M. J. 2013. Reports of the proportion of older people living in long-term care: a cautionary tale from New Zealand. *Australian and New Zealand Journal of Public Health,* 27, 264-271.

BROWN, M. 1987. Caring for profit: Economic dimension of Canada's health industry. Vancouver: Fraser Institute.

BUCHMUELLER, T., COUFFINHAL, A., GRIGNON, M. & PERRONNIN, M. 2002. Access to Physician Services: Does Supplemental Insurance Matter? Washington: National Bureau of Economic Research.

BUNTIN, M. B. & ZASLAVSKY, A. M. 2004. Too much ado about two-part models and transformation? Comparing methods of modeling Medicare expenditures. *J Health Econ,* 23, 525-42.

BURKE, S. 2009. *Irish Apartheid: Healthcare inequality in Ireland,* Dublin, New Island.

BUSSE, R., KRAUTH, C. & SCHWARTZ, F. W. 2002. Use of Acute Hospital Beds Does Not Increase as the Population Ages: Results from a Seven Year Cohort Study in Germany. *Journal of Epidemiology and Community Health,* 56, 289-93.

CALLAN, T., NOLAN, B., KEANE, C., SAVAGE, M. & WALSH, J. 2013. The Great Recession, Austerity and Inequality: Evidence from Ireland. *Intereconomics,* 48, 335-338.

CAMERON, A. & TRIVERDI, A. 1998. *Regression Analysis of Count Data,* Cambridge, Cambridge University Press.

CAMERON, A. C. & TRIVEDI, P. K. 2005. *Micoroeconometrics,* Cambridge, Cambridge University Press.

CENTRAL STATISTICS OFFICE 2013. Statbank. Ireland: Central Statistics Office (CSO).

CENTRAL STATISTICS OFFICE (CSO) 2013. Regional population projections 2016-2031.

CHANG, S., HE, Y. & HSIEH, C.-R. 2013. The determinants of health care expenditure toward the end of life: evidence from Taiwan. *Health Economics,* Forthcoming.

CHINTA, R., BURNS, D. J., MANOLIS, C. & NIGHSWANDER, T. 2013. "Cost creep due to age creep" phenomenon: pattern analyses of in-patient hospitalization costs for various age brackets in the United States. *Hosp Top,* 91, 69-80.

CLEMENTE, J., MARCUELLO, C., MONTANES, A. & PUEYO, F. 2004. On the international stability of health care expenditure functions: are government and private functions similar? *J Health Econ,* 23, 589-613.

COLOMBIER, C. & WEBER, W. 2011. Projecting health-care expenditure for Switzerland: further evidence against the 'red-herring' hypothesis. *Int J Health Plann Manage,* 26, 246-63.

COMAS-HERRERA, A., WITTENBERG, R., PICKARD, L. & KNAPP, M. 2007. Cognitive impairment in older people:future demand for long-term care services and the associated costs *International Journal of Geriatric Psychiatry* 22, 1037–1045.

CONTOYANNIS, P., HURLEY, J., GROOTENDORST, P., JEON, S. H. & TAMBLYN, R. 2005. Estimating the price elasticity of expenditure for prescription drugs in the presence of non-linear price schedules: an illustration from Quebec, Canada. *Health Econ,* 14, 909-23.

CONWAY, A., KENNEALLY, M., WOODS, N., THUMMEL, A. & RYAN, M. 2014. The implications of regional and national demographic projections for future GMS costs in Ireland through to 2026. *BMC Health Serv Res,* 14, 477.

COSTA-I-FONT, J. & GEMMILL-TOYAMA, M. 2010. Does cost sharing really reduce inappropriate prescriptions? . *CESifo working paper, no. 3002.* Munich, Germany: CESifo Group.

CRAGG, L. G. 1971. Some statistical models ofr limited dependent variables with application to the demand for durable goods. *Econometrica,* 39, 829.

CRIMMINS, E. M., SAITO, Y. & INGEGNENRI, D. 1997. Trends in disability free life expectancy in the United States. *Population and Development Review,* 23, 555-572.

CRONIN, H., O'REGAN, C., FINUCANE, C., KEARNEY, P. & KENNY, R. A. 2013. Health and aging: development of the Irish Longitudinal Study on Ageing health assessment. *J Am Geriatr Soc,* 61 Suppl 2, S269-78.

CSO 2013a. Statbank.

CSO 2013b. Thematic report on the Elderly. Cork: Central Statistics Office (Ireland).

CULLIS, J. & WEST, P. 1979. *The Economics of Health; An Introduction,* Oxford, Robertson.

CULYER, A. J. 1988. Health Expenditures in Canada: Myth and Reality; Past and Future. Toronto: Canadian Tax Foundation.

CULYER, A. J. 1990. Cost Containment in Europe. *Health Care Systems in Transition.* Paris: OECD.

CUTLER, D. & MEARA, E. 1997. The medical care costs of the young and the old: a forty year perspective. *NBER Working Paper, no.6114.*

DALGAARD, C.-J. & STRULIK, H. 2010. Optimal Aging and Death: Understanding the Preston Curve. University of Copenhagen. Department of Economics, Discussion Papers: 11-09.

DANG, T. T., P., A. & OXLEY, H. 2001. The fiscal implications of ageing: projections of age-related spending.: OECD Economics Department Working Papers No. 305.

DE MEIJER, C., KOOPMANSCHAP, M., D' UVA, T. B. & VAN DOORSLAER, E. 2011. Determinants of Long-Term Care Spending: Age, Time to Death or Disability? *Journal of Health Economics,* 30, 425-438.

DEATON, A. 2003. Health, inequality, and economic development. *Journal of Economic Literature* . 41, 113-58.

DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS POPULATION DIVISION 2013. World Population Prospects: The 2012 Revision. United Nations.

DEPARTMENT OF HEALTH & CHILDREN 1994. Shaping a healthier future. Dublin: Stationery Office.

DEPARTMENT OF HEALTH & CHILDREN 2001. Quality and fairness - a health system for you. Dublin: Stationery Office.

DEPARTMENT OF HEALTH (IRE) 2013a. Healthy Ireland: A Framework for Improved Health and Wellbeing 2013-2025. Dublin

DEPARTMENT OF HEALTH (IRE) 2013b. The Path to Universal Healthcare. Dublin: Department of Health.

DEPARTMENT OF HEALTH (IRE) 2014. Breifing material provided to Minister Leo Varadkar upon his appointment. Dublin.

DI MATTEO, L. 2005. The macro determinants of health expenditure in the United States and Canada: assessing the impact of income, age distribution and time. *Health Policy,* 71, 23-42.

DI MATTEO, L. & DI MATTEO, R. 1998. Evidence on the determinants of Canadian provincial government health expenditures: 1965–1991. *Journal of Health Economics,* 17, 211–228.

DICKY, D. & FULLER, W. 1979. Distribution of the estimators for Autoregressive Time Series with a Unit Root. *Journal of American Statistical Association,* 74, 427-437.

DIRECTORATE-GENERAL FOR ECONOMIC AND FINANCIAL AFFAIRS OF THE EUROPEAN COMMISSION 2009. 2009 Ageing Report:Economic and budgetary projections for the EU-27 Member States (2008-2060). Brussells: European Commission.

DOBSON, A. J. & BARNETT, A. G. 2008. *An introduction to generalized linear models,* Boca Raton, CRC Press.

DORMONT, B., GRIGNON, M. & HUBER, H. 2006. Health Expenditure Growth: Reassessing the Threat of Ageing. *Health Economics,* 15, 947-963.

DOW, W. H. & NORTON, E. C. 2003. Choosing Between and Interpreting the Heckit and Two-Part Models for Corner Solutions. *Health Services and Outcomes Research Methodology,* 4, 5-18.

DRUMMOND, M. F. 2005. *Methods for the economic evaluation of health care programmes,* Oxford ; New York, Oxford University Press.

DUAN, N. 1983. Smearing estimate: a non-parametric retransformation method. *Journal of the American Statistical Association,* 78, 605–610.

DUAN, N., MANNING, W. G., MORRIS, C. N. & NEWHOUSE, J. P. 1983. A comparison of alternative models of the demand for medical care. *Journal of Business and Economic Statistics,* 1, 115-126.

DUAN, N., MANNING, W. G., MORRIS, C. N. & NEWHOUSE, J. P. 1984. Choosing between the sample selection model and the Multi-part model. *Journal of Business and Economic Statistics,* 2, 283-289.

EHRLICH, I. & CHUMA, H. 1990. A Model of the Demand for Longevity and the Value of Life Extension *Journal of Political Economy,* 98, 761-82.

EUROSTAT 2013. Demographic - National data. Brussels: Eurostat.

EZZATI, M., FRIEDMAN, A. B., KULKARNI, S. C. & MURRAY, C. J. L. 2008. The Reversal of Fortunes: Trends in County Mortality and Cross-County Mortality Disparities in the United States. *PLoS Medicine,* 5.

FARAG, M., NANDAKUMAR, A. K., WALLACK, S., HODGKIN, D., GAUMER, G. & ERBIL, C. 2012. The income elasticity of health care spending in developing and developed countries. *International Journal Health Care Finance Economics* 12, 145-162.

FELDER, S., MEIER, M. & SCHMITT, H. 2000. Health care expenditure in the last months of life. *Journal of Health Economics,* 19, 679-95.

FELDER, S., WERBLOW, A. & ZWEIFEL, P. 2010. Do red herrings swim in circles? Controlling for the endogeneity of time to death. *J Health Econ,* 29, 205-12.

FISHMAN, P. A., GOODMAN, M. J., HORNBROOK, M. C., MEENAN, R. T., BACHMAN, D. J. & O'KEEFFE ROSETTI, M. C. 2003. Risk adjustment using automated ambulatory pharmacy data: the RxRisk model. *Med Care,* 41, 84-99.

FITZGERALD, J. 2013. The Effect of Redomiciled Plcs on GNP and the Irish Balance of Payments *In:* (ESRI), E. A. S. R. I. (ed.) *Quarterly Economic Commentary.* Dublin: ESRI.

FOGEL, R. 1994. Economic Growth, Population Theory, and Physiology: The Bearing of Long-Term Processes on the Making of Economic Policy. *American Economics Review,* 84, 369-95.

FOX, J. 2008. *Applied Regression Analysis and Generalised Linear Models,* London, Sage Publications.

FRIES, J., F, 1980. Ageing, natural death, and the compression of morbidity. *New England Journal of Medicine,* 303, 130–135.

FUCHS, V. R. 1984. "Though much is taken": reflections on ageing, health and medical care. *The Milbank Memorial Fund Quarterly Health and Society,* 61, 143-166.

FUCHS, V. R. 1998. Health care for the elderly: How much? Who will pay for it? *NBER Working Paper, no.6755.*

FUCHS, V. R. 2012. Major trends in the U.S. health economy since 1950. *N Engl J Med,* 366, 973-7.

GANDJOUR, A. 2009. Aging diseases--do they prevent preventive health care from saving costs? *Health Econ,* 18, 355-62.

GANDJOUR, A. & LAUTERBACH, K. W. 2005. Does prevention save costs? Considering deferral of the expensive last year of life. *J Health Econ,* 24, 715-24.

GARCÍA-GOÑI, M. & IBERN, P. 2008. Predictability of drug expenditures: an application using morbidity data. *Health Economics,* 17, 119-126.

GARCIA MARQUEZ, G. 1989. *Love in the Time of Cholera* London, Penguin Books.

GAULD, R. 2009. *New Zealand's Health Reforms - The continuing saga,* Wellington, Health Services Research Centre and INstitute of Policy Studies.

GEMMILL, M., THOMSON, S. & MOSSIALOS, E. 2008. What impact do prescription drug charges have on efficiency and equity? Evidence from high-income countries. *International Journal for Equity in Health,* 7.

GERDTHAM, U., ANDERSON, F., SOGAARD, J. & JÖNSSON, B. 1988. Econometric Analysis of Health Care Expenditures: A Cross-section Study of OECD Countries. . Centre for Medical Technology Assessment, University of Linkoping, Sweden.

GERDTHAM, U. & LÖTHGREN, M. 2000. On Stationarity and the Cointegration of International Health Expenditure and GDP. *Journal of Health Economics,* 19, 461-475.

GERDTHAM, U., SOGAARD, J., ANDERSSON, F. & JONSSON, B. 1992. An econometric analysis of health care expenditure: a cross-section study of the OECD countries. *Journal of Health Economics,* 11, 63–84.

GERDTHAM, U. G. 1992. Pooling International Health Care Expenditure Data. *Health Economics,* 1, 217-133.

GETZEN, T. E. 1992. Population ageing and the growth of health expenditures. *Journal of Gerontology: Social Sciences,* 47, S98-104.

GETZEN, T. E. 2000. Health care is an individual necessity and a national luxury: applying multilevel decision models to the analysis of health care expenditures. *J Health Econ,* 19, 259-70.

GHEORGHE, M., BROUWER, W. B. F. & VAN BAAL, P. H. M. 2014. Did the health of the Dutch population improve between 2001 and 2008? Investigating age and gender specific trends in quality of life. *Applied Health Economics and Health Policy* In press

GIANNONI, M. & HITIRIS, T. 2002. The regional impact of health care expenditure: the case of Italy *Applied Economics,* 34 1829-36.

GIBSON, T. B., OZIMINKOWSKI, R. J. & GOETZEL, R. Z. 2005. The effects of prescription drug cost sharing: A review of the evidence. *The American Journal of Managed Care,* 11, 730-740.

GINI, C. 1997. Concentration and dependency ratios (English translation). *Rivista di Politica Economica,* 769-789.

GINZBERG, E. 1980. The High Costs of Dying. *Inquiry,* 17, 293-295.

GLICK, H. A., DOSHI, J., SONNAD, S. & POLSKY, D. 2007. *Economic Evaluation of Clinical Trials,* Oxford University Press.

GLYNN, L. G., VALDERAS, J. M., HEALY, P., BURKE, E., NEWELL, J., GILLESPIE, P. & MURPHY, A. W. 2011. The prevalence of multimorbidity in primary care and its effect on health care utilization and cost. *Fam Pract,* 28, 516-23.

GODFREY, L. G. 1978. Testing for multiplicative heteroscedasticity. *Journal of Econometrics,* 8, 227-236.

GOLDMAN, D. & SHANG, B. 2008. Does age or life expectancy better predict health care expenditures? *Health Economics,* 17, 487-501.
GORECKI, P., NOLAN, A., BRICK, A. & LYONS, S. 2012. Delivery of Pharmaceuticals in Ireland: Getting a Bigger Bang for the Buck *Research Series.* Dublin: ESRI.
GOVERNEMENT OF IRELAND 2014. Health Identifiers Act. *15.* Dublin.
GOVERNEMENT OF NEW ZEALAND 2000. New Zealand Public Health & Disability Act
GRAY, A. 2004. Population Ageing and Health Care Expenditure. *Ageing horizons,* 15-20.
GRAY, J., MAJEED, A., KERRY, S. & ROWLANDS, G. 2000. Identifying patients with ischaemic heart disease in general practice: Cross sectional study of paper and computerised medical records. *British Medical Journal,* 321, 548-550.
GREENE, W. H. 2008. *Econometric analysis,* New Jersey, Prentice Hall.
GREENE, W. H. 2012. *Econometric analysis,* London, Pearson.
GROSSMAN, M. 1972a. Demand for Health - Theoretical and Empirical Investigation. *Nber Occasional Papers-National Bureau of Economic Research,* 1-115.
GROSSMAN, M. 1972b. On the Concept of Health Capital and the Demand for Health. *Journal of Political Economy,* 80, 223-255.
GRUENBERG, E. 1977. The failure of success. *Milbank Memorial Fund Quarterly Health and Society,* 55, 3-24.
GUJARATI, D., M., 1995. *Basic Econometrics,* Singapore, McGraw-Hill.
HÄKKINEN, U., MARTIKAINEN, P., NORO, A., NIHTILÄ, E. & PELTOLA, M. 2008. Aging, health expenditure, proximity to death, and income in Finland. *Health Econ Policy Law,* 3, 165-95.
HANLEY, G., MORGAN, S. & REID, R. 2010. Explaining prescription drug use and expenditures using the adjusted clinical groups case-mix system in the population of British Columbia, Canada. *Medical Care,* 48, 402-408.
HANSEN, P. & KING, A. 1996. The Determinants of Health Care Expenditure: a Cointegration Approach. *Journal of Health Economics,* 15, 127-137.
HANSEN, P. & KING A. 1998. Health Care Expenditure and GDP: Panel Data Unit Root Test Results - Comment. *Journal of Health Economics,* 17, 377-381.
HARDIN, J. & HILBE, J. 2013. *Generalized Estimating Equations,* ebook, CRC Press.
HAUSMAN, J. A. 1978. Specification tests in econometrics. *Econometrica,* 46, 1251-1271.
HAY, J. W., LEU, R. & FOHRER, P. 1987. Ordinary least squares and sample selection models of the health-care demand. *Journal of Business and Economic Statistics,* 5, 499-506.
HEALTH, N. Z. M. O. 2012. Mortality and Demographic Data 2009. Wellington
HECKMAN, J. 1979. Sample selection bias as a specification error *Econometrica,* 47 153-61.
HEFFORD, M., CRAMPTON, P. & FOLEY, J. 2005. Reducing health disparities through primary care reform: the New Zealand experiment. *Health Policy,* 72, 9-23.
HILL, S. C. & MILLER, G. E. 2010. Health expenditure estimation and functional form: applications of the generalized gamma and extended estimating equations models. *Health Economics,* 19, 608-27.
HIMSWORTH, R. L. & GOLDACRE, M. J. 1999. Does time spent in hospital in the final 15 years of life increase with age at death? A population based study. *BMJ,* 319, 1338-9.
HITIRIS, T. 1997. Health Care Expenditure and Integration in the Countries of the European Union. *Applied Economics,* 29, 1-6.
HITIRIS, T. & POSNETT, J. 1992. The Determinants and Effects of Health Expenditure in Developed Countries. *Journal of Health Economics,* 11, 173-181.
HOFFMAN, J. P. 2004. *Generalized linear models: an applied approach,* Boston, Pearson.
IACUS, S. M., KING, G. & PORRO, G. 2011. Multivariate Matching Methods That Are Monotonic Imbalance Bounding. *Journal of the American Statistical Association,* 106, 345-361.
JACOBZONE, S. 2002. Healthy Ageing and the Challenges of New Technologies. Can OECD Social and Health-Care Systems Provide for the Future? *In:* OECD (ed.) *Healthy Ageing and Biotechnology. Policy Implications of New Research.*

JATRANA, S., CRAMPTON, P. & NORRIS, P. 2011. Ethnic differences in access to prescription medication because of cost in New Zealand. *Journal of Epidemiology & Community Health,* 65, 454-460.

JENKINS, S. P., BRANDOLINI, A., MICKLEWRIGHT, J. & NOLAN, B. 2013. *The Great Recession and the Distribution of Household Income,* Oxford, Oxford University Press.

JOHNSON, D. & YONG, J. 2006. Costly Ageing or Costly Deaths? Understanding Health Care Expenditure Using Australian Medicare Payments Data. *Australian Economic Papers,* 45, 57-74.

JOINT COMMITTEE ON HEALTH AND CHILDREN 2014. Report on End of Life and Palliative Care in Ireland. Dublin: Houses of the Oireachtas.

JONES, A. 2000. Health Econometrics. *In:* CULYER, A. & J., N. (eds.) *Handbook of Health Economics.* Amsterdam: Elsevier.

JONES, A. 2007. *Applied Econometrics for Health Economists,* Oxford, Radcliffe.

JONES, A. 2010. Models for Health Care. York: Health Econometrics and Data Group (HEDG).

JONES, A. 2011. Models for Health Care. *In:* HENDRY, D. F. & CLEMENTS, M. P. (eds.) *The Oxford Handbook of Economic Forecasting.* Oxford: Oxford Univeristy Press.

JONES, M., KIMBREL, J., PROTUS, B. & GRAUER, P. 2010. Impact of functional decline and medications for treatment of dementia on time to death in dementia patients using hospice care. *Journal of the American Pharmacists Association,* 50, 291.

KANAVOS, P. & MOSSIALOS, E. 1996. The Methodology of International Comparisons of Health Care Expenditures: Any Lessons for Health Policy? *LSE Health.* The London School of Economics and Political Science.

KARATZAS, G. 2000. On the Determination of the US Aggregate Health Care Expenditure. *Appl Econ,* 32, 1085-1099.

KARLSSON, M. & KLOHN, F. 2014. Testing the red herring hypothesis on an aggregated level:ageing, time-to-death and care costs for older people in Sweden. *European Journal of Health Economics,* 15, 533-551.

KENNY, R. A., WHELAN, B., CRONIN, H., KAMIYA, Y., KEARNEY, P., O'REGAN, C. & ZEGAL, M. 2010. The Design of Irish Longitudinal Study on Ageing. The Design of Irish Longitudinal Study on Ageing (Tilda).

KIIL, A. & HOULBERG, K. 2014. How does copayment for health care services affect demand, health and redistribution? A systematic review of the empirical evidence from 1990 to 2011. *Eur J Health Econ,* 15, 813-28.

KILDEMOES, H., W,, CHRISTIANSEN, T. & GYRD-HANSEN, D. 2006. The impact of population ageing on future Danish drug expenditure. *Health Policy,* 75, 298 - 311.

KOHLER, U. & KREUTER, F. 2009. *Data Analysis Using Stata*, Stata Press.

KUO, R. & LAI, M. 2010. Comparison of Rx defined morbidity groups and diagnosis based risk adjusters for predicting healthcare costs in Taiwan. *BMC Health Serv Res,* 10.

LAMERS, L. 1999. Pharmacy costs groups: a risk adjuster for capitation payments based on the use of prescribed drugs. *Medical Care,* 37, 824-830.

LAMERS, L. 2001. Healthbased risk adjustment: is inpatient and outpatient diagnostic information sufficient? . *Inquiry 2001; 38:423,* 38, 423-431.

LAMERS, L. & VAN VLIET, R. 2004. The Pharmacy based Cost Group model: validating and adjusting the classification of medications for chronic conditions to the Dutch situation. *Health Policy,* 68, 113-121.

LAMERS, L. M. & VLIET, R. C. J. A. 2003. Health-Based Risk Adjustment: Improving the Pharmacy-Based Cost Group Model to Reduce Gaming Possibilities. *European Journal of Health Economics,* 4, 107-114.

LAYTE, R. 2007. An Analysis of the Impact of Age and Proximity of Death on Health Care Costs in Ireland. *Working Paper.* Dublin: ESRI.

LAYTE, R., MCGEE, H. & O'HANLON, A. 2007. Do Consultation Charges Deter General Practitioner Use Among Older People? A Natural Experiment. . *Working paper.* Dublin: ESRI.

LEU, R. 1986. The public private mix and international health care costs. *In:* CULYER, A. & JONSSON, B. (eds.) *Public and Private Health Services.* Oxford: Blackwell.

LEUNG, S. F. & YU, S. 1996. On the choice between sample selection and two-part models. *Journal of Econometrics,* 72, 197-229.

LICHTENBERG, F. 2013. The impact of pharmaceutical innovation on longevity and medical expenditure. *Economics and Human Biology,* Forthcoming.

LIU, L., STRAWDERMAN, R. L., COWEN, M. E. & SHIH, Y. C. 2010. A flexible two-part random effects model for correlated medical costs. *J Health Econ,* 29, 110-23.

LIU, L., STRAWDERMAN, R. L., JOHNSON, B. A. & O'QUIGLEY, J. M. 2012. Analyzing repeated measures semi-continuous data, with application to an alcohol dependence study. *Stat Methods Med Res*.

LOHR, K. N., BROOK, R. H., KAMBERG, C. J., GOLDBERG, G. A., LEIBOWITZ, A., KEESEY, J., REBOUSSIN, D. & NEWHOUSE, J. P. 1986. Use of medical care in the Rand Health Insurance Experiment. Diagnosis- and service-specific analyses in a randomized controlled trial. *Med Care,* 24, S1-87.

LUBITZ, J., BEEBE, J. & BAKER, C. 1995. Longevity and medicare expenditures. *New England Journal of Medicine,* 332, 999-1002.

LUBITZ, J. D. & RILEY, G. F. 1993. Trends in Medicare payments in the last year of life. *N Engl J Med,* 328, 1092-6.

MACHLIN, S. R. & DOUGHERTY, D. D. 2007. Overview of the methodology for imputting missing expenditure data in the medical expenditure panel survey. *Methodology Report no 19.* Rockville, MD: Agency for Healthcare Research and Quality.

MADSEN, J., SERUP-HANSEN, N. & KRISTIANSEN, I. S. 2002. Future health care costs--do health care costs during the last year of life matter? *Health Policy,* 62, 161-72.

MAIO, V., YUEN, E., RABINOWITZ, C., LOUIS, D., JIMBO, M., DONATINI, A., MALL, S. & TARONI, F. 2005. Using pharmacy data to identify those with chronic conditions in Emilia Romagna, Italy. *Journal of Health Services Research and Policy,* 10, 232-238.

MAJER, I. M., NUSSELDER, W. J., MACKENBACH, J. P., KLIJS, B. & VAN BAAL, P. H. 2011. Mortality risk associated with disability: a population-based record linkage study. *Am J Public Health,* 101, e9-15.

MALONE, D., BILLUPS SJ, VALUCK RJ & BL., C. 1999. Development of a chronic disease indicator score using a Veterans Affairs Medical Center medication database. *J Clin Epidemiol,* 52, 551-557.

MANNING, W. 2006. Dealing with skewed data on costs and expenditures. *In:* JONES, A. (ed.) *The Elgar Companion to Health Economics.* Cheltenham: Edward Elgar Publishing.

MANNING, W. & MULLAHY, J. 2001. Estimating log models: to transform or not to transform? *Journal of Health Economics,* 20, 461-494.

MANNING, W. G. 1998. The logged dependent variable, heterskedasticity and the retransformation problem. *Journal of Health Economics,* 17, 283-295.

MANNING, W. G., DUAN, N. & ROGERS, W. H. 1987. Monte Carlo evidence on the choice between sample selection and two-part models. *Journal of Econometrics,* 35, 59-82.

MANTON, K. G. 1982. Changing concepts of morbidity and mortality in the elderly population. *Milbank Mem Fund Q Health Soc,* 60, 183-244.

MARTIKAINEN, P., MURPHY, M., METSA-SIMOLA, N., HAKKINEN, U. & MOUSTGAARD, H. 2012. Seven-year hospital and nursing home care use according to age and proximity to death: variations by cause of death and socio-demographic position. *J Epidemiol Community Health,* 66, 1152-8.

MARTIN, J. J. M., LOPEZ DEL AMO GONZALEZ, M. P. & GARCIA, M. D. C. 2011. Review of the Literature on the Determinants of Healthcare Expenditure. *Appl Econ,* 43, 19-46.

MCCULLAGH, P. & NELDER, J. A. 1989. *Generalized Linear Models,* London, Chapman & Hall.

MCDAID, D., WILEY, M., MARESSO, A. & MOSSIALOS, E. 2009. Ireland: Health system review.Health Systems in Transition. . Copenhagen: World Health Organization 2009, on behalf of the European Observatory on Health Systems and Policies.

MCGRAIL, K., GREEN, B., BARER, M. L., EVANS, R. G., HERTZMAN, C. & NORMAND, C. 2000. Age, costs of acute and long-term care and proximity to death: evidence for 1987-88 and 1994-95 in British Columbia. *Age Ageing,* 29, 249-53.

MCKEOWN, K., HAASE, T. & TWOMEY, S. 2010. *Resources and Facilities for End-of-Life Care in Irish Hospitals, National Audit Report 1* [Online]. Dublin: Irish Hospice Foundation. Available: http://www.hospicefriendlyhospitals.net [Accessed 20th September 2010].

MCNAUGHTON, H., WEATHERALL, M., MCPHERSON, K., TAYLOR, W. & HARWOOD, M. 2002. The comparability of resource utilisation for Europeans and non-Europeans following stroke in New Zealand. *New Zealand Medical Journal,* 115, 101-103.

MENEC, V., LIX, L., STEINBACH, C., OKECHUKWU, E., SIRSKI, M., DAHL, M. & SOODEN, R.-A. 2004. Patterns of Health Care Use and Cost at the End of Life. Winnipeg: Manitoba Centre for Health Policy.

MIHAYLOVA, B., BRIGGS, A., O'HAGAN, A. & THOMPSON, S. 2011. Review of statistical methods for analysing healthcare resources and costs. *Health Economics,* 20, 897-916.

MILLER, T. 2001. Increasing longevity and Medicare expenditures. *Demography,* 38, 215–226.

MINISTRY OF HEALTH 2011. Tatau Kura Tangata: Health of Older Maori Chart Book 2011 Wellington: Ministry of Health (NZ).

MOODIE, P. 2008. PHARMAC and cardiovascular health in New Zealand. *Journal of the New Zealand Medical Association* 121.

MOORE, P. V., RICHARDSON, K., PEKLAR, J., GALVIN, R., BENNETT, K. & KENNY, R. A. 2012. Polypharmacy in adults over 50 in Ireland: Opportunities for cost savings and improved healthcare. Dublin TILDA.

MOSCA, I. 2007. Decentralization as a determinant of health care expenditure: empirical analysis for OECD countries. *Applied Economic Letters,* 14, 511-515.

MULLAHY, J. 1998. Much ado about two: reconsidering retransformation and the two-part model in health econometrics. *Journal of Health Economics,* 17, 247-281.

MULLAHY, J. 2009. Econometric Modeling of Health Care Costs and Expenditures A Survey of Analytical Issues and Related Policy Considerations. *Medical Care,* 47, S104-S108.

MURPHY, M. 2012. Proximity to death and health care costs. *In:* MCGUIRE, A. & COSTA-FONT, J. (eds.) *The LSE Companion to Health Policy.* Cheltenham: Edward Edgar

NAUGHTON, C., BENNETT, K. & FEELY, J. 2006. Prevalence of chronic disease in the elderly based on a national pharmacy claims database. *Age and Ageing,* 35, 633 - 636.

NELDER, J. A. & WEDDERBURN, R. W. M. 1972. Generalized linear models. *Journal of the Royal Statistical Society,* 135, 370-384.

NEWHOUSE, J. 1977. Medical Care Expenditure; A Cross-National Survey. *Journal of Human Resources,* 12, 115-125.

NEWHOUSE, J. 1987. Cross-National Differences in Health Spending; What do they Mean? . *Journal of Health Economics,* 6, 159-162.

NEWHOUSE, J. P. 1992. Medical care costs: how much welfare loss? *Journal of Economic Perspective,* 6, 322.

NEWHOUSE, J. P. & THE INSURANCE EXPERIMENT GROUP 1993. *Free For All? Lessons from the Health Insurance Experiment,* Cambridge, MA, Harvard University Press.

NOLAN, A., BURKE, H., CRONIN, H., HICKEY, A., KAMIYA, Y., KENNY, R. A., LAYTE, R., MATY, S., MCGEE, H., MOORE, P. V., MORGAN, K., MOSCA, I., MURPHY, C., NORMAND, C., O'REGAN, C. & O' SULLIVAN, V. (eds.) 2014. *The over 50s in a changing Ireland: Economic Circumstances Health and Well-being.*

NZIER 2004. Ageing New Zealand and Health and Disability Services: Demand Projections and Workforce Implications, 2001–2021. Wellington: Ministry of Health.

O'NEILL, C., GROOM, L., AVERY, A. J., BOOT, D. & THORNHILL, K. 2000. Age and proximity to death as predictors of GP care costs: results from a study of nursing home patients. *Health Econ,* 9, 733-8.

O'NEILL, P., MESTRE-FERRANDIZ, J., PUIG-PEIRO, R. & SUSSEX, J. 2013. Projecting Expenditures on Medicines in the NHS. London: OHE.

O'SHEA, M., TEELING, M. & BENNETT, K. 2013. The prevalence and ingredient cost of chronic comorbidity in the Irish elderly population with medication treated type 2 diabetes: a retrospective cross-sectional study using a national pharmacy claims database. *BMC Health Services Research,* 13, 23.

OECD 2011a. Health at a Glance 2011: OECD Indicators.

OECD. 2011b. *Health Data* [Online]. Available: http://www.oecd.org/health/health-systems/oecdhealthdata2012.htm [Accessed 5/05/ 2012].

OECD 2011c. Labour Force Statistics: Population projections", OECD Employment and Labour Market Statistics (database).

OECD 2013. Healthdata. Organisation for Economic Co-operation and Development.

OECD 2014a. Labour Force Statistics: Population projections. *OECD Employment and Labour Market Statistics (database).*

OECD 2014b. National Accounts Data.

OKUNADE, A. A., KARAKUS, M. C. & OKEKE, C. 2004. Determinants of health expenditure growth of the OECD countries: jackknife resampling plan estimates. *Health Care Manag Sci,* 7, 173-83.

OKUNADE, A. A. & MURTHY, V. N. 2002. Technology as a 'major driver' of health care cost: a cointegration analysis of the Newhouse conjecture. *Journal of Health Economics,* 21, 147-159.

OLIVEIRA MARTINS, J. & DE LA MAISONNEUVE, C. 2006. The drivers of public expenditure on health and long-term care: an integrated approach OECD.

PA CONSULTING GROUP 2007. Acute Hospital Bed Capacity Review: A preferred Health System in Ireland to 2020.

PALANGKARAYA, A. & YONG, J. 2009. Population ageing and its implications on aggregate health care demand: empirical evidence from 22 OECD countries. *Int J Health Care Finance Econ.*

PARK, R. 1966. Estimation with heteroscedastic error terms. *Econometrica,* 34, 888.

PARKIN, D., MCGUIRE, A. & YULE, B. 1987. Aggregate Health Care Expenditures and National Income. *Journal of Health Economics,* 6, 109-127.

PAYNE, G., LAPORTE, A., DEBER, R. & COYTE, P. C. 2007. Counting backward to health care's future: using time-to-death modeling to identify changes in end-of-life morbidity and the impact of aging on health care expenditures. *Milbank Q,* 85, 213-57.

PESARAN, M. H. 2004. General diagnostic tests for cross-section dependence in panels. *Working Papers in Economics, Paper No. 0435.* Cambridge, UK: University of Cambridge, Faculty of Economics.

PHARMAC 2009. Pharmaceutical Management Agency - Annual Report year ended 30th June 2009.

PHILIPSON, T. J. & BECKER, G. S. 1998. Old-Age Longevity and Mortality - Contingent Claims. *Journal of Political Economy,* 106, 551-573.

PHILLIPS, P. & PERRON, P. 1988. Testing for a Unit Root in Times Series Regression. *Biometrica,* 75, 335-346.

PNG, I. 2012. *Managerial Economics.,* New York, Routledge.

POLDER, J. J., BARENDREGT, J. J. & VAN OERS, H. 2006. Health care costs in the last year of life--the Dutch experience. *Soc Sci Med,* 63, 1720-31.

PRESTON, S. H. 1975. The changing relation between mortality and level of economic development. *Population Studies,* 29, 231-48.

PRIMARY CARE REIMBURSEMENT SERVICE 2009. Primary Care Reimbursement Service Statistical Claims and Payments 2008

Dublin: Health Service Executive.

PRIMARY CARE REIMBURSEMENT SERVICE 2011. Primary Care Reimbursement Service Statistical Claims and Payments 2010. Dublin: Primary Care Reimbursement Service.

PUHANI, P. A. 2000. The Heckman correction for sample selection and its critique. *Journal of Economic Surveys,* 14, 53-68.

RAMSEY, J. B. 1969. Tests for Specification Errors in Classical Linear Least Squares Regression Analysis *Journal of the Royal Statistical Society Series B* 31 350-371.
REINHARDT, U. E. 2000. Health care for the aging baby boom: lessons from abroad. *J Econ Perspect,* 14, 71-83.
REINHARDT, U. E., HUSSEY, P. S. & ANDERSON, G. F. 2002. Cross-National Comparisons of Health Systems Using OECD data, 1999. *Health Affairs,* 21, 169-81.
ROBERTS, J. 2000. Spurious Regression Problems in the Determinants of Health Care Expenditure: a Comment on Hitris. *Applied Economics Letters,* 7, 279-283.
ROBINE, J. M. & MICHEL, J. P. 2004. Looking Forward to a General Theory on Population Aging. *Journals of Gerontology Series A: Biological and Medical Sciences* 59, M590–97.
RUBIN, D. 1976. Inference and missing data. *Biometrika,* 63, 581-592.
SALAS, C. & RAFTERY, J. 2001. Econometric issues in testing the age neutrality of health care expenditure. *Health Economics,* 10, 669-671.
SCHNEEWEISS, S., SEEGER, J. D., MACLURE, M., WANG, P. S., AVORN, J. & GLYNN, R. J. 2001. Performance of comorbidity scores to control for confounding in epidemiologic studies using claims data. *American Journal of Epidemiology,* 154, 854-864.
SCITOVSKY, A. A. 1994. "The high cost of dying" revisited. *Milbank Quarterly,* 72, 561-91.
SCITOVSKY, A. A. 2005. "The high cost of dying": what do the data show? 1984. *Milbank Q,* 83, 825-41.
SCOTT, K., MARWICK, J. & CRAMPTON, P. 2003. Utilization of general practitioner services in New Zealand and its relationship with income, ethnicity and government subsidy. *Health Services management research* 16, 45-55.
SEN, A. 2005. Is health care a luxury? New evidence form OECD data. *International Journal of Health Care Finance and Economics,* 5, 147-164.
SESHAMANI, M. & GRAY, A. M. 2004a. Ageing and health-care expenditure: the red herring argument revisited. *Health Econ,* 13, 303-14.
SESHAMANI, M. & GRAY, A. M. 2004b. A Longitudinal Study of the Effects of Age and Time to Death on Hospital Costs. *Journal of Health Economics,* 23, 217-235.
SESHAMANI, M. & GRAY, A. M. 2004c. Time to death and health expenditure: an improved model for the impact of demographic change on health care costs. *Age Ageing,* 33, 556-61.
SIGELMAN, L. & ZENG, L. 1999. Analyzing Censored and Sample-Selected Data with Tobit and Heckit Models. *Political Analysis,* 8, 167-182.
SILWER, L. & LUNDBORG, C. S. 2005. Patterns of drug use during a 15 year period: Data from a Swedish county, 1988-2002. *Pharmacoepidemiology and Drug Safety,* 14, 813-820.
SIMOENS, S., KUTTEN, B., KEIRSE, E., VANDEN BERGHE, P., BEGUIN, C., DESMEDT, M., DEVEUGELE, M., LEONARD, C., PAULUS, D. & MENTEN, J. 2013. Terminal patients in Belgian nursing homes: a cost analysis. *Eur J Health Econ,* 14, 407-13.
SINNOTT, S.-J., BUCKLEY, C., O'RIORDAN, D., BRADLEY, C. & WHELTON, H. 2013. The effect of copayments for prescriptions on adherence to prescription medicines in publicly insured populations; a systematic review and meta-analysis. *Plos One,* 8.
SLOAN, K. L., SALES, A. E., LIU, C. F., FISHMAN, P., NICHOL, P., SUZUKI, N. T. & SHARP, N. D. 2003. Construction and characteristics of the RxRisk-V: a VA-adapted pharmacy-based case-mix instrument. *Med Care,* 41, 761-74.
SMITH, S., HEFFLER, S. & FREELAND, M. 1999. The Next Decade Of Health Spending: A New Outlook Health Expenditures Projection Team. *Health Affairs,* 18, 86-95.
SMYTH A, GLYNN LG, MURPHY AW, MULQUEEN J, C. M., REDDAN DN & 4., E. A. 2013. Mild chronic kidney disease and functional impairment in community-dwelling older adults. *Age and Ageing,* 42, 488-9.
SPIJKER, J. & MACINNES, J. 2013. Population ageing: the timebomb that isn't? *BMJ,* 347.
SPILLMAN, B. C. & LUBITZ, J. 2000. The effect of longevity on spending for acute and long-term care. *N Engl J Med,* 342, 1409-15.

STAM, P., VAN VLIET, R. & VAN DE VEN, W. 2010. Diagnostic, pharmacy based, and self reported health measures in risk equalization models. *Med Care,* 48, 448-457.

STATISTICS NEW ZEALAND 2009. National Population Projections: 2009 (base)–2061. Wellington: Statistics New Zealand.

STATISTICS NEW ZEALAND. 2011a. *Ethnic groups in New Zealand* [Online]. Wellington. [Accessed 8th July 2011].

STATISTICS NEW ZEALAND. 2011b. *National Population Estimates 2008* [Online]. Wellington: Statistics New Zealand. Available: http://www.stats.govt.nz/browse_for_stats/population/estimates_and_projections/national-pop-estimates.aspx [Accessed 21 June 2011].

STATISTICS NEW ZEALAND 2011c. Population change and structure. *Demographic trends 2010.* Wellington: Statistics New Zealand,.

STATISTICS NEW ZEALAND. 2012. *Infoshare* [Online]. Available: http://www.stats.govt.nz/infoshare/ [Accessed 14/12/ 2012].

STATISTICS NEW ZEALAND 2013. New Zealand Period Life Tables:2010-12. Wellington: Statistics New Zealand.

STEARNS, S. C. & NORTON, E. C. 2004. Time to include time to death? The future of health care expenditure predictions. *Health Econ,* 13, 315-27.

SULLIVAN, S. D., LYLES, A., LUCE, B. & GRIGAR, J. 2001. AMCP guidelines for submission of clinical and economic evaluation data to support formulary listings in US health plans and pharmacy benefits management organizations. *Journal of Managed Care Pharmacy,* 7, 272-282.

THE PHARMACUETICAL SOCIETY OF IRELAND 2008. *Pharmacy Practice Guidance Manual.*

TIAN, L. & HUANG, J. 2007. A two-part model for censored medical cost data. *Stat Med,* 26, 4273-92.

TOBIN, J. 1958. Estimation of relationships for limited dependent variables. *Econometrica,* 26, 24-36.

USHER, C., TILSON, L., BENNETT, K. & BARRY, M. 2012. Cost containment interventions introduced on the community drugs schemes in ireland-evaluation of expenditure trends using a national prescription claims database. *Clin Ther,* 34, 632-9.

VAN BAAL, P. H. & WONG, A. 2012. Time to death and the forecasting of macro-level health care expenditures: some further considerations. *Journal of Health Economics,* 31, 876-87.

VON KORFF, M., WAGNER, E. H. & SAUNDERS, K. 1992. A chronic disease score from automated pharmacy data. *Journal of Clinical Epidemiology,* 45, 197-203.

WAIDMANN, T. A. & LIU, K. 2000. Disability trends among elderly persons and implications for the future. *Journal of Gerontology,* 55, S298-307.

WANLESS, D. 2002. Securing our future health: Taking a long term view. London: HM Treasury.

WERBLOW, A., FELDER, S. & ZWEIFEL, P. 2007. Population ageing and health care expenditure: a school of 'red herrings'? *Health Economics,* 16, 1109-26.

WESTERHOUT, E. W. M. T. 2006. Does ageing call for a reform of the health care sector? *Cesifo Economic Studies,* 52, 1-31.

WHITE, H. 1980. A heteroscedasticity-consistent covariance matrix estimator and a direct test for heteroscedasticity. *Econometrica,* 48.

WIJEYSUNDERA, H. C., WANG, X., TOMLINSON, G., KO, D. T. & KRAHN, M. D. 2012. Techniques for estimating health care costs with censored data: an overview for the health services researcher. *Clinicoecon Outcomes Res,* 4, 145-55.

WOOLDRIDGE, J. M. 2009. *Introductory Economometrics: A Modern Approach*, South-Western.

WOOLDRIDGE, J. M. 2010. *Econometric analysis of cross section and panel data,* Cambridge, Mass. ; London, MIT.

WOUTERSE, B., HUISMAN, M., MEIJBOOM, B., DEEG, D. J. H. & POLDERA, J. J. 2013. Modeling the relationship between health and health care expenditures using a latent Markov model. *Journal of Health Economics,* 32, 423-439.

WREN, M.-A. 2011. *Ageing and the Balance of Care: An investigation into the Relationship between and Determinants of Acute Hospital Bed and Long-term Care Utilisation.* PhD, Trinity College Dublin.

WROBEL, M. V., DOSHI, J., STUART, B. C. & BRIESACHER, B. 2003. Predictability of prescription drug expenditures for Medicare beneficiaries. *Health Care Financ Rev,* 25**,** 37-46.

XIE, H., MCHUGO, G., SENGUPTA, A., CLARK, R. & DRAKE, R. 2004. A method for analyzing longitudinal outcomes with many zeros. *Ment Health Serv Res,* 6**,** 239-46.

YANG, Z., NORTON, E. C. & STEARNS, S. C. 2003. Longevity and health care expenditures: the real reasons older people spend more. *J Gerontol B Psychol Sci Soc Sci,* 58**,** S2-10.

ZHAO, Y., ASH, A. S., ELLIS, R. P., AYANIAN, J. Z., POPE, G. C., BOWEN, B. & WEYUKER, L. 2005. Predicting pharmacy costs and other medical costs using diagnoses and drug claims. *Med Care,* 43**,** 34-43.

ZWEIFEL, P., FELDER, S. & MEIERS, M. 1999. Ageing of population and health care expenditure: a red herring? *Health Econ,* 8**,** 485-96.

ZWEIFEL, P., FELDER, S. & WERBLOW, A. 2004. Population ageing and health care expenditures: New evidence on the "Red Herring". *Geneva Papers on Risk and Insurance:Issues and Practice,* 29**,** 653-667.

ZWEIFEL, P. & FERRARI, M. 1992. Is there a Sisyphys syndrome in health care? *In:* ZWEIFEL, P. & FRECH, H. E., III (eds.) *Health economics worldwide.* . Norwell, MA: Kluwer Academic.

ZWEIFEL, P., STEINMANN, L. & EUGSTER, P. 2005. The Sisyphus syndrome in health revisited. *International Journal of Health Care Finance and Economics,* 5**,** 127-45.