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The Chronic-ills of Multimorbidity

A cross-sectional examination of the prevalence, patterns and factors associated with multimorbidity in the Irish population aged 50 years and over and its corresponding impact on health and social care utilisation

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

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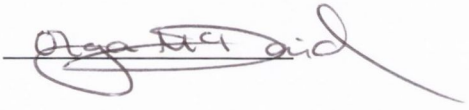
Signed:  Date: 6.3.2014

Olga McDaid

Summary

Multimorbidity predicts many adverse health outcomes, placing a heavy burden on the individual as well as population health. It has clear implications for current healthcare provision and with the projected ageing of the Irish population presents substantial challenges for future healthcare policy and planning. Population level evidence on multimorbidity is, however, limited. The factors driving multimorbidity prevalence are poorly understood and appropriate responses have yet to be integrated into population health planning and service delivery. The overall aim of this thesis was to gain a greater understanding of the prevalence, patterns and factors associated with multimorbidity at a population level in Ireland, as well as the corresponding impact of multimorbidity on health and social care utilisation. Three separate but related empirical studies were conducted based on the following central objectives:

1. To estimate the prevalence and non-random patterning of multimorbidity in the community-dwelling population aged 50 years and over in Ireland.
2. To examine the factors associated with multimorbidity in mid to late life in an Irish context.
3. To determine the impact of multimorbidity on health and social care utilisation and quality of care in Ireland.

Conceptual issues of multimorbidity definition and measurement were considered in this thesis to contextualise multimorbidity within population health and inform a framework for evaluating multimorbidity in community-dwelling populations.

Data were obtained from the first wave Irish Longitudinal Study of Ageing (TILDA), a cross-sectional sample (n = 8,612) representative of the community-dwelling population aged 50 years and over in Ireland. Population prevalence of multimorbidity was estimated and cluster analysis was employed to investigate non-random patterns of multimorbidity. The factors associated with having one condition distinct from those associated with increasing levels of multimorbidity was examined in a two-part modelling process. A multinomial model was employed to examine the factors associated with different types of multimorbidity. The Anderson Phase-3 Model of Health Service Utilisation is employed as an analytical framework to examine the impact of multimorbidity on health and social care utilisation controlling for other need, predisposing, enabling and behavioural factors. Multivariate logistic and two-part zero-truncated regression models were employed to assess the independent effect of increasing levels of multimorbidity on the propensity to use a health and social care service and intensity of service use in the previous year.

53.8% of the Irish population aged 50 years and over had threshold multimorbidity (≥ 2 conditions), 7.5% had physical-mental health multimorbidity and 3.3% had mental health multimorbidity. Prevalence was significantly higher in women, those living in rural areas and living alone. Significantly higher prevalence of multimorbidity with at least one mental health condition was found for permanently sick and disabled individuals and separated or divorced individuals. A social gradient was found for all multimorbidity in crude analysis and was more pronounced for multimorbidity with at least one mental health condition. Nine associative patterns of multimorbidity were identified from cluster analysis. Several factors influencing multimorbidity at a population level have been identified in analyses; however effect sizes for increasing levels of multimorbidity after the initial acquisition of a chronic condition were small. There was an evident distinction between factors influencing physical-mental health multimorbidity relative to physical only multimorbidity. Health and social care utilisation rates varied substantially according to chronic conditions and across healthcare utilisation type. Increasing levels of multimorbidity were significantly associated with both propensity to use GP services, outpatient visits and overnight stays in hospital as well as with increased intensity of GP and outpatient visits and hospital length of stay.

Overall, this picture indicates a substantial burden of multimorbidity in the Irish population aged 50 years and over and highlights the role of multimorbidity as a significant driver of healthcare in Ireland, across all healthcare services examined, even after controlling for age effects and other gerontological constructs such as disability and frailty. Further research is required to gain a more comprehensive understanding of the risk factors for multimorbidity and the factors associated with particular clusters of multimorbidity in an Irish context and internationally. As healthcare systems evolve to address demographic changes, existing vertical approaches to chronic disease management will need to reorient towards the management of complex patients with several co-existing conditions. Population based studies of multimorbidity are particularly useful as they provide generalisable estimates and contribute valuable data to inform population health and healthcare policy and planning for multimorbid patients.

Dedication

This thesis is dedicated to my late grandmother Margaret O'Reilly who helped shape my thinking on life and health in older age and served as a fond reminder of the why, not just the what.

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Glossary of Terms

Term	*Definition*
AC	Agglomerative cluster score
ACG	Adjusted Clinical Group system
ADL	Activities of Daily Living
BMI	Body Mass Index
CAPI	Computer Assisted Personal Interviewing
CASP-19	Control, Autonomy, Self-actualisation and Pleasure Scale
CHD	Coronary heart disease
CIRS	Cumulative Index Rating Scales
CIs	Confidence intervals
COPD	Chronic obstructive pulmonary disease
CSO	Central Statistics Office
CVD	Cardiovascular disease
df	Degrees of freedom
DUSOI	Duke Severity of Illness Checklist
EDs	Electoral Districts
ED	Emergency Department
ELSA	English Longitudinal Study on Ageing
ESRI	Economic and Social Research Institute
GMS card	General Medical Services card
GP	General Practitioner
HIPE	Hospital In-Patient Enquiry System
HIV	Human immunodeficiency virus
HSE	Health Services Executive
HSE-PCRS	Health Service Executive-Primary Care Reimbursement Service
HRQoL	Health-related quality of life
HRS	Health and Retirement Study
IADL	Instrumental Activities of Daily Living
ICD-9	International Classification of Disease, 9thEdition
ICF	International Classification of Function, Disability and Health

ICPC-2	International Classification of Primary Care, 2nd Edition
IPAQ	International Physical Activity Questionnaire
IPH	Institute of Public Health
nbreg	Negative binomial regression model
NIHSWS	Northern Ireland Health and Social Wellbeing Survey
OP	Outpatient
OSNI	Ordnance Survey of Northern Ireland
PHN	Public Health Nurse
PTSD	Post-traumatic stress disorder
QHNS	Quarterly Household National Survey
QoL	Quality of Life
SAHRU	Small Area Health Research Unit
SAPS	Small Area Population Statistics
sd	Standard deviation
SES	Socioeconomic status
SHARE	Study of Health, Ageing and Retirement in Europe
SLÁN	Survey of Lifestyle, Attitudes and Nutrition in Ireland
SRH	Self-rated health
negSRH	Negative self-rated health
TIA	Transient ischaemic attack
TILDA	The Irish Longitudinal Study on Ageing
VHA	Veterans Health Administration
WHO	Wor4ld Health Organization
ztnb	Zero-truncated negative binomial regression model

Chapter 1. Introduction and Conceptual Framework

1.1 Introduction

Multimorbidity, the co-occurrence of two or more chronic conditions in an individual, predicts many adverse health outcomes including unfavourable self-assessed health status (SchellPerruccio et al., 2012), poor quality of life (Agborsangaya et al., 2012, Bayliss et al., 2005, de Nobrega et al., 2009, Fortin et al., 2007a), the onset of additional health problems (John et al., 2003), functional impairment and progressive loss of mobility (McDaid et al., 2013, Stuck et al., 1999, Koster et al., 2004, Marengoni et al., 2009b), poor mental health symptoms (Barnett et al., 2012, Scott et al., 2009), increased healthcare utilisation (Agborsangaya et al., 2012, Costa et al., 2009, Terner et al., 2011, Glynn et al., 2011), high healthcare costs (Hoffman et al., 1996, Hodek et al., 2011) and mortality (Marengoni et al., 2010). In addition, managing multimorbidity is a complex process for individuals and health care systems alike. Given the increase in longevity largely attributable to improved nutrition and sanitation and increased medical intervention in the last century (Broe, 2003), the growing proportion of older people in developed societies living with chronic conditions and complex combinations of conditions poses a substantial population health challenge in the years ahead. Europe has the highest proportion of older people compared to any other region in the world and while Ireland's population remains relatively young compared to other European countries, it is expected to age substantially in the coming decades. Population projections estimate a significant increase in the proportion of older people in Ireland by 2041, with the largest increase set to occur in those aged 80 years and over (Central Statistics Office, 2008).

Evidence to date suggests that the burden of multimorbidity in community-dwelling people is high (Marengoni et al., 2011) and is likely to increase substantially in tandem with population ageing, thereby requiring an appropriate population health approach to prevention and management of multimorbidity. However, research about multimorbidity as a generic phenomenon and its import for population health remains deficient in many ways. Several issues, including ill-defined concepts and diverse operational definitions, large variation and poorly defined measurement approaches and a wide range of study populations, have led to an increasingly complex literature in the area. Studies have focused on multimorbidity in older age groups, neglecting the potentially large burden presenting in those who accumulate chronic conditions in mid-life. Moreover, evidence on multimorbidity has been concentrated on clinical

sub-populations of interest which cannot easily be translated to community-dwelling populations.

Widely acknowledged as one of the greatest challenges that will face health systems in the twenty first century, the burden of chronic conditions in developed countries has gained increasing prominence in healthcare policy in recent years. However policy approaches to address chronic conditions have been largely inadequate to date, focusing on silos of conditions and overlooking the substantial burden of multimorbidity. This may, in part, be attributed to the lack of data on the burden of multimorbidity at a population level. Large scale population based studies provide an invaluable source of data. In order to properly assess multimorbidity from a population health perspective and and its corresponding impact on national health and social care services. Increasing our understanding of multimorbidity from a population health perspective may not only provide valuable insights into the prevalence, patterns and consequences of multimorbidity in our society, but it may also provide direction for future healthcare policy and planning to reduce the burden of multimorbidity on community-dwelling individuals and on health and social care services. This thesis examines the construct of multimorbidity relevant to population health and investigates the prevalence, patterns and factors associated with multimorbidity at a population level as well as the health and social care burden of multimorbidity, generalisable to people aged 50 years and over living in Ireland.

The following section in this chapter introduces and develops the concept of *multimorbidity*, applied in this thesis as an overarching global term, and its measurement with a focus on its application to population health. Section 1.2 discusses the epidemiological and demographic change driving the need to investigate multimorbidity. Section 1.3 introduces the concept of multimorbidity and identifies challenges inherent to multimorbidity research. Section 1.4 discusses the issues with defining and measuring multimorbidity in current research practice, Section 1.4 presents a detailed discussion of concepts and operational definitions as applied in multimorbidity research. Sections 1.5 to 1.9 introduces some considerations for multimorbidity investigation, discusses measures applied in research to date and the important consideration of interdependent constructs defining patient complexity in later life as well as examining multimorbidity in a population health context. This is followed by an overview of the conceptual approach adopted in empirical analysis of this thesis (Section 1.10) and the main aims and objectives of the thesis (Section 1.11). The approach to reviewing the current evidence-base on multimorbidity is outlined in Section 1.12 and finally this chapter concludes with an outline of this thesis in Section 1.14.

1.2 CHRONIC CONDITIONS AND POPULATION HEALTH

1.2.1 Defining chronic conditions

Advances in epidemiology throughout history have led to the adoption of several definitions in order to qualify the health and major disease states presented in populations. Definitions have centred on two aspects: cause (i.e. communicable or non-communicable) and effect (i.e. acute or chronic). The conventional distinctions between these definitions are now increasingly challenged, leading to a rethinking of conventional epidemiological terminology. In recent years, substantial evidence has emerged implicating microorganisms as etiologic agents of chronic diseases for example: peptic ulcer disease with *Helicobacter pylori*, cervical cancer with several *human papillomaviruses*, Lyme arthritis and neuroborreliosis with *Borrelia burgdorferi*, AIDS with the *human immunodeficiency virus*, as well as liver cancer and cirrhosis with *hepatitis B and C viruses* (Knobler et al., 2004). Moreover, microorganisms have also been linked to chronic diseases such as atherosclerosis and cardiovascular disease (CVD), type 1 diabetes, inflammatory bowel disease, and a variety of neurological diseases (Knobler et al., 2004), with considerable implications for population health. A further challenge to the traditional definition of disease causation was proposed by Ackland et al., (2003) who contend that the determinants of chronic disease should be considered as vectors underpinned by the psycho-social, cultural, ethnic and socioeconomic attributes of populations, society and local communities. They highlight the vulnerability of certain population groups to risky health behaviours transferred through social 'vectors' including peer groups and the influence of societal conformity on lifestyle related health practices and associated outcomes. Risky behaviours are concentrated among poorer more deprived individuals and

> *'unhealthy behaviours as typical vectors for chronic diseases can be passed on through families, communities, and populations following demographic gradients'.*

In this context, the distinction between non-communicable and communicable diseases is more than just inappropriate, it is also unhelpful for securing a public health policy focus on disease prevention. It is intended that adopting a focus on upstream disease causation issues will motivate a more pragmatic approach to disease prevention at a population level.

Furthermore, the debate heretofore has centred on the cause and effect of conventional chronic diseases, overlooking additional factors that may be impacting on health burden at an individual and population level. Nolte and McKee (2008) qualify conventional diseases as physical conditions such as asthma, diabetes or heart disease. Expanding on the traditional focus of

chronic disease epidemiology, Hoffman (1996) advocated a shift in taxonomy to chronic health conditions; a more general term that encompasses both chronic disease and impairment. Defined as conditions of long-duration and slow progression, this term more closely reflects the WHO definition of health as physical, cognitive, social and emotional dimensions influenced by development across the life course (WHO 2006). This is an important distinction; increasingly, it is acknowledged that illness burden in populations is not limited to chronic physical diseases, but that mental illness and physical impairments are increasingly contributing to chronic condition burden. Advances in the debate on chronic condition burden would then benefit from further investigation to unearth the complex relationship and co-occurrence of physical, psychological and degenerative manifestations of morbidity. Investigations of multimorbidity to date have largely overlooked the import of such distinctions, in part perhaps due to the clinical focus of earlier studies and an emphasis on chronic disease diagnosis. Evidence now supports a focus on the cumulative impact of co-occurring conditions in complex patients and the burden of multimorbidity at a population level. This thesis proposes a broad nosological definition of chronic conditions to investigate, as fully as possible, the impact of multimorbidity on population health in an Irish context.

1.2.2 The population health burden of chronic conditions

Hoffman et al., (1996) contended that chronic conditions were becoming a significant public health concern and the dominant healthcare challenge as far back as the 1920's. Prevalence and incidence of chronic conditions have steadily increased since and are already having a major effect on mortality data across the world (Jadad et al., 2010). They are now the leading cause of mortality in every country in the world, except for those with the lowest levels of income; an estimated 60% of deaths worldwide in 2005 were attributable to chronic conditions *(World Health Organization, 2006).* Three chronic conditions accounted for 78.3% of the total number of deaths in the Republic of Ireland in 2006 (n=27,479). These included cardiovascular disease (n=9,662), cancer (n=7,868) and respiratory conditions (n=3,978), principally pneumonia and Chronic Obstructive Pulmonary Disease (COPD) (Central Statistics Office, 2006). A series of studies conducted by the Institute of Public Health in Ireland (IPH) point to the disproportionately high prevalence of a range of chronic conditions in older people in Ireland including diabetes, musculoskeletal conditions, coronary heart disease (CHD), stroke and hypertension, expected to rise dramatically by 2020 (Balanda et al., 2010). If current trends in the incidence of chronic conditions persist, coupled with population ageing trends, it is

estimated that the global burden of chronic conditions will cost a total lost output of US $47 trillion over the coming two decades (Bloom et al., 2011).

One of the major challenges this demographic shift presents for Irish society is how we can maintain health and quality of life for older people in the future. Of specific relevance in the coming years is how the Irish healthcare system will organise itself to deal with this demographic change and the projected higher burden of chronic conditions in older people. While the challenges brought on by chronic conditions are gaining recognition and the management of chronic conditions is now one of the primary aims of healthcare systems in the developed world, Horton (2005) argues that the challenge remains underestimated and neglected. There is currently a dearth in healthcare policy approaches at a national level to plan for an ageing population and many of the healthcare issues associated with population ageing remain relatively under-researched, limited by the lack of valid measures and well-defined constructs in later life.

1.2.3 Important considerations when planning for population ageing

Several important considerations arise when planning for this projected increase in the prevalence of chronic conditions. Firstly, while ageing has long been established as a risk factor for chronic conditions, especially functional conditions, age *per se,* is not always indicative of poor health as individual older people vary considerably in their health experience (Hodge, 2008). Age 65 is taken as the marker for later life, signalling retirement from employment, and other societal entitlements such as public pensions (Hodge, 2008), it is also considered a marker in the expected decline of health status. As people age beyond 65 years, it is expected that there will be an increased risk of illness and frailty. Thus, age 65 is often applied as a proxy definition for 'old age', marking a change in physical and social status brought on by the process of ageing. According to Hodge (2008) however, age in numerical terms is less a predictor of experience and more an indicator of a context in which one can expect life experiences to vary from those of younger age-groups. Given the diversity of the older population, distinction is required between the increasingly wide span of age ranges defined as old age, including the 'old' (aged 65-74 years), the 'old-old' (aged 75-84) and the very old (aged 85 years and older). Furthermore, each of these age cohorts will have accumulated a variety of experiences in early life and over their life-course within a wide array of social and personal contexts, referred to by the prominent sociologist Mannheim (1952) as the '*social location*' of an individual, namely the ways in which individuals are shaped by virtue of being embedded in societies, communities, and groups. It is

increasingly understood that the social context of generations will inevitably shape experiences in old age.

Secondly, evidence points to a high proportion of people aged under 65 years living with chronic conditions (Barnett et al., 2012, Taylor et al., 2010) challenging the blunt distinction between 'healthy' and 'unhealthy' populations before and after age 65. Accurate estimates of the health status of older populations are difficult to obtain and may also be subject to some biases. Prevalence estimates for chronic conditions may be biased by an increased propensity to access healthcare services with increased opportunity for diagnosis in older individuals compared to their younger counterparts. However this bias may be balanced by age-discrimination practices in clinical care where older patients experience a cumulative increase in delays to access for diagnosis, referrals, and treatment compared to younger patients (Kennelly and Bowling, 2001).

Thirdly, there has been a pronounced lowering of diagnosis thresholds in recent years for common chronic conditions such as hypertension and diabetes and recently revised clinical care guidelines promote the treatment of predisease conditions such as prehypertension and prediabetes (Hunt et al., 2012). As a direct result of these lowered diagnosis thresholds, prevalence rates for chronic conditions have increased substantially. Further to this, increased treatment of conditions can lead to *'prescribing cascades',* whereby a prescribed drug can lead to additional symptoms requiring further treatment and increasing the risk of polypharmacy and further adverse symptoms (Hunt et al., 2012).

Fourthly, knowledge on prevalence of chronic conditions at a population level is limited (Kupari et al., 1997) due to a lack of reliable longitudinal or cross-sectional data sources and collection of data on a wide range of chronic conditions. Investigations are generally limited to conditions that are most routinely recorded such as CVD and cancers (Hyde et al., 2009). To date, mortality data have proved the most objective and precise health outcome measure and therefore most widely applied (Costa-Font and Hernandez-Quevedo, 2012). Examination of mortality provides little evidence on the experience of living with chronic disabling conditions and is limited in its ability to inform population health planning. Its capacity to accurately measure chronic condition burden is constrained. Mortality's relationship with predictors of ill-health may be quite distant in time (Mullahy et al., 2001) and can also be subject to recording bias in death certificate records. Lauer et al., (1999) contend that even when medical records and death certificates are properly filled out, determining cause of death can be a very difficult task, particularly for older patients with multiple conditions.

Finally, despite the proliferation of chronic care programmes and healthcare interventions to address the increased prevalence of chronic conditions, little attention has been paid to the complexity of living with more than one chronic condition in later life and its corresponding impact on population health and healthcare use. However, multimorbidity has garnered increasing interest in national and international healthcare policy in recent years where the growing burden of multimorbidity and the disproportionate allocation of resources to a minority of high cost patients is increasingly recognised. With the projected trend towards population ageing, the prevalence of multimorbidity at a population level is likely to increase substantially in the years to come (Starfield, 2007, Fortin et al., 2007a, Valderas et al., 2007). Healthcare systems originally designed to respond to acute and episodic instances of care needs are increasingly faced with the substantial challenge of multimorbidity; a care need that does not easily fit into the current structure of healthcare delivery (Fortin et al., 2007b; Mercer et al., 2009; Plochg, Klazinga, and Starfield 2009; Starfield 2011). While there is an increasing focus on slowing the progression of chronic conditions and delaying functional limitations borne by chronic condition onset (Warshaw 2006), population health interventions and chronic condition management continues to focus on silos of conditions, overlooking the substantial impact of multimorbidity on health outcomes, quality of care and healthcare utilisation and costs.

1.3 The Challenge of Multimorbidity Research

While it is now well acknowledged that multimorbidity is the norm rather than the exception in mid-to-late life (Marengoni et al., 2011, Barnett et al., 2012, Mercer et al., 2009), few articles in the medical literature report on multimorbidity compared to the frequency of publications pertaining to individual chronic conditions (Fortin et al., 2005b). One possible explanation for the neglect of multimorbidity at a policy level is that Investigations into the phenomenon of multimorbidity are relatively recent and did not gain prominence in international journals until the 2000's. Although a burgeoning body of international literature is now emerging on multimorbidity, it has been argued that both the number and diversity of articles on multimorbidity are insufficient to provide a strong evidence-base on tackling the issue in healthcare. Results of a bibliometric study conducted in 2005 (Fortin et al.) illustrated the mismatch of the burden of multimorbidity in the general population and the number of peer-reviewed publications examining its implications. They found that for each article examining multimorbidity, there were 94 articles on hypertension, 74 on asthma and 38 on diabetes. The majority of the identified articles on multimorbidity were epidemiological studies reporting

prevalence or validation studies examining multimorbidity measurement. In addition, several of the identified articles were opinion pieces or editorials discussing the need to address multimorbidity as a phenomenon in modern medicine. Few of the identified studies reported on the causes and consequences of multimorbidity. These findings have been reiterated in a recent systematic review of ageing and multimorbidity conducted by Marengoni et al., (2011). This recent review also shows that while there has been a burgeoning investigation into multimorbidity in the intervening years since Fortin's bibliometric study, the evidence-base remains limited and the investigative effort is relatively small compared to other public health and clinical care topics.

The relative dearth of multimorbidity-focused research may in part be related to the wide range of methodological issues presented in researching the phenomenon. These include the definition of multimorbidity, the nature and number of conditions to include in multimorbidity measurement, the diagnostic criteria applied to the inclusion of conditions, study populations and settings and finally the source of data i.e. self-reported survey data or clinical databases. Moreover, research into multimorbidity has been constrained by a lack of available data appropriate to multimorbidity measurement. Current medical practice is oriented around silos of chronic conditions responding to the single disease management approach. Not surprisingly then, investigations into health conditions have followed suit. Large prospective studies to date have investigated leading chronic conditions in isolation with little regard for the influence of co-occurring conditions on health outcomes. Such studies (for example The Framingham Heart Study) have contributed much to the understanding of chronic disease epidemiology however the single disease focus is largely inadequate for examining the spectrum of multimorbidity in a population and its implications on health burden and healthcare utilisation. In response to this vertical approach to healthcare provision, there is now an emerging focus on healthcare interventions to improve the outcomes for patients living with multimorbidity (Salisbury, 2013). It is noteworthy however, that although multimorbidity is beginning to be recognised as a public health challenge in developed countries characterised by ageing societies, the distribution and combination of conditions still does not receive sufficient attention in the literature (Kirchberger et al., 2012, Marengoni et al., 2011, Fuchs et al., 2012) and remains poorly understood. There also remains a dearth of evidence on particularly high risk populations, the risk factors associated with multimorbidity and interventions to address multimorbidity in particularly vulnerable populations, despite a documented concentration of multimorbidity in more deprived populations, associated with increased use of healthcare services (Smith et al., 2008, Barnett et al., 2012).

1.4 Defining and measuring co-occurring conditions

This section presents a discussion on the challenges of defining, refining and measuring co-occurring conditions in current research practice.

1.4.1 Taxonomies and classification of comorbidity and multimorbidity

Evaluation of co-occurring conditions in later life is complicated by the lack of consensus on how to define and measure the concept. Debate centres on two constructs fundamental to the conceptualisation of co-occurring conditions; *comorbidity* and *multimorbidity*. The principle focus of this thesis is multimorbidity, nonethless any delineation of the concept of co-occurrence of conditions requires some definition of the concept of comorbidity. The concept of co-occurring conditions experienced by an individual was first introduced by Feinstein in 1976 as *comorbidity*; defined as the occurrence of a medical condition additional to an index disease or "*any distinct additional entity that has existed or may occur during the clinical course of a patient who has the index disease under study*". A large number and iterations of measurement indices have emerged in the literature in the interventing years ensuring that the term *comorbidity* has become synonmous with investigations into co-occurring conditions in the presence of an index condition. Two defining characteristics of comorbidity indices are a focus on an index condition and incorporated weighting according to condition severity. The Charlson Comorbidity Index was one of the first and is perhaps the best recognised measure of comorbidity (Charlson et al., 1987). It is generally applied in a clinical care setting as an approach to measuring comorbidity burden incorporating weighting according to condition severity and was initially validated to predict risk of death from comorbid disease in hospitalized patients. Comorbidity indices have diversified substantially since the introduction of the Charlson Index. A wide variety of indices have been applied in clinical settings and to a lesser extent in community settings to assess a diverse range of health related outcomes, for example:

Clinical study samples:

I. health related patient outcomes such as such as functional status, survival from heart attack and mortality (Mulrow et al., 1994, Greenfield et al., 1993, Hallstrom et al., 1996, Charlson et al., 1987, Incalzi et al., 1997);
II. healthcare utilisation patterns such as readmission or length of stay (Parkerson et al., 1993, Fan et al., 2002);

III. medication use (Linn et al., 1968);
IV. postoperative complications (Greenfield et al., 1993);
V. patient costs (Shwartz et al., 1996).

Community study samples:

I. health related outcomes such as self-reported health status, physical functioning, anxiety, depression, self-efficacy, HRQoL and mortality (Bayliss et al., 2005, Byles et al., 2005, Groll et al., 2005, McGee et al., 1999);
II. healthcare utilisation (Tooth et al., 2008, Byles et al., 2005, Von Korff et al., 1992).

While such indices reveal important findings on the impact of comorbidity burden, a major criticism of these indices is their focus on an index condition rather than on the individual who may be experiencing a broad range of conditions. In addition, they are unable to provide insight into the underlying relationships between different combinations of conditions that may occur simultaneously in an individual. To address these limitations, the term *multimorbidity* was introduced by van den Akker in 1996 to refer to any co-occurrence of two or more medical conditions within an individual. This conceptualisation indicates a shift from a given index condition to a person centred focus on the individual experiencing multiple conditions. van den Akker (1996) proposed a distinction between *comorbidity* and *multimorbidity* to ensure clarity in further investigations:

- comorbidity – '*any distinct additional entity that has existed or may occur during the clinical course of a patient who has the index disease under study (as per the initial Feinstein definition)*';
- multimorbidity - the '*co-occurrence of multiple chronic or acute conditions within one person*'.

The introduction of the term *multimorbidity* to capture the general phenomenon of co-occurring conditions has certainly aided in the distinction between investigations of co-occurring conditions from a relative view point (i.e. where the index condition is considered as central) to a more global consideration of co-occurring conditions. However, there is still no widespread consensus on defintions and certain conceptual challenges remain in the taxonomy of co-occurring conditions. Definitions continue to be applied interchangeably and many further iterations have continued to emerge in the literature. For example: multiple chronic conditions; multiple morbidity; multiple long-term disorders; limiting long-term illnesses; polypathology and

multicomorbidity. Furthermore, over a decade after van den Akker's proposed distinction between *comorbidity* and *multimorbidity*, leading researchers continue to use the term *comorbidity* as the overarching term, encompassing all operational definitions. Interestingly, a recent review of definitions authored by Valderas et al., (2009) used the term *comorbidity* as a general term to explore conceptualistions of co-occurring conditions rather than the relative term proposed by Feinstein and reiterated by van den Akker. While Valderas et al., acknowledged the lack of consensus on concept definitions as a substantial challenge for researchers, no consideration was given to distinguishing the concepts of *comorbidty* or *multimorbidity* in their paper.

1.4.2 Operational definitions and multimorbidity measurement approaches

The conceptualisation of multimorbidity is complicated by the proliferation of a wide range of operational definitions, which emerged from the need to measure multimorbidity in research rather than any defined conceptual approach. Notwithstanding the import of adopting a valid measurement approach, varied application of measures has led to an increasingly complex research area. To date a variety of data sources have been exploited and a variety of approaches have been undertaken to measure the prevalence and impact of multimorbidity. While the different multimorbidity measurement approaches have been well debated in the literature there is little consensus on the best approach (van den Akker et al., 2001, Diederichs et al., 2011a, Salisbury et al., 2011, Guthrie, 2011, Huntley et al., 2012, De Groot et al., 2003). Few studies on multimorbidity outcomes have clearly stated operational definitions and few studies have primarily aimed to investigate methods in multimorbidity research; rather evidence of measurement has emerged from a small number of systematic review studies investigating measures applied in a diverse range of multimorbidity papers (Diederichs et al., 2011b, Huntley et al., 2012, De Groot et al., 2003, Fortin et al., 2012). Few conclusions can then be drawn from the literature, however, there is a growing consensus that no one measurement approach will serve all research and clinical purposes effectively (Valderas et al., 2009, Marengoni et al., 2011).

Operational definitions in the literature appear to be guided by four broad considerations:

1. The research question.

This will determine the appropriate measurement approach for outcomes of interest. For example measurement approaches can vary according to research questions on prevalence,

patterns, health impacts, healthcare utilisation or investigations to guide clinical decision making on specific conditions, although there are no standard guidelines available to researchers on valid approaches for specific outcomes.

2. The availability of data to support investigations related to the research question.

This will determine the number, type and nature of conditions (referred to in this thesis as nosology) included in a multimorbidity measure. In the absence of reliable population-wide electronic health records, population samples are generally based on self-reported data, while studies in primary care and hospital settings have access to medical records or laboratory results. Some more recent studies have used a variety of approaches to cross-validate measures (Britt et al., 2008, Marengoni, 2008). Large administrative databases and electronic health records provide a greater number of conditions compared to population health surveys. There is little guidance in the literature on what conditions to include, and how to include them in multimorbidity measures. The rationale for inclusion of conditions varies substantially, and is often not described in published articles. In a systematic review of the issue, Diederichs et al., (2011b) found that inclusion of conditions was primarily driven by condition prevalence, and to a lesser extent its impact on health related outcomes such as functional status, health status and mortality.

3. The population sample.

This can be restricted by age, sex, particular types of healthcare use (i.e. such as hospital inpatient samples or primary care samples), or outcomes of interest (i.e. disabled individuals in the U.S. Medicare sample (Grau and Kovner, 1991)). This is often determined by either the research questions or the availability of data to support investigations related to the research question.

4. The decision to weight the data according to severity or outcomes.

Indices to assess multimorbidity burden can differentially weight a range of conditions or diseases applying weights based on mortality, severity or likely healthcare utilisation (Valderas, 2009). Alternatively, multimorbidity measures can be based on simple counts of conditions in individuals (based on patient self-reported/clinical assessment/pharmaceutical records) indicating the presence or absence of the conditions under consideration.

1.4.2.1 Index or simple condition counts?

Multimorbidity indices are in effect a quantitative approach to measuring condition concurrence (with or without accounting for condition severity or weights based on other outcomes of interest). It is increasingly acknowledged that the rate of aggregation of conditions, often exceeds the rate expected by chance alone (Marengoni and Fratiglioni, 2011). This focus on quantifying the impact of additional levels of multimorbidity however overlooks the non-random patterning of conditions and this oversight could potentially lead to inadequate care management. Furthermore, a single index of multimorbidity is unable to predict a diverse range of outcomes (Byles et al., 2005). Although simple counts of conditions have also been critiqued in the literature this approach is appropriate for application to a wide variety of empirical enquiries and moreover, it allows for the investigation of patterns of multimorbidity.

1.4.2.2 Patterns of conditions

It is hypothesised that conditions can co-occur for a large number of reasons including: underlying etiological associations, or common underlying risk factors (Valderas et al., 2009); general disease susceptibility or interaction between gene and environment (Rhee et al., 2005); associations between conditions in a self-perpetuating and mutually reinforcing causality (De Groot et al., 2003); an expression of life events, coping styles, psychosocial and cultural factors on organ systems and underlying pathogenic mechanisms such as chronic inflammation (Marengoni and Fratiglioni, 2011). To date investigations into the biological mechanisms and underlying pathophysiology of condition patterns has been limited. Several studies to date have investigated the non-random patterning of multimorbidity through simple analysis of condition pairs (or dyads), triads (Verbrugge et al., 1989, van den Akker et al., 1998b, Marengoni et al., 2008) and some have examined condition quads (Min et al., 2007). The mathematical approach to generating all possible combinations of objects is generally referred to as *combinatorics*, and it has been applied in multimorbidity investigations to generate all possible combinations of conditions. The co-occurrence of condition combinations are then examined using observed and expected ratios of condition occurrence (Verbrugge et al., 1989, van den Akker et al., 1998b) or estimates of odds ratios or risk ratios. More recently, some studies have adopted more sophisticated statistical techniques namely factor and cluster analysis to examine the overall distribution of conditions in a study sample, based on simple counts of conditions (Prados-Torres et al., 2012, Schafer et al., 2010, John et al., 2003, Marengoni et al., 2009a).

The clinical and public health implications of identifying multimorbidity patterns are substantial (Marengoni et al., 2011). In particular, longitudinal analysis of pattern incidence could enable the identification of underlying causal mechanisms. Primary and secondary prevention programmes targeting non-random clustering of conditions could contribute to a substantial reduction in multimorbidity burden in later life. Treatment burden, polypharmacy and drug-drug, drug-disease interactions are a well-known consequence of poor clinical management of multimorbid patients (Guthrie, 2011). Increased awareness of non-random patterns of condition co-occurrence could assist in the development of appropriate care models and clinical guidelines for multimorbid patients enabling better care management and patient outcomes.

1.4.2.3 Summary of measurement approaches informing operational definitions of multimorbidity in the literature

Leading on from the considerations and approaches to measurement discussed here, measurement of co-occurring conditions can be summarised into two conceptual constructs and four main operational definition approaches classified as the following:

Comorbidity implying a temporal relationship between conditions and defined by the consideration of an index condition:

1. Comorbidity index
    a. weighted for severity or other outcomes of interest
    b. non-weighted

Multimorbidity based on counts of co-occurring conditions defined by the equal consideration of all conditions. Multimorbidity can be weighted to determine specific outcomes:

2. Multimorbidity Index
    a. weighted for severity or other outcomes of interest
    b. non-weighted (referred to as a simple count of conditions)
3. Multimorbidity defined by a cut-off of condition levels
    a. ≥ 2 conditions; or
    b. ≥ 3 conditions
4. Multimorbidity patterns defined as random or non-random combinations of conditions, depending on methodological approach
    a. Combinatorics of conditions (i.e. all possibly patterns of a total number of conditions)

- pairs or dyads
- triads
- quads

b. Condition clusters derived from factor analysis or cluster analysis

1.4.3 Classification of co-occurring condition associations

Several authors have contributed to the classification of comorbidity and multimorbidity. These classifications have been summarised in a recent paper by Lappenschar et al. (2012) and their summary has been adapted here to include further classifications contributed by van den Akker et al. (1996) and Schellevis et al. (1993) as detailed in Table 1.1. Each of the papers presented in this summary introduce concepts related to the co-occurrence of multiple conditions. Classifications can be mutually exclusive or overlapping and are largely organised according to either:

1. the mechanisms for the co-existance of multiple diseases/conditions; or
2. the implications of co-occuring conditions on clinical care.

1.4.3.1 Classifications according to mechanism of co-occurrence

Evidently, all co-ocurrence of conditions will fulfill the concurrent condition classification proposed by Schellevis et al. (1993). Some co-occurring conditions will occur at a rate greater than expected by chance; Lappenschaar et al. (2012) proposed that this be referred to as cluster comorbidity. Some of these statistically significant associations can be explained by known causal relationships (referred to as causal comorbidity), while others remain unexplained by current epidemiological knowledge. Valderas et al. (2009) proposed three mechanisms of association between conditions:

Model 1 - direct causation: the pathophysiology of one disease leads to another disease;

Model 2 - associated risk factors: risk factors are correlated, i.e. one causes the other;

Model 3 - heterogeneric risk factors: risk factors are independent but influence both diseases.

1.4.3.2 Classification according to implications of co-occurring conditions

There is a distinction made between diagnostic and prognostic comorbidity by Kaplan et al. (1974). For diagnostic comorbidity, different diseases can share specific symptamotology, making a diagnosis more difficult, while for prognostic comorbidity, comorbid diseases alter the prognosis of the patient, mainly in a negative direction, sometimes as would be expected (cogent) or other times unexpected (non-cogent). A further classification by Angold et al. (1999), principally applied in psychiatric comorbidity is the distinction between homotypic comorbidity, where diseases/conditions belong to the same diagnostic group for example, depression and dysthemic disease, and heterotypic comorbidity, where diseases/conditions belong to a different diagnostic group for example, depression and a personality disease. Lastly, conditions are classified as concordant or disconcordant by Piette et al. (2009). Concordant conditions share the same pathophysiology for example, heart disease and stroke due to artheriosclerosis, or they can share a specific therapy, for example β-blockers are prescribed for both hypertension and cardiac arrhythemias. Discordant conditions do not share either the same pathophysiology or types of management.

Table 1.1 Classification of co-occurring condition associations (adapted from Lappenschaar et al., 2012)

Author	Classification	Definition
Kaplan et al. (1974)	diagnostic	an associated disease can simulate symptoms of the index disease
	prognostic	diseases, in relation to an index disease graded according to their anticipated effects on therapy and life expectancy
	cogent	comorbidid ailments expected to impair a patient's survival
	noncogent	other ailments
Schellevis et al. (1993)	concurrent	the random co-existance of diseases
	cluster	indicating statistically significant associations between diseases without a causal explanation
	causal	describes disease clustering with a pathophysiologial relation between the different diseases (i.e. indicating shared risk factors
	complicating	indicating that one disease is caused by another disease and cannon be explained without its precursor
Kraemer (1995)	random	co-occurrence is completely random
	clinical	the response to a disease depends on the presence of another disease
	epidemiological	there is an unknown mechanism that bonds diseases together

	familial	the occurrence of diseases within a family is higher than one would expect purely based on epidemiological chance
Van den Akker (1996)	simple	co-occurring diseases whether coincidental or not
	associative	not (known to be) causal
	causal	implying a causal relation amongst co-occurring diseases
Angold et al. (1999)	homotypic	diseases with a diagnostic grouping
	heterotypic	diseases from different diagnostic groupings
Piette et al. (2006)	concordant	diseases are part of the same pathophysiologic or management profile
	discordant	diseases that are not directly related in either pathogenesis or management and do not share an underlying prediposing factor
Valderas (2009)	non-etiological	there is no etiological association between diseases
	direct causation	one disease may cause the other
	associated	the risk factors for diseases are correlated
	heterogeneity	the risk factors are not correlated but affect both diseases
	independence	the presence of the diagnostic features of diseases is due to another distinct dinsease

1.5 Important Considerations in Defining the Nature of Multimorbidity

Differentiating the nature of health conditions is an important first step in defining and measuring multimorbidity. Several considerations present when constructing a multimorbidity measure and it should be noted here that the choice of construct to include in multimorbidity measures are often limited by the nature of conditions recorded in available data sources. This has led to a complex mélange of conditions in multimorbidity measurement and while much research has been conducted in recent years to distinguish between these common constructs, in the absence of a conceptual framework for guiding multimorbidity measurement, this diversity in measurement will continue.

Four main considerations are addressed here:

- Condition nosology
- Chronicity of conditions
- One distinct condition or a gerontological syndrome?
- Severity of conditions

1.5.1 Condition nosology

A further consideration centers on the differentiation between the concepts of chronic disease and chronic conditions as discussed discussed in Section 1.2.1 There has been a recent call to broaden the definition of multimorbidity (Mercer et al., 2009); reorienting the measurement approach to go beyond the conventional definition of chronic disease to reflect a more comprehensive assessment of chronic condition burden. A shift towards a more comprehensive definition of multimorbidity expressed as a measure of chronic conditions allows for the inclusion of a wide range of conditions that may co-occur and interact to impact on an individual's health including impairments and mental health illnesses, providing a more valid reflection of an individual's health burden.

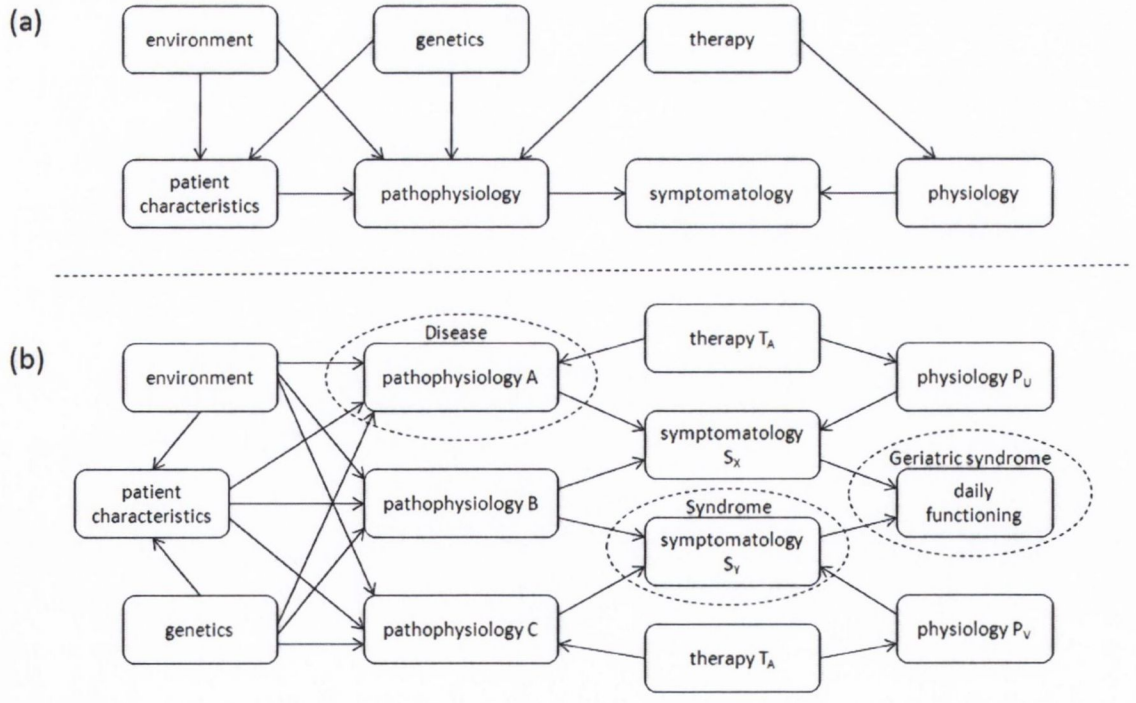
1.5.2 Chronicity

While many studies of multimorbidity evaluate the inclusion of conditions according to chronicity, what constitutes chronicity is rarely defined (Fortin et al., 2012). O'Halloran et al. (2004) conducted a literature review to explore the concept of chronicity, specifically for use in primary care populations with ICPC-2. The ICPC-2 is a classification designed for primary care, developed by the World Organisation of Family Doctors (WONCA, 1983). It classifies data relating to patient reasons for encounter, problems managed, non-pharmacological treatments, referrals, and orders for pathology and imaging and is used in primary care across Europe. The characteristics which were found to be indicative of chronic conditions were: aetiology; duration; onset; recurrence/pattern; prognosis; sequelae; diagnosis; severity and prevalence. Specifically, having condition consequences or sequelae that impact on an individual's quality of life was seen as important factor in establishing chronicity.

1.5.3 Conditions or syndromes? – Analysis of singular or groupings of conditions

Conditions can be a distinct condition or disease (e.g. diabetes) or can form one element of a geriatric syndrome (i.e. a combined set of specific symptomatology that leads to impaired daily functioning). For example the combination of polyneuropathy, impaired vision and using drugs that impair a patients consciousness (e.g. benzodiazepine) often leads to a high risk of recurrent falls (Lappenschaar et al., 2012). In addition, some recent studies have examined multimorbidity from an organ system perspective where conditions sharing known pathophysiological characteristics are grouped together. This approach is supported in the literature, although it may lack specificity in measuring patterns of chronic conditions. The differences between a distinct disease model and a multiple disease model is specified in Figure 1.1 as depicted by Leppenschaar et al. (2012). The single disease model (a) is the most straightforward model to deal with in clinical practice however the appropriateness of this single condition focus has been challenged in recent years (Boyd and Fortin, 2010, Guthrie, 2011).

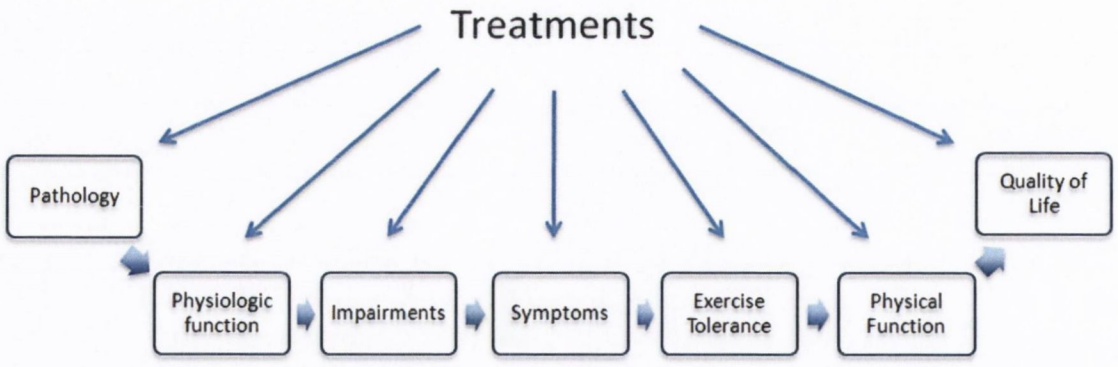
Figure 1.1 Abstract model of a single disease (a) and multiple diseases (b) developed by Lappenschaar et al., 2012



1.5.4 Condition severity

Despite the value of considering the impact of all constituent conditions affecting a patient, it can be argued that defining multimorbidity by a count of the presence or absence of multiple conditions simplifies, and can also underestimate, the contribution of individual conditions to multimorbidity burden. In essence, ignoring the severity of individual conditions can lead to a biased interpretation of impact measures (Boyd et al., 2007b, Walker, 2007, Fortin et al., 2006). However, there is little consensus on the best approach to incorporating severity measures of individual conditions into multimorbidity measurement, specifically in the absence of valid clinical measures of severity, which are often lacking in population prevalence studies. Boyd et al. (2007b) argue that understanding of the true impact and consequences of diseases and their comorbidities has been constrained by the lack of established tools and procedures for classifying disease severity. They proposed a framework to measure disease severity for older adults with comorbidity. A disease-specific approach was used to review each severity classification based on the framework outlined in Figure 1.2 reflecting the complexity associated with classifying severity measures of concurrent conditions.

Figure 1.2 Causal pathways of disease to disability, permitting classification of severity at each point (Boyd et al., 2007)

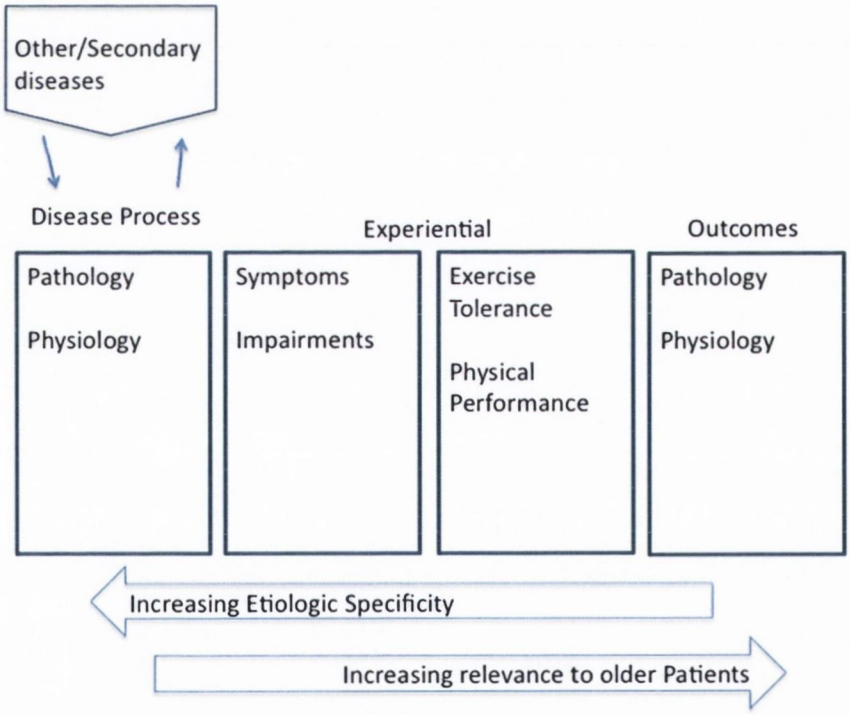


Taking into account the diverse range of severity measurements for specific diseases and the problems it poses for measuring severity in concurrent conditions, they acknowledge that much work remains to be done to develop a unified system of severity classification appropriate for multimorbidity. Furthermore, the severity of a condition is experienced within the individual and may continually change depending on the stage of the condition (Perrin, 1993). Therefore it is argued that self-reporting on its own may not be a valid measure of severity (Perrin, 1993, Holman and Lorig, 2000) and additional subjective measures are required to accurately capture

the severity of the condition. This is particularly problematic in studies that are not configured for multimorbidity analyses.

A particular concern in severity classification is varied etiological specificity of classification systems. Underlying pathophysiology of comorbid diseases may overlap. The authors acknowledge that these relationships may be more complex in older adults and a key challenge in considering the optimal clinical severity measure (illustrated in Figure 1.3) is that etiologic specificity may be highest at the level of pathology, but the components of severity most relevant for patients may be much less disease specific. While condition severity is an important consideration for a range of outcomes of interest, including mortality risk, counts of equally weighted concurrent conditions allows for the identification of interactions between conditions, thereby offering a simpler way to identify individuals in the community at risk of negative outcomes as a result of multimorbidity.

Figure 1.3 Components for assessing disease severity (Boyd et al., 2007)



1.6 MULTIMORBIDITY MEASUREMENT APPROACHES

Taking into account the issues related to multimorbidity definition measurement of multimorbidity requires several considerations including: the operational definition of

multimorbidity; the nosology of included conditions; and consideration of condition chronicity and severity. Even with less complex measures of multimorbidity, such as condition counts, methodological variation makes it difficult to assess the validity of findings between studies. Although inclusion criteria for conditions have been shown to impact on the prevalence rates recorded by different studies, few studies cite inclusion and exclusion criteria for conditions and many studies limit the inclusion to conditions which are chronic in nature, although chronicity is rarely defined (Huntley et al., 2012). The number of diseases is also related to the level of disease abstraction. For example Diederichs et al.(2011a) point out that some measures count cancer as one condition while others count each recorded malignancy separately. In addition, measures may include counts of single health conditions or counts based on organ system domains. It is now well acknowledged that no single multimorbidity measurement approach will serve all research and clinical purposes effectively (Huntley et al., 2012, Fortin et al., 2012, Marengoni et al., 2011, Byles et al., 2005, Guthrie, 2011) and it has been suggested that research undertaken to assess the impact of multimorbidity on a range of outcomes be validated for predicting each specific outcome of interest (Huntley et al., 2012).

Multimorbidity measures can be based on individual condition counts or organised according to organ system domains to reduce potential overlap between similar conditions. While either approach is supported in the literature (Fortin et al., 2012), variation in measurement approaches limits effective comparison of prevalence rates. Ascertainment of conditions is also largely determined by the objectives of the study and availability of relevant data. Few community population studies use clinical examination to ascertain condition diagnosis, rather most studies of multimorbidity in community-dwelling samples reply on respondent self-report of a clinician diagnosis or administrative databases of healthcare payments. While the strengths and limitations of these approaches have been well documented, the use of self-reported conditions is generally considered appropriate for assessment of multimorbidity in community-dwelling samples (Fortin et al., 2012).

Few studies have examined multimorbidity using nationally representative data (Salive, 2013). There is limited knowledge on the prevalence of physical-mental health multimorbidity, particularly at a national level although one study in Scotland estimates this to be high (8.3% in adults ≥ 16 years) with a consistent social gradient. The prevalence of mental health multimorbidity is under-researched and this is the first study to distinguish between general threshold multimorbidity, physical multimorbidity with a mental health component and mental health multimorbidity.

1.6.1 Condition counts in population health studies

Condition counts are the most commonly applied multimorbidity measurement approach in community-dwelling population studies; defined as a simple enumeration of the number of conditions experienced by an individual (Huntley et al., 2012, Fortin et al., 2012, Marengoni et al., 2011). Although population studies are often limited in scope for integrating severity measures, counts have been shown to reliably predict a range of outcomes in community-dwelling samples including functioning, quality of life and healthcare utilisation (Fortin et al., 2012). Furthermore, measuring multimorbidity from simple condition counts enables the identification of non-randomly occurring patterns of multimorbidity: allowing equal weighting for each condition.

1.6.2 Multimorbidity Indices applied in population health studies

Multimorbidity indices are commonly applied in clinical settings, although their application to community-dwelling population samples to date has been limited. Some indices originally validated in clinical settings have subsequently been adapted to evaluate non-clinical outcomes such as healthcare costs (Shwartz et al., 1996) and a range of outcomes in the general population including:

- functional status;
- health related quality of life and
- quality of healthcare outcomes.

In a systematic review of indices examining co-occurring conditions, Diederichs et al.(2011b) point to the heterogeneity of comorbidity indices, a focus on diseases with high prevalence and a propensity towards examing multimorbidity in patient groups with high levels of disease severity. For these reasons, comorbidity indices may not be appropriate for examination of multimorbidity in general community-dwelling populations. In a further systematic review of studies on measurement of multimorbidity in primary care and community-dwelling populations, Huntley et al.(2012) identified five commonly applied indices:

- The Charlson Index
- The Adjusted Clinical Groups System (ACG)
- The Cumulative Index Rating Scale (CIRS)

- The Chronic Disease Score and subsequent adaptations including the RxRisk Score
- The Duke Severity of Illness Checklist (DUSOI)

Thirty-eight of the identified studies applied the Charlson Index or a variation of this index, in primary care and community populations (Perkins et al., 2004, Charlson et al., 2008). Twenty-five studies applied the Adjusted Clinical Groups (ACG) System originally designed to predict future morbidity and use of healthcare resources (Starfield et al., 1991) based on a population/patient case-mix adjustment system using medical records or insurance claims. The Cumulative Index Rating Scale (CIRS) was used in ten studies assessing a range of outcomes including patient demographic characteristics, measures of process and healthcare utilisation and health outcomes. The CIRS index uses a scoring system, weighting morbidity measured by 14 body system domains. It can be applied directly in healthcare consultations or from medical records. The Chronic Disease Score and subsequent adaptations including the RxRisk score uses classes of medication identified in pharmacy datasets as a proxy measure for chronic conditions. This score demonstrated associations between self-rated health, functional status, hospitalisation rates and mortality (Naessens et al., 2011, Von Korff et al., 1992, Mayo et al., 2005, Di Bari et al., 2006). The Duke Severity of Illness (DUSOI) measures a person's illness score based on four parameters of each diagnosis, namely symptoms, complications, prognosis without treatment, and treatment potential and was found to demonstrate associations between age, sex, healthcare utilisation, and quality of life.

An identified strength of multimorbidity indices is their ability to incorporate a measure weighted in relation to condition severity or other outcomes of interest such as mortality, hospital admission, or healthcare use. This is particularly challenging however in the absence of valid recording of condition severity. Some studies have weighted condition severity measured by patient self-reports (i.e. patients or survey respondents report the presence or absence of a condition and their perceived severity of the condition) although this approach is limited and introduces potential self-reporting biases. Where this data is not available, some studies have examined condition severity based on pre-specified criteria such as prescription drug use (Guthrie, 2011). Even with objective measures, weighting of multimorbidity indices is problematic and scoring schemes or weightings are generally designed for single outcomes in specific groups of patients limiting their generalisability of these indexes to other populations in other settings. Furthermore, in a study aimed to derive a generic multimorbidity index for predicting a range of outcomes, Byles et al.(2005) found that a single index of multimorbidity could not reliably predict a variety of outcomes of interest.

1.6.3 Approaches to measuring multimorbidity patterns

Few studies have examined non-randomly occurring condition combinations at a population level. The dearth of research into multimorbidity patterns may be in part due to the earlier focus on multimorbidity indices, which do not allow for identification of component patterns of multimorbidity. Moreover, approaches were until recently limited by the lack of appropriate statistical analysis for analysing health conditions as dichotomous variables (i.e. an individual either has a condition or does not have the condition). Studies have applied a variety of approaches including investigation of the most common combinations of conditions including pairs, triads and quads of conditions and calculations of the observed probability of condition combinations compared to the expected probability. More recent developments in statistical methods for grouping interrelated conditions include exploratory factor analysis and cluster analysis. Cluster analysis allows for the dichotomous nature of health condition data to identify non-randomly occurring patterns of multimorbidity unlike factor analysis which requires that data is in a continuous format (Holden et al., 2011). In contrast to the focus on individual combinations of conditions, cluster analysis provides an overall pattern of how conditions are associated with each other in a specified population and provides insight into where particular condition combinations of interest occur in the overall pattern.

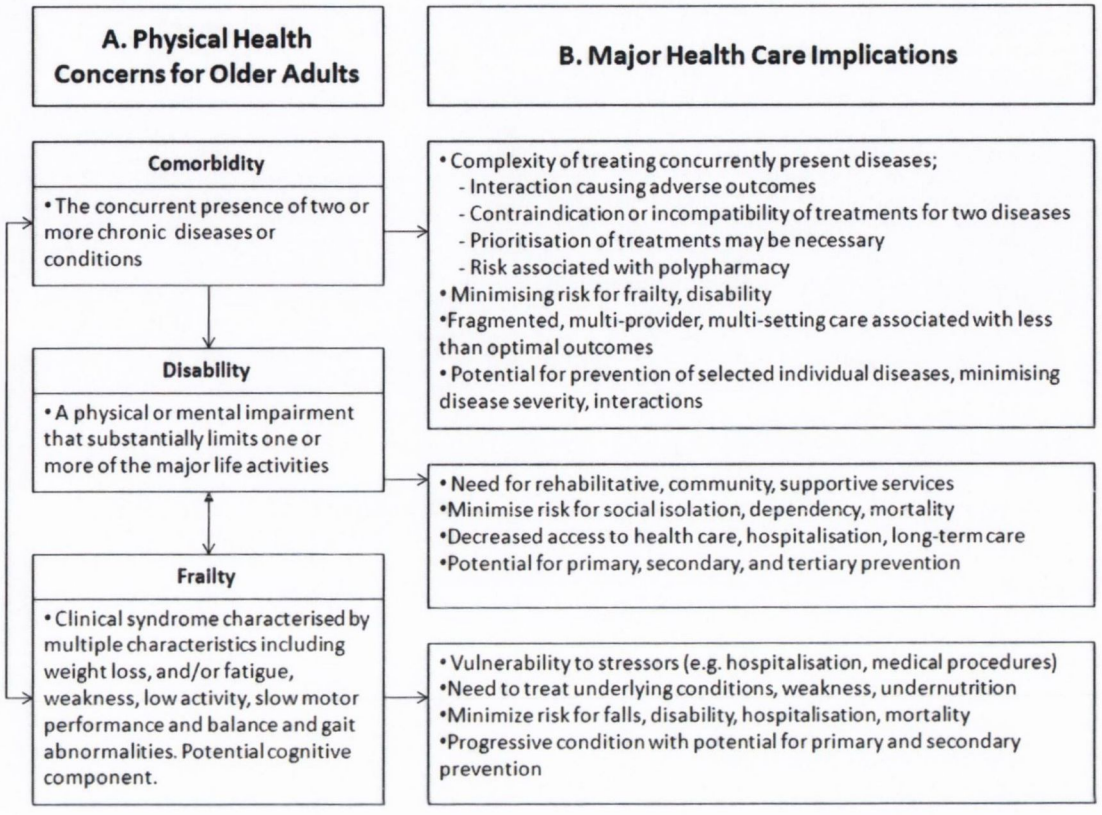
1.7 Constructs defining patient complexity

The use of other gerontological constructs to describe an older persons health status, such as frailty (i.e. a state of increased vulnerability that may result from decreased physiologic reserve (Fried et al., 2004) and disability (i.e. any restriction or lack of the ability to perform an activity in the manner or within the range considered normal for the individual (World Health Organization, 2011) are often used interchangeably with multimorbidity to identify vulnerable older adults and further complicate the conceptualisation of multimorbidity. In response to growing consensus that these are three distinct clinical entities that are causally related, Fried et al.(2004) explored the conceptualisation of these constructs. An individual may experience all three distinct constructs simultaneously each of which may be causally related and each may have an exacerbating effect on the others. They concluded that frailty is distinct from but overlapping with both multimorbidity (referred to in the paper as comorbidity but the conceptualisation of comorbidity in the article is actually referring to the construct of multimorbidity) and disability. Both frailty and multimorbidity predict disability, adjusting for each other; disability may well exacerbate frailty and multimorbidity, and comorbid diseases

may contribute, at least additively, to the development of frailty. Fried et al. also suggest that the presence of disability or frailty could contribute to the development or progression of chronic conditions. They conclude that the causal relationships described can provide an explanation for the frequent co-occurrence of these gerontological constructs and advocate the need to differentiate between these constructs in order to identify appropriate clinical interventions. In addition, each construct has distinct implications for healthcare practice as outlined in Figure 1.4. A further conceptual approach to explaining these constructs is gaining increased recognition in recent years. The 'accumulation of multiple deficits' considers many potential deficits including at least 10 chronic conditions, shown to be predictive of death (Mitnitski et al., 2002). Examining multimorbidity from a health burden perspective, incorporating geriatric conditions such as falls and incontinence and physical impairments, would contribute much to the debate on the inter-play of these gerontological constructs.

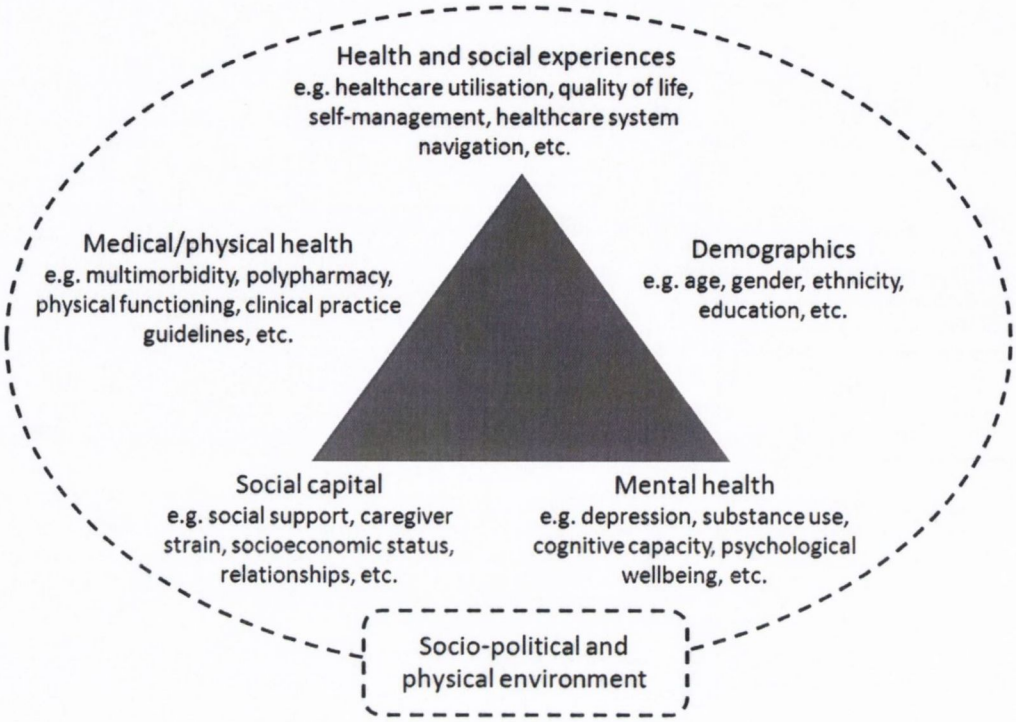
The inter-relationship between single conditions, geriatric syndromes and the gerontological constructs described by Fried et al.(2004) that manifest in later life present a complex challenge to clinicians treating older patients. There is now a developing awareness in health systems that the construct of multimorbidity is contributing to increasingly complex patients. Although Mercer and colleagues (2007) assert that defining patient complexity solely as two or more conditions does not mean that patients with multimorbidity are complex patients. Several other factors may be contributing to complexity, including condition severity and underlying psychological and social issues.

Figure 1.4 Theoretical pathway of the inter-relationships between multimorbidity, disability and frailty: definitions and major healthcare implications as presented by Fried et al., 2004



Schaink et al.(2012) have recently proposed a unifying framework for patient complexity encompassing complexity due to multimorbidity, psychosocial factors and healthcare utilisation. These complexities are represented within the Framework as influenced by five key health dimensions identified in a scoping review of the literature. These relate to: medical/physical health; mental health; demographics; social capital; health and social experiences. Multimorbidity here represents a substantial facet, among multiple influences on patient complexity. While the authors include multimorbidity as a core influence on patient complexity, they stress that in some cases, patient complexity may be driven by other factors distinct but related to multimorbidity. While multimorbidity may be exerting a direct impact on patient complexity, it may also be interacting with other health dimensions to exacerbate the patient's complexity.

Figure 1.5 The Complexity Framework developed by Schaink et al. (2012)



The proportion of multimorbid patients who may be considered complex in terms of the health dimensions delineated in the Complexity Framework remains unclear and further research is required to investigate the concept of 'complexity' in multimorbid patients. The influence of multimorbidity on healthcare utilisation is perhaps the most extensively researched, while the influence of access to appropriate healthcare on patient complexity is unclear. Mercer and colleagues (2012, 2007) offer some evidence of an inverse care law contributing to patient complexity in deprived areas of Scotland. A further intervention study targeting GP practices in deprived areas of Glasgow found increased patient enablement attributable to an increase in GP consultation times for complex patients (Mercer and Watt, 2007).

This Framework proposed by Schaink et al. (2012) offers the first systematic approach to classifying multimorbidity relevant complexity. However, some limitations are evident. The inter-relationship between multimorbidity, disability and frailty are not considered here and are perhaps among the leading drivers of patient complexity in later life. In addition, the model overlooks the contribution of condition severity levels and potential synergistic interactions of individual conditions to patient complexity. A further consideration is that mental health and physical health are represented in the Framework as two distinct health dimensions, although recent evidence points to the high co-prevalence of co-occurring mental-physical health conditions, which was especially prevalent and manifest at an earlier age in individuals from more deprived neighbourhoods (Barnett et al., 2012). The influence of social capital and

demographics on multimorbidity related complexity remains relatively under-researched, however the impact of the broader physical and social environment are well-recognised predicators of poor health outcomes.

1.8 Multimorbidity, patient complexity and adverse outcomes

Condition management is a challenging task when considering the complex interaction of the mutual dependencies within the multiple disease model (*Figure 1.1*), related to pathophysiology, symptomatology, therapy and prognosis. Recent evidence points to the failures of the current single disease management approach to deal adequately with the more complex model of concurrent condition interactions outlined above. This is especially problematic when discordant conditions co-occur in an individual (Guthrie, 2011). Condition concordance refers to the overlap of treatment regimens for different conditions. Treatments for concordant conditions are more likely to overlap and prove beneficial for the patient. For example, management of hypertension, stroke and diabetes are significantly concordant in that management of cardiovascular risk is core to their chronic management (Guthrie, 2011). In contrast, other conditions may be discordant in that their treatment may have no overlap, and treatment for one condition may complicate treatment for another condition. Clustering of conditions may in part be explained by common genetic susceptibility or shared risk factors. A further consideration is that treatment of discordant conditions may lead to side effects (expected or unexpected) and patients may be more likely to develop an additional complication or indeed treatment for one condition may give rise to incidence of another condition. For example, corticosteroid-induced osteoporosis may occur in patients receiving treatment for a range of conditions, including asthma and autoimmune conditions such as rheumatoid arthritis (Ruf et al., 2008). The risk of adverse drug reactions increases with increased polypharmacy related to multimorbidity (Guthrie, 2011, Fulton and Riley Allen, 2005, Noel et al., 2005, Nobili et al., 2011, Smith S.M. et al., 2010).

Problems arise when treatment decisions are taken within a single disease framework or where decisions are guided by concordant condition specialisms, with little attention given to the impacts of treatment regimens on discordant conditions. Conceptualising the co-occurrence of conditions according to an index condition brings this issue into focus. Medical investigations guided by an index condition, will focus on known comorbidities and will likely overlook co-occurring discordant conditions. This may lead to patients taking large numbers of interacting and potentially conflicting drugs (Guthrie, 2011).

Current approaches to caring for people with multimorbidity have been critiqued in the literature with an emerging evidence-base pointing to the increased treatment burden and avoidable complications associated with multimorbidity due to risks associated with complex care and poor care co-ordination (Guthrie, 2011, Zhang et al., 2009, Mercer et al., 2009, Smith and O'Dowd, 2007). Orszag and Emanual (2010) argue the burden of healthcare costs are unevenly distributed with substantial cost savings to be gained from a reduction in avoidable complications arising as a result of chronic conditions. It is noted that approximately one fifth (22%) of all healthcare spending is attributable to potentially avoidable complications such as hospital admissions for patients with congestive heart failure for shortness of breath due to fluid overload (de Brantes et al., 2009). Given the substantial population burden of chronic conditions with an increasing proportion of older people in the population, and the impact of costly complications arising from complex care needs, Emanuel et al. (2012) identify the real driver of healthcare costs in the U.S. as the increasing burden of multiple medical conditions.

Recently studies have turned their attention to the role of age relative to increasing chronicity, acknowledging the growing burden of chronic conditions in an ageing population and the disproportionate allocation of resources to a minority of high cost patients (Emanuel, 2012). Given the now well-established association between multimorbidity and poor health outcomes including unfavourable self-rated health, reduced quality of life, increased disability and mortality, it is not surprising that multimorbidity is closely linked to high usage and expenditure in healthcare systems. Such healthcare systems originally designed to respond to acute and episodic instances of care needs are increasingly faced with the substantial challenge of multimorbidity; a care need that does not easily fit into the current structure of healthcare delivery (Fortin et al., 2007b, Plochg et al., 2009, Starfield, 2011, Mercer et al., 2009). While there is an increasing focus on slowing the progression of chronic conditions and delaying functional limitations borne by chronic condition onset (Warshaw, 2006), chronic condition management continues to focus on silos of conditions, overlooking the substantial impact of multimorbidity on health outcomes, quality of care and healthcare utilisation and costs.

A progressive escalation of healthcare utilisation rates have been documented in some developed countries over the past decade, in tandem with population ageing (Moineddin et al., 2010). Debate on the impact of ageing on healthcare utilisation continues although it is now generally recognised that although older people are higher users of healthcare services compared to younger people, age *per say* is not a significant driver of healthcare utilisation, rather, much of the increase in healthcare utilisation is associated with poorer health outcomes (Golberstein et al., 2007, Terner et al., 2011) and concentrated in the final years of life, even

after adjustment for age (Wolff et al., 2002, Murray et al., 2005, McGail et al., 2000). Notably, multimorbidity has also been found to have a larger effect on costs of healthcare compared to age (Hodek et al., 2011). A growing body of evidence points to a significant heterogeneity of health service use among older people identifying distinct patterns of healthcare users from low to high use throughout later life (Moineddin et al., 2010). Many older people were found to be resilient throughout the later years of their life, requiring little healthcare services, however, others transition quickly from low to higher levels of healthcare use. Once older people become higher users of healthcare they are unlikely to transition back and have a higher probability of death than those in moderate or lower utilisation groups. Increasing age is strongly correlated with increased chronicity and multimorbidity (Marengoni et al., 2011). The demographic shift towards an ageing population is likely to lead to increasing levels of chronic conditions at a population level and a subsequent increase in demand for and use of healthcare services in years to come.

1.9 Contextualising multimorbidity in population health

Knowledge on the relationship between multimorbidity and healthcare utilisation at a population level is particularly important for population health and health services planning, where emphasis is on the global contribution of multimorbidity to health outcomes and resource use, rather than an emphasis on specific diseases or services. Two main considerations are relevant to the debate on the overall impact of multimorbidity on healthcare burden at a population level. Use is likely to be driven by both the prevalence of multimorbidity and the impact of multimorbidity on specific healthcare services. This point is illustrated in Figure 1.6, where levels of use are categorised according to the combination of impact of multimorbidity at the individual level (i.e. the per capita effect) and the prevalence of multimorbidity at a population level.

Figure 1.6 Impact of multimorbidity on population healthcare use (adapted from Broemeling et al.2005)

		IMPACT	
		Low	**High**
PREVALENCE	**High**	High prevalence & low impact	High prevalence & high impact
	Low	Low prevalence & low impact	Low prevalence & high impact

Applying resource rankings for chronic conditions, Rapoport et al. (2004) conclude that healthcare utilisation is driven by the number of people who have a condition i.e. the overall prevalence, rather than the per capita effect of chronic conditions. However the severity of conditions, which may be a predictor of related healthcare utilisation was not accounted for in their analysis. Prevalence of multimorbidity is generally measured by the number of individuals in the population with a threshold of two or more chronic conditions (Fortin et al., 2012, van den Akker et al., 1996). Recent evidence points to the influence of patient complexity as a driver of healthcare (Valderas et al., 2009, Schafer et al., 2010, Gully et al., 2011, Tinetti et al., 2012). However, this simple measure of prevalence may be overlooking other important aspects of multimorbidity that may be contributing to the burden of healthcare including increasing levels of multimorbidity and co-occurring physical and mental health multimorbidity and potentially complex combinations of conditions. Van den Bussche et al. (2011a) proposed a further threshold of three or more co-occurring conditions indicating complex multimorbidity. Healthcare utilisation is likely to be driven by a range of need factors manifesting as complexity including multimorbidity and other gerontological constructs such as disability and or frailty.

1.10 Overview of the conceptual approach adopted in empirical analysis of this thesis.

1.10.1 Definition of multimorbidity

Given the continued confusion of conceptualisations, the default to use *comorbidity* as a general rather than relative term and the need for a global term to encompass all investigations of co-occurring conditions, I adopted a clear distinction between the terms multimorbidity,

comorbidity and the operational definition of co-occurring conditions in this thesis. This thesis is concerned with the prevalence, patterns and factors associated with multimorbidity in community-dwelling older people and its corresponding impact on population health and health care provision. This approach warrents a focus on *multimorbidity,* treating all conditions equally as distinct from comorbidity which is concerned with the impact of additional conditions on a condition of interest (index condition), implying a temporal relationship between conditions, more appropriate to inform clinical investigations. Retaining the definition proposed by van den Akker, *multimorbidity* is referred to in this thesis as:

'the co-occurrence of multiple chronic or acute conditions within one person'.

The term multimorbidity is applied as an overarching global term referring to *all* conceptualisations of co-occurring conditions within an individual. Where relevant to analysis and interpretation, the operational definition of multimorbidity will be specified.

1.10.2 Operational definitions of multimorbidity

Several operational definitions of multimorbidity are applied in this thesis. These are:

Threshold multimorbidity - the co-occurrence of multiple chronic conditions within one individual measured as ≥ 2 conditions.

Complex multimorbidity - the co-occurrence of multiple chronic conditions within one individual measured as ≥ 3 conditions.

Physical multimorbidity - the co-occurrence of two or more mental health conditions in one individual, without a mental health component.

Physical-mental multimorbidity - the co-ocurrance of at least one physical and one mental health condition in an individual.

Mental health multimorbidity - the co-occurrence of two or more mental health conditions in one individual.

Concurrent counts of conditions or multimorbidity levels - increasing from 2 conditions to include all levels of multimorbidity.

Multimorbidity clusters - non-randomly co-occurring patterns of condition associations identified in cluster analysis.

1.10.3 Condition nosology

In keeping with recent recommendations in the literature (Mercer et al, 2009), this thesis is concerned with a more comprehensive assessment of chronic conditions as distinct from the conventional definition of chronic disease. The approach to defining chronic conditions in this thesis draws from the definition put forward by the World Health Organization (2006) as health problems that require on-going management over a period of years or decades. Noting the considerable influence that non-conventional conditions may exert on the health status and healthcare utilisation of older people, a wide range of chronic conditions were considered for inclusion in multimorbidity measurement for this thesis, adopting the taxonomy of *chronic conditions* rather than *chronic diseases.* A broad nosological approach to multimorbidity is adopted in this thesis allowing for the inclusion of gerontological contructs such as falls and incontinence as well as mental health conditions, impairments and chronic physical diseases.

1.11 Aims and objectives of empirical research

Multimorbidity is an increasingly problematic issue in population health. The presence of more than one chronic condition in an individual predicts many adverse health outcomes, including the onset of additional health problems, functional impairment, progressive loss of mobility, hospitalisations, mortality, poor mental health symptoms, poor quality of life and unfavourable self-assessed health status. This places a heavy burden on the individual as well as population health and may be considerably influencing trends in healthcare utilisation and quality of care for older people. The interdependence of constructs and measurement of co-occurring conditions has led to increasing complexity in the literature giving rise to a broad range of operational definitions associated with multimorbidity research and posing a substantial challenge to future research. It is increasingly acknowledged that measurement is context dependent requiring different applications according to data source and type as well as the population and outcomes of interest (Marengoni et al., 2011, Valderas et al., 2009). Considerable emphasis was then placed on the selection of appropriate constructs and operational definitions appropriate to the three main empirical enquiries in this thesis.

Appropriate responses to multimorbidity have yet to be integrated into population health planning and health service delivery in Ireland. There is an identified dearth of national and international multimorbidity research, the primary aim of this thesis was then to gain a greater understanding of multimorbidity at a population level in Ireland and its corresponding impact on health and social care outcomes in people aged 50 years and over. Specifically the three main objectives of this thesis are:

1. to estimate the prevalence and non-random patterning of multimorbidity in the community-dwelling population aged 50 years and over in Ireland;
2. to examine the factors associated with multimorbidity in mid-to-late life in an Irish context;
3. to determine the impact of multimorbidity on health and social care utilisation and quality of care in Ireland.

1.12 Review of the current evidence-base

A literature review was carried out to examine the current evidence-base on multimorbidity relevant to the aims of this thesis. In particular, three aspects of multimorbidity were explored in the literature: the prevalence and patterns of multimorbidity, the determinants of multimorbidity and the burden of multimorbidity on health and social care utilisation and quality of care.

The literature review search strategy in this thesis was informed by the operational definition of multimorbidity adopted in this thesis and specific empirical objectives outlined in Section 1.11. A series of pilot database searches were conducted to refine the subterms adopted in the literature search. Variations of the term multimorbidity were considered in the literature search including the term comorbidity. Following on from the conceptual approach outlined in Section 1.10, the term *comorbidity* was not used in the search string primarily as it was less sensitive to studies of community-dwelling samples. The term *polypathology* was also omitted as it yielded studies with a clincical focus. It was decided to include the terms *multiple chronic diseseases* OR *conditions* as these terms appeared to be more sensitive after initial pilot searches. Terms for prevalence and patterns of multimorbidity, as well as determinants of multimorbidity and healthcare outcomes and were also included in the final search string.

Searches were piloted in March 2010. This was an iterative process and was informed by key academics in the area and the medical librarian in Trinity College Dublin. Given the proliferation of literature on multimorbidity subsequently, a further search was conducted in May 2012 to include all up to date references. Current awareness analysis continued up to time of finalising the thesis and where relevant articles were identified, the literature review was updated to include these.

1.12.1 Electronic databases

This thesis is mainly concerned with multimorbidity from a population health perspective, which draws on literature from both health and social science fields. Several electronic databases were searched to inform this literature review using selected key terms to maximise the yield of relevant articles. Research Pro, provided through the Trinity College Library, is a tool that enables users to conduct a meta-search of multiple electronic databases across a wide variety of fields. An initial meta-search was conducted in Research Pro to assess the quantity of articles relating to the themes of this study across a variety of databases, applying the following search string as a subject search:

> *[(multimorbidity OR multiple chronic diseases OR multiple chronic conditions) AND ((prevalence OR patterns) OR (health* OR outcome*) OR (determinants OR risk factors or inequality*))].*

The databases searched in the metasearch covered a broad range of resources including peer-reviewed publications and grey literature. While Research Pro is a useful tool for determining suitable databases for topic searches, due to the varying boolean search approaches within databases, Research Pro may be less sensitive in retrieving articles from some databases than others. After an initial search on Research Pro, searches were then performed on each individual database and likely relevant articles were recorded. Two databases were identified from this process that would provide a wide range of relevant articles: ISI Web of Science (n= 620) and Scopus (n=819). A direct database search was then conducted in both of these databases.

Research Pro did not provide an option for searching PubMed, however two previous systematic literature reviews had used PubMed to identify relevant studies (Huntley et al., 2012, Marengoni et al., 2011) and this database was considered an important source of multimorbidity literature, consequently a search of PubMed was also completed to inform this literature review. Mesh terms were generated using PubMed. Despite recommendations from a bibliometric review

conducted by Fortin and colleagues in 2005, multimorbidity is not included as a mesh term in PubMed. Cormorbidity is included as a mesh term in PubMed however a trial search using this term yielded a large number of non-relevant articles based mainly on clinical samples investigating clinical outcomes. After conducting several sensitivity analysis of the search terms it was considered more appropriate to search for key terms in the title or abstract of the article.

1.12.2 Search selection criteria

Teasing out the distinctions in the search queries helped to establish the inclusion and exclusion criteria for the literature review. Refining the criteria was an iterative process incorporating learning from the exploration of key terms in the literature search and informed by search criteria adopted in published systematic literature reviews of multimorbidity. Three main issues emerged when refining the search criteria, these were the varying definitions of multimorbidity in the literature, varying approaches to condition nosology and the emphasis of studies on older populations. Many of the studies examining multimorbidity concentrate on people aged 65 years and over. As this study is focused on people aged 50 years and over it necessitated the inclusion of studies on the total adult population to capture people aged between 50 and 65 years. In line with more recent investigations into multimorbidity relevant to a population health perspective, this thesis adopted a broad nosological definition of multimorbidity including sensory impairments, mental health and geriatric syndromes as awell as chronic physical conditions. There were therefore no restrictions placed on the inclusion or exclusion of specific conditions in the literature search. The search was further restricted to studies relevant to community-dwelling older people. However, studies examining differences in prevalence rates between settings were included in order to qualify differences in prevalence rates between community and other settings. Full details of the search criteria are listed in Table 1. 2

Table 1.2 Search selection criteria applied in the literature review

Selection criteria classification	***Inclusion criteria***	***Exclusion criteria***
A	Primary focus on multimorbidity	Primary focus on comorbidity or an index condition
B	Focus on an older population or includes adults aged 50 years and over within the study	Exclusive focus on a younger population (i.e. <50 years)
C	Focus on general community-dwelling population	Exclusive focus on non-community resident populations (i.e. hospitalised or institutionalised older people)
D	Quantitative analysis of multimorbidity in community-dwelling populations OR review	Qualitative analysis of morbidity burden

	articles OR editorials	OR healthcare interventions
E	Focus on measures AND/OR prevalence AND/OR patterns AND/OR healthcare utilisation AND/OR quality of care AND/OR determinants of multimorbidity	Exclusive focus on health outcomes as a result of multimorbidity OR healthcare interventions.
F	Consideration of physical conditions only AND/OR physical and mental health conditions	Exclusive focus on mental health multimorbidity
G	Articles published between 1975 to date	
H	Full text articles available in English or French	

1.12.3 Article review

EndNote X3 was used as a reference tool and the results of all database searches were imported into separate files then merged to identify duplicates. In total, the literature search yielded 1,704 likely relevant articles across the three databases. This was reduced to 161 likely relevant articles after deleting duplicates. All articles were then downloaded in portable document format (pdf) and stored in EndNote. A three-step process was applied to the article review. An initial review of all titles and their abstracts was conducted according to the inclusion and exclusion criteria and any articles that did not meet the inclusion criteria were excluded. A further review of the full text of the retrieved articles was then conducted to ensure selected articles met the selection criteria.

1.12.4 Additional literature sources

As there is a risk of overlooking relevant publications in any database due to inaccurate or incomplete indexing or weak search strategies (CRD, 2008), three additional approaches were taken to ensure a comprehensive review of the research questions were conducted.

1. The CIHR Applied Research Chair – Health Services and Policy Research on Chronic Diseases in Primary Care in Sherbrook University Canada provides a comprehensive list of published resources relevant to multimorbidity[1]. The published reference list was hand searched and listed studies meeting the specified criteria in the literature search were also included in this literature review.
2. Secondary references from bibliographies of review studies and other included studies were also hand searched to ensure all relevant articles were reviewed.

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[1] http://www.usherbrooke.ca/crmcspl/en/resources/publications/

3. Further searches were carried out in Google Scholar to ensure relevant grey literature not identified in the database search was not overlooked.

1.12.5 Current awareness analysis

A series of alerts were set up in the searched databases using the same search term used in the initial search of the cited databases. Email alerts were sent to the researcher's email address when a new article matching the predefined search string was published. The researcher also received email alerts from the CIHR Applied Research Chair from Sherbrook University website when new publications on multimorbidity were published online. All potentially relevant studies were screened as they arose and those fulfilling the selection criteria were considered in the review.

1.13 Conclusion

Multimorbidity predicts many adverse health outcomes, placing a heavy burden on the individual as well as population health. It has clear implications for current healthcare provision and with the projected ageing of the Irish population presents substantial challenges for future healthcare policy and planning. Population level evidence on multimorbidity is however limited. Early investigations of comorbidity were restricted to common diseases of interest, in clinical populations, with little attention paid to the population burden of multimorbidity. The term *multimorbidity* is applied in this thesis as an overarching global term referring to *all* conceptualisations of co-occurring conditions within an individual, allowing for a more complete assessment of the burden of multimorbidity at a population health level. Operational definitions and constructs have been explicitly defined in this thesis with the aim of enhancing the precision and generalisability of research findings, enabling improved understanding and comparison of outcomes in future research into multimorbidity in Ireland and across international studies. This has also guided the approach to the three empirical analyses presented in Chapter 3, 4 and 5.

1.14 Thesis outline

The literature reviewed in this thesis was used to inform the objectives and empirical analysis presented in each chapter. It is presented in the relevant introductory and background sections

to each chapter. The principal findings from each of the empirical analyses are presented at the end of each chapter, summarised in the discussion (*Chapter 6*) in the context of the current evidence-base.

Chapter 2 presents an overview of the methodological approaches applied to address the three main empirical enquiries in this thesis. TILDA is used as the primary data source in all analyses and the TILDA sampling procedure is described in this Chapter. Two further data sources were employed to obtain measures on relative material deprivation and proximity to healthcare services, these are described in full. The conceptual approach to modelling multimorbidity and process outcomes including health and social care and indicators of quality of care are also detailed in this Chapter.

Chapter 3 adopts an exploratory descriptive approach to examine the prevalence of multimorbidity, according to increasing numbers of conditions and different multimorbidity types including threshold multimorbidity (i.e. ≥ 2 conditions), physical-mental health multimorbidity and mental health multimorbidity. The multimorbidity measurement approach is refined in this chapter and is used as the measure of multimorbidity in all further analyses. Prevalence of multimorbidity is considered across a range of socio-demographic variables to identify groups in the populations with particularly high multimorbidity prevalence. Given that the distribution of condition combinations in the population may occur more frequently than expected, this study also examines the non-random associations of chronic conditions at the population level through cluster analysis without *a priori* etiological hypotheses. Clusters are examined by socio-demographic characteristics to determine robust cluster pairings and differences in sub-populations.

In *Chapter 4,* the factors associated with multimorbidity in the Irish population aged 50 years and over are examined in explanatory models of multimorbidity, based on a proposed theoretical framework and informed by the findings in Chapter 3. The process of accumulating multiple conditions is examined relative to the onset of morbidity. It is hypothesised that several demographic factors found to be associated with multimorbidity in other studies such as sex and age are also significantly associated with the onset of morbidity and increasing levels of multimorbidity. The role of socioeconomic and lifestyle related factors are also examined as potential risk factors for multimorbidity. A further analysis explores the factors associated with different types of multimorbidity including physical multimorbidity with and without a mental health component.

The independent effect of multimorbidity on the use of a wide range of health and social care services is tested in *Chapter 5*, relative to other need factors including disability, frailty and self-rated health and a wide range of predisposing and enabling covariates as proposed by the Anderson Phase-3 Model of Health Service Utilisation (Anderson, 1995). The effect of different types of multimorbidity on utilisation of health and social care services is also estimated to explore the differential impact of physical-mental health multimorbidity on healthcare use. Finally, the relationship between multimorbidity and quality of care is examined using Emergency Department visits and polypharmacy as two proxy indicators for quality of care outcomes.

A general discussion of the findings of the empirical analyses is presented in the last chapter (Chapter 6). This chapter recaptures the main findings of the empirical analyses and the implications for policy and healthcare practice are presented with particular attention paid to areas for further research.

Chapter 2. Introduction to the Empirical Analysis

2.1 Introduction

This thesis is comprised of three separate but related empirical analyses to investigate multimorbidity in an Irish context. The research enquiries are statistical in nature, and analytical decisions were initially determined by the availability of data appropriate to each research enquiry. This chapter provides a detailed account of data sources exploited in the empirical analysis of multimorbidity, specifically in relation to its prevalence, patterning and impact on process measures, including health and social care utilisation. An empirical investigation into the factors associated with multimorbidity in an Irish context is also detailed. The general empirical analysis approach undertaken is introduced in this chapter. The objectives of the empirical analysis are presented in Section 2.2, including a detailed description of TILDA as the primary data source in this thesis and two secondary data sources including variables on health services location provided by Health Atlas Ireland and the SAHRU index of deprivation outlined in Section 2.3. The general approach to the empirical analyses of multimorbidity and health and social care utilisation are detailed in Sections 2.4 and 2.5 respectively. The approach to model specification and statistical analyses throughout the study are presented in Sections 2.6 and 2.7. Section 2.8 provides details on ethical approval for the study and the approach to data management and cleaning is discussed in Section 2.9. It is intended that this chapter provide an introduction to the general empirical analysis approach employed in this thesis. Specific methodological approaches are presented in each chapter, corresponding to each to the three objectives set out in Section 2.2. This chapter concludes with a general discussion of the methodological advantages and limitations of the approach to the empirical analyses adopted in this thesis (Section 2.10); more specific limitations of analyses corresponding to the empirical objectives of each study are outlined in further chapters.

2.2 Objectives of empirical analysis

The conceptualisation of multimorbidity continues to be problematic despite attempts to refine operational definitions. The multimorbidity analyses presented in this thesis have been guided by the framework set out in Chapter 1. To inform the overall aim of this thesis three separate but related empirical enquiries are undertaken to contribute to a greater understanding of the

prevalence, patterns and factors associated with multimorbidity and its corresponding impact on health and social care outcomes in an Irish context.

Specifically the main empirical objectives of this thesis are:

4. to estimate the prevalence and non-random patterning of multimorbidity in the community-dwelling population aged 50 years and over in Ireland;
5. to examine the factors associated with multimorbidity in mid-to-late life in an Irish context;
6. to determine the impact of multimorbidity on health and social care utilisation and quality of care in Ireland.

Specific objectives for each of the three studies conducted to inform the overall aim of this thesis are detailed in the relevant chapters.

2.3 Data sources

Secondary data analysis was carried out on the first wave results of *The Irish Longitudinal Study of Ageing* (TILDA), a large-scale national survey conducted between October 2009 and February 2011. A further two data sources, the SAHRU Index of Deprivation and Health Atlas Ireland geocoded data on health services location were merged into the TILDA dataset for analysis purposes. The SARHU Index of Deprivation provides a measure of relative material deprivation suitable for health services research compatible with the TILDA dataset. Data provided by Health Atlas Ireland allowed for the inclusion of a measure of healthcare availability as a potential confounder in analyses. These three data sources were merged into one master data file for the analysis presented in Chapters 3 to 5 and their relevance in the context of the thesis objectives are detailed in Sections 2.3.1 to 2.3.5

2.3.1 Data on multimorbidity in Ireland

Any study examining multimorbidity is driven by the quality of available data. In this case, a primary consideration is to obtain data that are representative of the general community-dwelling older population in Ireland to reliably inform the measurement of multimorbidity. The most appropriate data to inform multimorbidity research at a population level have not yet been

established; however some conclusions can be drawn from the literature. These conclusions can be summarised as:

- data should not be limited to the narrow conceptualisation of chronic disease; rather they should incorporate some measure of physical impairment and mental health; covering the broad spectrum of chronic condition burden in the older population.
- measurement should be limited to conditions deemed to be chronic that exert some impact on individual health burden; and
- consideration should be given to appropriate measures of condition severity, although this is problematic in population prevalence studies as condition severity is a subjective concept and self-reported condition severity may be subject to reporting bias.

The most appropriate measure to reflect objective multimorbidity burden at a population level is likely to be obtained from large administrative healthcare databases recording confirmed clinical diagnosis. In Ireland, the Hospital In-Patient Enquiry (HIPE) Scheme is a health information system designed to collect medical and administrative data at a national level (ESRI, 2012). However, the recording of health status data in Ireland is limited by the absence of a unique patient identifier in the Irish healthcare system (HIQA, 2009). Each HIPE discharge record codes a discreet episode of care. An episode of care begins at admission into hospital and ends at discharge from (or death in) that hospital (ESRI, 2012). The unit of measurement for HIPE is then based on discharges from, and deaths in acute hospitals. This facilitates analysis of hospital activity rather than incidence or prevalence of disease. In the absence of a unique identifier, where patients may have been admitted to one or more hospitals for the same or different diagnoses or have repeated admissions, care episodes are not linked. Furthermore, HIPE does not collect data on additional healthcare episodes including Emergency Department, outpatient nor primary care visits. Clinical diagnosis obtained outside the acute hospital setting, for example in primary care, is then not linked to HIPE data. In short, it is not possible to accurately track a patient's care trajectory, nor ensure all clinical diagnosis have been recorded for an individual patient in Ireland at a population level. In the absence of reliable administrative data on population health, surveys are an obvious choice of data on the health status of community-dwelling people in Ireland.

2.3.2 TILDA survey

While a number of studies have provided population-based data on the health status of older people living in Ireland (Garavan and McGee, 2001, Morgan et al., 2008, O'Hanlon et al., 2004), there have been no large population-based cohort studies of ageing in Ireland; unlike many other developed countries (Deeg et al., 1993, Marmot et al., 2002, Shock et al., 1984). Therefore, until recently, there were few reliable data available at a population level on older people's health status in Ireland. TILDA was established to address this research gap with an emphasis on high quality research design considering a range of multi-domain indicators. It is a large prospective cohort study developed to bring about a step-change in the quality, quantity and prominence of information and research on ageing in Ireland. TILDA is based on a nationally representative cluster sample of 8,175 community-dwelling individuals aged 50 years and over, thus allowing for inferences about the older Irish population. The principle objective of TILDA is the provision of an integrated and representative database covering all the key domains of older adults lives including: economic, health, and social data investigated through a variety of research questions using several modalities (Kenny et al., 2010). TILDA collects a wide range of data on self-reported chronic conditions. Counts of self-reported chronic conditions are widely applied in the measurement of multimorbidity in the literature and were found to be the most common approach to multimorbidity measurement in population prevalence studies (as described in Section 2.4) (Huntley et al., 2012). Therefore TILDA was viewed as the most appropriate data source to inform the measurement of multimorbidity at a population level in Ireland. Given the inclusion of a broad range of variables, additional to health status, the TILDA data set also allows for exploration of complicated inter-relationships of factors relevant to the objectives of this thesis. For this reason, the TILDA dataset was chosen as the primary source of data to inform the objectives of this thesis. A more detailed discussion of the data available in TILDA to inform each of the objectives of this thesis is presented in corresponding chapters.

2.3.2.1. TILDA sampling design

The general population of persons aged 50 years or over living in residential addresses in the Republic of Ireland, and their spouses or partners of any age were targeted for inclusion in the study. Full details of the cohort profile, including study sample and response rates have been described in Kearney et al., (2011) and Kenny et al.,(2010). They are summarised in this section to provide context for the analytic approach in this thesis.

The Irish Geodirectory was used as the sampling frame for TILDA as it contains an up-to-date listing and mapping of all residential addresses in the Republic of Ireland, compiled by the Irish postal service, *An Post,* and Ordinance Survey Ireland (OSI). The Geodirectory has been used for a variety of surveys and its properties are well established (Kenny et al., 2010). An initial multi-stage probability sample of addresses based on the Geodirectory, was chosen by means of the RANSAM sampling procedure developed by the Economic and Social Research Institute (ESRI) (Whelan, 1979). Trained social interviewers carried out the main TILDA questionnaire in participants' homes using computer-aided personal interviewing (CAPI) techniques (Kenny et al., 2010). A self-completion questionnaire was also administered to all respondents. Respondents were also invited to participate in a physical assessment component. This was to be undertaken in the respondents' home, facilitated by a qualified research nurse, or in a local TILDA Health Assessment Centre. Successful interviews were obtained in 6,282 of the 10,128 estimated eligible households, giving an adjusted response rate of 62% for all elements of the study. For the purpose of this study all indicators were extracted from either the main questionnaire or the self-completion questionnaire except for data on obesity levels, obtained from BMI measurement in the health assessment. Data analysis was limited to those aged 50 years or over in the sample, excluding a small proportion of the overall sample of partners and spouses (n = 329).

Comparison with the Irish population using data from the Quarterly Household National Survey (QNHS) demonstrates that individuals with lower levels of education attainment are under-represented in the TILDA sample. Minor differences in response rates between gender and age groups were also identified (Kenny et al., 2010). Design effect calculations were carried out to determine and correct for sampling error in TILDA and sampling weights were developed to allow for this differential in non-response by age and gender and educational attainment. The primary analytical unit applied in this study is the individual respondent; however analyses of the economic and social data are based on household unit. Sampling weights were derived in all statistical analyses presenting population estimates to account for the stratified sampling approach taken in TILDA. All analyses in this study include an adjustment for clustering of responses at the household and geographical primary cluster levels.

2.3.2.2 Multimorbidity measurement in TILDA

Multimorbidity is the primary outcome measure in this empirical analysis. Considerable emphasis has been placed on the measurement approach applied to multimorbidity in this study

in keeping with best practice and ensuring comparability across other population aging studies. TILDA includes only conditions considered to have public health significance i.e. conditions that are most prevalent among middle-aged and elderly persons and/or which are most likely to result in morbidity, functional impairment and social isolation. Measures are designed to capture the respondents' health and functional status as fully as possible, taking account of the constraints of survey time and resources. While TILDA is likely then to have captured a substantial proportion of the multimorbidity burden of older people in Ireland, some conditions are not recorded and this is likely to lead to an underestimation of the true prevalence of multimorbidity burden in the community-dwelling older population in Ireland.

A standard approach to assessment of multimorbidity in population surveys is based on counts of self-reported conditions. Measurement of multimorbidity based on self-reported conditions has been a contentious issue in the literature; namely due to issues of validity and reliability and the lack of condition severity indicators as detailed in Chapter 2. In an effort to reduce the subjectivity of a self-report methodology, the chronic health conditions questions in TILDA were designed such that respondents were asked to report health conditions where a doctor has ever told them that they have a particular condition. This is *in lieu* of asking the respondent whether they have a particular condition. This questioning approach is consistent with methods used in other ageing cohort studies including the English Longitudinal Study of Ageing (ELSA) (Taylor et al., 2007), The Study of Health Ageing and Retirement in Europe (SHARE) (Börsch-Supan and Jürges, 2005) and the Health and Retirement Survey in the United States (HRS) (Heeringa and Connor, 1995) and is intended to encourage respondents to only report conditions that have been diagnosed by a medical doctor and exclude those based on a self-diagnosis.

Measures were designed in keeping with criteria developed by the Health and Retirement Study (HRS) in the United States (Fisher et al., 2005) and are directly comparable with those recorded in other large-scale cohort studies listed above (Kearney et al., 2011). The criteria guiding the development of health item responses placed emphasis on:

- high quality measures that can provide maximally valid and reliable information;
- proven items and instruments from the scientific literature, counterbalanced by the need to create new items responsive to modern hypotheses and conceptualisations of health, and its inter-relationship with social and economic factors;
- items and instruments that are at least in part represented in other recent national and international surveys in order to compare and contrast findings;

- measures that can be administered repeatedly and be sensitive to subtle changes in health status;
- measures that are appropriate for persons of various socioeconomic backgrounds;
- level of item difficulty that is suitable for participants with high and low functional status.

A detailed discussion of the approach to multimorbidity measurement is provided in Chapter 3 and a full listing of all self-reported health conditions recorded in TILDA is included in Appendix 3.1. All self-reported chronic conditions captured in TILDA were considered for inclusion in the measurement of multimorbidity in this study. Investigation of multimorbidity as an outcome of interest in this empirical analysis is guided by the operational definitions outlined in Section 1.10. Multimorbidity is primarily treated as a global measure applying the conventional threshold definition of multimorbidity as ≥ 2 conditions. Recent studies attest to a high prevalence of physical and mental health comorbidity especially in more deprived populations (Barnett et al., 2012), denoting the importance of applying a second measurement approach for co-occurring physical-mental health conditions. Mental-mental health multimorbidity is also measured, although detailed investigations are limited by the low numbers of these conditions in TILDA. Finally, acknowledging the import of combinations of individual conditions on health and healthcare burden and the potential complex interaction of conditions, this thesis is also interested in individual component conditions and multimorbidity patterns in the population. A further measurement approach then examines the effect of non-randomly occurring condition combinations identified through cluster analysis.

2.4 General approach to the empirical analysis of multimorbidity

Variable structures for multimorbidity measurement were determined by the enquiry at hand and previous methodological approaches applied in the literature. A series of bivariate and multivariate analysis were performed to investigate the empirical association between multimorbidity and independent variables of interest. A sequential approach was applied to data analysss. Initially, data were investigated to ensure variables were appropriate to the enquiry at hand and to ensure that selected variables best captured the mechanism of interest (i.e. only variables with an independent impact on health sequelae were selected for inclusion in the multimorbidity measure). Variable structure then determined the nature of models selected for bivariate and multivariate analyses. The methodological approaches applied in each empirical study are presented in detail in corresponding chapters.

The analysis of multimorbidity in this study takes four main forms:

1. Prevalence of multimorbidity is examined through analyses of mean number of conditions and weighted and unweighted prevalence estimates for three types of multimorbidity. These are:
    a. physical only multimorbidity
    b. physical multimorbidity with a mental health dimension (i.e. with at least one mental health condition)
    c. mental health multimorbidity (i.e. two or more co-occurring mental health conditions).
2. A cluster analysis was employed to investigate non-random patterns of associative multimorbidity without any *a priori* hypothesis.
3. Numbers of co-occurring chronic conditions were modelled as count data to examine the factors associated with increasing multimorbidity levels.
4. Two types of multimorbidity are considered as dichotomous variables, indicating the presence or absence of multimorbidity type, and examined in multivariate analysis to test for differences in factors associated with different types of multimorbidity. These are: physical only multimorbidity and physical multimorbidity with a mental health dimension (i.e. with at least one mental health condition). It was not possible to meaningfully examine the factors associated with mental health multimorbidity due to the small number of cases of mental health morbidity in the TILDA sample.

2.4.1 Multimorbidity prevalence analysis

Firstly, descriptive analyses are employed to examine the prevalence of multimorbidity in the TILDA sample, generalisable to the community-dwelling population aged 50 years and over in Ireland. Multimorbidity prevalence data were investigated using frequencies, percentages, cross-tabulations and graphical display of data. The mean number and standard deviation of concurrent conditions as well as population prevalence estimates for threshold multimorbidity (≥ 2 conditions), physical-mental health multimorbidity and mental health multimorbidity were estimated. A *t*test was used to test for differences in mean number of concurrent conditions for dichotomous variables and one-way Anova was used to test differences in mean number of concurrent conditions between variables with more than two categories. A Pearson's χ^2 test for 2xn tables was used to test for differences in the prevalence of all multimorbidity (i.e. threshold multimorbidity, physical-mental health multimorbidity and mental health multimorbidity)

between categories in each demographic characteristic. Alternative non-parametric tests were used for data that were not normally distributed. Tests were two-tailed with significance set at the conventional 0.05 level. A Bonferroni-adjusted significance level was calculated for χ^2 tests to account for multiple comparisons and increased possibility of a type-1 error.

2.4.2 Multimorbidity patterns analysis

The non-random patterning of multimorbidity in this thesis was examined by cluster analysis. The analytical approach to clustering of conditions in this study was informed by the nature of the chronic condition data in TILDA. Clusters were identified from chronic condition categories, rather than clusters of patients, represented in their natural unit of measurement as a dichotomous variable (i.e. condition is either present, or absent). Variables for each of the 28 self-reported chronic conditions available in TILDA were coded as 0 or 1 to indicate presence or absence of the condition and a programme was written in R Statistical Package (Release R-2.15.2) to produce the hierarchical clustering matrix. The *p X n* data matrix was imported into R from STATA 12 and transposed to a *p X p* proximity matrix of dissimilarity coefficients among the chronic condition categories.

Similarity measures (S_{ij}) for binary data are based on a 2 x 2 contingency table (see Figure 2.1 A.) where cell *a* represents the number of positive matches and cell *d* represents the number of negative matches. Several similarity coefficients are available for binary data in cluster analysis and the choice of coefficient depends on:

i. the relative weighing for positive matches; and
ii. the relative weighting of negative matches.

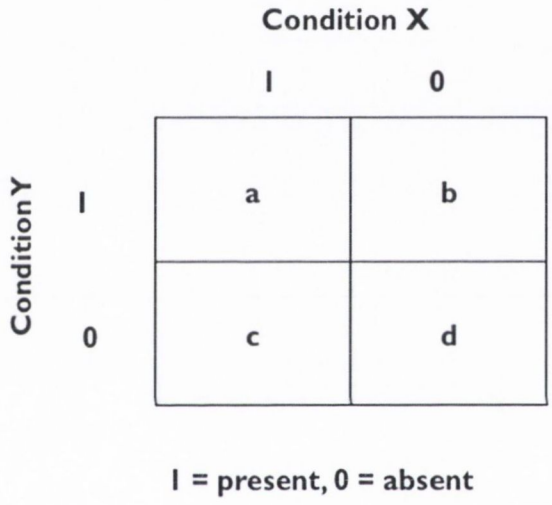
As negative matches between variables are non-informative in this scenario and there is no *a priori* reason to weight positive matches more heavily than non-matches (cells *b* and *c* in Figure 2.1.A.) this guided the choice of similarity measure in the analysis. A Jaccard binary similarity coefficient measure satisfies the criteria required to assign zero weighting to negative matches and equal weights to positive matches and non-match elements of the two diagnosis (Cornell et al., 2007).

A proximity matrix was then generated that satisfied the conceptual model that multimorbidity patterns reflect the likelihood that one or more chronic conditions occur conditionally. As described by Cornell et al, S_{ij} is then the proportion of cases that have both condition *i* and

condition *j* relative to the number of persons who have either condition *i* or condition *j* or both. For example in this case (see Figure 2.1.B), examining the proximity of high cholesterol and high blood pressure in the TILDA dataset, the Jaccard similarity coefficient is computed as 0.316 (see Figure 2.2.) The proximity matrix is then made up of a set of dissimilarity coefficients obtained from the similarity coefficient by setting $d_{ij} = 1 - s_{ij}$.

Figure 2.1. Two-by-two contingency table for binary comorbidity data (adapted from Cornell et al., 2007 and Vu et al., 2011).

A.



B.

$$\text{Jaccard similarity coefficient} = \frac{ad - bc}{ad + bc}$$

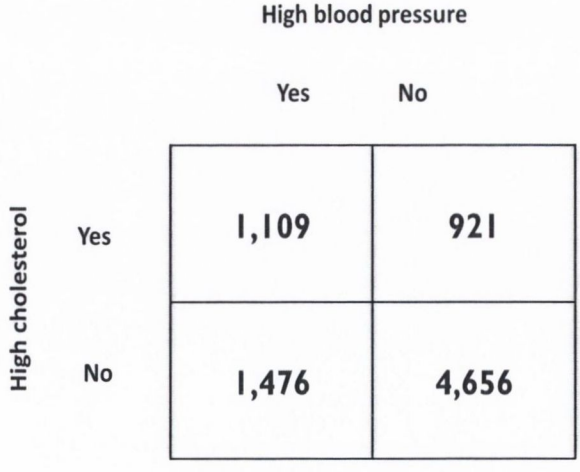
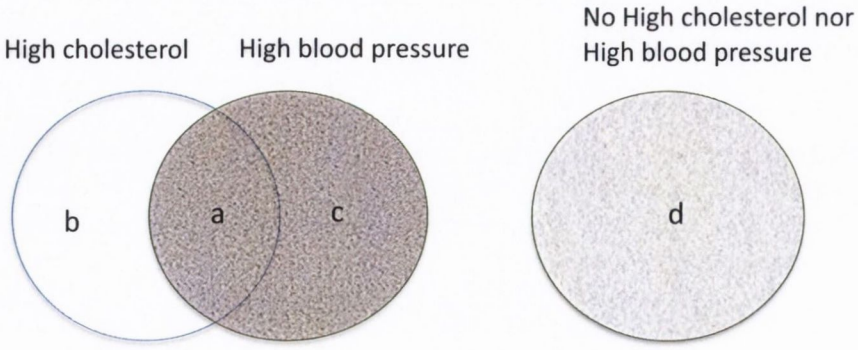


Figure 2.2. Computation of Jaccard similarity coefficient (adapted from Cornell et al., 2007 and Vu et al., 2011).



$$S_{ij} = \frac{Highcholesterol \cap Highbloodpressure}{Highcholesterol \cap Highbloodpressure}$$

Jaccard's Coefficient: $$S_{ij} = \frac{a}{a+b+c}$$

$$= \frac{1{,}109}{1{,}109+921+1{,}476}$$

$$= 0.316$$

The Lance-Williams flexible method for hierarchical agglomerative clustering (Kaufman and Rousseeuw, 1990) was applied to the proximity matrix to identify the most highly associated conditions among respondents in the TILDA sample, including those with no reported conditions, one chronic condition and multimorbidity. The flexible-beta approach was applied with β set at the conventional 0.05 level. A dendrogram was produced from the 'Plot' function in R depicting the successive grouping of chronic conditions into clusters at each step in the hierarchical algorithm. The agglomerative coefficient (AC) provides a measure of the amount of structure found by the algorithm, based on the ratio of between-cluster dissimilarities to within-cluster dissimilarities, ranging between 0 (no structure) and 1 (completely defined structure). A Jaccard dissimilarity coefficient of ≤ 1.0 was taken as the cut-off point to identify strong associations between conditions in the cluster solution.

2.4.3 Modelling multimorbidity as an outcome measure

The empirical analysis of multimorbidity in this thesis follows the general approach adopted in morbidity analysis of cross-sectional data as described in detail by Lappenschaar et al. (2012). Cross-sectional data are presented in a dataset of N_i observations of respondents viewed as possible outcomes of measured random variables. Variables represent several domains examined in the TILDA survey including, for example, health status, and demographic and socioeconomic indicators. Outcome variables denoted as O_i can be distinguished from explanatory variables, denoted as E_i. Some explanatory variables can act on a group level, i.e. they have the same value for each individual patient within a certain grouping, denoted as L_i.

Linear regression models are an obvious choice for many analyses, as dependent variables of interest are often continuous in nature and satisfy the assumption of normal distribution. However, it is much more likely that dependent variables take the form of categorical or count data in epidemiological investigations. Measures of morbidity or multimorbidity generally take the form of dichotomous response variables indicating the presence or absence of individual conditions or in the case of threshold multimorbidity, variables indicate the presence or absence of ≥ 2 conditions. The presence or absence of a condition in TILDA respondents, represented as a dichotomous response variable (i.e. yes or no), does not satisfy the normal distribution assumption, they are bounded by 0,1 compared to continuous variables, which in theory can take any value between plus or minus infinity. Therefore dichotomous variables require an alternative analytical approach, appropriate to non-parametric data. These are referred to as generalized linear models, which include the necessary transformation and choice of appropriate error distribution explicitly into the model (Lappenschaar et al., 2012).

These models are defined by three components: an outcome variable O with an expected value $E[O|e]$, a linear additive regression equation that produces an unobserved (latent) predictor η of the outcome variable , and a link function that links the expected values of the outcome variable $O$to the predicted values for n. Unlike the normal distribution, the mean and variance of a binomial distribution are not independent(Lappenschaar et al., 2012). The mean is denoted by P and the variance is denoted by $P^*(1-P)/n$, where n is the number of observations, and P is the probability of the event occurring (i.e. the probability of having multimorbidity for any one individual in the TILDA sample). When analysing a proportion as a response, a logistic or logit transformation is used to link the dependent variable to the set of explanatory variables this has the form:

$$n = logit\left(E[O|e] = \log\frac{E[O|e]}{1 - E[O|e]}\right)$$

and can be expressed as

$$Logit(P) = Log[P/(1 - P)]$$

The odds of a respondent having multimorbidity is given by $[P/(1 - P)]$, the probability of a respondent having multimorbidity divided by one minus the odds of having multimorbidity.

To examine the association of smoking with multimorbidity let:

$$P_{ij}\,(1 - P_j) = \exp(\beta_o + \beta_i x_i)$$

With Y = multimorbidity and x_i = smoking status, the logistic regression model for predicting multimorbidity can be expressed as:

$$Log\left(\frac{P_i}{1 - P_i}\right) = logit(P_i) = \beta_o + \beta_i x_i$$

where P_i is the probability of an individual having multimorbidity and x_i is the individuals smoking status (0 = non-smoker, 1 = smoker). Therefore the parameter β_o gives the log odds of an individual non-smoker having multimorbidity (when x_i = 0) and β_i shows how these odds differ for individuals with multimorbidity (when x_i = 1).

Models predicting morbidity and multimorbidity are presented as exponentiated odds ratios in this analysis, expressed as:

$$P_{ij}\,(1 - P_j) = \exp(\beta_o + \beta_i x_i)$$

2.4.3.1 Modelling increasing levels of multimorbidity

It can be noted that multimorbidity data are non-negative integers with a value corresponding to the number of conditions in an individual, generally referred to as counts of conditions. The probability of increasing numbers of co-occurring conditions in an individual can be conceived to have a limited number of possibilities; it is likely that individuals will only accumulate a limited number of conditions before the body is compromised and death occurs. The distribution of

conditions is then similar to a Poisson distribution where the probability of an event occurring reduces with an increase in frequency.

Let γ_i represent the number of conditions in an individual. Each γ_i is extracted from the Poisson distribution with a positive intensive parameter μ_i. The probability that γ_i will occur N times is given by:

$$\Pr(\gamma_i = N) = \frac{e^{-\mu_i}\,\mu_i^N}{N!}$$

where:

i = 0, 1, 2, 3... individuals.

Explanatory variables are included by specifying the intensity parameter:

$$\mu_i = e\left(\sum_{ij} b_j X_{ij}\right) > 0$$

where b_i = the j-ith coefficient and

X_{ij}= the j-ith explanatory variable corresponding to the i –ith individual.

Thus, the following distribution of numbers of conditions γ_i is obtained, conditioned to the covariant vector X_i:

$$f(y_i|x_i) = \frac{e^{-\alpha_i}\mu_j^{y_i}}{y_i!}, y_i =),1,2,3..,$$

The expected value of this function and the variance are given by:

$$E[y_i|x_i] = VAR[y_i|x_i] = \mu_i = e^{(\Sigma_{ij} b_j x_{ij})}$$

However, application of the Poisson model may be limited in analysis of multimorbidity due to some limitations. A characteristic of multimorbidity data is the typically large numbers of people living without any chronic conditions or living with only one condition, although this is likely to be lower in older populations relative to younger populations. Morbidity becomes an increasing feature of life as individuals age, with the likelihood of accumulating one chronic condition as well as the likelihood of accumulating multiple conditions increasing with increasing age (Marengoni et al., 2011). Ignoring the high numbers of respondents in the data with no conditions can lead to over dispersion in the Poisson model, implying a greater variance in the data, than that assumed in the model. Furthermore, although possible, it is unlikely that increasing numbers of chronic conditions in an individual are un-related, violating another assumption of the Poisson model.

As an alternative to the Poisson model in order to account for unobserved heterogeneity and over-dispersion of multimorbidity data, a negative binomial is a more appropriate choice of model, which is obtained by assuming that the model intensity parameter has a stochastic component e^{v_i}, where v_i assumes a gamma distribution (Cameron and Trivedi, 1998). The negative binomial model is specified as:

$$h(y|\mu, a) = \frac{r(a^{-1} + y)}{r(a^{-1})r(y+1)}\left(\frac{a^{-1}}{a^{-1}+\mu}\right)^{a^{-1}}\left(\frac{\mu}{\mu + a^{-1}}\right)^{y}$$

with equal mean and variance:

$$E[y|\mu, a] = \mu$$

$$V[y|\mu, a] = \mu(1 + a\mu)$$

where:

a represents the data over dispersion term and $\mu_i = e^{(\Sigma_{ij} b_j x_{ij})} > 0$

In the case of a = 0, the variance is equal to the mean, indicating that there is no over dispersion and the model is reduced to a poisson model.

A further consideration of multimorbidity in this thesis is that diagnosis of a first condition and further conditions may occur as two distinct stochastic processes. An individual may present to a physician with symptoms of a condition prompting a first diagnosis. Diagnosis of a first chronic

condition means that the threshold between being a 'healthy' individual (i.e. as measured by the absence of a chronic condition) and 'unhealthy' individual is crossed. Another way to interpret this is the process of moving from a non-patient to becoming a chronic condition patient, requiring treatment. Diagnosis of further conditions is then influenced by the physician, as well as the individual respondent. For this reason, morbidity in this study was examined as a two-part process. In the first stage, a logit model was employed to estimate the probability of an individual having a chronic condition diagnosis. In the second stage, a truncated at zero model was used to estimate the increasing number of co-occurring conditions diagnosed in an individual, considering only the sub-sample of individuals with morbidity (i.e. y_i greater than zero).

2.4.3.2 Modelling multimorbidity type

As indicated there are three types of multimorbidity investigated in this thesis. The first is what is generally defined as multimorbidity in the literature: ≥ 2 co-occurring conditions in an individual. However, considering physical and mental health conditions equally may be masking distinct processes and outcomes related to the co-occurrence of physical and mental health conditions. It has been suggested in the literature that multimorbidity with a mental health component is more prevalent in less affluent individuals (Barnett et al., 2012) compared to the level of physical-mental health in more affluent individuals. However, the factors that may be driving this difference have not yet been established. Distinct from count data, multimorbidity type is not ordered and is characterised as a categorical variable with three independent categories. The first category contains anyone in the sample without multimorbidity (i.e. those with less than two of any of the 25 self-reported conditions examined). The second contains those who have two or more physical conditions, but no mental health condition. The third contains only those with two or more conditions, one of which is a mental health condition.

A multinomial logistic regression model is employed to investigate the difference in independent variables predicting each category of the variable where U_{ij} denotes the respondent's utility *i* for having one or other of three types of multimorbidity. It is assumed that $U_{ij} = V_{ij} + \varepsilon_{ij}$ where V_{ij} is the deterministic component of the utility and ε_{ij} is the random component of the model. It is assumed that the errors are independent and have a type 1 extreme value distribution and the respondent *i* is multimorbidity type (Y_i) takes the value of 1 through 3 and the model is specified as:

$$\Pr(Y_i = j) = \frac{e^{V_{ij}}}{\sum_{k=1}^{3} e^{V_{ik}}}, k = 1,2,3 \Pr(Y_i = j) = \frac{e^{V_{ij}}}{\sum_{k=1}^{3} e^{V_{ik}}}, k = 1,2,3$$

The log-likelihood function of the multinomial logit model is given by:

$$InL = \sum_{i=1}^{n} \sum_{j=1}^{3} d_{ij} \ln \frac{e^{V_{ij}}}{\sum_{k=1}^{j} e^{V_{ik}}}$$

A defining feature of the multinomial logistic regression coefficient is that it estimates $K - 1$ models, where K is the number of levels of the dependent variable. This allows for examination of parameter estimates relative to the reference group specified in the model. The standard interpretation of the multinomial logit is that for a unit change in the independent variable, the logit of the outcome m relative to the reference group is expected to change by its respective parameter estimate given that all other variables in the model are held constant (Paudel et al., 2013). For the empirical analysis of multimorbidity type an initial examination of the two multimorbidity categories (i.e. with and without a mental health component) are estimated relative to the base category of no multimorbidity (i.e. ≤ 1 condition). A further estimation considers the parameters of physical-mental multimorbidity relative to physical only multimorbidity.

2.4.4 Inclusion of a relative measure of material deprivation

A primary objective of the empirical analyses was to establish the factors associated with multimorbidity in community-dwelling older people in Ireland. A comprehensive range of individual respondent characteristics were recorded in TILDA, however it is now well acknowledged that few personal characteristics are truly exogenous to the environment within which an individual resides. The balance of current evidence points to the importance of contextual impacts on health independent of personal characteristics (MacIntyre and Ellaway, 2003). To overcome the issue of large amounts of missing data on individual level measures of socioeconomic status in TILDA, and to ensure adequate acknowledgement of the contextual impacts of an individual's environment on multimorbidity status, a measure of *relative material deprivation* appropriate for health and health services research was incorporated into the TILDA database and used as an area-based measure of deprivation for TILDA respondents. The deprivation index used in this thesis was obtained from the Small Area Health Research Unit

(SAHRU) in 2011 and merged into the TILDA database. The SAHRU 2006 index is applied in this study as a measure of area-based deprivation attributable to each individual in the TILDA dataset. The methodological approach applied in constructing the SAHRU index has previously been described in detail (Kelly and Teljeur, 2007). The conceptual basis of the index is similar in design to the widely regarded Carstairs and Townsend indices in the United Kingdom (UK)(Carstairs and Morris, 1991),with certain modifications in view of differences in definition and scope between census variables in the UK and Ireland (Kelly and Teljeur, 2007). The Index is based on Small Area Population Statistics (SAPS), provided by the CSO from Census data. The constituent variables of the 2006 SAHRU Index are based on four indicators:

- **Unemployment (UE)** - the proportion of the economically active population (15 years or older) unemployed or seeking a first time job.
- **Low Social Class (SC)** - proportion of population in social class 5 or 6.
- **No Car (NC)** - proportion of permanent private households without a car.
- **Local Authority Rented Accommodation (LA)** - proportion of permanent private households rented from a local authority, or in the process of being acquired from a local authority.

SAPS data are generally released at a District Electoral Division area. In total, there are nearly three and a half thousand electoral divisions (EDs) in Ireland however, the CSO does not release SAPS on some sparsely populated EDs for reasons of anonymity. To overcome this, these sparsely populated EDs are generally merged with neighbouring EDs. As a result, in 2006 SAPS data were made available on 3,409 EDs. Corresponding relative deprivation scores for each of the 3,409 EDs were calculated for the 2006 SAHRU index, by employing Principal Component Analysis; widely considered as a robust and common approach for analysis of deprivation indices. An Excel file was obtained from SAHRU with a full listing of all iterations of the Index for every ED in the country (N=3,409) to generate an appropriate measure of area based deprivation in the TILDA dataset. An Excel file was generated and cleaned to contain only variables pertaining to the 2006 index and was imported into SPSS. This file included six variables:

- ED_ID: identifier used by the Central Statistics Office for the 3,409
- ED Name
- County or Area as appropriate
- Score'06 - Deprivation score 2006
- Decile'06 - Deprivation Index 2006 (1 is least deprived, 10 is most deprived)
- Population'06 - total population in EDs in 2006

As previously described, the sampling procedure applied in TILDA was based on households sampled within clusters or EDs. In total 640 EDs were sampled. Every ED in the country has a unique identifier number used by the CSO. This unique number was common to both the SAHRU data file, and the full TILDA data file. Given the sensitive nature of the data contained in the TILDA file, only one version of the TILDA file contains the full data along with ED codes and, in keeping with data protection guidelines, it is only accessible by senior TILDA management. Therefore, the Researcher provided an SPSS file containing the variables from the 2006 index to a senior member of the TILDA team, who assisted in matching the SAHRU data with the ED data listed in the full TILDA data file. In advance of the formal matching process, an initial hand search of 20 EDs was conducted to ensure that unique identifiers for EDs corresponded between datasets, based on ED names. Five EDs were identified in TILDA that were not identified in the SAHRU dataset. These had been merged into larger EDs by the CSO when releasing the SAPS due to potential anonymity issues. To overcome this, the five EDs (Brisha, Inishcaltra North, Canuig, Greenhall, Derrycunlagh and Glenco) were attributed the deprivation score of their corresponding merged ED in the SAHRU file. Matching was then conducted in SPSS and data were tested to ensure that scores reflected the values in the SAHRU index file. During this process, it was considered that there was potential to identify individual respondents in extremely deprived areas in the merged dataset due to low numbers of individuals in some EDs. To ensure that this was avoided, and in keeping again with data protection guidelines, extreme index scores, i.e. ≥ 8.50, were recoded to 8.50 with the consequence of slightly reducing the variance of the SAHRU index score. This did not, however, affect the decile scores. For ease of interpretation, the decile scores are applied in analyses in this thesis.

2.5 Empirical analysis of health and social care utilisation

2.5.1 Conceptual approach to modelling health and social care utilisation

A key consideration in determining the impact of multimorbidity burden on healthcare services is that use is not, in and of itself, a good measure of need. Healthcare utilisation is a product of a complex mix of factors which can be roughly divided into those influencing the demand for healthcare and those influencing the supply of healthcare (Layte et al., 2009). The Anderson and Newman Behavioural Model of Health Service Use (Anderson and Newman, 1973), has become the defining model for examining healthcare utilisation and was adopted here Anderson's Phase-3 Model of Health Service Utilisation (Anderson, 1995) was adopted in the empirical analysis

(Chapter 5) to model the impact of multimorbidity on healthcare utilisation. Indicators are integrated into a testable model as groups of independent variables assessing correlates that either impede or facilitate health service utilisation. The model proposes that an individual's access to, and use of, services is a function of three components: predisposing characteristics, enabling resources, and need factors. Predisposing characteristics are defined as socio-cultural characteristics of the individual that exist prior to the illness or disability that identify the propensity of the individual to use healthcare services. Enabling resources are described as the means available to individuals to use services and include logistical aspects of obtaining care. Need refers to the direct health status of the individual that may prompt health service use. Anderson et al. (1973) hypothesised that each component would vary in their independent contribution to the prediction of health service utilisation. It was further hypothesised that need factors would be the primary predictors of non-discretionary behaviour (i.e. behaviour that was dictated by the seriousness of the health status or dictated by a healthcare provider), while predisposing and enabling factors would be more predictive of discretionary behaviour (i.e. behaviour that largely depends on the individual's own decision to seek care).

While a major criticism of the analytical model is that the many iterations and additional components have made analysis unwieldy. Similarly, researchers note the flexibility of the model and the ability to add other domains relevant to additional areas of study (Aday and Awe, 1997). Many researchers have applied the 1973 model in analysis but have also incorporated other factors of particular interest to their research (Garavan, 2007, Bass et al., 1992). Multimorbidity was added to the general model as a need factor to assess its contribution to a range of health and social care outcomes. Given the multidimensional nature of the measures captured in TILDA, a large variety of variables were available for consideration as enabling and predisposing factors in the model, these are detailed in Chapter 6.

2.5.2 Modelling healthcare utilisation data

Healthcare utilisation is regularly analysed using least squares regression although such data do not generally satisfy the standard assumptions underlying OLS methodology including normality, homoskedasticity and independence assumptions. Healthcare utilisation data is rarely normally distributed. Numbers of visits, admissions and length of stay generally have a mode at or close to zero and a distribution with a long, heavy right tail. Utilisation data also violates the second assumption of homoskedasticity i.e. that the variance is the same for any fixed combination of the covariates. In normally distributed data, the mean and variance are independent, however,

the standard deviation has been shown to increase with the mean in healthcare utilisation data (Diehr et al., 1999). In contrast, for the Poisson distribution the standard deviation increases with the square-root of the mean. For the reasons outlined in preceding paragraphs, certain assumptions are not met by this model. The model may present over-dispersion and a further violation may arise where healthcare visits are not independent; in the case of visits to a doctor for example, one visit may be related to a previous visit.

Similar to multimorbidity data, a further characteristic of healthcare utilisation data is that service use has two distinct stochastic processes: the propensity to first use a service and the frequency or intensity of service use after first contact with the service. It is reasonable in the case of healthcare to assume that the agents determining these two processes are distinct. The initial decision to contact services is determined by the individual themselves, while the decision for a return visit or length of stay in hospital is generally determined by a physician. This prompts the need to model the propensity to use services and the intensity of service use as a two-part process. The initial stage is modelled as using a binomial distribution i.e. the probability that the use of service threshold is crossed. The second process is modelled as a zero-truncated negative binomial model. The second stage models only the sub-sample of individuals who have had an experience of healthcare and can be interpreted as the intensity of service use, once the threshold of service use has been crossed.

The construction of a negative binomial hurdle model is described in detail by de Souza Noronha et al. (2002), specified as using two likelihood functions parametrically independent, each representing a stage in the estimation procedure. Let Y_i represent the number of times an individual i seeks to attend a GP, where Y_i is ≥ 0 and d_i is a binary variable which assumes a value of 1 when medical contact is established and zero when it is not. The likelihood function for the negative binomial hurdle model L_{BN}^{H} can be specified as:

$$L_{BN}^{H} = \prod_{i \varepsilon \Omega} pr\{y_i = 0 \mid x_i\beta_1, a_1\}^{1-d_i} \left(1 - pr\{y_i = 0 \mid x_i\beta_1, a_1\}\right)^{d_i} \times \prod_{i \varepsilon \Omega_1} \frac{pr\{y_i \mid x_i\beta_2, a_2\}}{pr\{y_i \geq 1 \mid x_i\beta_2, a_2\}}$$

where:

i = 1,2,3,... individuals;

α_3 = over dispersion parameter of data in stages, being s = 1, 2;

Ω = whole sample; and

Ω_1 = subsample comprising only individuals who searched for a healthcare service.

As the primary aim of regression analyses in this thesis was to develop an explanatory model of exposures on outcomes, formal stepwise techniques were not applied as recommended in the literature (Hosmer and Lemeshow, 2000). The selection procedure for explanatory variables in each model was based on the conceptual framework and purposeful selection of variables from bivariate analyses. Assessment of significance in bivariate models at more traditional levels such as 0.05 can fail to identify variables known to be important in predicting outcomes, therefore as a general rule, measures that were significant at the p=0.10 bivariate level were entered into the multivariate regression analysis to examine variables independently associated with outcomes (Bursac et al., 2008, Hosmer and Lemeshow, 2000). A general to specific method was employed in preliminary analysis of all models starting with a complex model of all potential explanatory variables and progressively excluded variables that were found to be insignificant in the overall model (Greene 2008 & Campos 2005). As a model with few variables will have greater numerical stability and will be more easily generalisable, the most parsimonious models were retained and presented in the results (Hosmer and Lemeshow, 2000). Following the iterative process of variable selection as proposed by Hosmer and Lemeshow, covariates were removed from the models if they were non-significant and not a confounder. Significance was evaluated at 0.10 alpha level and confounding was estimated as a change in any remaining parameter of greater than 20% compared to the full model.

Separate models were derived for each outcome variable in all analyses. Independent variables were modelled as binary (0,1) or categorical depending on number of categories. In the case of categorical explanatory variables, dummy variables were created to contrast different categories. For each variable a baseline category was defined and all remaining categories were contrasted to the baseline. For k categories of a variable, $k-1$ dummy variables were created to investigate the differences in each category with respect to the dependent variable. Variables were examined individually at first in bivariate analysis for each outcome of interest. In cases where a variable showed significance in crude analysis (bivariate), it was selected to be added to the multivariate model. Groups of similar variables and alternative versions of the same variables were examined to assess the strength of association with each outcome. In the case where variables may have been related and remained significant in the presence of each other, tests for multicollinearity were undertaken to assess the effect of related dependent and independent variables in the presence of each other. All independent variables were tested for

multicollinearity by examining their Variance Inflation Factor (VIF) and tolerance. Evidence of multicollinearity was indicated by VIF values ≥ 5 and tolerance values ≤ 0.20.

2.5.3 Geographical access to healthcare services – Health Atlas Data

One potential confounder on the impact of multimorbidity on health and social care utilisation in Ireland is the geographical availability of healthcare services. Theoretically, if healthcare provision has the effect of improving health, patients living close to healthcare service, such as GPs and hospitals, should maintain better health status than those living further from services and this should then be reflected in healthcare utilisation figures. However, studies contradict this. It is argued that utilisation often increases with local availability with the effect unlikely to be explained by health status alone implying that supply of healthcare services may increase demand (Teljeur, 2001). A logical conclusion is then that service utilisation figures are likely to be inflated with closer proximity to health services and will provide a biased estimation of the true health needs of the population. It is important to control for this when assessing the burden of multimorbidity in community-dwelling older people on healthcare utilisation rates.

Data on the geographical availability of health services at a local level were not available in TILDA. To overcome this, a data set was requested from Health Atlas Ireland, which would enable the modelling of geographical access to healthcare services in Ireland. Raw data were obtained from Health Atlas Ireland including the geocodes of all general practices (n=1981), community hospitals (n=52) and general acute hospitals (n=38) in Ireland, presented as X, Y coordinates in an Excel database. Health Atlas Ireland uses Geodirectory codes providing the precise geographic location (X, Y co-ordinates) for health services in Ireland, enabling accurate geo-demographic mapping and analysis. Geocoding is defined as:

> *"*the process by which an entity on the earth's surface [a household or hospital for example], is given a label identifying its location with respect to some common point or frame of reference*" (Goodchild, 1984 p.33)*

The Irish Grid was devised by Ordnance Survey Ireland and presents a system of geographic grid references commonly used on the island of Ireland (Leahy, September 26, 2008). For the purpose of the Irish Grid, Ireland is divided into 20 squares, each identified by a single letter. X,Y coordinates are references on the Irish Grid and the Irish Transverse Mercator (implemented jointly by the Ordnance Survey of Ireland (OSI) and the Ordnance Survey of Northern Ireland (OSNI) in 2001 to synchronise with newly developed GPS technology. The X coordinate identifies

the exact easterly location, while the Y coordinate identifies the exact northerly location. If the X, Y coordinate for a building is known it can be pinpointed on a large-scale map at the exact spot - within one meter - where the two coordinates intersect (GeoDirectory, 2012).

In order to match the health services location data with the TILDA data file an SPSS file was created including geocoded data (X, Y coordinates) of all TILDA respondents' household locations, unique identifier numbers, gender and dates of birth. The geocoded data obtained from Health Atlas Ireland were then imported into the SPSS file. To compute the geographical distance to each healthcare service for every individual respondent in TILDA a series of computations were performed in SPSS, to calculate the minimum distance from the respondent's home to the nearest GP and hospital. These variables were based on a 'minimum eulicidean distance' algorithm previously developed by Professor Brendan Whelan (Kenny et al., 2010). This was a two-step process. The first step was to calculate the distance for every respondent to each healthcare service location in the country. The shortest of the distances was then taken as the respondent's minimum distance to each type of healthcare service location. For each individual respondent in the TILDA sample, using the X, Y coordinate of their household location as recorded in TILDA, the distance in meters from each respondent's household was calculated for:

1. all GP practices in Ireland;
2. all community hospitals in Ireland;
3. all general acute hospitals in Ireland;
4. all community OR general acute hospitals;

A second calculation was then applied to produce the minimum distance from each respondent's household to every service listed above. This gives four variables in the dataset, listed below, all providing information on distance in meters to the nearest healthcare services. These variables were then merged into the enhanced TILDA dataset to allow for further detailed analysis of the variables according to the characteristics in the TILDA sample.

1. nearest GP (in meters), compared to all GP practices in Ireland;
2. nearest community hospital (in meters), compared to all community hospitals in Ireland;
3. nearest general acute hospital (in meters), compared to all general acute hospitals in Ireland;
4. nearest hospital (in meters), compared to all community OR general acute hospitals;

These four variables on proximity to healthcare services were merged into the enhanced TILDA data file to allow for controlling for the effect of proximity to healthcare services on utilisation outcomes.

2.6 Model specification testing

The Vuong likelihood ratio test (Vuong, 1989) was employed in all modelling processes to test if the dependent variables in regression models were overdispersed. In all cases the following hypothesis was tested:

$$H_0 : \alpha = 0$$

$$H_1 : \alpha > 0$$

The likelihood ratio test is obtained through the difference between the difference between the log-likelihood of the Poisson model and the negative binomial model:

$$LR = -2\left(LN_{poisson} - LN_{nbreg}\right)$$

where:

$LN_{poisson}$ = log-likelihood of the poisson model;

LN_{nbreg} = log-likelihood of the negative binomial model.

When α = 0, the negative binomial model is nested to the Poisson model and the data are not over-dispersed. In all cases in this study, the likelihood ratio test was equal to zero and hypothesis H_0 was accepted.

2.7 General approach to statistical analyses

All variables were initially examined using descriptive statistics. Frequencies and means were computed for dichotomous and categorical variables to obtain the crude prevalence of each of the dependent variables, the independent variables and other covariates examined in analyses.

Each of the hypothesised independent predictors was examined using cross-tabulations to determine if bivariate associations existed between the predictor and the outcome. Other covariates were also examined in relation to both the independent predictors and the outcomes.

After preliminary analysis of the data, hypothesised predictors, confounders and effect modifiers were included in the multivariate regression models. Coefficients and confidence intervals were computed based on the adjusted model. In generalized linear models exponentiated coefficients (i.e. Odds Ratios (ORs), Incident Rate Ratios (IRRs) and Relative Risk Ratios (RRRs) were computed to estimate the effect on outcomes given exposure, controlling for other covariates. Models for all main effects are estimated and presented with confidence intervals and P-values. In cases where significant interaction effects are detected, models are presented with main and interaction effects as above.

TILDA is conducted using a complex sample design as described in Section 2.3.2.1 above. A key concern of using survey data is how the sampling design influences estimation of the variance for given parameters. Failure to accommodate for survey design could lead to inaccurate estimation of the standard errors, however due to the large sample size of TILDA; there should be enough power to detect differences in the data. The TILDA sampling design is accounted for in this thesis by applying pre-designed survey weights into analyses. In this case, the svy command was used in STATA-12 to estimate parameters that incorporate the strata, cluster and unequal weights of observations.

2.8 Ethical approval

Formal approval to pursue secondary data analyses of first wave TILDA data to inform this thesis was formally granted in May, 2008. Ethical approval for conducting the study was sought and granted by the Centre for Health Policy and Management/Centre for Global Health Research Ethics Committee in Trinity College Dublin in March 2010. A data confidentiality agreement was signed in order to access data from Health Atlas Ireland and permission to access the SAHRU Index of Deprivation was granted from SAHRU in Trinity College Dublin.

2.9 Data management and data cleaning

All data were imported into the TILDA dataset, housed in TILDA offices, under data protection guidelines. The final dataset containing all variables including the SAHRU index variables and minimum distance to healthcare variables obtained from Health Atlas were imported to STATA 12 for analysis. For the purpose of conducting the cluster analysis of multimorbidity variables, a data file containing relevant variables was imported into R and analysis was conducted in R to generate a clustering matrix and dendrogram. Adhering to best practice guidelines, all analysis results were stored in an encrypted file on the Researcher's personal computer.

Information was captured on 8,175 respondents in total for the first wave of TILDA. During the data-cleaning phase, 329 observations were dropped as respondents were aged less than 50 years. A further 12 observations were dropped as respondents age was missing and one respondent's age was recorded as 105 years. This was also deleted from the data set as an outlier. In addition, three respondents had a large number of missing responses including sex and age and these were also deleted from the dataset prior to analysis. The cleaned dataset had 8,162 remaining observations on people aged 50 years and over in Ireland. Two standard approaches were employed to deal with missing cases for specific variables examined in analyses. Where variables were missing fewer than 20 cases these were dropped in advance of analyses using list wise deletion. For variables with multiple categories and a large proportion of missing data, a separate "unclassified" category was created for the missing cases. For example, those who did not report BMI were assigned to an unclassified category for this variable.

2.10 Strengths and limitations of empirical analyses

The approach to empirical analyses applied in this thesis has a number of strengths and limitations. Strengths include the large sample size representative of a national community-dwelling older population, representative of the people aged 50 years and over living in Ireland. This allowed for greater power for investigating relationships between multimorbidity and a wide range of factors including individual health burden and process measures at a population level. The breadth of measures available in the TILDA survey as well as the additional measures included in the merged datasets presented a unique opportunity for studying multimorbidity related factors in a national community-dwelling sample. A significant limitation of this thesis is the cross-sectional design of the empirical analyses, based on first wave TILDA data, precluding any meaningful inferences of causality. The methodological approach applied in this study will

however provide a useful baseline for investigating multimorbidity incidence and related factors in future waves of TILDA data, allowing for one of the first longitudinal examinations of multimorbidity at a national level. A notable advantage of empirical analyses of TILDA data is the close harmonisation of health measures with other national longitudinal studies on ageing so as to ensure adoption of best practice and comparability of results. While international comparison is beyond the scope of this study, the methodological approach developed in this thesis based on internationally comparable data presents an opportunity to develop meaningful international comparisons of multimorbidity prevalence and related outcomes in large-scale nationally representative ageing cohort studies which has been limited to date.

Quality of the empirical analyses is largely determined by the quality of the underlying data. Barnett and colleagues (2012) highlight that no standard approach for the measurement of multimorbidity exists, and that definition and subsequent selection of morbidities to include in a multimorbidity measure is inevitably partly subjective and dependent on the data available. Like Barnett and colleagues this study specifically sought to include core morbidities as recommended in a systematic review conducted by Diederichs et al. (2011b). However, two considerations remain. Multimorbidity is measured on self-reported conditions only, which is subject to reporting bias. Self-reported health status is subject to self-declaration bias due to under-reporting of diagnosis or forgetfulness. However every effort was made during survey design and delivery to ensure that bias was avoided in TILDA. Data on self-reported chronic conditions may be underestimating the true prevalence of chronic disease burden, especially for conditions with such as high blood pressure and high cholesterol. However, measures of multimorbidity based on self-reported chronic conditions have been shown to perform almost as well in predicting a range of outcomes compared to more sophisticated measures (Fortin et al., 2012). In addition, alternative data sources for examining multimorbidity in community-dwelling populations are also vulnerable to bias. For example data obtained from primary care records are subject to issues of condition abstraction and are biased towards those attending services. A further criticism may be the lack of diagnosed severity levels in the measurement of multimorbidity. No account has been taken of the degree of condition severity, which may be impacting on differential contributions to the overall burden of multimorbidity in individuals as severity was not objectively measured for many of the conditions in TILDA. The best approach to considering condition severity in self-reported health conditions is unclear and the balance of evidence suggests that weighted measures are not suitable for investigating multiple outcomes (Byles et al., 2005, Fortin et al., 2007b, Fortin et al., 2012). Un-weighted counts of conditions are generally considered as a valid methodological approach to measuring a range of multimorbidity

outcomes (Huntley et al., 2012, Fortin et al., 2012) and attempts were made to include only conditions producing negative health sequelae in this thesis, minimising potential bias.

Respondents with only one or none of the listed chronic conditions, indicating no multimorbidity in this study, may have other unlisted chronic conditions. It is therefore important to note that the reported prevalence of multimorbidity is only based on the set of chronic conditions in the TILDA survey when interpreting these findings. While attempts were made to minimise over-counting of conditions and symptoms, some individuals who report having multimorbidity may essentially be reporting manifestations of the same condition.

It is noteworthy that social desirability biases associated with peoples' tendencies to view/present themselves as better than average and to avoid extreme responses have shown to be relevant to health behaviour predictors, therefore introducing bias in the analysis of lifestyle risk factors as predictors of multimorbidity. There may also be a circular argument for health behaviours and health care utilisation and multimorbidity in that 'sick people' are less likely to exercise and are more likely to attend services and receive diagnoses for conditions additional to their initial diagnosis.

There is an increasing consensus in the literature that household income, after taxes and transfers, appropriately adjusted to account for family size and assigned to each individual within the family, is the best readily available measure of individual socioeconomic status, although the utility of income as a measure of socioeconomic status for individuals no longer participating in the workforce has been questioned (McMunn et al., 2009). Wealth rather than income has been identified as a better indicator of access to resources in later life. Detailed variables on assets were also recorded in TILDA to account for this. Unfortunately, while TILDA attempts to provide particularly good household income and assets data, a substantial proportion of data on these variables are missing due to question non-response. However, housing tenure has been identified as a powerful proxy indicator for wealth in other longitudinal ageing studies (Connolly et al., 2010) and was shown to correlate highly with other measures of wealth recorded in TILDA. This is a useful proxy measure for socioeconomic status as it has a low number of missing responses (n=468) relative to other individual measures of SES. It should be noted that approximately 8% of the study respondents rent accommodation. In such cases respondents reported on the value to their rental property.

The imported SAHRU deprivation variable also provides an area-based measure of socioeconomic status for all TILDA respondents. It was intended to model the deprivation

measure merged into the TILDA dataset as an area level indicator of relative material deprivation. This would have allowed for investigation of the hypothesis that multimorbidity is more pronounced in more deprived areas, even after controlling for the effects of individual level socioeconomic status indicators such as education and income. The hypothesis centres on the issue of individuals living within neighbourhoods sharing more similar characteristics than those selected from a population at random, subject to common influences (Austin et al., 2001). However, the structure of the data across areas sampled in TILDA was too diverse to allow for any meaningful analysis of an area level effect on multimorbidity risk. A single level modelling approach was then favored over a multi-level modelling approach and deprivation levels were modeled as a proxy indicator of individual deprivation status. It is noted that modelling neighbourhood level indicators to make inferences about statistical relationships at the individual level falls prey to the notion of ecological fallacy, a fallacy inherent in making causal inferences from group data to individual behaviours (MacIntyre and Ellaway, 2003). A single level modelling approach does not take account of the differences in area level factors and is likely to result in biased standard errors and increases the risk of type 1 errors.

A previous study on multimorbidity prevalence in primary care found a higher rate of psychological disorders for non-responders compared to responders, suggesting that mental health related multimorbidity may be greater in non-responders (van den Akker et al., 1998a). It was not possible however to examine the differences between responders and non-responders in TILDA due to the lack of available information on non-responders.

Finally, the requirement of community-dwelling older people to provide written informed consent for inclusion in the TILDA study will have resulted in the exclusion of some older adults, with cognitive impairment or dementia. Although the questionnaire includes a component on cognitive functioning, the lack of a clinical psychological assessment limits the ability to make a formal assessment of dementia or other psychiatric conditions. Furthermore, TILDA excludes institutional dwelling older people, leading to an underrepresentation of frailer older people in the study. This is likely to have led to selection bias of healthier older adults living in the community with the resultant effect of an underestimation of debilitating chronic conditions in older age groups. Investigation into the TILDA cohort over time will compensate for the underestimation of this group of older people, however given the cross-sectional nature of this study on wave 1 base-line data, an accurate effect of under-estimation cannot be determined at this time.

Chapter 3. Empirical Analysis of Multimorbidity Prevalence and Patterns in Ireland's Older Population

3.1 Introduction and background

Multimorbidity is now the norm rather than the exception for older people in developed countries (Marengoni et al., 2011, Fortin et al., 2012, Salive, 2013). Population based studies of multimorbidity burden are particularly useful as they provide generalisable estimates and contribute valuable information to inform healthcare policy and planning. The relative burden of multimorbidity varies depending on the level of assessment i.e. at an individual or a population level. The burden of chronic conditions at a population level is driven by prevalence, such that a highly prevalent condition with a moderate impact for individuals will account for a higher population burden compared to the population burden of a rare but severe condition (Pope, 1988). Multimorbidity is becoming increasingly common in community-dwelling populations, necessitating a focus on the general population distinct from clinical sub-populations. While international evidence points to especially high prevalence of multimorbidity in older ages (Marengoni et al., 2011, Barnett et al., 2012, Fortin et al., 2012, Salive, 2013), it has also been suggested that a large proportion of multimorbidity at a population level is accounted for by those aged below 65 years and populations living in more deprived areas may accumulate chronic conditions at an earlier age (Barnett et al., 2012). This necessitates a shift in the focus from the clinical concept of *comorbidity* to a more comprehensive assessment of multimorbidity in a population health context acknowledging the broader determinants of multimorbidity and implications for at-risk population sub-groups.

The likely increasing prevalence of multimorbidity burden as a result of the projected increase in chronic conditions is particularly relevant given the demographic shift towards an ageing population. Increased population prevalence of multiple conditions requiring on-going management and treatment along with the complexity of co-occurring condition symptoms and interactions that this gives rise to will likely lead to a substantial increase in demand for health and social care services in the years to come with inherent challenges for health and social policy and national budgets. Nonetheless, prevalence of multimorbidity in nationally representative samples is largely under-researched (Salive, 2013) and recognition of the substantial population health challenge posed by multimorbidity has been slow.

This Chapter examines the prevalence and patterns of multimorbidity in an Irish context based on secondary data analyses of first wave TILDA data. The following sections of this Chapter introduce the evidence-base to date on the prevalence and patterns of multimorbidity in a national and international context (Sections 3.1.1. and 3.1.2) and objectives of this study are outlined in Section 3.1.3. A detailed account of the empirical analyses approach to examining prevalence and patterns in this study is provided in Section 3.2. The results of the empirical analyses are presented in Section 3.3 and these findings are discussed in Section 3.4. A detailed discussion of findings in the context of the overall objectives of the thesis is presented in full in Chapter 6.

3.1.1 Multimorbidity prevalence

3.1.1.1 Multimorbidity prevalence across study settings and between different samples

Knowledge of population prevalence of multimorbidity remains elusive in the absence of agreed operational definitions and measurement approaches. Studies have adopted a variety of approaches to analysing prevalence in a disparate range of study populations and settings, making it difficult to meaningfully compare results (Marengoni et al., 2009a, Fortin et al., 2012). A previous systematic review of multimorbidity across all settings found that estimates ranged from 20% to 30% when the full population was considered and 55% to 98% when studies were limited to older populations (Marengoni et al., 2011). However the latter figure was derived from a primary care sample of consecutive patients which likely overestimated the burden of multimorbidity (Fortin et al., 2005a).

Differences between prevalence estimates may be explained by the wide range of approaches applied to multimorbidity measurement and the different samples considered from a range of settings. Prevalence rates vary substantially between study settings (Fortin et al., 2009) and attempts to validly compare estimates between settings is limited due to varying sample characteristics, operational definitions of multimorbidity, condition abstraction, the number of conditions considered, and the nosology of conditions included in the definition of multimorbidity. Schram et al.(2008) posit that studies adopt alternative methodologies to set setting specific goals or objectives driving the observed difference in prevalence rates. Studies of community-dwelling samples are largely interested in epidemiology and the impact of multimorbidity at some population level while studies conducted on primary care and hospital

samples are more concerned with improvements in clinical outcomes.

Prevalence of multimorbidity in community samples is substantially lower compared to primary care samples (Cazale and Dumitru, 2008, Fortin et al., 2010), likely reflecting methodology bias rather than any real observed difference in prevalence (Schram et al., 2008). Multimorbidity in primary care samples may be biased upwards due to frequent attender bias (Fortin et al., 2009) and downwards due to self-selection bias in community samples, where healthier individuals are more likely to opt into studies compared to those who are unwilling or unable to participate due to illness burden (Søgaard et al., 2004). Estimates of prevalence in community samples are also likely to be biased downwards as they generally exclude individuals with severe dependency residing in institutional care. However, even when studies are limited to community-dwelling samples, varying prevalence rates have been observed, ranging from 13% to 83% with a median prevalence of 63% and a mode of 67% for older adults (Salive, 2013).

3.1.1.2 Multimorbidity in national prevalence studies

Studies examining multimorbidity from a population health perspective are generally limited in their scope, as few datasets have been designed to capture the multimorbidity experience in community-dwelling populations. Reliable measurement of multimorbidity at a population level is then challenging and largely dependent on the quality of the data available. As a result, despite the proliferation of studies examining multimorbidity in recent years, few studies have examined multimorbidity in nationally representative samples. A recent systematic review identified 17 studies reporting multimorbidity prevalence in community-dwelling samples that included older people (Salive, 2013). Six of the identified studies were based on nationally representative survey samples of multimorbidity measured by self-reported conditions (Loza et al., 2009, Hoffman et al., 1996, Verbrugge et al., 1989, Partnership for Solutions, 2004, Rapoport et al., 2004, Broemeling et al., February 2005). Three further studies using self-reported multimorbidity based on nationally representative samples of community-dwelling populations were identified in the literature examined for this thesis (Cazale and Dumitru, 2008, Fuchs et al., 1998, Fuchs et al., 2012). Overall prevalence estimates in the identified studies ranged from 30% when all ages (at least 12 years and older) were considered (Loza et al., 2009) to 67% when a sample was limited to those aged 65 years and over (Partnership for Solutions, 2004). Prevalence estimates were substantially influenced by numbers of conditions included in the multimorbidity measure. Two of these studies included all conditions classified by the International Classification of Disease - 9th revision (ICD-9) codes (Hoffman et al., 1996, Partnership for

Solutions, 2004). In studies examining a limited selection of conditions, the recorded number of conditions ranged from 6 (Cazale and Dumitru, 2008) to 22 conditions (Rapoport et al., 2004, Fuchs et al., 2012). While there is no agreed convention for condition inclusion in multimorbidity measures, Fortin et al. (2012) contend that prevalence is likely to be underestimated in studies including less than seven conditions and is more reliable in studies including 132 or more. The diversity of approaches to multimorbidity measurement adopted in the small number of published population studies identified reflect the heterogeneous approach to definition and measurement observed in other study settings (Guthrie, 2011, Marengoni et al., 2011, Fortin et al., 2012) and limits meaningful comparison between international studies.

Assessment of the difference in prevalence rates in published studies is further limited by the heterogeneity of reporting styles. Not all studies provide an estimate of threshold multimorbidity and in cases where it is presented measurement cut-off varies; defined as either ≥ 2 conditions or ≥ 3 conditions. Other studies present multimorbidity according to levels of concurrent conditions only, from none to six or more. Furthermore, some studies report multimorbidity prevalence stratified by demographic sub-groups, according to age or sex without overall prevalence estimates. Despite the influence of chronicity on multimorbidity prevalence (Perrin, 1993), chronicity is rarely addressed in studies, and some studies include acute and chronic conditions which unnecessarily inflates prevalence rates (Salive, 2013).

The nosology of conditions included in the assessment of multimorbidity has until recently been restrictive. Studies generally consider only conventional chronic diseases such as CVD, CHD, diabetes and respiratory conditions and overlook the contribution of mental health conditions and geriatric syndromes such as hearing impairment and incontinence. While the association between mental health conditions and many physical diseases is well documented in the literature (Pieper et al., 2008, Scott et al., 2007, Goldston and Baillie, 2008), little attention has been paid to the prevalence and broad range of co-occurring mental and physical health conditions at a population level. Recent evidence suggests that mental health conditions are more prevalent in people with increased levels of multimorbidity and that this association has a consistent social gradient (Barnett et al., 2012), highlighting the need to examine mental health as a component of multimorbidity.

3.1.1.4 Prevalence of physical-mental health multimorbidity and mental health multimorbidity

There has been little attempt to investigate patterns and prevalence of physical-mental health multimorbidity in community-dwelling older populations. Only three studies identified in this thesis have explicitly examined the prevalence of physical-mental health multimorbidity in community samples (Ajmera et al., 2012, Andrade et al., 2010, Barnett et al., 2012). Nonetheless, findings from these few studies indicate that prevalence is high, is associated with increasing levels of multimorbidity and is more pronounced in certain demographic groupings. Ajmera et al. (2012) recorded a prevalence of 13.8% in a nationally representative sample of aged, disabled and non-institutionalised Medicare beneficiaries in the U.S (n=8,963). Prevalence was higher in women, and separated/divorced individuals. Younger adults had a fourfold increased prevalence rate compared to older adults (44.2% vs. 9.9%). A modest trend was found for educational status with those who did not have a high school education recording a higher prevalence compared to all other levels. Individuals living in poverty had almost twice the prevalence compared to their more affluent counterparts. High levels of mental-physical multimorbidity were also found for those reporting poor self-rated health and disability.

These findings are largely supported in a study conducted by Andrade et al. (2010) based on a community-dwelling urban sample in Sao Paulo, Brazil (n=1,464). In addition, average educational status and being an unskilled manual worker or a homemaker were found to be protective from mental-physical health multimorbidity. In contrast to the finding of Ajmera et al, low income was found to be protective in the Brazilian study, although, crude prevalence estimates in a large-scale study (n=1,751,841) conducted Barnett et al. (2012) provide support for a clear socioeconomic trend in the prevalence of mental-physical health multimorbidity in Scotland. An almost twofold increased prevalence was found in persons living in the most deprived areas of Scotland compared to those living in the least deprived areas (5.9% vs. 11.0%). Prevalence of mental-physical health multimorbidity also increased with increasing multimorbidity levels and this was more pronounced in persons from more deprived areas. Notably, the presence of one mental health condition increased the likelihood of occurrence of another in the U.S. sample (Ajmera et al., 2012).

Notwithstanding the now well established social gradient in general health status, the observed social gradient in physical-mental health multimorbidity observed in recent studies and a clearly demonstrated social gradient in mental health (Pinto-Meza et al., 2012), it has not yet been established if this observed gradient also holds true for mental health multimorbidity.

3.1.1.3 Multimorbidity prevalence in Irish studies

Although the prevalence of major chronic diseases in the general population has been described across the island of Ireland (Balanda et al., 2010), limited evidence has been generated on multimorbidity prevalence and the broad spectrum and interplay of chronic conditions affecting people in Ireland. Three recent studies have reported multimorbidity prevalence based on Irish data and have contributed some knowledge in this area (Naughton et al., 2006, Glynn et al., 2011, McDaid et al., 2013). However, each study adopted a substantially different methodological approach limiting meaningful comparison across studies. Prevalence estimates for threshold multimorbidity, defined as ≥ 2 conditions in all three studies, varied considerably from 11% for the population aged 18 years and over in a community-dwelling sample based on self-reported conditions (McDaid et al., 2013) to 27% for people aged ≥ 70 years assessed from a national prescribing database (Naughton et al., 2006) and 66% for primary care patients aged ≥ 50 years (Glynn et al., 2011).

Naughton et al. (2006) examined multimorbidity (≥2 conditions) in persons aged 70 years and older in Ireland based on prescription data from the national Health Service Executive-Primary Care Reimbursement Service (HSE-PCRS) database for 2004. It is acknowledged that this approach lacks specificity for certain conditions as some medications have broad licensed indications (Naughton et al., 2006). To increase the validity of their methodological approach, the authors limited the inclusion of chronic conditions to those claiming three scripts in the previous 12 months. Nonetheless, the validity of pharmacy claims databases in measuring multimorbidity is contested in the literature. Issues of misclassification of conditions due to off-label drug prescriptions and under-representation of persons not represented in the claims database were raised by Salive (2013). In addition, Von Korff (1992) highlighted that information in claims databases is, by, definition based on utilisation data and is thus subject to biases.

> *'The use of routine healthcare data as a measure of health status is subject to potential biases introduced by differentials in the level of utilisation among persons with comparable illness severity and by provider variation in diagnosis and treatment of similar illness states'.*

Any assessment of morbidity status that is not based on a patient's own self-evaluation of *'his or her level of illness or an assessment derived from standardised clinical examinations'* is then considered a less reliable measure of health status.

Estimates of multimorbidity provided by Naughton et al. are conservative compared to other studies of this population age group. This is largely attributable to the consideration of morbidity

based on organ system domains rather than counts of single chronic conditions. The reported gender difference in prevalence of individual chronic conditions and prevalence of pairwise combinations of conditions should also be interpreted with caution as these findings may be reflecting gender biases in primary care attendance and prescribing rather than a true higher prevalence of chronic conditions in women. Notwithstanding the methodological limitations with the study, it provided the first estimate of multimorbidity in a large sample of the older Irish population and demonstrated a strong association between chronic conditions and a decline in locomotor activity and social participation. It also suggested an under-estimation of prevalence for specific chronic conditions in Ireland in a previous study based on a sample of community-dwelling older people (Garavan and Windmer, 2001).

McDaid et al. (2013) examined the prevalence of multimorbidity (≥2 conditions) in persons aged 50 years and older across the island of Ireland (n=6,159). Similar to Naughton et al, assessment of multimorbidity was also based on four organ system domains: CVD (heart attack, angina or stroke), respiratory disease (COPD or asthma), diabetes and musculoskeletal pain. Self-reported data were obtained from two population-representative studies of health: the 2007 Survey of Lifestyle, Attitudes and Nutrition in the Republic of Ireland (SLAN) and the 2005 Northern Ireland Health and Social Wellbeing Survey (NIHSWS) harmonised for comparison of prevalence and associated outcomes between the jurisdictions. Measures of multimorbidity and health-related outcomes were limited however as the primary aim was to compare multimorbidity across the jurisdictions necessitating the inclusion of only conditions that mapped across both surveys. Furthermore, neither study was specifically designed for analysis of multimorbidity in older populations. The low prevalence estimates are accounted for by the measurement of multimorbidity based on organ domains rather than individual conditions and although the conditions included are similar to other population investigations based on self-reported survey data, the limited number of conditions examined and the narrow definition applied in the multimorbidity measure which excluded mental health or physical impairments, probably underestimates the true burden of multimorbidity in the Irish population. Notwithstanding the limited multimorbidity measure, findings indicate that multimorbid community-dwelling individuals across the island of Ireland are at the highest risk of disability, poor self-rated health and poor quality of life.

Glynn et al. (2011) estimated prevalence of multimorbidity in a nationally representative sample of primary care patients in Ireland aged 50 years and over limited to patients with two or more consultations in the previous 24 months (n=3,309). Patients with chronic conditions were identified from a complete manual search of patient medical records in three primary care

practices in a mixed urban/rural setting in the west of Ireland, based on 147 potential chronic conditions as classified by ICPC-2 coding. In contrast to international evidence, there was no difference found for prevalence estimates between men and women, however similar to other primary care prevalence studies, a higher prevalence and a higher burden of multimorbidity (indicated by a higher level of co-occurring conditions) was found for older age groups (Fortin et al., 2012, Fortin et al., 2005a, Marengoni et al., 2011). A substantially higher prevalence of multimorbidity was also found for those entitled to a General Medical Services (GMS) card compared to those who were ineligible (78.8% vs. 52.5% respectively). Assessment for a GMS medical card in Ireland is based on an income means test with nationally established income thresholds, although a proportion of the population also qualify on the basis of age, particular long-term health needs and participation in Government activation schemes (Nolan et al., 2007). On the 1st of July 2001, all persons aged over 70 years, irrespective of means, became universally entitled to a medical card. However, the Health Act 2008 provided that all such 'over 70s' medical cards would become means-tested from the 1st of Jan 2009. An upper income eligibility threshold of €36,500 per year was set for single persons and €73,000 per year for couples (Kenneally, 2009). The increased prevalence of multimorbidity according to GMS entitlement is then likely reflecting the higher age demographic, but also a greater burden of multimorbidity in lower socioeconomic status groups indicated by lower levels of income among the eligible group. A further possible explanation of the higher prevalence in this group is increased diagnosis among frequent attenders at medical services enabled by greater health care access.

3.1.2 Multimorbidity patterns

Research into multimorbidity is still in its infancy, and to date has focused on attempts to quantify the phenomenon. More recent advances in statistical methodology namely factor or cluster analysis has allowed for more reliable investigation of non-random patterns of co-occurring conditions enabling researchers to qualify the relationships between, and patterns of conditions in a study sample. Co-occurring conditions can have a non-causal statistical association or conditions can co-occur at a rate exceeding a level expected by chance alone, suggesting a common pathophysiological cause (van den Akker et al., 1998b, Schellevis et al., 1993). Current evidence indicates that the rate of accumulation of concurrent conditions often exceeds the rate expected by chance alone, based on crude statistical techniques such as the comparison of observed to expected pairwise or triad associations (multimorbidity coefficients) or the estimation of odds or risk ratios (Marengoni et al., 2011). The increased focus on the

patterning of multimorbidity in recent years, in the advent of such techniques has, however, generally been limited again to clinical subgroups such as hospitalised older adults (Marengoni et al., 2010). Identifying non-randomly occurring patterns of conditions in community-dwelling populations is particularly important for public health and health care planning for an ageing population. Qualifying patterns of multimorbidity in large samples generalisable to community-dwelling populations allows for investigation into how and why conditions cluster in general and enables a more comprehensive assessment of the biological or environmental mechanisms determining condition relationships. Increased knowledge of current patterns may enable the prediction of subsequent morbidity incidence in an individual and may provide insight into underlying pathophysiological mechanisms. Several processes are hypothesised to influence multimorbidity patterns: associations may be as a result of direct etiological mechanisms (causal multimorbidity) or an association between common risk factors (associative multimorbidity); general disease susceptibility; interactions between gene and environment; an association between conditions in a self-perpetuating and mutually reinforcing causality; common underlying pathogenetic mechanisms such as chronic inflammation and/or influences of psychosocial and lifestyle related stressors over the lifecourse moderated by cultural factors and individual coping mechanisms (Marengoni and Fratiglioni, 2011). It is also possible that conditions may co-occur due to implications of treatment regimens for discordant conditions. For example, corticosteroid-induced osteoporosis may occur in patients receiving treatment for a range of conditions, including asthma and autoimmune conditions such as rheumatoid arthritis.

In addition to the contribution that this understanding can make to public health and disease prevention an understanding of how conditions co-occur and produce negative health related outcomes for populations may conceivably provide an evidence-base for predicting healthcare use in the general population. Moreover, advances in the understanding of multimorbidity patterns could lead to a greater understanding of patient complexity and improvements in the quality of life of multimorbid patients. Despite advances in statistical techniques, leading authors argue that there is a paucity of studies applying clustering techniques to the analysis of combinations of chronic conditions and the distribution of multimorbidity patterns does not receive sufficient attention in the literature (Fuchs et al., 2012, Kirchberger et al., 2012, Marengoni and Fratiglioni, 2011, Cornell et al., 2007).

3.1.2.2 Patterns of multimorbidity clusters

A total of nine studies were identified in the literature that examined non-randomly occurring multimorbidity patterns using advanced statistical techniques, five of which employed a cluster analysis technique (Cornell et al., 2007, John et al., 2003, Marengoni et al., 2009a, Formiga et al., 2013, Graciani, 2004). Four of the remaining studies employed exploratory factor analysis to identify multimorbidity patterns (Kirchberger et al., 2012, Holden et al., 2011, Schafer et al., 2010, Prados-Torres et al., 2012). This approach generally uses principal component factor analysis to group sets of chronic conditions; after computing a factor score for each patient the factor scores are clustered. Cornell et al. (2007) argue that the use of this analytical approach to examine multimorbidity clusters is problematic for two reasons: firstly, factor scores are continuous rather than the natural binary form of condition variables examined in multimorbidity, these binary variables may cluster together on a factor because they share similar distributions rather than some underlying common trait (Nunnelly and Berstein, 1994). Secondly, factor analysis uses a measure of association (phi coefficient or tetrachoric correlation) that incorporates information from negative as well as positive matches.

Cornell et al. (2007) advanced a statistical analysis approach appropriate to identifying patterns of multimorbidity from binary chronic condition variables and tested their analytical approach using a large Veterans Health Administration sample in the U.S. (n=1,327,328) based on 45 conditions categories obtained from ICD-9 codes. In order to identify clinically relevant multimorbidity patterns they organised their analysis of multimorbidity clusters around Milligan's (1996) five basic considerations (Table 3.1) and applied a set of three criteria.

Table 3.1 Milligan's Five Basic Considerations for Cluster Analysis

1	***Which variables to include in the analysis?***
2	***What unit of measurement to use for the variables?***
3	***What proximity measure to use as an index of similarity or dissimilarity among the variables?***
4	***What type of clustering algorithm to use?***
5	***What criteria to use for determining the number and quality of clusters in the data?***

Clusters were only considered valid if they:

- matched known epidemiological associations;
- were relevant to physicians for co-management purposes; or
- were known to respond to chronic disease management approaches.

Using agglomerative hierarchical clustering they identified six clinically valid clusters from 23 chronic conditions that met the *a priori* criteria for clusters relevant to chronic disease management. These included: Metabolic, Obesity, Liver, Neurovascular, Mixed Anxiety-Depression and Dual Diagnosis. The Metabolic Cluster included diabetes, hypertension, hyperlipidemia and Ischemic Heart Disease. The Obesity Cluster included osteoarthritis, low back pain, enlarged prostate, GERD and obesity. The Neurovascular Cluster included peripheral vascular disease, stroke, TIA, Alzheimer's disease and seizures. The Liver Cluster included hepatitis B, hepatitis C, chronic liver disease and HIV. The Mixed Anxiety-Depression Cluster included depression PTSD and other anxiety disorders. Lastly, the Dual Diagnosis cluster included substance abuse, alcohol dependence, schizophrenia and bipolar disease.

Conditions included in clusters were largely concordant, given the cluster evaluation criteria, however, this methodological approach may be overlooking valid discordant condition associations that have not yet been established in the epidemiological literature or that are not considered in clinical care management. Identifying only condition clusters that fit into current healthcare delivery systems is likely to under-represent the burden of multimorbidity clusters in a given population and overlook the impact of discordant conditions at a population level. Furthermore, medical insurance and healthcare administration data is limited in its application to community-dwelling general populations for several reasons. Condition prevalence may be under-stated due to lack of access to healthcare or restrictive diagnostic criteria for reimbursement resulting in lower levels of diagnosis or over-stated due to noncurrent diagnosis. Large administrative and medical insurance databases have also been criticised for their tendency to under-report multimorbidity (Fortin et al., 2010).

John et al. (2003) employed a similar statistical approach to identify multimorbidity clusters in a small sample of community-dwelling American Indian Elders using self-reported condition counts (n=1,039). The analytical approach undertaken did not however examine an *a priori* hypothesis and a four-cluster structure was identified from 11 conditions. The first, a cardio-pulmonary cluster, included stroke, heart disease, diabetes, tuberculosis, urinary tract or bladder problems and high blood pressure. A sensory-motor cluster included vision problems, hearing

problems and problems with teeth or gums. Both arthritis and depression were found to cluster independently.

Two further studies examined multimorbidity in small samples of community-dwelling older people. Formiga et al. (2013) examined the patterning of multimorbidity using cluster analysis on a small sample of community-dwelling inhabitants aged 85 years and over in Spain. There was a high prevalence of multimorbidity the sample with 95.1% reporting two or more of 16 conditions based on self-reported counts validated by clinical history and examination. A four-cluster structure was identified. The first included COPD and malignancy. The second included atrial fibrillation, heart failure and visual impairment, chronic kidney disease, stroke, high blood pressure and diabetes. The third included dementia, Parkinson's disease, dyslipidemia, peripheral arterial disease and anemia. Auditory impairment was found to cluster independently.

Marengoni et al. (2011) recently conducted a cluster analysis of multimorbidity patterns in a small sample of urban dwelling participants in Stockholm aged 77 years and over from first follow up of a prospective cohort study, (n=1,099). A five-cluster structure was identified from 30 chronic conditions detected in the sample. The first one included hypertension, heart failure, chronic atrial fibrillation and CVD. The second one included thyroid dysfunction, COPD and CHD. The third included diabetes, visual impairment and deafness. The fourth included depression, dementia and hip fracture. The last of the five clusters included malignancy and anemia. There was little difference found between cluster structures for sex except for depression, which clustered most closely with malignancy in women and hip fracture in men. The non-random association of depression also varied by age groups; clustering with CVD in younger age groups and dementia in older age groups. Conditions were assessed by clinical examination improving reliability of diagnosis. However, the study sample was biased with women disproportionately represented and generally found to be older and less educated than the males in the study.

Similar to prevalence estimates, findings on multimorbidity clusters are difficult to compare given the wide variety of demographic characteristics, sample sizes and numbers and nosolgy of conditions included. Nonetheless, some conclusions can be drawn from the literature. CHD and CVD conditions are largely concordant in cluster analysis indicating well-established pathophysiological mechanisms. Respiratory conditions appear to cluster closely with CHD and CVD (John et al., 2003, Marengoni et al., 2009a). A definite sensory-motor cluster was detected in the American Indian sample, although visual impairment and hearing impairment were found to cluster with diabetes in another sample (Marengoni et al., 2009a). Both hypertension and

hyperlipidemia clustered together in a metabolic cluster in the large U.S. sample (Cornell et al., 2007) however, this was not supported in other studies. When mental health conditions were considered depression and anxiety formed a definite associative cluster (Cornell et al., 2007) well recognised in the literature (Hirschfeld, 2001, Klemenc-Ketis et al., 2009). Differences in the clustering of depression was found for sex and age in the Stockholm sample, suggesting that associative multimorbidity including a mental health component may vary according to demographic characteristics.

3.1.3 Objectives

This study examines the prevalence and patterns of multimorbidity in community-dwelling persons, aged 50 years and over in Ireland, using nationally representative cross-sectional data from TILDA. Several analytical approaches were employed to investigate the prevalence and patterns of multimorbidity as recommended in previous studies of multimorbidity prevalence (John et al., 2003, Marengoni, 2008). Drawing on the evidence-base of the conceptualisation and measurement of multimorbidity as applied to community-dwelling older populations in Chapter 1, the multimorbidity measurement approach adopted in this thesis is outlined in this Chapter in Section 3.2. The empirical analyses are presented in two parts in this chapter. Only conditions satisfying a set of criteria addressing condition chronicity, nosology and import for population health were included in the measurement of multimorbidity prevalence. Initial analyses focus on the prevalence of multimorbidity; this is followed by an examination of the patterns of multimorbidity. A key focus of this analysis is the prevalence of three types of multimorbidity; multimorbidity presented as threshold multimorbidity (i.e. ≥2 of any condition considered) and concurrent number of conditions; physical-mental health multimorbidity (≥ 2 conditions with at least one mental health condition) and mental health multimorbidity (≥2 mental health conditions). Where relevant, multimorbidity prevalence and burden is estimated according to a number of socio-demographic indicators and single conditions. Finally, a series of cluster analyses provide evidence of associative patterns of multimorbidity in the general population and in socio-demographic subgroups.

Given the identified dearth of nationally-representative prevalence rates, a principle objective of this study was to estimate and evaluate the prevalence of multimorbidity in the Irish population aged 50 years and over using self-reported counts of chronic conditions from first wave TILDA data. A second objective was to estimate the prevalence of physical-mental health multimorbidity and mental health multimorbidity in the same sample. Prevalence of each of the

three multimorbidity constructs (i.e. multimorbidity, physical-mental health multimorbidity and mental health multimorbidity) was then investigated according to single chronic conditions and a wide range of socio-demographic characteristics including individual level and area level measures of socioeconomic status.

A third objective was to examine the non-random patterns of multimorbidity at a population level for people aged 50 years and over in Ireland, considering all available chronic conditions in TILDA. It is hypothesised in this study that each associative cluster reflects a hierarchical structure associated with a common underlying pathological origin or process, shared lifestyle risk factors or they are linked as sequelae of drug treatment. Patterning of non-random multimorbidity clusters were also evaluated for differences between socio-demographic characteristics. This is one of the first studies to examine multimorbidity using cluster analysis in a nationally representative community-dwelling sample and the first to examine it in an Irish context. Examination of prevalence and patterns of multimorbidity at a population level allows insight into co-occurring conditions in the general population, as distinct from clinical sub-populations, important for assessing risk factors for clusters and to inform health policy and care planning. Examination according to socio-demographics allows for the identification of vulnerable groups particularly susceptible to multimorbidity and specific chronic condition clusters.

3.2 Empirical analyses

The empirical analysis in this chapter was conducted in two parts, guided by the research objectives. Initial analysis examined the prevalence of multimorbidity from three conceptual approaches including threshold multimorbidity (≥ 2 conditions), physical-mental health multimorbidity and mental health multimorbidity in a nationally representative sample of older people in Ireland. Secondly, multimorbidity patterns are examined in the same sample using cluster analysis. All analyses are based on secondary data from the first wave results of TILDA. All questions on chronic conditions considered in the multimorbidity measure were taken from the 2010, wave 1 CAPI questionnaire. Recorded chronic conditions are self-reported, following a doctor's diagnosis. All self-reported chronic conditions captured in TILDA were considered for inclusion in the measurement of multimorbidity in this study. All questions on health conditions in the CAPI 1 questionnaire are listed in Appendix 3.1 and presented with corresponding codes for the multimorbidity prevalence measure and patterns analysis, response numbers in the TILDA sample, unweighted and weighted prevalence rates and 95% confidence intervals. The

following two sections (3.2.1 and 3.2.2) provide a detailed description of the construction of the multimorbidity prevalence measure. Section 3.2.3 describes the empirical approach undertaken in the cluster analysis to identify associative multimorbidity patterns.

3.2.1. Constructing the multimorbidity prevalence measure

3.2.1.1 Multimorbidity inclusion criteria

To date there are no agreed criteria for inclusion of conditions in multimorbidity measurement (Fortin et al., 2012). However, some conclusions can be drawn from the literature and a set of criteria was established to guide the measurement of multimorbidity prevalence in this thesis taking account of recent recommendations (Perrin, 1993, Diederichs et al., 2011b, Barnett et al., 2012, Guthrie, 2011, Salive, 2013, Fortin et al., 2012, van den Akker et al., 1998b). Conditions were included in the multimorbidity prevalence measure if they satisfied five criteria:

1. conditions are chronic in nature and had been previously diagnosed by a doctor;
2. conditions are chronic diseases, sensory impairments, mental health conditions or geriatric syndromes[2]:
3. conditions have been considered in other studies of multimorbidity;
4. conditions are of public health interest due to their population prevalence; and
5. conditions contribute independently to the health burden in the older Irish population.

3.2.1.2 Core conditions, chronicity and severity

Recently authors have also called for a core set of conditions to be included in any multimorbidity measurement (Guthrie, 2011, Barnett et al., 2012) based on a recent systematic review of the literature (Diederichs et al., 2011b). Secondary data analysis of population surveys may be limited in scope in this regard as authors may not have had input into the construction of the questionnaire. However, 15 of the 17 recommended core conditions were available in TILDA for inclusion in the multimorbidity measure in this thesis. A further consideration in multimorbidity measurement is that the health burden of individuals is likely to be differentially

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[2] Classifications are not mutually exclusive and some conditions may overlap classification categories.

impacted by severity levels of individual conditions. Perrin (1993) argues that conditions with little effect on the patient, in the form of either physical or mental sequelae, or conditions where on the balance of probability, severity is not sufficient to impact on the patient's everyday functioning, should not be included in a classification of chronic conditions. Moreover, O'Halloran et al. (2004) argue that only conditions that are chronic in nature warrant inclusion in multimorbidity measurement. However, as discussed in Chapter 1, consideration of severity is problematic in population prevalence studies as it is a subjective concept and self-reported severity measures may be subject to reporting bias.

To address the limitation of the absence of valid objective measures of condition severity levels in the TILDA questionnaire and to ensure that sufficient attention is given to the multidimensional nature of health burden, a series of regression analyses were performed on individual chronic conditions to assess their influence on three health burden sequelae: self-rated health, disability and quality of life, controlling for a range of covariates. Only conditions with an independent association with health sequelae were considered for inclusion in the multimorbidity prevalence measure.

3.2.1.3 Classification of conditions

The multimorbidity prevalence measure applied in this thesis is designed to capture, as effectively as possible, the chronic multimorbidity burden of older people living in Ireland, although it is acknowledged that unavoidable omission of certain chronic and acute conditions, not recorded in TILDA could lead to an under-estimation of total multimorbidity burden. In keeping with the WHO definition of chronic conditions as detailed in Chapter 1 and in concordance with van den Akker et al. (1998b) and more recent studies of multimorbidity (Hudon et al., 2008, Barnett et al., 2012, Marengoni et al., 2009a, Formiga et al., 2013), this study has adopted a broad nosological approach to multimorbidity measurement. As the study is concerned with the health burden in older people, it was considered important to include non-conventional physical conditions that may be impacting on the functioning and quality of life of older adults, referred to here, in keeping with Salive (2013), as *geriatric syndromes*. For example, falls are a common and often devastating problem among older people, leading to significant morbidity, mortality and use of health care services including premature nursing home admissions (HSE, 2008). The presence of urinary incontinence was considered a chronic condition as it is not only a health condition in and of itself but it can also lead to many other complications and health concerns, particularly among older people. In particular, incontinence

can increase the risk of falls from attempts to reach the toilet quickly (Kenny et al., 2010). It was also thought important to consider questions on sensory decline as they have been shown to cluster with chronic conditions in older populations (Marengoni et al., 2009a, John et al., 2003) and they are associated with a variety of negative outcomes, including reduced physical functioning, falls, increased dependency, withdrawal from social activities, and diminished quality of life (Kenny et al., 2010).

3.2.1.4 Debatable conditions

The inclusion of cardiovascular risk factors and obesity in the measurement of multimorbidity continues to be a subject of debate. Schram et al. (2008) contend that although considering cardiovascular risk factors such as high blood pressure and high cholesterol as chronic conditions is debatable, they are strongly associated with negative health consequences and mortality, they require treatment and can present complexities when co-occurring with other conditions, thereby increasing healthcare utilisation and justifying their use in multimorbidity studies. High cholesterol and high blood pressure while generally identified as cardiovascular risk factors they have also been considered as chronic conditions in their own right and several other studies have included them in the measurement of multimorbidity (Salive, 2013) justifying their consideration in this thesis. The inclusion of obesity as a chronic condition remains contentious and the directionality of the relationship between obesity and multimorbidity has not yet been established and it has been considered elsewhere as a risk factor of multimorbidity, rather than a disease in its own right (Taylor et al., 2010). In a recent literature review on multimorbidity measures only five of 39 studies included obesity as a chronic condition. (Diederichs et al., 2011b). In response to a recent multimorbidity publication in the Lancet (Barnett et al., 2012), Wang and colleagues highlighted the omission of obesity in the measure of multimorbidity as a concern. Notwithstanding the debate on the chronicity of obesity, access to high quality data on obesity in community surveys is problematic. Data on BMI in TILDA is only available for respondents who attended for health assessment. Although this is likely to result in a higher validity in weight reporting, there are a large number of missing cases in the obesity variable (n=2,380). This is in contrast to the high level of response for self-reported data for all other conditions under consideration. As a result obesity was not included in the measure of multimorbidity in this thesis.

3.2.1.5 Chronic conditions recorded in TILDA

All self-reported chronic conditions recorded in TILDA were considered for inclusion in the measurement of multimorbidity in this thesis. Certain individual conditions were grouped into categories where appropriate. Cardiovascular disease was a key focus of the CAPI physical health module as it is the leading cause of death in Ireland (Kenny et al., 2010). Questions assessing the prevalence of chronic conditions in TILDA were then separated into a focus on cardiovascular disease and all other conditions. Each chronic condition variable considered for inclusion in the multimorbidity measure is detailed in this section. Conditions are presented here as recorded in the TILDA questionnaire. For analysis purposes, a series of dichotomous variables were generated indicating if a condition was present or absent (coded as 0,1), for all chronic conditions.

Cardiovascular Disease (TILDA PH201)

Participants were asked if a doctor had ever told them that they had any of the following diagnoses associated with coronary heart disease:

- Heart attack,
- Angina,
- Heart failure,
- Stroke,
- Ministroke, or Transient Ischaemic Attack (TIA).

Respondents were also asked if they had ever been diagnosed with:

- An abnormal heart rhythm,
- Diabetes,
- High blood pressure, or
- High cholesterol.

If respondents reported high blood pressure or high cholesterol they were also asked if they were currently on medication to control these conditions. High blood pressure or cholesterol were only deemed present in cases where individual's self-reporting of the condition was confirmed by their self-rated medication treatment status. This resulted in a more conservative measure, although arguably more reliable, of high blood pressure and high cholesterol prevalence by 14.5% and 24.7% respectively.

Other Chronic Conditions (TILDA PH301)

In addition to cardiovascular conditions, respondents are asked whether a doctor has ever told them they have or have had:

- Chronic lung disease (such as chronic bronchitis or emphysema),
- Asthma,
- Arthritis (osteoarthritis or rheumatoid arthritis or other),
- Osteoporosis,
- Cancer or a malignant tumor (including leukaemia or lymphoma but excluding minor skin cancers),
- Parkinson's disease,
- Dementia or organic brain syndrome or senility,
- Serious memory impairment,
- Stomach ulcers,
- Varicose ulcers (due to varicose veins),
- Cirrhosis or serious liver damage, or
- Any emotional, nervous or psychiatric problems, including depression or anxiety.

Mental health conditions (TILDA PH316)

If respondents reported the presence of emotional, nervous or psychiatric problems they were asked to qualify what type they have from a list of:

- Anxiety,
- Depression,
- Emotional problems,
- Mood swings,
- Manic depression,
- Hallucinations,
- Schizophrenia,
- Psychosis,
- Something else.

Falls (TILDA PH401) and Fractures (TILDA PH414)

Respondents were asked if and how many times they had fallen in the past year and if they had sustained either a hip or wrist fracture. Two dichotomous variables were derived from these questions to indicate if a respondent had 1) more than one fall in the past year and 2) a hip or wrist fracture in the past year.

Incontinence (TILDA PH601 & PH602)

Respondents are asked if during the past 12 months they have lost any amount of urine beyond their control (PH601) and if so, did this happen more than once during a one month period (PH602).

Hearing (TILDA PH10) and Vision (TILDA PH102) Impairment

Respondents appraised their general hearing according to a five-category likert response "excellent, very good, good, fair, or poor". General vision was appraised on a six-point scale indication if eyesight was "excellent, very good, good, fair, or poor, registered or legally blind". Questions were classified into two variables: hearing impairment and visual impairment. Hearing impairment was dichotomised into those reporting poor hearing and other. Vision impairment was dichotomised into those reporting poor vision or being registered or legally blind and other.

3.2.1.6 Grouped conditions

After further consideration of the chronic condition variables, it was decided to combine the following variables due to issues of potential overlap in reporting and potential over-counting in the data. There are no specified guidelines on how to deal with these conditions in the multimorbidity literature, however grouping certain conditions to avoid over counting is consistent with other studies (Marengoni et al., 2009a, Britt et al., 2008). Asthma and lung disease were grouped together under chronic respiratory conditions, stroke and TIA were grouped together as cerebrovascular accidents, angina and heart attack were grouped together under CHD, osteoarthritis, rheumatoid arthritis and any other arthritis were grouped together under arthritis and recurrent falls or a fracture were also grouped together.

Table 3.2 Combined conditions for global multimorbidity prevalence measure

Condition reference name	***Conditions included***
Chronic respiratory conditions	asthma OR chronic lung disease
Cerebrovascular accidents	stroke OR TIA
CHD	angina OR heart attack
Arthritis	osteoarthritis OR rheumatoid arthritis OR other arthritis
Falls and fractures	recurrent falls OR a fracture

3.2.1.7 Analytical approach to assess chronicity of conditions recorded in TILDA

Dependent Variables in Health Sequelae Models

As discussed in Section 3.2.1.2, three health sequelae were considered in analyses to determine the independent influence of each chronic condition considered in the multimorbidity measure on the multidimensional health burden of older people in Ireland. Conditions are only included in the multimorbidity measure if they demonstrate an independent negative effect on at least one of the following health sequelae: self-rated health, disability and quality of life.

Self-rated health

The first sequelae of interest, self-rated health, is a common approach to investigating health related outcomes in the literature (Jurges, 2008). A large number of empirical studies have demonstrated that a person's own appraisal of their general health (commonly referred to as self-rated health) is a powerful predictor of health outcomes in later life including functional decline and subsequent mortality, even after controlling for a variety of physical, socio-demographic and psycho-social health status indicators (Winter et al., 2007, Lee, 2000, Kaplan et al., 1996, Idler and Benyamini, 1997).

Self-rated health in TILDA is based on the well-validated question '*Would you say your health is...*' with responses ranked on an ordinal scale of 1 to 5 (5 being excellent, 4 very good, 3 good, 2 fair, 1 poor). This study is interested in assessment of good versus poor self-rated health and as such requires a dichotomous dependent variable. Assessment of self-rated health as a dichotomous variable it is a common approach in analyses of self-rated health status (Mackenbach et al., 1994, Manor, 2000, Manderbacka et al., 1998), nonetheless, taking account of recent recommendations (Finnas et al., 2008), the treatment of self-rated health as a dichotomous variable requires some methodological considerations. Sensitivity analyses were conducted to assess the most appropriate cut-off point for dichotomising the 5-point likert scale into good versus poor health and the most appropriate category for inclusion of moderate self-reported health status. Overall, 75.1% of older adults rate their health as excellent (14.2%), very good (27.9%) or good (33%) and 24.9% rate their health as fair (19.4%) or poor (5.5%). Lower self-rated health (categorised as fair and poor) was found to be associated with more negative health outcomes examined for multimorbidity and disability. Sensitivity analyses confirmed that health characteristics of respondents reporting moderate health status (i.e. good health) are more aligned with more positive health categories (i.e. very good and excellent) compared to

fair and poor self-rated health categories. When self-rated health was dichotomised a large majority of respondents who reported poorer self-rated health status had multimorbidity compared to those reporting good health, categorised as excellent, very good and good (44% v's 81% respectively (χ^2= 831.9 p<0.001)). Significant differences were also found between those reporting poor and good self-rated health for disability (χ^2= 821.3 p<0.001). In keeping with previous studies examining self-rated health in TILDA (Barrett et al., 2011), a binary outcome variable was then generated as poor health *(poor/fair)* versus good health (excellent/very good/good).

Disability

The Disability Act (2005) defines disability as "...a substantial restriction in the capacity of the person to carry on a profession, business or occupation in the Irish State or to participate in social or cultural life in the Irish State by reason of an enduring physical, sensory, mental health or intellectual impairment". This definition is in line with the International Classification of Functioning, Disability and Health (ICF) by the World Health Assembly in May 2001 and it contains the concept "substantial restriction" which is seen as a restriction that – (a) is permanent or likely to be permanent, results in a significant difficulty in communication, learning or mobility or in significantly disordered cognitive processes, and (b) gives rise to the need for services to be provided continually to the person. However, in geriatric practice, disability is described as a transient or permanent inability to carry out daily tasks (Kamiya et al., 2012). The most commonly used measures of disability are self-reports of activities of daily living (Burden of Disease Network Project, 2004).

TILDA respondents were asked a series of questions, assessing their capacity to carry out a range of Activities of Daily Living (ADLs) and Instrumental Activities of Daily Living (IADLs). TILDA respondents were shown two separate show cards listing ADLs and IADLs and in each case the following text was read out to them: '*Because of a health or memory problem, do you have any difficulty doing any of the activities on this card? Exclude any difficulties you expect to last less than three months*'. In keeping with previous studies examining disability in TILDA (Kamiya et al., 2012), disability is conceptualised in this study as disability in activities of daily living. A binary variable was generated indicating disability measured by the presence of at least one of seven ADL's or one of seven IADLs[3] as listed below. This measure of disability is in line with geriatric

[3] The original ADL scale was developed by Katz et al. in 1963, described as "...activities which people perform habitually and universally", the IADL scale was subsequently developed by Lawton and

literature, where disability is defined and analysed as people reporting one or more ADL or IADL limitations (Kamiya et al., 2012, Balzi et al., 2010, Saliba et al., 2000).

Show card for ADLs

1. Dressing, including putting on shoes and socks
2. Walk across a room
3. Bathing or showering
4. Eating, such as cutting up food
5. Getting in or out of bed
6. Using the toilet, including getting up or down
7. None of these

Show card for IADLs

1. Preparing a hot meal
2. Doing household chores (laundry, cleaning)
3. Shopping for groceries
4. Making telephone calls
5. Taking medications
6. Managing money such as paying bills and keeping track of expenses
7. None of these

Quality of Life

The impact of health conditions on quality of life is an important patient-centered health outcome measure, not least because advances in medicine and technology may or may not represent gains in quality of life (QoL) for individuals affected by chronic conditions. Quality of life is measured by the CASP-19 scale in the TILDA questionnaire. The 19-item likert scale is self-administered and has early evidence of good psychometric properties (Hyde et al., 2009, Kenny et al., 2010). It is based on a needs satisfaction model of Quality of Life in early old age and has four ontologically-grounded domains of need and the concepts assessed provide the acronym: Control, Autonomy, Self-actualisation and Pleasure (CASP). High scores correspond to higher quality of life. The CASP-19 scale was developed with an older population in mind and, unlike

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Brody in 1969 to provide an additional set of validated questions to assess more complex limitations in activities. ADL comprises seven items to measure the abilities to walk across a small room, brush hair or teeth, eat, use the toilet, transfer, dress, and bathe. IADL comprises 15 items to measure the ability for household management such as prepare meals, do housework, manage money, and use the telephone.

many Quality of Life instruments, measures qualities distinct from health enabling a more holistic assessment of the impacts of chronic conditions on an individual's quality of life. The optimal approach to analysing quality of life scales remains up for debate (Abreu et al., 2008). Although such scales tend to generate discrete, asymmetrical and limited distributions, they are often treated as continuous due to the extensive numbers of categories. Traditional analytical methods such as linear regression that assume at least approximate normalcy are likely inappropriate since the data is asymmetrical. Ordinal logistic regression models have generally proven appropriate for quality of life scale analysis. However, for the purpose of this analysis, we are interested in estimating the likelihood of respondents with a chronic condition reporting below average quality of life. Therefore in keeping with previous investigations into the impacts of chronic conditions on quality of life (Netuveli et al., 2005), the CASP-19 score was reverse coded and dichotomised at the median CASP-19 value into those reporting above average or below average scores.

INDEPENDENT VARIABLES IN HEALTH SEQUELAE MODELS

A series of multivariate logistic regression models were estimated to assess the association between each chronic condition and each health sequelae. As well as the well-established link between ageing and a range of health outcomes, there is now clear evidence of social variation in determinants of health at an individual and a population level in Ireland (O'Shea and Kelleher, 2001). In addition, it has been shown that self-reported health outcomes are prone to reporting heterogeneity. Specifically, age, gender and socioeconomic determinants can differentially influence individual reporting behaviour (Shmueli, 2003, Pfarr et al., 2012). Bound (1991) raised the concern that self-rated health amongst older people in particular is endogenous to economic status, the so-called "justification hypothesis". The main implication of reporting heterogeneity in health outcome measures is the need to adjust the measures not only for the determinants of health but also for the determinants of reporting heterogeneity. Kapteyn, Smith and van Soest (2007) advocated "anchoring vignettes" to control for different levels of subjective *toughness* with respect to self-rated health, however this is not available in TILDA. Several independent variables were then controlled for in each multivariate model, including sex, age, gender, education, General Medical Services (GMS) entitlement and house value.

Sex

The dichotomous variable for sex is presented as 0= male, 1 = female.

Age

Respondents were asked the month and year of their birth. Age was computed assuming that the date of birth of each respondent at interview was the first of the specified month recorded. For comparability with other national and international literature age was modelled as an interval variable classified into 10-year age bands (i.e. 50-59, 60-69, 70-79 and age 80yrs +).

GMS

It has been shown elsewhere that measures of self-reported disease-specific morbidity are strongly related to medical service eligibility in Ireland, measured by entitlement to a GMS card. GMS eligibility has been shown to be the most consistent predictor of self-rated health in a previous general population health survey in Ireland (Kelleher et al., 2003). Therefore, GMS entitlement is included in this analysis as an explanatory factor for predicting health sequelae. Respondents are asked if they are currently in receipt of a medical card, subsequently, medical card status is classified into two categories: full medical card coverage and not full medical card coverage and modelled as a binary variable indicating full entitlement to a GMS medical card or non-entitlement.

Socioeconomic status – education, income and wealth.

It is argued that socioeconomic status indicators are core determinants of health outcomes in later life (Smith et al., 1999). However, measuring socioeconomic status in the older Irish population is problematic. There is a well-acknowledged reticence in Ireland to disclose actual income in survey responses and the high level of missing data on income in TILDA (26.1%) reflects this. Furthermore, income is generally considered a less reliable indicator of socioeconomic status in older people compared to their working age counterparts and the use of occupational status indicators for people no longer in the labour market has been questioned (Bowling, 2004, Artazcoz and Rueda, 2007, Grundy and Holt, 2001). GMS eligibility has previously been used as a reliable proxy measure of actual income in other population surveys (Kelleher et al., 2003). However, it is likely to be a less reliable predictor of income in older age groups, due to policy changes to entitlement in the last decade. Between 2001 and 2008 all persons over 70 years in Ireland, irrespective of means, became universally entitled to a medical card. Universal entitlement was subsequently withdrawn in 2009 and an upper income eligibility threshold of €36,500 per year was set for single persons and €73,000 for couples (Kenneally, 2009), thereby reducing the discriminatory power for explaining socioeconomic differentials in older age groups. Educational status has been shown to be a consistent predictor of a range of health outcomes, although, educational attainment in Ireland may also lack discriminatory power, as it

is age related; linked to the introduction of free secondary level education in Ireland after 1968. In particular it has been found that exogenous changes in the schooling of men born into lower social class families in Ireland during the late 1940s and 1950s had a statistically significant positive effect on their self-reported health (O'Sullivan, 2012). Nonetheless, it may still be important to consider the effect of educational status on health outcomes due to issues of health literacy in later life (Berkman et al., 2011). Educational attainment is modelled as a categorical variable, classified into three categories from higher to lower levels of education (third level and above, secondary, primary or none).

Table 3.3 Summary of dependent and independent variables examined in multivariate regression analysis

Dependent variables	
Poor self-rated health	0 = excellent/good/average, 1 = poor/fail
Disability	0 = no disability, 1 = at least one ADL or IADL
Quality of life	0 = above average CASP-19 score, 1 = below average CASP-19 score
Independent variables	
Condition X from list	0 = absence of condition, 1 = presence of condition
Covariates	
Age group	0 = 50-59yrs, 1 = 60-69yrs, 2 = 70-79yrs, 3 = 80yrs+
Sex	0 = male, 1 = female
Educational status	0 = third level +, 1 = secondary, 2 = primary/none
GMS card entitlement	0= no medical card coverage, 1 = full medical card entitlement
House value	1 = ≤€80,000, 2 = €80,001-160,000, 3 = €160,001-240,000, 4 = €240,001-320,000, 5 = €320,001-400,000, 6 = €400,001-480,000, 7 = €480,001-520,000, 8 = ≥€520,001

It has also been argued that wealth, rather than income, is a better indicator of access to resources in later life and has an additional advantage of providing an indicator of life-time living standards (McMunn et al., 2006). Previous longitudinal studies on ageing have confirmed that wealth is a stronger predictor of the onset of illness in older ages than income (McMunn et al., 2009). Respondents in TILDA are asked to report their overall financial resources recorded as household assets, as well as household income. Again, however, there was a noted reluctance to answer questions on assets in TILDA with a large number of missing responses. Less than half of

TILDA respondents reported on their wealth (51.7% missing data). To overcome this, a series of sensitivity analysis were conducted to test the power of alternative socioeconomic indicators with lower levels of missing data, in predicting health outcomes. Housing tenure was found to behave similar to other indicators of wealth in TILDA, reflecting previous findings by McMunn et al. (2006) and Connelly et al. (2010) that house value is a powerful indicator of accumulated wealth that is highly correlated with current health status and is thereby a useful proxy indicator for wealth in older populations. An additional variable 'household value' is then included as a more robust proxy measure of wealth for TILDA respondents in this study. Household value is modelled as a categorical variable classified into seven categories, measured in increasing increments of 80,000 (*as per Table 3.3*).

Regression Models

The multivariate logistic regression models were specified as:

$$Logit\ (Health\ sequelae\ Y) =$$

$$a + \beta_1 condition + \beta_2 sex + \beta_3 agegroup_i + \beta_4 education_i + \beta_5 GMScard + \beta_6 housevalue_i$$

Where:

Health sequelae *Y* = odds of negative health outcome

Only conditions exhibiting an independent negative association on at least one health sequelae (i.e. self-rated health OR quality of life OR disability) were included in the multimorbidity measure.

3.2.2 Statistical analyses of multimorbidity prevalence

Frequencies, percentages, cross tabulations and graphical displays were used to evaluate and present descriptive analysis. Population prevalence (weighted %) and 95% confidence intervals (CIs) were estimated for each chronic condition considered in the multimorbidity prevalence measure. The mean number and standard deviation of concurrent conditions as well as population prevalence estimates for threshold multimorbidity (≥ 2 conditions), physical-mental health multimorbidity and mental health multimorbidity according to population characteristics are presented in Table 3.8. The mean number and standard deviation of concurrent conditions was estimated for each chronic condition in Table 3.10.

A *t*test was used to test for differences in mean number of concurrent conditions between men and women and between urban and rural dwellers. A one-way Anova was used to test differences in mean number of concurrent conditions between categories of marital status, nationality, living arrangement, educational attainment, employment status, house value and deprivation deciles. The prevalence (weighted %) of all concurrent conditions was calculated as well as the prevalence of physical-mental health multimorbidity and mental health multimorbidity. A Pearson's χ^2 test for 2xn tables was used to test for differences in the prevalence of all multimorbidity (i.e. threshold multimorbidity, physical-mental health multimorbidity and mental health multimorbidity) between categories in each demographic characteristic. Tests were two-tailed with significance set at the conventional 0.05 level. A Bonferroni-adjusted significance level was calculated for χ^2 tests to account for multiple comparisons and increased possibility of a type-1 error.

Men were under-represented in the TILDA sample. In the Irish population, after age 19, women outnumber men at a rate of 100:98.1. After applying sampling weights, the estimated proportion of women compared to men in the study cohort reflected the national differential of a higher proportion of older women (51.1%) compared to men (48.9%) in the older Irish population. Persons aged 85 years and over were also under-sampled in TILDA and again, sample weighting accounted for this in the analysis. All analyses for multimorbidity prevalence were conducted in STATA/SE 12.1 for Mac.

3.2.3 Statistical analysis of multimorbidity patterns

A cluster analysis was employed to investigate patterns of associative multimorbidity without any *a priori* hypothesis. The underlying premise of cluster analysis is that the distribution of chronic conditions is concentrated in clusters that differ significantly from the distribution by chance. A STATA file containing all chronic condition variables was imported into R version 2.1.5 for Mac OS X and analysis was conducted to generate a cluster matrix of relevant chronic conditions, presented in a dendrogram. All reported chronic conditions in TILDA were considered for inclusion in the cluster analysis (n= 33) (*see Appendix 3.1*). Conditions, which had previously been grouped for inclusion in the multimorbidity measure (*see Section 3.2.1.6*), were considered individually to establish true non-random associations. As multiple significance testing between chronic condition clusters would give a high probability of finding a significant difference just by chance, only conditions where prevalence was greater than 1% in the TILDA sample were included in analysis (Marengoni et al., 2009a). This approach is also likely to minimise 'chaining'

in the cluster solution i.e. the sequential joining of low prevalence associations into existing clusters (Vu et al., 2011). Three conditions did not meet these criteria and were then excluded from analysis: liver disease (0.56 %), Parkinson's disease (0.52%) and memory disorders (0.64%). A total of 28 individual conditions were then included in the cluster analysis. Full details of all included conditions with coding abbreviations and prevalence rates are detailed in Table 3.4.

Table 3.4 Chronic conditions included in cluster analysis and coding legend

Conditions entered in cluster analysis	***Condition number codes***	***Condition label codes***	***n***	***Prevalence >1% (weighted % and 95% CIs)***
Angina	C1	Ang	447	4.7 (5.2-6.2)
Heart attack	C2	HA	377	4.7 (4.3-5.2)
Congestive heart failure	C3	HF	87	1.1 (0.8-1.3)
Stroke	C4	ST	133	1.6 (1.4-1.9)
TIA	C5	TIA	174	2.1 (1.8-2.5)
Heart murmur	C6	HM	387	4.5 (4.1-5.0)
Abnormal heart rhythm	C7	HR	586	7.0 (6.4-7.6)
Diabetes	C8	Diab	632	8.1 (7.4-8.7)
High blood pressure	C9	HBP	2585	32.4 (31.3-33.5)
High cholesterol	C10	Chol	2030	24.7 (23.7-25.7)
Falls	C11	Fall	586	7.4 (6.8-8.1)
Fractures	C12	Frac	1125	14.3 (13.5-15.1)
Incontinence	C13	Incon	764	9.3 (8.6-10.0)
Vision impairment	C14	Vis	146	2.1 (1.8-2.5)
Hearing impairment	C15	Hear	193	2.8 (2.4-3.2)
Chronic lung disease	C16	LD	329	4.2 (3.8-4.7)
Asthma	C17	Ast	750	9.3 (8.6-10.0)
Osteoarthritis	C18	Oart	1041	12.2 (11.5-13.0)
Rheumatoid arthritis	C19	Rart	682	8.7 (8.1-9.4)
Unclassified arthritis	C20	OTart	562	7.2 (6.6-7.8)
Osteoporosis	C21	Ostp	786	9.4 (8.7-10.1)
Cancer	C22	Can	512	6.2 (5.6-6.8)
Stomach ulcers	C23	STUL	571	7.2 (6.6-7.8)
Varicose ulcers	C24	VUL	271	3.4 (3.0-3.8)
Alcohol or substance abuse	C25	Abuse	131	1.8 (1.4-2.1)
Anxiety	C26	Anx	388	4.7 (4.2-5.1)
Depression	C27	Dep	437	5.2 (4.7-5.8)
Other mental health conditions	C28	OMen	192	2.4 (2.1-2.8)

For the purpose of cluster analysis, variables took the value of '1' when a co-occurring condition was present and '0' when it was absent. Under this method, the most similar conditions formed a first order cluster and then gradually merged with the most similar clusters in the dataset until a single cluster solution containing all multimorbidity patterns was obtained. An average linkage method, suitable for most clustering analysis and suitably robust (Everitt et al., 2001), was applied to measure the distance between two clusters. An agglomerative hierarchical method was employed to cluster co-occurring chronic condition variables, as it was neither possible nor desirable to identify the number of clusters *a priori*. Previous studies have also demonstrated the effectiveness of this statistical approach in identifying non-random multimorbidity clusters (Cornell et al., 2007, Vu et al., 2011). While the TILDA sample is representative of the older population in Ireland, it is a relatively small sample compared to that used in similar analysis conducted by Cornell et al. (N=8,162 vs. N=1,327,382) therefore a hierarchical cluster analysis approach was adopted here to overcome issues of sample size in cluster analysis (Hair et al., 1998) in keeping with other multimorbidity cluster analysis (John et al., 2003, Marengoni et al., 2009a, Formiga et al., 2013).

The methodological approach adopted in this study is similar to that applied by Cornell et al., although, unlike the methodological approach taken by Cornell et al, clinical guidelines were not used to inform the cluster selection in this study for the reasons cited in Section 3.1.2.2. Furthermore, hierarchical agglomerative clustering (Kauffman and Rousseeuw, 1990) was applied to the proximity matrix to identify the most highly associated conditions among all respondents in the TILDA sample, including those with no reported conditions, one chronic condition and multimorbidity. This is distinct from the Cornell study in that they only conducted analysis on individuals with multimorbidity.

There is no consensus on the best approach to identify clusters within the overall cluster structure and to date establishment of clusters has been largely subjective. As the primary aim was to identify non-random multimorbidity patterning in a community-dwelling population, all condition clusters displaying a strong statistical association are considered relevant in this analysis. For the purpose of cluster analysis in this study, chronic condition data were disaggregated as much as possible to investigate all non-random condition clusters in the TILDA data and patterns were identified if they indicated a Jaccard score of less than 1.0.

3.3 Results

3.3.1 Condition prevalence and chronicity

3.3.1.1 Single chronic conditions

Chronic condition prevalence rates were estimated from first wave TILDA data; a nationally representative population survey of community-dwelling persons aged 50 years and over (n=8,162) in Ireland. The numbers of people in the TILDA sample reporting conditions and the estimated population prevalence for each chronic condition are presented in Table 3.6. The most prevalent doctor diagnosed conditions in people aged 50 years and over in Ireland were high blood pressure (32.4%) arthritis (27.6%), high cholesterol (24.7%), recurrent falls or a fracture (17.7%) and chronic respiratory conditions including chronic lung disease and asthma (12.2%). It is estimated that between 8% and 10% of the population are affected by osteoporosis (9.3%), incontinence (9.2%), CHD (8.5%) and diabetes (8.0%). For mental health conditions, doctor diagnosed depression was slightly more prevalent than anxiety (5.2% and 4.6% respectively) and it was estimated that 2.4% of the population over 50 years had been diagnosed with another mental health condition such as psychosis or schizophrenia. Hearing and vision impairments affected 2.7% and 2.1% of the population respectively and there was low reported prevalence (<1%) for memory disorders (0.7%), liver disease (0.5%) and Parkinson's disease (0.5%). CHD and cerebrovascular accidents including stroke and transient ischaemic attacks are particularly prevalent in men in older ages while a higher proportion of older women have high blood pressure and high cholesterol (Table 3.6). Older women also show higher prevalence for arthritis, osteoporosis and varicose ulcers, geriatric syndromes including falls and incontinence as well as a higher prevalence for vision impairments compared to older men. Older men have a higher prevalence of hearing impairment compared to older women.

3.3.1.2 Estimated chronic condition sequelae

Results of the estimated logistic regression models investigating the impact of single chronic conditions on health sequelae are presented in Table 3.5, including odds ratios and 95% confidence intervals for the main effects. A positive effect on the likelihood of reporting a negative outcome was found for all health burden sequelae for each of the 25 conditions modelled, although, some of these effects were not significant at the conventional 95%

confidence interval level. All chronic conditions were found to have a statistically significant association with negative self-rated health, even after controlling for known confounders and the potential for reporting bias. Presence of individual chronic conditions had a relatively smaller impact on quality of life compared to other health sequelae. The presence of heart failure (OR: 1.5, 95% CI: 0.79-2.7), osteoporosis (OR: 1.2, 95%CI: 1.0-1.5), varicose ulcer (OR: 1.2 95% CI 0.9-1.7), liver disease (OR: 1.8 95% CI 0.8-3.9), memory disorders (OR: 2.2 95%CI: 0.9-5.2) and a history of cancer (OR: 1.1, 95%CI: 0.9-1.4) did not reliably predict below average quality of life. However, each of these conditions reliably predicted poor self-rated health and disability except for heart failure, which did not reliably predict disability (OR: 1.7 95% CI 1.0-2.9). All 25 conditions did exert an impact on at least one sequelae indicating chronicity and satisfying the criteria for inclusion in the multimorbidity prevalence measure. Multimorbidity was subsequently estimated in this study as the presence of two or more of these 25 chronic conditions (*listed in Table 3.5 and Appendix 1)*. Despite a low prevalence (<1%) for certain conditions including memory disorders, liver disease and Parkinson's disease as well as hearing and vision impairments, such conditions were more strongly associated with negative health sequelae compared to some other more prevalent conditions.

Table 3.5 Independent associations of chronic conditions with health sequelae in TILDA

			Effect on poor SRH *		Effect on disability *		Effect on below average QoL*	
Prevalence ranking	**Chronic Conditions Included In Measure Of Multimorbidity**	**Total n=8,162 (weighted %)**	**Number with poor SRH (weighted %) Total n= 1,092 (24.9%)**	**OR (95% CI)**	**Number with disability (weighted %) Total n= 986 (12.9%)**	**OR (95% CI)**	**Number with below average QoL (weighted %) Total n=2,617 (46.1%)**	**OR (95% CI)**
8	Angina/heart attack	671 (8.5)	334 (51.4)	3.2 (2.7-3.8)	166 (26.2)	1.8 (1.4-2.2)	266 (61.0)	1.8 (1.4-2.2)
22	Heart failure	87 (1.1)	59 (68.7)	6.0 (3.7-9.8)	20 (24.1)	*1.7 (1.0-2.9)*	30 (57.4)	*1.3 (0.8-2.3)*
16	Stroke/TIA	291 (3.6)	146 (49.9)	2.8 (2.2-3.6)	113 (62.9)	3.1 (2.4-4.1)	104 (36.9)	1.8 (1.3-2.5)
14	Heart murmur	388 (4.6)	143 (39.4)	2.0 (1.6-2.5)	78 (20.6)	1.7 (1.3-2.2)	157 (56.7)	1.6 (1.3-2.1)
11	Abnormal heart rhythm	588 (7.1)	255 (45.6)	2.8 (2.3-3.4)	139 (25.5)	2.1 (1.7-2.6)	229 (57.2)	1.7 (1.4-2.1)
9	Diabetes	634 (8.0)	316 (51.7)	3.3 (2.7-3.9)	136 (22.6)	1.8 (1.5-2.3)	226 (53.8)	1.3 (1.0-1.6)
1	High blood pressure	2,591 (32.4)	888 (36.2)	2.1 (1.9-2.4)	450 (18.4)	1.5 (1.3-1.8)	869 (50.6)	1.3 (1.2-1.5)
3	High cholesterol	2,032 (24.7)	677 (35.9)	2.0 (1.8-2.2)	327 (17.2)	1.4 (1.2-1.7)	676 (48.2)	1.2 (1.0-1.3)
4	Falls/fracture	1,416 (17.7)	473 (35.8)	1.8 (1.6-2.1)	270 (20.5)	2.0 (1.7-2.3)	518 (54.6)	1.5 (1.3-1.7)
7	Incontinence	765 (9.2)	297 (41.4)	2.1 (1.8-2.5)	232 (32.5)	3.2 (2.7-3.9)	302 (59.8)	1.8 (1.5-2.2)
20	Vision impairment	147 (2.1)	100 (68.5)	5.1 (3.5-7.5)	69 (49.9)	3.9 (2.7-5.6)	64 (76.4)	2.5 (1.5-4.2)
18	Hearing impairment	194 (2.7)	103 (55.8)	3.0 (2.2-4.0)	73 (40.1)	3.4 (2.5-4.8)	73 (63.0)	1.7 (1.2-2.6)
5	Chronic respiratory	988 (12.2)	429 (45.7)	2.9 (2.5-3.3)	197 (21.1)	1.9 (1.6-2.3)	372 (54.7)	1.3 (1.1-1.6)
2	Arthritis	2,255 (27.6)	814 (38.7)	2.3 (2.0-2.6)	541 (25.7)	3.2 (2.8-3.7)	825 (54.3)	1.7 (1.5-1.9)

6	Osteoporosis	786 (9.3)	274 (37.7)	2.1 (1.8-2.5)	156 (22.5)	1.9 (1.5-2.3)	271 (49.3)	*1.2 (1.0-1.5)*
12	Cancer	512 (6.1)	185 (37.6)	1.8 (1.4-2.2)	81 (17.1)	1.3 (1.0-1.7)	177 (48.9)	*1.1 (0.9-1.4)*
24	Parkinson's disease	43 (0.5)	34 (81.7)	15.0 (6.7-33.7)	18 (41.9)	3.8 (1.9-7.5)	20 (73.1)	3.4 (1.4-8.3)
10	Stomach Ulcer	572 (7.2)	210 (38.2)	2.0 (1.6-2.4)	113 (20.4)	2.0 (1.6-2.6)	231 (58.1)	1.6 (1.3-2.0)
17	Varicose Ulcer	271 (3.5)	95 (37.5)	1.5 (1.1-2.0)	74 (29.2)	2.1 (1.6-2.9)	86 (51.2)	*1.2 (0.9-1.7)*
25	Liver disease	46 (0.5)	24 (53.0)	3.0 (1.6-5.6)	15 (30.7)	3.5 (1.8-6.7)	19 (64.0)	*1.8 (0.8-3.9)*
23	Memory disorders	51 (0.7)	27 (53.6)	2.6 (1.4-4.7)	30 (57.4)	8.7 (4.7-16.3)	20 (67.5)	*2.2 (0.9-5.2)*
21	Alcohol or substance abuse	131 (1.6)	57 (46.5)	2.1 (1.4-3.1)	25 (17.7)	1.9 (1.2-3.0)	62 (70.5)	2.5 (1.5-4.1)
15	Anxiety	388 (4.6)	146 (40.2)	2.0 (1.6-2.5)	92 (25.5)	2.7 (2.1-3.5)	192 (71.2)	3.3 (2.5-4.4)
13	Depression	437 (5.2)	174 (42.4)	2.2 (1.8-2.7)	105 (25.5)	2.7 (2.1-3.5)	215 (70.4)	2.9 (2.2-3.8)
19	Other mental health conditions	192 (2.4)	90 (49.5)	2.6 (1.9-3.5)	56 (31.2)	3.2 (2.3-4.5)	100 (78.7)	3.8 (2.5-5.8)

+ Adjusted for sex, age group, educational status, GMS status, and house value.
* Italics indicate non-significant coefficients.

Table 3.6 Prevalence (weighted % and 95% CIs) of chronic conditions by sex and age groups

Chronic health conditions	Total Population Prevalence	Sex Male (M) Female (F)	50-59 years 40.4 % (39.3-41.6)	60-69 years 31.0 (3.0-3.2)	70-79 years 19.9 (19.9-20.8)	80+ years 8.7 (0.4-8.0)	Total
Angina or heart attack	8.6 (7.9-9.3)	M	4.3 (3.3-5.5)	11.2 (9.5-13.2)	22.2 (19.2-25.5)	21.0 (16.4-26.5)	11.0 (10.0-12.1)
		F	2.5 (1.8-3.2)	6.0 (4.8-7.5)	9.4 (7.4-11.7)	15.6 (11.8-20.4)	6.3 (5.6-7.2)
Heart failure	1.1 (0.8-1.3)	M	1.1 (0.7-1.8)	1.6 (1.0-2.5)	2.1 (1.3-3.4)	1.9 (0.8-4.2)	1.5 (1.1-2.0)
		F	0.3 (0.1-0.7)	0.6 (0.3-1.2)	1.5 (0.9-2.6)	0.3 (0.1-1.4)	0.6 (0.4-0.9)
Stroke/TIA	3.6 (3.2-4.0)	M	0.9 (0.5-1.5)	3.7 (2.7-4.9)	7.1 (5.4-9.2)	9.7 (6.6-14.1)	3.5 (3.0-4.2)
		F	2.0 (1.4-2.8)	2.6 (1.8-3.6)	6.8 (5.1-9.0)	6.9 (4.3-10.8)	3.7 (3.1-4.4)
Heart murmur	4.5 (4.1-5.0)	M	3.1 (2.3-4.2)	3.3 (2.4-4.5)	5.6 (4.2-7.6)	7.1 (4.6-10.9)	3.9 (3.3-4.6)
		F	4.7 (3.8-5.8)	5.7 (4.6-7.2)	4.7 (3.5-6.5)	5.6 (3.6-8.4)	5.1 (4.5-5.8)
Heart rhythm	7.0 (6.4-7.6)	M	4.4 (3.4-5.6)	8.7 (72-10.6)	11.7 (9.6-14.3)	15.5 (11.5-20.6)	7.9 (7.1-8.9)
		F	4.0 (3.2-5.1)	5.0 (3.9-6.4)	9.2 (7.4-11.5)	11.0 (7.8-15.4)	6.1 (5.4-7.0)
Diabetes	8.1 (7.5-8.7)	M	6.3 (5.1-7.8)	11.0 (9.3-12.9)	13.7 (11.4-16.4)	12.7 (9.0-17.7)	9.6 (8.7-10.7)
		F	4.5 (3.6-5.6)	6.3 (5.1-7.9)	9.7 (7.6-12.2)	9.7 (6.8-13.6)	6.7 (5.9-7.5)
High blood pressure	32.4 (31.4-33.7)	M	19.5 (17.5-21.7)	34.7 (32.0-37.6)	42.9 (39.3-46.6)	45.0 (38.8-51.4)	30.5 (29.0-32.0)
		F	20.4 (18.5-22.5)	33.5 (30.9-36.2)	51.1 (47.4-54.8)	53.4 (47.5-59.2)	34.2 (32.7-35.8)
High cholesterol	24.7 (23.7-25.7)	M	18.2 (16.2-20.3)	27.5 (25.0-30.2)	27.3 (24.3-30.6)	19.4 (15.0-24.8)	23.0 (21.6-24.4)
		F	16.9 (15.2-18.8)	31.0 (28.5-33.7)	36.0 (32.6-39.7)	28.3 (23.3-34.0)	26.4 (25.0-27.8)
Falls or fracture	17.8 (16.9-18.7)	M	19.7 (17.7-21.9)	17.6 (15.4-19.9)	16.6 (14.0-19.5)	12.4 (8.7-17.4)	17.9 (16.7-19.3)
		F	13.4 (11.8-15.1)	16.0 (14.1-18.2)	24.7 (21.7-28.1)	23.3 (18.6-28.8)	17.6 (16.4-18.8)
Incontinence	9.3 (8.6-10.0)	M	2.5 (1.7-3.6)	4.6 (3.5-6.0)	6.5 (4.9-8.5)	10.5 (7.1-15.3)	4.5 (3.8-5.2)
		F	11.9 (10.4-13.5)	13.1 (11.3-15.1)	15.6 (13.0-18.5)	19.6 (15.5-24.6)	13.8 (12.7-15.0)
Vision	2.1 (1.8-2.5)	M	1.7 (1.1-2.6)	1.0 (0.5-1.8)	2.4 (1.5-3.9)	3.9 (2.1-7.1)	1.7 (1.3-2.3)
		F	1.4 (0.9-2.2)	1.5 (1.0-2.4)	3.8 (2.5-5.6)	6.8 (4.2-10.9)	2.5 (2.0-3.1)
Hearing	2.7 (2.4-3.2)	M	3.2 (2.3-4.3)	2.8 (2.0-4.0)	4.8 (3.4-6.7)	5.7 (3.2-9.7)	3.5 (2.9-4.2)
		F	0.8 (0.4-1.4)	1.3 (0.8-2.2)	4.3 (2.9-6.2)	4.5 (2.6-7.8)	2.1 (1.6-2.6)
Respiratory	12.3 (11.5-13.1)	M	9.8 (8.3-11.5)	11.3 (9.6-13.3)	9.9 (8.0-12.3)	11.5 (8.2-16.0)	10.4 (9.5-11.5)
		F	14.4 (12.7-16.2)	13.4 (11.6-15.4)	15.8 (13.2-18.8)	11.4 (8.3-15.6)	14.1 (13.0-15.2)
Arthritis	27.8 (26.7-28.8)	M	13.3 (11.6-15.2)	23.4 (21.0-26.0)	29.1 (25.9-32.6)	36.7 (30.8-42.9)	21.0 (19.8-22.5)
		F	20.3 (18.4-22.3)	35.0 (32.4-37.7)	49.5 (45.8-53.3)	49.7 (43.9-55.6)	33.9 (32.4-35.5)

Osteoporosis	9.4 (8.7-10.0)	M	1.1 (0.7-1.8)	2.7 (1.9-3.8)	1.7 (1.0-2.8)	3.5 (1.8-6.5)	1.9 (1.5-2.4)
		F	10.2 (8.8-11.7)	18.6 (16.5-20.8)	22.6 (19.6-25.9)	19.8 (15.3-25.1)	16.3 (15.1-17.5)
Cancer	6.2 (5.6-6.8)	M	2.6 (1.9-3.6)	5.9 (4.7-7.5)	9.9 (7.9-12.3)	6.0 (3.8-9.4)	5.3 (4.6-6.1)
		F	5.8 (4.8-7.0)	7.4 (6.1-9.0)	9.9 (7.9-12.5)	5.1 (3.1-8.2)	7.1 (6.3-8.0)
Parkinson's	0.5 (0.4-0.7)	M	0.2 (0.1-0.8)	0.5 (0.2-1.2)	1.1 (0.5-2.1)	1.0 (0.3-3.0)	0.5 (0.4-0.8)
		F	0.2 (0.1-0.5)	0.5 (0.2-1.2)	0.4 (0.1-1.1)	1.8 (0.7-4.4)	0.5 (0.3-0.8)
Stomach	7.3 (6.6-7.9)	M	8.8 (7.4-10.5)	9.2 (7.6-11.1)	7.8 (6.0-10.2)	5.0 (2.9-8.3)	8.5 (7.6-9.5)
		F	6.8 (5.7-8.1)	5.6 (4.4-7.0)	5.6 (4.0-7.8)	5.9 (3.8-9.2)	6.1 (5.4-6.9)
Varicose	3.4 (3.0-3.8)	M	1.6 (1.0-2.4)	2.2 (1.5-3.3)	3.2 (2.1-4.8)	4.8 (2.8-8.2)	2.3 (1.9-2.9)
		F	2.7 (2.0-3.7)	3.5 (2.6-4.6)	7.2 (5.5-9.4)	8.1 (5.5-11.8)	4.4 (3.8-5.2)
Cirrhosis	0.6 (0.4-0.7)	M	0.8 (0.4-1.4)	0.7 (0.3-1.3)	0.8 (0.3-1.7)	0	0.7 (0.4-1.0)
		F	0.6 (0.3-1.1)	0.5 (0.3-1.1)	0.3 (0.1-1.1)	0	0.5 (0.3-0.7)
Memory disorder	0.6 (0.5-0.8)	M	0.5 (0.2-1.1)	0.5 (0.2-1.0)	1.1 (0.5-2.3)	1.9 (0.8-4.6)	0.7 (0.5-1.0)
		F	0.2 (0.1-0.6)	0.5 (0.2-1.0)	1.1 (0.5-2.4)	1.1 (0.4-3.0)	0.6 (0.4-1.0)
Alcohol or substance abuse	1.8 (1.4-2.1)	M	3.3 (2.4-4.4)	3.3 (2.3-4.5)	2.5 (1.6-3.9)	0.9 (0.2-3.4)	3.0 (2.4-3.6)
		F	1.1 (0.7-1.7)	0.3 (0.1-0.9)	0.5 (0.2-1.3)	0.2 (0.0-1.3)	0.6 (0.4-0.9)
Anxiety	4.6 (4.2-5.1)	M	3.3 (2.5-4.3)	3.4 (2.5-4.6)	2.8 (1.8-4.2)	0.8 (0.2-3.2)	3.0 (2.5-3.7)
		F	7.9 (6.7-9.3)	6.6 (5.3-8.1)	4.2 (3.0-5.8)	2.4 (1.2-4.8)	6.2 (5.4-6.9)
Depression	5.2 (4.7-5.7)	M	4.8 (3.8-6.1)	5.4 (4.2-6.9)	3.4 (2.3-4.9)	2.7 (1.3-5.5)	4.6 (3.9-5.3)
		F	7.6 (6.4-9.0)	6.2 (5.0-7.7)	4.2 (3.0-5.8)	1.8 (0.8-3.9)	5.9 (5.2-6.6)
Other mental health conditions	2.4 (2.1-2.8)	M	2.2 (1.5-3.1)	2.2 (1.4-3.3)	1.3 (0.7-2.5)	0.4 (0.1-3.0)	1.9 (1.5-2.4)
		F	4.5 (3.5-5.7)	2.5 (1.7-3.5)	1.5 (0.9-2.6)	1.1 (0.4-3.0)	3.0 (2.4-3.5)

3.3.2 Multimorbidity prevalence

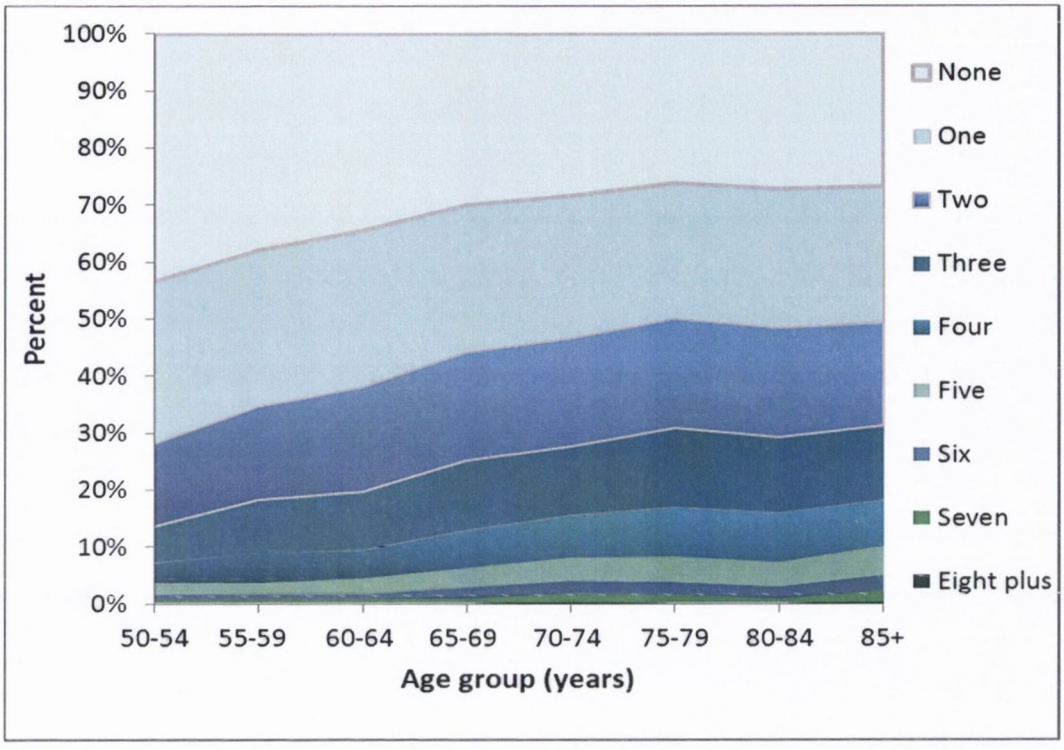
3.3.2.1 Multimorbidity prevalence according to demographic characteristics

It was estimated that 53.8% (n=4,356) of the population in Ireland aged 50 years and over had threshold multimorbidity (≥ 2 conditions). 25% (n=2,078) of people aged 50 years and over in Ireland had one condition and 21% (n=1,728) had none of the 25 chronic conditions examined in this thesis. Adopting the definition of complex multimorbidity defined by van den Bussche et al. (2011a), 32.8% (n=2,625) of the older Irish population had complex multimorbidity (≥ 3 conditions). The number and estimated population prevalence (weighted %) of concurrent chronic conditions are presented in *Table 3.7*. The burden of concurrent conditions ranged from 2 to 13 co-occurring chronic conditions, although the proportion of those with eight or more concurrent conditions was low (1%, n=89). Over 5% (n=399) of people aged 50 years and over living in Ireland were found to have six or more chronic conditions.

Threshold multimorbidity prevalence was higher in women compared to men and (58.5% vs. 48.8%, p<0.001) (*see* Table *3.9*). Women had a higher proportion of multimorbidity at every level compared to their male counterparts (*see Table 3.9*). 6.2% of women had six or more conditions compared to 4% of men.

The proportion of people with threshold multimorbidity was found to increase incrementally with increasing 10-year age bands from 39% in persons aged between 50 and 59 years to 70% in people aged 70 to 79 years and 80+ years (p=0.007)(*see Table 3.9*). There was however, a levelling off of this increase after age 75 (*see Figure 3.1*), with people aged between 80-84 years recording lower prevalence rates for increased levels of multimorbidity compared to those aged 75-80 years. Interestingly, the trend in increasing levels of multimorbidity is less pronounced between the 70-79 year and the 80+ year age group compared to any other age group (*see Table 3.9*). The risk of developing additional chronic conditions increases rapidly with increasing age, however, over 70% of those aged between 70 and 79 years had threshold multimorbidity, 19% had only one condition and only 10% had no chronic condition. There was a slightly higher burden of multimorbidity observed in persons aged 80 years and over with 17.6% reporting five or more conditions compared to 16.1% in those aged between 70 and 79 years.

Figure 3.1. Prevalence of concurrent chronic conditions by five-year age groups



Significantly different multimorbidity prevalence rates were detected for categories of marital status ($p<0.001$). Widowed persons had a substantially higher prevalence of threshold multimorbidity (69.3%) compared to any other marital status groupings. Widowed and separated or divorced individuals had a higher mean number of concurrent conditions compared to any other marital status grouping (3.0 and 2.8 respectively, $p<0.001$). Individuals living alone had significantly higher prevalence ($p<0.001$) and mean number of conditions ($p=0.002$) compared to those living with a spouse (61.7% vs. 46.5%, and 2.8 vs. 2.5) or those living with other relatives (61.7%vs. 56.4% and2.8 vs. 2.4).

While both the mean number of concurrent conditions and threshold multimorbidity prevalence estimates for Irish, Northern Irish and British individuals was similar (2.6-2.7 and 53.3-54.0%), a lower prevalence and mean number of conditions was recorded for other nationality groupings a (39.9% and 2.2). However the low number of 'other nationalities' represented in TILDA (n=102) does not allow for meaningful comparison of rates among such nationality categories. A slightly higher prevalence of threshold multimorbidity and mean number of concurrent conditions was found for respondents living in urban areas compared to rural areas (56.3% vs. 50.6% $p<0.001$ and 2.6vs. 2.5 $p= 0.018$).

3.3.2.2 Multimorbidity prevalence according to socioeconomic status

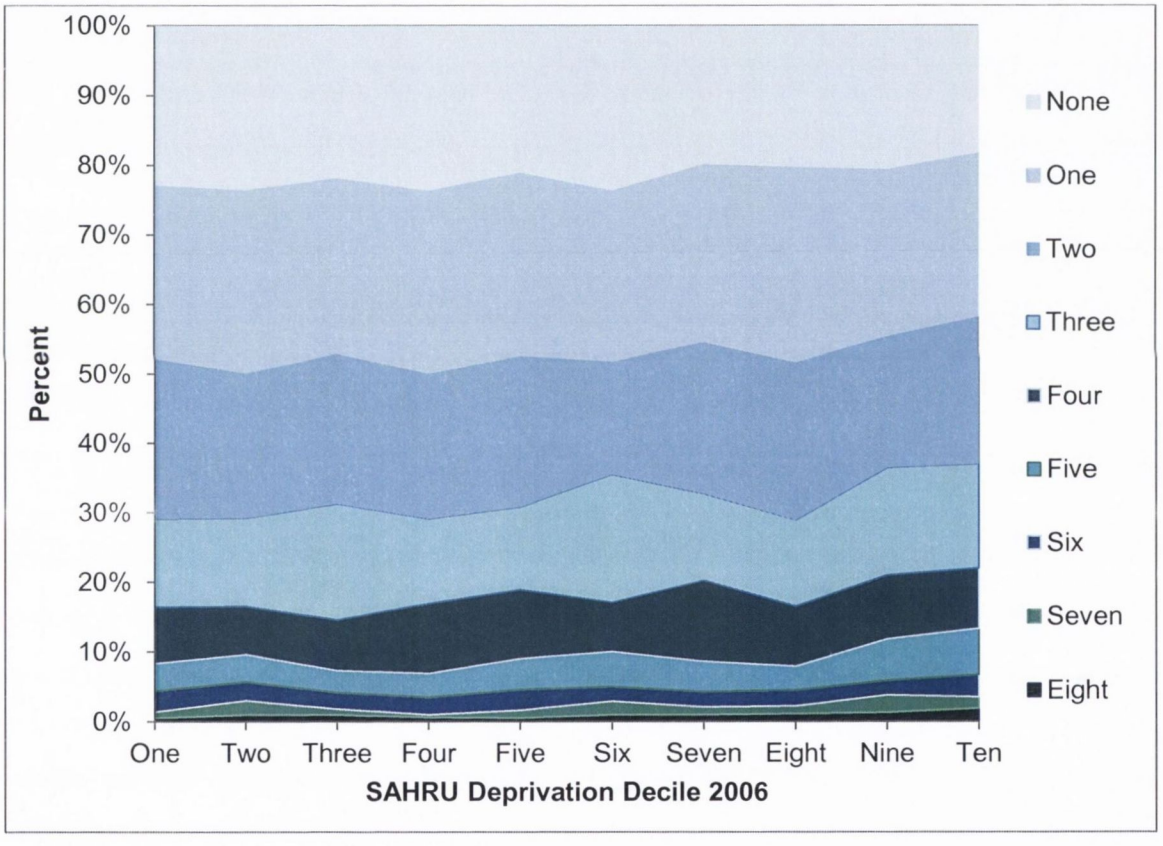
Multimorbidity varied inversely with educational attainment. A significantly higher proportion of individuals with only primary or no formal education had threshold multimorbidity compared to those who had completed secondary level or third level education (62.4% vs. 47.8% and 48.8% respectively, $p<0.001$). The mean number of concurrent conditions was the same in those with secondary and third level educational attainment, while those with only primary school education were found to have a significantly higher mean number of conditions compared to either secondary or third level educational attainment (2.9 vs. 2.4 and 2.9 vs. 2.4, $p<0.001$). Multimorbidity prevalence varied significantly across employment status groupings ($p<0.001$). Employed people (both self-employed and employees) reported the lowest prevalence (37.3% and 34.6% respectively) and mean number of concurrent conditions (1.9 for both) compared to any other employment status grouping. Those who were permanently sick or disabled reported the highest prevalence (87.9%) and mean number of concurrent conditions (3.7), followed by retired individuals (65.7%, 2.8) and homemakers (60.9%, 2.8). Those in education or training (34.0%, 2.3) or who were unemployed (42.5%, 2.3), were found to have a modest level of multimorbidity compared to all other groupings. These findings should be interpreted with caution as those in education or training and unemployed persons are generally younger compared to most other categories of employment status (median age 54 years and 56 years respectively vs. 56 years for employed persons, 58 years for self-employed, 70 years for retired persons, 64 years for homemakers and 58 years for permanently sick and disabled persons).

Multimorbidity prevalence varied significantly between house value categories ($p=0.002$). The prevalence and mean number of concurrent conditions was similar for all bands of house value from €160,001 upwards (ranging between 50.1% to 52.6% and 2.4 to 2.5 concurrent conditions). Prevalence was highest in those living in houses with the lowest values i.e. <€80,000 (57.8%) and between €80,001 and 160,000 (56.2%). Mean numbers of concurrent conditions were significantly higher for individuals with a house valued at €80,000 or less compared to all other categories except for those in the €400,000-€480,000 and €480,001-€520,000 categories. These results did not reflect a clear socioeconomic gradient in multimorbidity as previously reported (Barnett et al., 2012).

A modest, although statistically significant increase in multimorbidity prevalence ($p=0.01$) and mean number of conditions ($p<0.001$) was found for increasing area level deprivation. Prevalence and mean number of concurrent conditions differed for individuals living in the most affluent areas compared to for those living in the most deprived areas (52.3% vs. 58.3% and 2.5

vs. 2.7 respectively), indicating an observed difference in multimorbidity levels of 4% between the most deprived and most affluent deprivation areas. Between category differences were only found to be significant for decile 10 vs. decile 1 (p=0.02), decile 10 vs. decile 3 (p=0.04), decile 10 vs. decile 4 (p=0.02) and decile 10 vs. decile 8 (p=0.02). Complex multimorbidity (i.e. greater than 3 or more concurrent conditions) was found to be more prevalent in individuals living in the two most deprived deciles (i.e. nine and ten) compared to any other decile. However there was no clear socioeconomic gradient in increasing concurrent conditions across deciles. In fact, a lower prevalence was observed for higher multimorbidity levels in decile eight compared to decile six and seven (*see Figure 3.2*).

Figure 3.2 Prevalence of concurrent chronic conditions by SAHRU deprivation deciles



3.3.2.3 Physical-mental health multimorbidity prevalence

Physical-mental health prevalence multimorbidity was estimated to be 7.5% (n=613) for all individuals aged 50 years and over in Ireland. The prevalence of physical-mental health multimorbidity increased substantially with increasing levels of multimorbidity; 13% of all persons with multimorbidity have physical-mental health multimorbidity whereas over half of those with 8 or more conditions (52.8%) have physical-mental health multimorbidity.

Significantly more women (8.3%) compared to men (6.6%) had physical-mental health multimorbidity (p=0.009). The proportion of persons with physical-mental health multimorbidity increased inversely with age. Persons aged under 60 and 70 years had twice the prevalence of physical-mental health multimorbidity compared to their older counterparts (8.2 and 8.3 vs. 3.2% p<0.001). Significant differences were also detected across marital status categories for physical-mental health multimorbidity prevalence (p<0.001). An approximate threefold increase in physical-mental health multimorbidity was found for separated or divorced persons compared to their married counterparts (18.3% vs. 6.2%). Those individuals who never married also had a slightly elevated rate of physical-mental health multimorbidity compared to those who married (8.3% vs. 6.2%). Those reporting a Northern Irish nationality also had a substantially higher prevalence compared to those reporting Irish (11.3% vs. 7.3%) or British nationality (11.3% vs. 8.9%). Physical-mental health multimorbidity prevalence was low among other nationality groupings (3.8%). Prevalence was also higher for those living in urban areas compared to rural areas (8.3% vs. 6.4%, p=0.002) and those living alone compared to those living with a spouse or living with others (10.3% vs. 6.3% and 6.8% respectively, p<0.001).

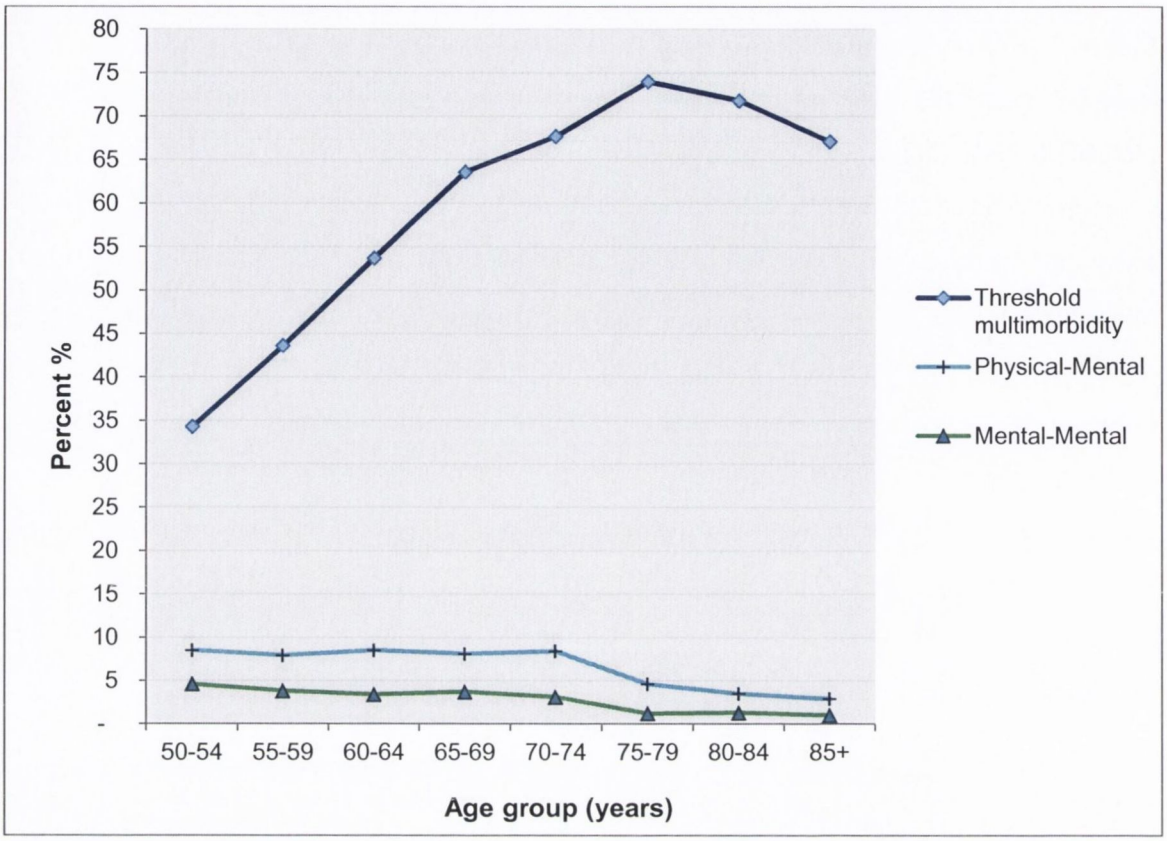
Significant differences in physical-mental health multimorbidity were found across employment status categories (p<0.001). Self-employed persons were found to have comparatively very low prevalence (3.0%) compared to all other categories. Permanently sick or disabled individuals had substantially higher prevalence compared to any other employment status grouping; four times higher than those in employment (22.8% vs. 5.6%) and over seven times more than those who were self-employed (22.8% vs.3.0%). Unemployed persons and those in education or training were twice as likely to have physical-mental health multimorbidity compared to their employed counterparts (10.6% vs. 5.6% and 9.1 vs. 5.6% respectively). A social gradient was also found for house value (p=0.008) and deprivation deciles (p=0.01) with more affluent persons reporting approximately 30% less physical-mental health prevalence compared to their least affluent counterparts (i.e. persons living in houses valued at €80,000 or under had significantly higher prevalence compared to those living in high value houses i.e. ≥560,001 (9.6% vs. 6.8%) and those living in the most deprived areas had significantly higher prevalence compared to those living in the most affluent areas (9.0% vs. 6.4%). This observed social gradient in physical-mental health multimorbidity was not incremental, with those living in houses worth between €400,001 and €480,000 and those living in deprivation decile 2 (second most affluent) reporting similar levels of prevalence as the least affluent.

3.3.2.4 Mental health multimorbidity prevalence

Mental health multimorbidity prevalence was estimated to be 3.3% (n=266) for all individuals aged 50 years and over in Ireland. The prevalence of mental health multimorbidity also increased substantially with increasing levels of multimorbidity. Those with eight or more concurrent conditions were over 26 times more likely to report mental health multimorbidity compared to those with only two conditions (39.5% vs. 1.5%). This trend in mental health multimorbidity was highly statistically significantly ($p<0.001$). Mental health multimorbidity was more prevalent in women (3.8% vs. 2.7%, $p= 0.008$) and in younger age groups with those aged between 50-59 years having approximately fourfold increased prevalence compared to the oldest age group i.e. aged 80 years and over (4.1% vs. 1.2%, $p<0.001$) (*see Figure 3.3*). Prevalence also varied significantly between marital status categories ($p<0.001$). Separated or divorced persons had a threefold higher prevalence compared to married persons (8.8% vs. 2.9%). Those who never married also had a comparatively higher prevalence rate compared to married individuals (2.9% vs. 4.1%). Interestingly, widowed individual's had the lowest prevalence rate of mental health multimorbidity (2.2%) although this finding should be interpreted with caution as widowed individuals had a higher median age compared to all other marital status categories (73 years compared to 63 years for never married, 61 years for married individuals and 58 years for separated/divorced individuals). Almost twice as many Northern Irish reported mental health multimorbidity compared to either Irish (5.8% vs. 3.2%) or British (5.8% vs. 3.0%) nationalities ($p=0.025$). Prevalence was also significantly higher among those living in urban areas compared to rural areas (3.8% vs. 2.7%, $p=0.011$) and those living alone compared to those living with a spouse or other relatives (3.9% vs. 2.7% and 3.9% vs. 3.5%, $p=0.048$).

Prevalence varied significantly across employment status categories ($p<0.001$). A substantial proportion of individuals who are permanently sick or disabled have mental health multimorbidity; almost seven times higher than those in employment (13.8% vs. 2.0%) and fourteen times higher compared to self-employed persons (13.8% vs. 0.9%). Unemployed persons (6.4%) and those in education or training (9.1%) were also found to have comparatively higher prevalence rates. There was a statistically significant social gradient found for house value ($p=0.004$) and for deprivation deciles ($p=0.013$). The crude socioeconomic gradient in mental health multimorbidity was greater than that for any multimorbidity type with an observed doubling in the prevalence of those living in the most deprived area compared to the least deprived area (2.4% vs. 4.8%). Those living in the most affluent area (decile 1) had a higher prevalence of mental health multimorbidity compared to those living in deciles 2 and 3 (2.4% vs. 1.7% and 1.9% respectively).

Figure 3.3 Population prevalence of all type multimorbidity in the older Irish population



3.3.2.5 Multimorbidity prevalence according to individual chronic conditions

Multimorbidity prevalence was high for each of the 25 chronic conditions considered (*see Table 3.10*). The mean number of concurrent conditions ranged between 3.3 and 5.4. Of all conditions, falls/fractures were most likely to occur independently, with 18.1% occurring without additional conditions, followed by cancer (15.9%). Heart failure had the highest prevalence of multimorbidity. Almost all cases of heart failure co-occurred with at least one other chronic condition (97.7%). Individuals reporting heart failure had 5.4 mean concurrent conditions. Those reporting other mental health conditions distinct from anxiety or depression (including: emotional problems; mood swings; manic depression, hallucinations, schizophrenia and psychosis) had 5.0 mean concurrent conditions. Fewer than ten percent of cases of stroke/TIA (3.9%), other mental health conditions (5.1%), angina/heart attack (6.4%), abnormal heart rhythm (8.2%), vision impairment (8.2%), anxiety (91.2%), Parkinson's disease (8.8%), hearing impairment (9.2%), incontinence (9.9%) and alcohol or substance abuse (9.9%) conditions occurred independently. While memory disorders had a moderate prevalence of threshold multimorbidity (88.9%), it ranked third highest for the mean number of concurrent conditions (4.8).

A high prevalence of physical-mental health co-occurrence was observed for all mental health conditions. There was only a minimal difference detected for the prevalence of physical-mental health multimorbidity between mental health conditions. Other mental health conditions had the highest prevalence rate (82.6%) followed by alcohol or substance abuse (82.3%), depression (81.0 %) and anxiety (80.9%). Liver disease had the highest rate of physical-mental health multimorbidity compared to any other physical health condition. Prevalence was also notably high for persons with memory disorders (29.0%) vision impairment (18.4%) and hearing impairment (14.5%). Lowest prevalence was observed for Parkinson's disease (9.1%), varicose ulcer (9.2%), high blood pressure (9.7%) and heart failure (9.8%).

Mental health multimorbidity was most prevalent for other mental health conditions (74.5%), followed by anxiety (56.6%), depression (54.4%) and alcohol or substance abuse (35.9%). Memory disorders also had a high prevalence (16.1%) and again liver disease had the highest prevalence compared to all other chronic conditions (14.9%). A high prevalence rate was also observed for vision (9.4%) and hearing impairments (7.3%), heart failure (7.8%) and incontinence (7.1%). Lowest prevalence was observed for high blood pressure (3.6%), angina/heart attack (3.9%) and high cholesterol (4.0%).

Table 3.7 Prevalence of concurrent chronic conditions in first wave TILDA 2010

Conditions	**Prevalence of concurrent conditions [number (weighted %)]**											
None	1728 (21.0)	1728 (21.0)	1728 (21.0)	1728 (21.0)	1728 (21.0)	1728 (21.0)	1728 (21.0)	1728 (21.0)	1728 (21.0)	1728 (21.0)	1728 (21.0)	1728 (21.0)
One	2078 (25.2)	2078 (25.2)	2078 (25.2)	2078 (25.2)	2078 (25.2)	2078 (25.2)	2078 (25.2)	2078 (25.2)	2078 (25.2)	2078 (25.2)	2078 (25.2)	2078 (25.2)
Two [+]	[4356 (53.8)]	1731 (21.0)	1731 (21.0)	1731 (21.0)	1731 (21.0)	1731 (21.0)	1731 (21.0)	1731 (21.0)	1731 (21.0)	1731 (21.0)	1731 (21.0)	1731 (21.0)
Three [+]		[2625 (32.8)]	1151 (14.1)	1151 (14.1)	1151 (14.1)	1151 (14.1)	1151 (14.1)	1151 (14.1)	1151 (14.1)	1151 (14.1)	1151 (14.1)	1151 (14.1)
Four [+]			[1474 (18.7)]	697 (8.8)	697 (8.8)	697 (8.8)	697 (8.8)	697 (8.8)	697 (8.8)	697 (8.8)	697 (8.8)	697 (8.8)
Five [+]				[777 (9.9)]	378 (4.7)	378 (4.7)	378 (4.7)	378 (4.7)	378 (4.7)	378 (4.7)	378 (4.7)	378 (4.7)
Six [+]					[399 (5.1)]	201 (2.6)	201 (2.6)	201 (2.6)	201 (2.6)	201 (2.6)	201 (2.6)	201 (2.6)
Seven [+]						[198 (2.5)]	109 (1.4)	109 (1.4)	109 (1.4)	109 (1.4)	109 (1.4)	109 (1.4)
Eight [+]							[89 (1.1)]	38 (0.05)	38 (0.05)	38 (0.05)	38 (0.05)	38 (0.05)
Nine [+]								[51 (0.6)]	21 (0.3)	21 (0.3)	21 (0.3)	21 (0.3)
Ten [+]									[30 (0.3)]	18 (0.2)	18 (0.2)	18 (0.2)
Eleven [+]										[12 (0.1)]	9 (0.1)	9 (0.01)
Twelve [+]											[3 (0.02)]	2 (0.01)
Thirteen [+]												[1 (0.01)]

Table 3.8 Prevalence of multimorbidity in people aged 50 years and over in TILDA according to demographics and socioeconomic indicators

Variable (n=missing)	Categories	n	%	Weighted % (95% CI)	Concurrent conditions (mean ± standard deviation)	Percentage (95% CI) with threshold multimorbidity	Percentage (95% CI) with Physical-mental health multimorbidity	Percentage (95% CI) with mental health multimorbidity
Totals		**1,862**			**2.6 ± 1.7**	**4,365 (53.8%)**	**613 (7.5%)**	**266 (3.3%)**
Sex	Male	3,740	45.8	48 .9 (47.7-50.1)	2.4±1.6	48.8 (47.1-50.4)	6.6 (5.8-7.4)	2.7 (2.2-3.3)
	Female	4,422	54.2	51.1 (49.9-52.3)	2.6±1.7	52.2 (56.9-60.7)	8.3 (7.4-9.2)	3.8 (3.3-4.5)
					p=1.000	*p<0.001*	*p=0.009*	*p=0.008*
Age groups	50-59	3,271	40.1	41.1 (39.9-42.2)	2.1±1.5	39.0 (37.3-40.1)	8.2 (7.2-9.3)	4.1 (3.5-4.9)
	60-69	2,589	31.7	30.8 (29.7-31.9)	2.6±1.6	57.8 (55.8-59.8)	8.3 (7.2-9.5)	3.5 (2.8-4.3)
	70-79	1,677	20.5	19.7 (18.7-20.7)	3.0±1.8	70.6 (68.2-72.9)	6.6 (5.5-8.0)	2.2 (1.6-3.1)
	80+	625	7.7	8.3 (7.6-9.1)	3.0±1.8	70.0 (68.2-72.9)	3.2 (2.1-4.9)	1.2 (0.5-2.5)
					p<0.001	*p=0.007*	*p<0.001*	*p<0.001*
Marital status	Married	5,631	67.0	66.0 (64.7-67.1)	2.4±1.6	49.9 (48.5-51.3)	6.2 (5.6-6.9)	2.9 (2.4-3.4)
	Widowed	1,190	14.6	15.2 (14.4-16.2)	3.0±1.8	69.3 (66.4-72.0)	7.7 (6.2-9.5)	2.2 (1.5-3.4)
	Separated/divorced	551	6.7	6.3 8 (6.2-7.4)	2.8±1.9	54.3 (49.7-58.8)	18.3 (15.0-22.2)	8.7 (6.5-11.6)
	Never married	790	9.7	12.0 (11.1-12.8)	2.6±1.6	54.8 (51.0-58.5)	8.3 (6.6-10.4)	4.1 (3.0-5.7)
					p<0.001	*p<0.001*	*p<0.001*	*p<0.001*
Nationality	Irish	7,401	90.7	92.0 (91.4-92.6)	2.6±1.7	54.0 (52.8-55.2)	7.3 (6.7-8.0)	3.2 (2.8-3.7)
	Northern Irish	348	4.3	3.7 (3.3-4.1)	2.7±1.7	53.3 (47.7-58.9)	11.3 (8.2-15.4)	5.8 (3.6-9.2)
	British	305	3.8	3.2 (2.8-3.6)	2.6±1.7	53.7 (47.7-59.6)	8.9 (6.0-13.0)	3.0 (1.6-5.5)
	Other nationality	102	1.2	1.1 (0.9-1.3)	2.2±1.5	39.9 (52.3-55.0)	3.8 (1.1-12.0)	0.7 (0.1-4.5)

					p=0.424	*p=0.103*	*p=0.0426*	*p=0.0255*
Location of Household	Urban	4,240	52.0	57.6 (56.4-58.8)	2.6±1.7	56.3 (54.7-57.9)	8.3 (7.5-9.2)	3.8 (3.2-4.4)
	Rural	3,910	48.0	42.4 (41.2-43.6)	2.5±1.7	50.6 (49.0-52.3)	6.4 (5.7-7.3)	2.7 (2.2-3.3)
					p=0.018	*p<0.001*	*p=0.002*	*p=0.011*
Living arrangement	Lives with spouse	3,237	40.0	36.7 (35.6-37.8)	2.5±1.6	46.5 (44.6-48.3)	6.8 (5.9-7.8)	3.5 (2.9-4.3)
	Living with other persons	3,109	38.1	38.8 (37.6-40.0)	2.4±1.6	56.4 (54.6 (58.2)	6.3 (5.5-7.3)	2.6 (2.1-3.3)
	Living alone	1,816	22.2	24.5 (23.5-25.6)	2.8±1.7	61.7 (59.3-64.1)	10.3 (8.9-11.8)	3.9 (3.1-4.9)
					p=0.002	*p<0.001*	*p<0.001*	*p=0.048*
Educational attainment (3)	Primary/no formal education	2,501	30.6	38.2 (37.1-39.4)	2.9±1.8	62.4 (60.4-64.4)	7.7 (6.7-8.8)	3.6 (2.9-4.4)
	Secondary	3,261	40.0	43.2 (42.1-44.4)	2.4±1.6	48.8 (47.0-50.6)	7.0 (6.1-7.9)	3.0 (2.4-3.6)
	Third level	2,397	29.4	18.5 (17.8-19.3)	2.4±1.5	47.8 (45.7-49.9)	8.3 (7.2-9.5)	3.5 (2.8-4.4)
					p<0.001	*p<0.001*	*p=0.256*	*p=0.308*
Employment status (105)	Employed	2,043	25.4	24.6 (23.6-25.6)	1.9±1.2	37.3 (35.1-39.5)	5.6 (4.6-6.7)	2.0 (1.4-2.7)
	Self-employed	886	11.0	11.2 (10.5-12.0)	1.9±1.2	34.6 (31.5-38.0)	3.0 (2.0-4.4)	0.9 (0.4-1.7)
	Retired	3,041	37.7	36.6 (35.5-37.7)	2.8±1.7	65.7 (63.8-67.5)	6.8 (5.9-7.8)	2.5 (2.0-3.2)
	Homemaker	1,274	15.8	16.0 (15.1-16.8)	2.8±1.7	60.9 (58.0-63.6)	7.7 (6.3-9.3)	3.8 (2.8-5.0)
	In education/training	44	0.5	0.5 (0.3-0.6)	2.3±1.5	34.0 (21.2-49.6)	9.1 (3.7-20.8)	9.1 (3.7-20.8)
	Permanently sick/disabled	379	4.7	5.5 (4.9-6.0)	3.7±2.3	87.9 (75.4-83.7)	22.8 (18.8-27.3)	13.8 (10.6-17.7)
	Unemployed	390	4.8	5.6 (5.0-6.1)	2.3±1.5	42.5 (37.5-47.7)	10.6 (7.7-14.4)	6.4 (4.3-9.4)
					p<0.001	*p<0.001*	*p<0.001*	*p<0.001*
House value in thousands	≤ €80,000	1,432	18.9	21.5 (20.5-22.6)	2.8±1.9	57.8 (55.1-60.5)	9.6 (8.5-11.4)	5.0 (3.9-6.2)

(583)								
	€80,001-160,000	1,376	18.2	18.6 (17.6-19.5)	2.6±1.6	56.2 (53.4-58.9)	6.6 (5.3-8.0)	2.5 (1.8-3.5)
	€160,001-240,000	1,022	13.5	13.2 (12.4-14.0)	2.5±1.7	51.2 (47.9-54.4)	8.3 (6.7-10.3)	3.9 (2.8-5.4)
	€240,001-330,000	1,877	24.8	24.3 (23.3-25.3)	2.5±1.6	52.6 (50.2-55.0)	6.2 (5.1-7.4)	2.6 (2.0-3.5)
	€320,001-400,000	588	7.8	7.4 (6.8-8.0)	2.4±1.6	50.1 (45.8-54.4)	6.4 (4.6-8.9)	3.0 (1.9-4.9)
	€400,001-480,000	172	2.3	2.0 (1.7-2.4)	2.4±1.6	52.5 (44.5-60.3)	9.8 (6.0-15.7)	2.1 (0.7-5.7)
	€480,001-560,000	478	6.4	5.9 (5.4-6.5)	2.5±1.5	52.0 (47.2-56.8)	7.6 (5.4-10.5)	2.2 (1.1-4.4)
	≥ €560,001	625	8.2	7.1 (6.5-7.7)	2.4±1.5	51.3 (47.0-55.5)	6.8 (4.9-9.3)	3.2 (1.9-5.2)
					p<0.001	*p=0.002*	*p=0.008*	*p=0.004*
Deprivation Decile	1	1,082	13.3	12.0 (11.2-12.7)	2.5±1.6	52.3 (49.1-55.5)	6.4 (5.0-8.2)	2.4 (1.6-3.6)
	2	565	6.9	6.5 (5.9-70.0)	2.5±1.7	50.3 (45.9-54.7)	9.4 (7.1-12.3)	2.7 (1.5-4.6)
	3	580	7.1	6.7 (6.6-7.8)	2.4±1.6	53.0 (48.7-57.3)	4.8 (3.2-7.0)	1.7 (0.9-3.3)
	4	555	6.8	6.7 (6.1-7.2)	2.4±1.5	50.2 (45.8-54.7)	5.3 (3.6-7.6)	1.9 (1.0-3.5)
	5	725	8.9	8.8 (8.2-9.5)	2.5±1.6	52.7 (48.9-56.6)	6.3 (4.7-8.4)	3.7 (2.5-5.4)
	6	604	7.4	7.1 (6.6-7.8)	2.6±1.7	51.9 (47.7-56.1)	7.8 (5.8-10.3)	4.3 (2.9-6.3)
	7	747	9.1	8.8 (8.1-9.4)	2.5±1.6	54.6 (50.8-58.4)	9.0 (6.4-11.5)	3.2 (2.1-4.9)
	8	790	9.7	9.5 (8.8-10.2)	2.4±1.7	51.7 (48.1-55.4)	6.8 (5.2-8.8)	3.2 (2.2-4.6)
	9	1,251	15.3	15.8 (14.9-16.6)	2.7±1.8	55.5 (52.5-58.4)	8.0 (6.5-9.7)	3.3 (2.4-4.5)
	10	1,263	16.5	18.0 (17.1-19.0)	2.7±1.8	58.3 (55.4-61.2)	9.0 (7.5-10.8	4.8 (3.7-6.1)
					p<0.001	*p=0.010*	*p=0.010*	*p=0.013*
Number of conditions	0	1,728	21.2	21.0 (20.0-21.9)	..	..	..	..
	1	2,078	25.5	25.2 (4.2-26.2)	..	..	..	..
	2	1,731	21.1	21.0 (20.1-22.0)	..	..	5.9 (4.8-7.1)	1.5 (1.0-2.2)

3	1,151	14.1	14.1 (13.3-14.9)	..	..	10.6 (8.9-12.6)	3.5 (2.5-4.8)
4	697	8.5	8.8 (8.2-9.5)	..	..	16.1 (13.5-19.2)	6.6 (4.9-8.8)
5	378	4.6	4.7 (4.2-5.2)	..	..	21.8 (17.8-26.4)	8.3 (5.8-11.6)
6	201	2.5	2.6 (2.2-3.0)	..	..	40.9 (33.8-48.3)	25.1 (19.3-32.1)
7	109	1.3	1.4 (1.2-1.7)	..	..	46.1 (36.6-56.0)	30.1 (22.0-39.5)
8+	89	1.1	1.1 (0.9-1.4)	..	..	52.4 (41.2-63.2)	39.5 (29.3-50.6)
						p<0.001	*p<0.001*

† Differences between means within each variable differed significantly p<0.0001 (t test for independent samples for sex and location of household; one way ANOVA for age groups, nationality, marital status, living arrangement, educational status, house value and deprivation decile).

Table 3.9. Prevalence of multimorbidity in people aged 50 years and over in Ireland by sex and age group

			Prevalence	Prevalence by sex		Prevalence by age groups (in ten years)			
			Weighted % (95% CI)	Weighted % (95% CI)		Weighted % (95% CI)			
	n	%		Males	Females	50-59 yrs	60-69 yrs	70-79 yrs	80+ yrs
No conditions	1728	(21.2)	21.0 (20.0-21.9)	24.7 (23.3-26.2)	17.5 (16.4-18.7)	30.7 (29.0-32.3)	17.9 (16.4-19.5)	10.6 (9.2-12.3)	10.3 (8.0-13.2)
One condition	2078	(25.5)	25.2 (24.2-26.2)	26.5 (25.1-28.0)	24.0 (22.7-25.4)	30.3 (28.7-32.0)	24.3 (22.6-26.0)	18.8 (16.8-20.9)	19.7 (16.5-23.4)
Two conditions	1731	(21.1)	21.0(20.1-21.9)	20.6 (19.3-22.0)	21.4 (20.1-22.7)	18.6 (17.3-20.1)	23.1 (21.4-24.8)	22.8 (20.7-25.1)	20.6 (17.3-24.3)
Three conditions	1151	(14.1)	14.1 (13.3-14.9)	13.2 (12.1-14.3)	15.0 (13.9-16.2)	9.3 (8.3-10.4)	16.7 (15.2-18.3)	18.2 (16.3-20.3)	17.7 (14.7-21.3)
Four conditions	697	(8.5)	8.8 (8.1-9.5)	7.1 (6.3-8.0)	10.4 (9.4-11.5)	5.6 (4.8-6.5)	8.7 (7.6-9.9)	13.4 (11.7-15.4)	14 (11.1-17.5)
Five conditions	378	(4.6)	4.7(4.2-5.2)	3.9 (3.3-4.6)	5.5 (4.8-6.3)	2.5 (2.0-3.2)	4.7 (3.9-5.7)	7.4 (6.2-8.9)	8.7 (6.6-11.6)
Six plus conditions	399	(4.9)	5.1(4.6-5.6)	4.0 (3.4-4.7)	6.2 (5.5-7.1)	3.0 (2.4-3.7)	4.6 (3.8-5.5)	8.7 (7.3-10.3)	8.9 (6.7-11.7)
Total	8,162	100	100	100	100	100	100	100	100
Threshold multimorbidity	*4,365*	*(53.4)*	*53.8 (52.6-54.9)*	*48.8 (47.1-50.4)*	*58.5 (56.9-60.1)*	*39.0 (37.3-40.8)*	*57.8 (55.8-59.8)*	*70.6 (68.2-72.9)*	*70.0 (65.8-73.8)*

Table 3.10 Multimorbidity prevalence and mean number of chronic conditions according to each chronic condition

Chronic Condition	Number (weighted %)	Cases with multimorbidity	Concurrent conditions	Cases with physical-mental multimorbidity	Cases with mental multimorbidity
	Total n=8,162	weighted % (95%CIs)	mean SD	weighted % (95%CIs)	weighted % (95%CIs)
Heart failure	87 (1.1)	97.7 (91.1-99.4)	5.4±2.2	9.8% (5.0-18.4)	7.8 (3.5-16.6)
Stroke/TIA	291 (3.6)	96.1 (93.2-97.8)	4.5#2.3	12.3 (8.8-16.8)	4.7 (2.7-8.2)
Other mental health conditions	192 (2.4)	94.9 (90.6-97.3)	5.0±2.5	82.6 (76.3-87.6)	74.5 (67.6-80.4)
Angina/heart attack	671 (8.5)	93.7 (91.6-95.4)	4.2±2.2	10.3 (8.2-12.9)	3.9 (2.6-5.7)
Abnormal heart rhythm	588 (7.1)	91.8 (88.9-93.9)	4.2±2.2	13.6 (10.9-16.8)	6.3 (4.5-8.8)
Vision impairment	147 (2.1)	91.8 (85.8-95.4)	4.6±2.4	18.4 (12.7-25.9)	9.4 (5.6-15.5)
Anxiety	388 (4.6)	91.2 (87.9-93.7)	4.4±2.4	80.9 (76.6-84.6)	56.6 (51.4-61.7)
Parkinson's disease	43 (0.5)	91.2 (76.7-97.0)	3.9±2.0	9.1 (2.9-25.1)	5.1 (1.3-18.6)
Hearing impairment	194 (2.7)	90.8 (85.5-94.3)	4.2±2.4	14.5 (10.2-20.3)	7.3 (4.4-11.8)
Incontinence	765 (9.2)	90.1 (87.7-92.1)	3.8±2.1	15.9 (13.3-18.9)	7.1 (5.4-9.4)
Alcohol or substance abuse	131 (1.6)	90.1 (83.4-94.2)	4.2±2.4	82.3 (74.3-88.2)	35.9 (27.8-44.8)
Diabetes	634 (8.0)	89.9 (87.1-92.1)	3.8±2.0	11.4% (9.0-14.3)	5.1 (3.6-7.1)
Depression	437 (5.2)	89.9 (86.3-92.5)	4.3±2.4	81.0 (76.8-84.5)	54.4 (49.4-59.2)
Liver disease	46 (0.5)	89.3 (76.4-95.6)	4.6±3.1	41.0 (27.3-56.3)	14.9 (7.0-28.9)
High cholesterol	2,032 (24.7)	89.2 (87.7-90.5)	3.5±1.8	10.7 (9.3-12.2)	4.0 (3.2-5.1)
Memory disorders	51 (0.7)	88.9 (74.4-95.6)	4.8±2.8	29.0 (17.8-43.7)	16.1 (8.1-29.3)
Osteoporosis	786 (9.3)	88.7 (86.3-90.7)	3.5±2.0	11.5 (9.4-14.0)	4.6 (3.3-6.3)
Heart murmur	388 (4.6)	88.7 (84.9-91.7)	4.1±2.2	14.2 (10.9-18.3)	5.6 (3.6-8.7)
Varicose Ulcer	271 (3.5)	87.8 (83.2-91.4)	3.8±2.1	9.2 (6.2-13.5)	4.4 (2.5-7.8)
Arthritis	2,255 (27.6)	86.5 (85.0-87.9)	3.4±1.9	12.1 (10.8-13.6)	5.1 (4.2-6.1)
Chronic respiratory	988 (12.2)	85.9 (83.5-88.0)	3.4±2.0	11.4 (9.5-13.6)	4.2 (3.1-5.7)
High blood pressure	2,591 (32.4)	85.1 (83.5-86.5)	3.3±1.8	9.7 (8.5-10.9)	3.6 (2.9-4.4)
Stomach Ulcer	572 (7.2)	84.3 (80.8-87.2)	3.7±2.2	15.0 (12.2-18.3)	6.9 (5.1-9.4)
Cancer	512 (6.1)	84.1 (80.5-87.2)	3.4±2.0	12.7 (9.9-16.1)	5.4 (3.7-7.9)
Falls/fracture	1,416 (17.7)	81.9 (79.7-84.0)	3.3±2.1	12.9 (11.2-14.9)	5.6 (4.5-7.1)

3.3.3 Multimorbidity patterns

The non-random aggregation of chronic conditions was investigated using cluster analysis, applying the criteria set out in Section 2.4.2. The clustering of conditions observed for the full TILDA sample (n=8,160) is graphically presented in *Figure 3.4* in the form of a dendrogram. The Jaccard dissimilarity coefficient is represented on the vertical axis. Lower values of the Jaccard dissimilarity coefficient indicate a closer association between conditions. Associations forming at a higher level in the dendrogram have a higher Jaccard dissimilarity score indicating lower degree of association compared to those at a lower level in the dendrogram. The numbers of respondents reporting pairwise associations between conditions included in the cluster analysis and their and population pairwise prevalence estimates are shown in *Table 3.11.*The cluster solution for the full TILDA sample had an agglomerative coefficient of 0.49 indicating a moderate structure present in the data. A nine-cluster structure was derived from the cluster solution, graphically displayed in the cluster dendrogram in *Figure 3.4.*

Table 3.11 Clusters and associated conditions

Cluster ID	***Associated conditions included in cluster***
1 - Coronary Heart Disease	Angina and heart attack
2 - Cardio risk factors	High blood pressure and high cholesterol
3 - Cerebrovascular	Stroke, TIA, heart failure and alcohol abuse
4 - Sensory	Visual and hearing impairments
5 - Cardio irregularities	Heart murmur and abnormal heart rhythm
6 – Metabolic and cancer	Diabetes, other arthritis, cancer, stomach and varicose ulcers.
7 - Musculoskeletal and incontinence	Rheumatoid arthritis, fractures, incontinence and falls
8 - Musculoskeletal and respiratory	Osteoarthritis, osteoporosis and respiratory conditions: lung disease and asthma.
9 - Mental health	Anxiety, depression and other mental health conditions.

Four clusters included two conditions each: angina and heart attack clustered together in the *CHD cluster*; high blood pressure and high cholesterol clustered together in the *Cardio risk factor cluster*; visual and hearing impairments clustered together in the *Sensory cluster* and heart murmurs and abnormal heart rhythm clustered together in the *Cardio irregularities* cluster. A *Mental health cluster* included three conditions: anxiety, depression and other mental health conditions. Three clusters included four conditions: stroke and TIA clustered with heart failure

and alcohol abuse in the *Cerebrovascular cluster* and rheumatoid arthritis and fractures clustered with incontinence and falls in the *Musculoskeletal and incontinence cluster*; a second *Musculoskeletal and respiratory cluster* was derived including osteoarthritis and osteoporosis and asthma and chronic lung disease. Finally a *Metabolic and cancer cluster* was identified including diabetes, other arthritis such as fibromyalgia, lupus and gout, cancer, stomach and varicose ulcers.

3.3.3.1 Differences in dendrogram solutions according to demographic characteristics

Applying the same analytical approach, a series of dendrogram were generated to test for differences in overall patterns of multimorbidity according to sex, age and deprivation decile.

ROBUST CLUSTERS

In all cluster solutions, anxiety, depression and other mental health conditions formed a strong individual mental health cluster distinct from physical health conditions and impairments. It is noteworthy that alcohol and substance abuse, generally considered a mental health condition, was found to cluster most closely with physical conditions, specifically heart failure, stroke and TIA. Several other pairwise combinations were observed as robust clusters across population subgroups; reliably forming first order clusters in all solutions, although higher order clusters for these conditions did vary depending on subgroups. Robust pairwise combinations reflected some well-established pathophysiological associations and comorbid patterns:

- angina and heart attack (Théroux and Fuster, 1998);
- high blood pressure and high cholesterol (Castelli and Anderson, 1986);
- stroke and TIA (Mergenthaler et al., 2004);
- heart murmur and abnormal heart rhythm (Lilly, 2012);
- lung disease and asthma (Boulet and Boulay, 2011).

The close association of these conditions validate the approach taken in *Section 3.2.1.6* where some of these conditions were grouped together for multimorbidity prevalence analysis (i.e. angina and heart attack, stroke and TIA and lung disease and asthma). A pairwise association between osteoporosis and osteoarthritis was observed to be robust in all but one cluster solution – men. Fractures and rheumatoid arthritis was a robust pairing in all cluster solutions except for in women. The pairing of falls and incontinence was robust in all cluster solutions

except for men where falls clustered most closely with fractures and rheumatoid arthritis. Incontinence in men clustered most closely with cancer.

SUMMARY OF DIFFERENCES BETWEEN DEMOGRAPHIC CHARACTERISTICS.

Dendrogram representing the non-random patterning of conditions according to three demographic characteristics are presented in Appendix 3.5 to 3.13. The solution for women (*see Appendix 3.5*) in the sample reflected several of the same clusters as the overall population (sample size 4,422, AC 0.49). However, falls and incontinence clustered most closely with rheumatoid arthritis and diabetes then formed a higher order cluster with the stomach ulcer and cancer cluster. Fractures were observed to cluster most closely with the osteoporosis and osteoarthritis cluster in women rather than clustering with rheumatoid arthritis as observed in the total population cluster solution. Several clusters in the subgroup for men (*see Appendix 3.5*, sample size 3,783, AC 0.48) varied from the total population and from those found in women.

Age was divided into two groups to test for differences in clusters between younger and older age groupings. Given the observed changes in prevalence of multimorbidity for those aged 75 years and over the full sample was divided into two groups to investigate age related associative multimorbidity patterns; those aged less than 75 years (*n=6,821, AC 0.5)* and 75 years and over a (*n=1,339, AC 0.48)* (*see Appendix 3.7 and 3.8*). Cluster solutions varied substantially between these age groups. In the older age group, heart failure clustered more closely with angina and heart attack rather than clustering with stroke and TIA. Cardio-risk factors (i.e. heart murmur and abnormal heart rhythm) clustered with cerebrovascular accidents (i.e. stroke and TIA) in the older group and with cancer and stomach ulcers in the younger group. Unlike the close associations found with sensory impairments (i.e. vision and hearing) and cardiovascular conditions in the full population solution and in younger ages, vision clustered most closely with varicose ulcers and hearing clustered most closely with alcohol or substance abuse in older ages. Notably rheumatoid arthritis did not cluster with fractures in the older group, where it clustered with cancer and stomach ulcers. Fractures were closely associated with the robust pairing of osteoarthritis and osteoporosis in older ages. Diabetes clustered most closely with other arthritis and varicose ulcers in the in younger age group.

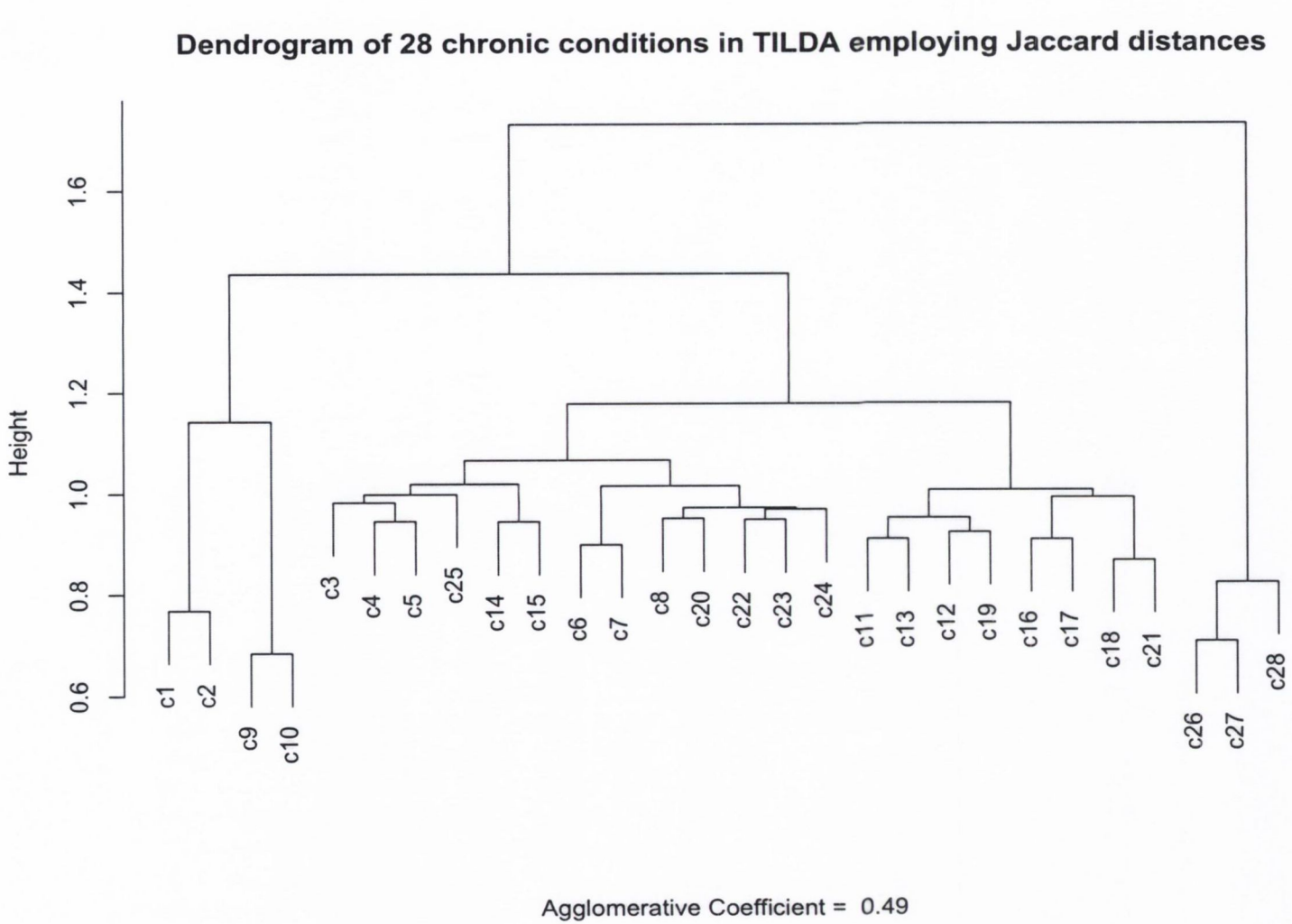
Two dendrogram were generated (see *Appendix 3.9 and 3.10*), comparing the most affluent deciles (i.e. decile 1, 2 and 3) (sample size 2,226, AC 0.38) to the most deprived deciles (i.e. 9 and 10) (sample size 2,513, AC 0.57). As the two most deprived deciles had a substantially larger

sample size (n=2,513) compared to the two most affluent deciles (n=1,646), it was decided to include the three most affluent deciles in the affluent sub-grouping (n=2,226) for comparative purposes. Both cluster solutions varied substantially from the full population solution and each other. Other arthritis clustered most closely with heart murmur and abnormal heart rhythm in more deprived persons, whereas it clustered most closely with stomach ulcers in more affluent persons. Varicose ulcers formed an association with vision impairment and hearing impairment in more deprived persons compared to its close association with cancer and diabetes in more affluent persons. Cancer, stomach ulcers and alcohol and substance abuse formed a three-condition cluster in the most deprived subgroup. A close association was also found for fractures, osteoporosis and osteoarthritis in deprived deciles, which then formed a closer association with high blood pressure and high blood cholesterol not observed in any other solution. Heart failure clustered most closely with heart attack and angina, rather than stroke and TIA in the most deprived subgroup.

3.3.3.2 Disaggregating mental health conditions in cluster analysis

To control for the strong association between mental health conditions in the overall cluster solution, each mental health condition included in the robust mental health cluster (i.e. anxiety, depression and other mental health conditions) were entered into the dendrogram separately to observe its association with the other health conditions. Anxiety (n=388, AC 0.38) was found to cluster most closely with osteoarthritis and diabetes, and formed a higher order cluster with cancer, ulcers and alcohol and substance abuse. Depression (n=437, AC 0.39) was found to cluster most closely with stomach ulcers and alcohol and substance abuse. Other mental health conditions (n=192, AC 0.38) was found to form a close association with alcohol and substance abuse and only formed a higher level cluster with other physical health conditions after the 1.0 Jaccard cut-off. Frequencies and estimated population prevalence for pairwise conditions are presented in Table 3.12 for all conditions included in the cluster analysis.

Figure 3.4



Cluster Legend

C1	**Ang**	Angina
C2	**HA**	Heart attack
C3	**HF**	Heart failure
C4	**ST**	Stroke
C5	**TIA**	Trans ischaemic attack
C6	**HM**	A heart murmur
C7	**HR**	An abnormal heart rhythm
C8	**Diab**	Diabetes
C9	**HBP**	High blood pressure
C10	**Chol**	High cholesterol
C11	**Fall**	Falls
C12	**Frac**	Fractures
C13	**Incon**	Incontinence
C14	**Vis**	Vision impairment
C15	**Hear**	Hearing impairment
C16	**LD**	Chronic lung disease
C17	**Ast**	Asthma
C18	**Oart**	Osteoarthritis
C19	**Rart**	Rheumatoid arthritis
C20	**OTart**	Unclassified arthritis
C21	**Ostp**	Osteoporosis
C22	**Can**	Cancer
C23	**STUL**	Stomach ulcers
C24	**VUL**	Varicose ulcers
C25	**Abuse**	Alcohol or substance abuse
C26	**Anx**	Anxiety
C27	**Dep**	Depression
C28	**OMen**	Other mental health conditions

Table 3.12 Frequency and population prevalence rates (weighted %) of pairwise combinations of conditions. Read down for proportion of respondents with condition C1-28 that also have any condition C1-28 and read across for number respondents with pairwise conditions.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28
C1		155	37	20	33	56	110	72	281	246	56	79	55	19	20	34	72	78	72	46	49	36	59	23	14	25	32	13
C2	1.9		43	24	30	36	72	61	195	198	38	50	37	14	24	30	41	47	46	40	21	23	37	15	13	13	18	9
C3	0.4	0.6		7	7	15	32	21	51	47	15	14	11	2	4	8	5	12	16	8	9	9	15	4	3	3	7	4
C4	0.3	0.3	0.1		16	12	27	19	78	58	21	25	31	10	9	12	14	17	23	11	12	12	9	5	6	10	10	7
C5	0.4	0.4	0.1	0.2		16	38	22	99	87	23	27	20	6	12	12	25	34	22	19	21	16	24	8	4	8	9	6
C6	0.6	0.4	0.2	0.1	0.1		90	40	159	132	44	63	59	16	14	21	49	75	49	42	64	28	39	18	6	31	33	16
C7	1.4	0.9	0.3	0.3	0.4	1.0		73	271	216	64	109	75	18	28	34	71	124	79	46	79	56	71	39	11	41	50	20
C8	0.9	0.7	0.3	0.2	0.3	0.5	0.9		372	287	61	88	76	25	22	30	72	85	63	57	34	45	48	24	14	37	44	22
C9	3.6	2.5	0.6	1.0	1.2	1.9	3.2	4.8		1109	210	373	312	71	70	115	267	414	299	253	239	198	181	102	43	137	140	64
C10	3.1	2.5	0.7	0.7	1.0	1.5	2.5	3.7	13.8		178	308	214	49	59	89	203	330	238	174	242	150	170	59	40	115	126	55
C11	0.8	0.4	0.2	0.3	0.3	0.5	0.8	0.8	2.6	2.2		120	114	25	34	38	80	116	78	53	70	43	59	32	17	45	61	33
C12	1.1	0.7	0.1	0.3	0.4	0.7	1.4	1.2	4.9	3.9	1.6		133	26	45	53	130	165	132	91	181	71	92	56	31	72	71	47
C13	0.8	0.6	0.1	0.4	0.2	0.7	0.9	1.0	3.9	2.6	1.5	1.7		24	33	52	110	163	90	93	125	82	74	49	9	67	82	40
C14	0.3	0.2	*0.02*	0.1	0.1	0.2	0.3	0.4	1.0	0.7	0.4	0.4	0.3		18	14	13	24	20	18	20	12	22	16	4	17	19	13
C15	0.3	0.3	*0.04*	0.1	0.2	0.1	0.4	0.3	1.0	0.8	0.5	0.6	0.5	0.3		9	24	28	32	19	29	17	20	5	5	17	21	13
C16	0.4	0.4	0.1	0.1	0.1	0.3	0.4	0.4	1.4	1.1	0.5	0.7	0.6	0.2	0.1		92	59	45	24	67	28	41	16	10	27	33	16
C17	0.9	0.5	*0.05*	0.1	0.3	0.4	0.8	1.0	3.4	2.6	1.0	1.7	1.3	0.2	0.4	1.2		135	77	49	126	50	65	31	19	49	56	25
C18	0.9	0.5	0.1	0.2	0.4	0.8	1.4	1.0	5.0	3.8	1.3	2.0	1.9	0.3	0.4	0.7	1.6		30	1	216	79	90	50	17	68	77	24
C19	0.9	0.6	0.2	0.3	0.3	0.6	1.1	0.8	3.8	2.9	1.0	1.9	1.2	0.3	0.4	0.6	1.0	0.3		4	79	44	63	37	17	40	55	32
C20	0.7	0.5	0.1	0.1	0.2	0.5	0.5	0.7	3.3	2.4	0.7	1.2	1.2	0.2	0.3	0.3	0.7	*0.01*	*0.05*		40	36	53	38	12	52	43	20
C21	0.7	0.3	0.1	0.1	0.3	0.8	0.9	0.4	3.0	3.0	0.9	2.3	1.6	0.3	0.4	0.8	1.5	2.7	1.0	0.5		68	75	48	11	56	58	26
C22	0.5	0.3	0.1	0.1	0.2	0.3	0.6	0.5	2.5	1.8	0.5	0.9	1.0	0.2	0.2	0.4	0.6	0.9	0.6	0.5	0.4		54	31	13	30	43	14
C23	0.8	0.5	0.2	0.1	0.3	0.4	0.8	0.6	2.2	2.0	0.8	1.2	0.9	0.3	0.3	0.5	0.8	1.0	0.8	0.7	0.9	0.6		30	26	52	63	26
C24	0.4	0.2	*0.04*	*0.05*	0.1	0.2	0.5	0.3	1.4	0.7	0.4	0.7	0.6	0.2	0.1	0.2	0.4	0.6	0.4	0.5	0.6	0.4	0.4		5	14	14	10
C25	0.2	0.2	*0.03*	0.1	*0.04*	0.1	0.1	0.2	0.5	0.5	0.2	0.4	0.1	*0.05*	0.1	0.1	0.3	0.2	0.2	0.2	0.1	0.2	0.3	0.1		23	34	27
C26	0.3	0.2	*0.03*	0.1	0.1	0.4	0.5	0.5	1.7	1.4	0.6	0.9	0.8	0.2	0.2	0.3	0.6	0.7	0.5	0.6	0.6	0.4	0.6	0.2	0.3		188	103
C27	0.4	0.2	0.1	0.1	0.1	0.4	0.6	0.5	1.7	1.5	0.8	0.9	1.0	0.2	0.3	0.4	0.7	0.8	0.7	0.6	0.6	0.5	0.7	0.2	0.5	2.2		113
C28	0.2	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.8	0.7	0.4	0.6	0.5	0.2	0.2	0.2	0.3	0.2	0.4	0.2	0.3	0.2	0.3	0.1	0.4	1.3	1.5	

3.4 Discussion

The overall aim of this exploratory study was to examine the prevalence and non-random patterns of multimorbidity in an Irish context. A broad nosological approach to multimorbidity measurement was adopted to include sensory impairments, mental health and geriatric syndromes as well as chronic physical diseases. This provided for a more comprehensive evaluation of multimorbidity burden in the Irish population. To account for the lack of valid severity measurements in TILDA, only conditions with a significant impact on health sequelae were included in the measurement of multimorbidity prevalence. This measure included a core set of chronic conditions as recommended in recent review studies (Diederichs et al., 2011a, Fortin et al., 2012), which were considered to be of substantial import to population health considering their high prevalence and associated negative impact on health outcomes.

The most prevalent conditions in the older Irish population were high blood pressure, high cholesterol, arthritis, recurrent falls and fractures and chronic respiratory. Prevalence of conditions varied according to age group and sex. Older women had a higher prevalence of many of the chronic health conditions considered in this analysis; however, older men had a far greater prevalence of CHD and cerebrovascular accidents. Examination of conditions according to sequelae raised two considerations. Firstly, despite a low prevalence for certain conditions including memory disorders, liver disease and Parkinson's disease as well as hearing and vision impairments, such conditions were more strongly associated with negative health sequelae compared to some other more prevalent conditions. This finding underscores the need to examine both the prevalence and impact of conditions to measure the burden of chronic conditions at a population level and to inform appropriate population health responses. Secondly, strength of associations for conditions varied substantially across health sequelae. For example hearing impairment was strongly associated with disability but had only a slight impact on quality of life. Memory disorders were strongly associated with disability relative to self-rated health. This may be related to the sensitivity of the sequelae measures; specifically the quality of life measure appears to be less sensitive compared to the other measures. However, it is also likely picking up on condition specific sequelae. This suggests the need to examine conditions and multimorbidity across a range of outcomes to gain a more accurate representation of their burden on community-dwelling populations.

3.4.1 Multimorbidity prevalence

Several analytical approaches were employed to investigate the prevalence and patterns of multimorbidity in Ireland's older population as recommended in previous multimorbidity prevalence studies (Marengoni, 2008, Fortin et al., 2012, John et al., 2003). Threshold multimorbidity was evaluated using the conventional definition of two or more conditions in an individual (van den Akker et al., 1996). While it is difficult to meaningfully compare prevalence rates between studies for the many reasons outlined earlier, prevalence estimates for threshold multimorbidity (53.8%) and mean number of concurrent conditions (2.6 ± 1.7) for people aged 50 years and over in Ireland was comparable to other prevalence estimates for community-dwelling older people: 63.1% and 2.7 mean conditions for persons aged 60 years and over in the United States (Verbrugge et al., 1989); 58.6% for persons aged 65 to 94 years living in an urban region of Germany (Kirchberger et al., 2012) and 53.8% for persons aged 60 years and over in rural India (Khanam et al., 2011). Moreover, extending the international findings that multimorbidity is the norm rather than the exception for older people (Guthrie, 2011), findings from this study highlight that multimorbidity affects over half the population aged 50 years and over in Ireland, further supporting the contention that multimorbidity is not a phenomenon reserved for old age alone (Taylor et al., 2010, Barnett et al., 2012).

A substantial burden of multimorbidity was observed for the community-dwelling population in Ireland with concurrent condition burden ranging from two to 13 conditions in the sample. 32.8% of the population aged 50 years and over had complex multimorbidity (i.e. ≥ 3 conditions) and 5% were found to have six or more concurrent conditions indicating a significant burden for these individuals. The high burden of concurrent conditions in some older people was reflected in other multimorbidity prevalence studies (Agborsangaya et al., 2012, Barnett et al., 2012, van den Bussche et al., 2011a).

It is difficult to compare national prevalence rates as two studies were based on disease system groupings rather than individual conditions (McDaid et al., 2013, Naughton et al., 2006). However, population multimorbidity prevalence rates for people aged 50 years and over in Ireland were over 10% higher in a study carried out by Glynn et al. (2011) compared to the estimated prevalence in this thesis (66.2% vs. 53.8%), although this is likely to be explained by the higher prevalence rates in primary care samples in general compared to those yielded from population health surveys (Fortin et al., 2012). The differential in estimated prevalence may be explained by the limited number of self-reported conditions considered in this thesis compared

to all conditions extracted from patient records in the Glynn study. It is noteworthy however that a higher prevalence for four or more conditions was recorded in this thesis compared to that recorded in the Glynn study (18.7% vs. 11%) indicating a higher burden of multimorbidity in the community-dwelling population.

Prevalence of physical-mental health multimorbidity is high in the Irish population although slightly lower comparable to a recent study of community-dwelling adults in Scotland (7.5% vs. 8.3%) however, this is likely due to an age effect reflecting the lower prevalence in the older TILDA sample (aged 50 years and over) compared to the full adult sample (aged 16 years and over) in the Scottish study. A small but significant proportion (3.3%) of people aged 50 years and over had two or more mental health conditions. In keeping with previous findings (Barnett et al., 2012), the prevalence of physical-mental health multimorbidity and mental health multimorbidity increased substantially with increasing levels of multimorbidity.

Prevalence of multimorbidity was high for all conditions. Heart failure had the highest mean number of concurrent conditions and was least likely to occur independent of other conditions this finding is supported in Marengoni et al. (2009a). A high mean number of concurrent conditions was also observed for other mental health conditions and memory disorders. The high prevalence of multimorbidity for memory disorders, an indicator of dementia in later life (Jonker et al., 2000), is in contrast to previous findings by Marengoni et al. (2009a) where dementia was found to have the lowest level of multimorbidity prevalence in older individuals (aged 77 years and older) compared to fourteen other prevalent chronic conditions. However, the higher rate found in this study may be explained by the inclusion of mental health conditions in the measure of multimorbidity prevalence in this thesis, although it is noted that prevalence of comorbidity in dementia patients is still a subject for debate (Lyketsos et al., 2005, Sanderson et al., 2002).

The high prevalence of physical-mental health and mental health multimorbidity observed for liver disease reflected the well-established relationship between alcohol and substance abuse and mental health comorbidity (Regier et al., 1990). The high prevalence of multimorbidity with at least one mental health condition for persons with vision impairments may be explained by the effects of age related visual impairment on depression and anxiety (Casten et al., 2004, Augustin et al., 2007). While it is reported that levels of mental health problems in persons with hearing impairment is similar to the general population with some excess of organic disorders and emotional and psychological disorders (du Feu and Fergusson, 2003), hearing impairment

was associated with a high prevalence of mental health multimorbidity in this study. The observed relationship between mental health and heart disease observed here while well acknowledged is not yet well understood (Martens et al., 2010).

Also consistent with international evidence; multimorbidity was significantly higher in older women in Ireland compared to their male counterparts (Marengoni et al., 2011). Women also had a higher prevalence of both physical-mental and mental health multimorbidity. The well-established association between increasing levels of multimorbidity and increasing age (Marengoni et al., 2011) was also observed in this thesis, but only up to age 75 years. There was an observed reversal in this trend for prevalence of multimorbidity and mean number of concurrent conditions after age 75. This levelling off of multimorbidity in older age groups has not, to my knowledge, been reported in other population prevalence studies of multimorbidity. However, a similar age trend was reported for levels of multimorbidity in community-dwelling older people hospitalised for a falls related injury in Australia (Vu et al., 2011). While this trend may be reflecting a survivor bias effect i.e. more vulnerable individuals die earlier from more fatal conditions or a saturation effect of coping with increased multimorbidity, it is also possible that fewer new cases of conditions are diagnosed in older people, indicating an age bias in diagnosis by health professionals. Another explanation may be that older, more multimorbid persons were not captured in this analysis as they are more likely to be institutionalised.

In contrast to previous findings by Andrade et al. (2010), it is noteworthy that the prevalence of physical-mental health and mental health multimorbidity increased inversely with age in this sample. Younger age groups had a twofold higher prevalence of physical-mental health multimorbidity and a fourfold increased prevalence of mental health multimorbidity compared to their older counterparts. It is interesting that prevalence of physical-mental health and mental health multimorbidity was considerably lower for individual's aged 75 years and over. Again however, this may be due to a mental health diagnosis bias in older age groups.

Prevalence estimates were consistently higher for all types of multimorbidity (i.e. threshold multimorbidity, physical-mental health and mental health multimorbidity) for those living in urban areas and those living alone. It is noteworthy that a threefold increased prevalence for physical-mental and mental health multimorbidity was observed for separated or divorced individuals compared to those who were married. The particularly high rate of multimorbidity observed for separated or divorced individuals, especially pronounced for multimorbidity with at

least one mental health condition was previously reported by Ajmera et al. (2012) in a U.S sample.

While threshold multimorbidity rates were similar across British, Irish and Northern Irish nationalities, a substantially higher prevalence of physical-mental and mental health multimorbidity was observed for those reporting a Northern Irish nationality compared to any other. A recent study in Australia noted the high prevalence of multimorbidity among UK and Irish emigrants (Taylor et al., 2010) however, both nationalities were grouped as one variable in analysis. Given the significant difference in prevalence rates between Irish and British and Northern Irish nationalities recorded in this thesis it is recommended that further investigation into patterns of multimorbidity prevalence among emigrant groups consider each nationality separately. In all analyses, multimorbidity was found to be significantly lower for 'other nationalities' although this finding should be interpreted cautiously as the median age for 'other nationalities' (55.5 years) was lower compared to British, Northern Irish and Irish nationalities. Comparison of prevalence rates across a broader range of nationalities is limited in TILDA due to the low numbers of 'other nationality' respondents. Given the low prevalence of multimorbidity among 'other nationalities', it would be interesting to investigate if a healthy immigrant effect is operating in an Irish context as evidenced in other countries (Kennedy et al., 2006, Kobayashi and Prus, 2012).

While a clear social gradient was observed for threshold multimorbidity and educational attainment, a u-shaped pattern was observed for both physical-mental and mental health multimorbidity similar to findings reported by Andrade (2010). Estimated prevalence for multimorbidity with at least one mental health condition was lowest for those reporting secondary school educational attainment, while those with a third level education reported similar levels to those with only a primary school education. Unsurprisingly, individuals who were permanently sick or disabled had the highest reported level of multimorbidity compared to any other employment category. Employment, but especially self-employment appeared to be protective for multimorbidity including one or more mental health conditions. Unemployed persons had a slightly higher prevalence, however unemployed individuals had a lower mean age and examination of lifecourse effects of unemployment on multimorbidity may yield a more pronounced effect. A modest socioeconomic gradient measured by area level deprivation status and house value was confirmed for all types of multimorbidity including threshold multimorbidity and physical-mental health multimorbidity and was most pronounced for mental health multimorbidity similar to findings reported by Barnett et al. (2012).

3.4.2 Multimorbidity patterns

Cluster analysis allowed for the identification of non-random patterning of the 28 conditions examined in this thesis, generalisable to the national Irish population aged 50 years and over. The analysis examined how individual chronic conditions are associated with each other and provides insight into where particular condition combinations of interest occur in the overall pattern. In contrast to the assessment criteria developed by Cornell et al. (2007) based on clinically relevant clusters in a similar study, this analysis aimed to identify non-random multimorbidity patterns at a population level without *a priori* hypothesis. Nine associative multimorbidity clusters in the older Irish population were identified in this study. Five robust pairwise combinations reflecting some well-established pathophysiological associations were identified, however, in general clusters varied when they were compared by sex, age group and deprivation status, indicating the need to examine patterns of multimorbidity and tailor healthcare interventions according to socio-demographic characteristics.

The sample size for this analysis is smaller than the Cornell study and comparing results between studies is problematic given the wide variation in sample characteristics, however results in this thesis broadly reflect patterns of condition clustering in the Cornell study and in other cluster analyses based on similar sample sizes and methodological approaches (Formiga et al., 2013, Marengoni et al., 2009a, Vu et al., 2011, John et al., 2003). In particular, hearing and vision impairment have been found to cluster closely in other studies (Marengoni et al., 2009a, John et al., 2003) as well as anxiety and depression (Cornell et al., 2007). Notably alcohol abuse was found to cluster most closely with cerebrovascular conditions in this study but formed part of a definite mental health cluster in the Cornell analysis. It is also noteworthy that hearing and vision impairment formed a higher order cluster with cerebrovascular conditions in this study, perhaps reflecting a neurovascular link for such impairments. The cluster of osteoporosis and osteoarthritis is not explained by any underlying pathophysiological mechanism, however, these may be linked as a result of treatment effects (Avci and Bachmann, 2004). Musculoskeletal conditions formed two clusters although the distance between clusters was minimal; indicating two similar age related degenerative clusters, not detected in other studies. Interestingly, diabetes clustered with cancer and ulcers, which is not found in other studies, there is a known link between other arthritis such as gout and diabetes (Mc Hugh et al., 2009) and this cluster may be promoted through the well-established lifestyle related risk factors that these conditions share such as poor diet and smoking. While it is not possible to prove pathophysiological relationships between conditions in clusters in cross-sectional analysis, part of the association

may be causal. Several of the clusters in the dendrogram, reflected well establish physiological pathways; in particular the robust pairings identified across population subgroups are well established in the literature.

It is noteworthy however, that several multimorbidity clusters do not neatly reflect conventional clinical care specialisms. For example, diabetes and cancer are discordant in terms of clinical care programmes although they cluster at a population level. Moreover, geriatric syndromes such as falls and incontinence and impairments such as hearing and vision cluster closely with physical health conditions in all demographic groups, not only in older age groups. Discordant clusters identified in the solutions require further analysis to establish mechanisms for their association. These may be as a result of common genetic or lifestyle risk factors, underlying pathophysiological mechanism or discordant treatment regimes. These findings have two important implications. Firstly, classification of conditions used in multimorbidity measurement according to disease systems may be overlooking important patterns in multimorbidity epidemiology influenced by either shared risk factors or drug treatment. Secondly, this finding challenges the current organisation of clinical care; healthcare in many developed countries is organised according to well-established organ system specialisms. This model of organisation is likely overlooking important patterns of concurrent chronic conditions in the general population and may be resulting in adverse outcomes and poor care quality not only for individuals with higher levels of multimorbidity but also on those presenting to the health services with discordant or not-yet established patterns of multimorbidity. Furthermore, healthcare for older people organised around chronic physical diseases is likely ignoring the burden of geriatric syndromes, sensory impairments and mental health on clinical outcomes in treatment programmes.

A strong independent cluster of mental health conditions was found in all cluster analyses, distinct from physical conditions. This is in contrast to the high level of physical-mental health multimorbidity found in prevalence analyses and similar findings indicating a high prevalence of physical-mental health multimorbidity with a strong social gradient in Scotland (Barnett et al., 2012). In addition, this analysis did not find any difference in mental health clustering patterns between the most deprived and most affluent persons in this sample. While the random patterning of mental health conditions is found to be quite independent in this study, this is likely to be due to the strong association between mental health conditions and the high prevalence of physical-mental health multimorbidity observed underscores the importance of parity of mental health and physical health in healthcare provision. Concurrent depression and

chronic physical conditions have been shown to impact negatively on healthcare management (Katon, 2011) and healthcare systems continue to treat physical and mental health as discordant conditions to the detriment of patient's quality of care. It has been suggested however, that issues with quality of care for people with physical and mental health multimorbidity may be as a result of fragmented care rather than the presence of the multimorbidity (Ajmera et al., 2012). The higher prevalence of multimorbidity with a mental health component in more deprived individuals indicates a need to tailor healthcare interventions towards this particularly vulnerable group.

3.4.3 Strengths and limitations

A significant strength of this analysis was the large population based sample generalisable to the population aged 50 years and over in Ireland. To date few studies have examined the prevalence of concurrent conditions and multimorbidity type in a large sample generalisable to the community-dwelling populations and this is the first study to examine it in an Irish context. Furthermore, few studies have examined the prevalence of multimorbidity-prevalence according to different types of multimorbidity in community-dwelling samples. This study employed a large number of recommended conditions in the measure of multimorbidity based on a broad nosological framework. It is likely that this captured a large proportion of the multimorbidity burden in the community. Furthermore, this is the first study to examine the non-random clustering of multimorbidity at a population level in Ireland.

General limitations of the empirical analysis are outlined in Chapter 2. Further to this some specific limitations of this analysis should be acknowledged. 182 respondents reported the presence of a long-term illness not covered by those asked in the questions on chronic conditions. It is not clear how many of these would have more than one condition therefore multimorbidity may have been slightly underestimated in this study due to the limited number of conditions asked in the chronic condition section of the questionnaire. However, this represents a small proportion (2.2%) of the population reporting a chronic illness that was not recorded in the multimorbidity measure. The limitations of self-reported conditions to estimate multimorbidity prevalence has been well debated in the literature (Fortin et al., 2007b). However, the use of self-reported doctor diagnosed conditions is a valid approach to investigating multimorbidity in a community-dwelling population sample (Fortin et al., 2012). While it was not possible to obtain validated measures of severity for included conditions from

the TILDA data, only conditions with an independent impact on health sequelae were included in the multimorbidity measure. Prevalence may be under-estimated for some conditions as self-reported doctor diagnosed prevalence has been found to substantially under estimate the true prevalence of certain conditions, including cardiovascular disease and diabetes. The true prevalence of these conditions are likely to be substantially higher due to undiagnosed cases (Australian Govenment, 2011) and would result in a higher level of multimorbidity than observed in this study. Both under-reporting and over-reporting has been found to occur on a large scale for chronic condition prevalence in community interview surveys. The net effect of this misreporting was found to tend towards underestimating the prevalence of chronic conditions in the general population, this was especially evident for those with a lower educational attainment suggesting an underestimation of inequalities in morbidity (Mackenbach et al., 1996). Therefore any examination of inequalities of multimorbidity based on self-reported chronic conditions should acknowledge the import of the potential under-estimation of chronic conditions in lower socioeconomic groups and it is acknowledged here that the social gradient found for multimorbidity prevalence in this thesis may be under-estimated.

Identification of mental health conditions with routine self-reported survey data may be limiting, nonetheless this methodology is often used for assessing mental health conditions in a community and this study had the added benefit of analysing mental health conditions with a wide range of physical conditions that are not routinely collected in other mental health surveillance systems. The sample size for other mental health conditions in the TILDA sample is low and while it would be interesting to assess the non-random clustering of all mental health conditions, it was not possible to conduct meaningful analysis of the individual conditions considered under the category of other mental health conditions in this thesis.

As there was a low number of 'other nationalities' represented within the data, it was not possible to meaningfully consider multimorbidity in immigrant groups. Consideration of the multimorbidity in the Travelling community would be an interesting question for further studies as they have a considerably reduced life-expectancy rate in Ireland, however, investigation of multimorbidity according to ethnicity was limited in this study as data on ethnic minority groups was not recorded in TILDA.

One limitation of hierarchical cluster analysis is its inability to assign conditions to more than one cluster. Evidently, some conditions may be expected to be part of more than one pattern and conditions in one cluster may have important associations with conditions in another cluster

(Garcia-Olmos et al., 2012, Cornell et al., 2007). Garcia-Olmos et al. (2012) employed correspondence analysis; an exploratory, multivariate technique that converts a data matrix into a scatter plot, to depict relationships between conditions in overlapping categories. This allows for a more comprehensive assessment of multimorbidity patterning at a population level and its potential for use should be explored in further research. However, this study aimed to investigate the overall pattern of conditions in the general older population in Ireland and in socio-demographic subgroups to establish associative multimorbidity in the older Irish population. This broad approach to multimorbidity patterning is useful to identify unknown pathophysiological associations and guide population health measures and clinical care for an ageing population.

This study has many advantages; mainly that it is based on well-validated measures from a large nationally representative survey with a wide range of variables to assess population prevalence of all types multimorbidity investigated according to a range of socio-demographic indicators. In addition, the study sample size was sufficient to observe non-random patterns of condition clustering representative of the older Irish population in Ireland; however the generalisability of patterns in subgroups is questionable due to the reduced sample size for these analyses. The omission of certain conditions from the multimorbidity measure has likely led to an under-representation of multimorbidity in the Irish population. In particular, the omission of chronic kidney disease is notable due to its recently documented high burden in the UK population (Kearns et al., 2013). Low numbers of certain conditions observed in the TILDA data limited the inclusion of all conditions in the cluster analysis. For example, numbers for liver disease, which had indicated a high level of co-occurrence with mental health in the prevalence analysis, were too low for inclusion in the cluster analysis. Inclusion of low prevalence conditions may have resulted in an adjustment of observed clusters. However, given the robust associations observed across sub-groups, these adjustments may not have affected the general patterning of conditions.

3.5 Conclusions

Quantifying the burden of multimorbidity using a comprehensive measure of multimorbidity as well as qualifying the relationships between conditions and overall pattern at a population level

is important for the development of policy and healthcare interventions to address the substantial challenge posed by multimorbidity. There was a high multimorbidity prevalence and burden recorded for the community-dwelling population aged 50 years and over in Ireland. 53.8% had threshold multimorbidity (≥ 2 conditions), 32.8% had complex multimorbidity (≥ 3 conditions), 7.5% had physical-mental health multimorbidity and 3.3% had mental health multimorbidity. A small but significant proportion of the total population in this age group had six or more conditions (5%). Nine associative multimorbidity clusters were identified. Five robust pairwise combinations reflected some well-established pathophysiological associations, however, in general clusters varied when they were compared by sex, age group and deprivation status, indicating the need to examine patterns of multimorbidity and tailor healthcare interventions according to socio-demographic characteristics. The prevalence of multimorbidity was also examined according to demographic characteristics in this chapter; factors associated with multimorbidity are tested in multivariate analyses in Chapter 4. Findings from both chapters will be discussed in more detail in Chapter 6 with a view to identifying at risk population sub-groups and potential factors that may be driving multimorbidity in the Irish population.

Chapter 4. Factors associated with multimorbidity in the community-dwelling population of Ireland aged 50 years and over.

4.1 Introduction

Analyses of the prevalence of multimorbidity for people age 50 years and over in Ireland in Chapter 3 reflect international findings that managing two or more chronic conditions is now the norm rather than the exception. While a substantive literature exists on the risk factors for specific chronic conditions and general health status measures such as self-rated health, there is an evident lack of published studies investigating factors associated with accumulating multiple chronic conditions. Two recent systematic reviews highlighted the lack of available data on factors associated with multimorbidity as a substantial gap in the literature (Marengoni et al., 2011, Gijsen et al., 2001).

Studies to date have been limited in several ways. Firstly, samples are generally small, restricted to regions within countries, or older ages, reducing their generalisability. Secondly, few studies have examined the factors influencing multimorbidity in multivariate analyses, rather the evidence-base is largely limited to descriptive studies of differential prevalence of multimorbidity between sample characteristics. Of those studies examining multimorbidity in multivariate analyses, some are based on a restricted number of conditions in the multimorbidity measure and most control for only a limited number of covariates. Moreover, multivariate analyses investigating factors associated with multimorbidity have used restricted definitions of multimorbidity as a dependent outcome, defined as the presence or absence of 2 or more, or three or more conditions. While there is descriptive evidence that factors influencing multimorbidity with and without mental health component may be different, this has not been examined in multivariate analysis. In addition, there is no evidence to date of the factors influencing increasing levels of multimorbidity, distinct from those influencing morbidity i.e. one chronic condition, although it has been proposed that this may be an important distinction (Tucker-Seeley et al., 2011).

Finally, a significant limitation of studies examining factors associated with multimorbidity is the cross-sectional design of all studies examined, which precludes any meaningful analyses of causal risk factors for multimorbidity. Studies examining risk factors at a population level have generally been restricted to singular conditions and few large-scale longitudinal studies have

included sufficient data to assess a comprehensive chronic condition health burden to allow for investigation of a valid measure of multimorbidity. The TILDA study provides a valuable source of information on a wide range of chronic condition and socio-demographic and lifestyle related factors that may be contributing to the risk of multimorbidity in Ireland, generalisable to the community-dwelling population aged 50 years and over. While it is acknowledged here that longitudinal analyses are required to establish causality in any examination of risk factors for multimorbidity, this study examines the first wave of TILDA data to assess the factors associated with multimorbidity in the population with the explicit understanding that this study will act as a baseline to inform analyses of risk factors using future waves of TILDA data, thereby allowing for one of the first investigations of multimorbidity causality in community-dwelling populations. Identifying factors independently associated with multimorbidity in multivariate analyses of Irish data will contribute to an increased understanding of multimorbidity with the potential to provide valuable information for health promotion initiatives and policy interventions in the future.

Previous studies highlight the influential role of a range of factors on multimorbidity prevalence and risk including age, gender and lifestyle factors such as obesity and physical activity as well as socioeconomic factors including education, income, deprivation and childhood socioeconomic status, although few studies have qualified the independent nature of these associations using multivariate analyses. Even in studies adjusting for covariates, the number of factors considered in the models is generally low. Factors associated with multimorbidity can be roughly divided into modifiable risk factors such as lifestyle related factors and non-modifiable factors, such as age and gender. A further consideration is the social and economic contexts within which people live their lives. Studies to date have shown the important role of family structure and social connectedness on individual's multimorbidity status. The effect of area level deprivation and relative measures of socioeconomic status add a further complexity to examining factors that may influence multimorbidity. While it is not possible to modify age and sex factors, an understanding of the myriad of behavioural factors that influence multimorbidities in older age will be important to contribute to an understanding of populations most at risk of multimorbidity and how such risk may be modified. To date there is limited evidence on the impact of lifestyle factors or socioeconomic factors on multimorbidity risk in the general population. In addition, a recent study examining the impact of early life factors associated with multimorbidity found evidence for a negative effect of childhood financial hardship on current multimorbidity status; this was modified by earnings throughout the lifecourse. This points to the need to consider the impact of factors across the lifecourse on health outcomes in later life.

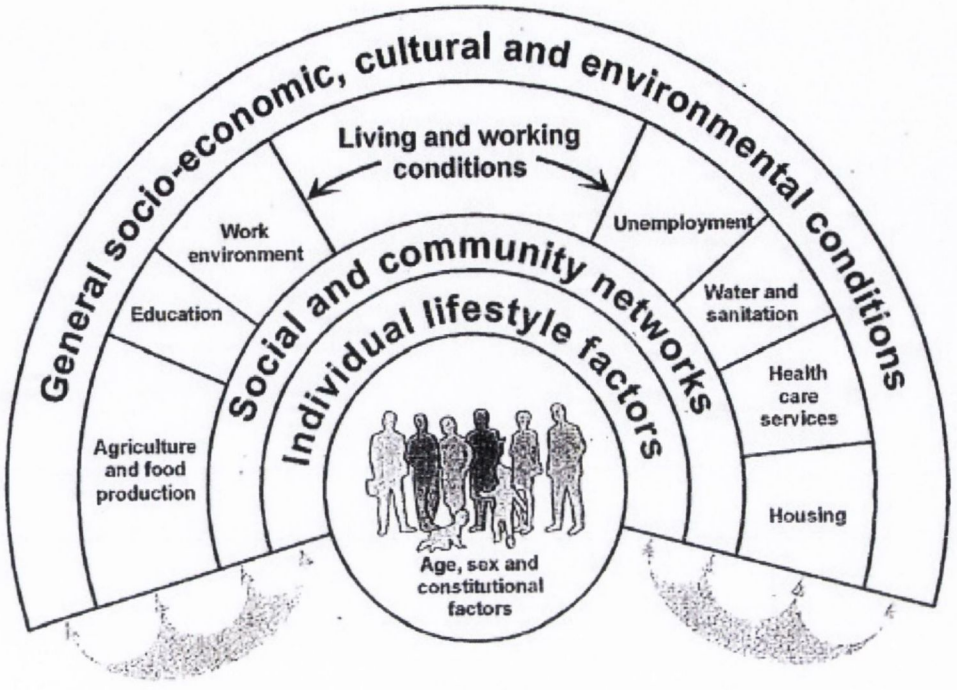
To address this significant gap in the literature, two main objectives are considered in this chapter. The primary objective of this study is to consider the factors influencing the accumulation of increasing numbers of chronic conditions in the population of Ireland aged 50 years and over. A further objective is to examine whether the factors associated with multimorbidity are similar across dimensions of multimorbidity, namely distinguishing between factors associated with multimorbidity with and without a mental health component (i.e. the presence of at least one mental health condition).

The current evidence-base on factors associated with multimorbidity including modifiable and non-modifiable risk factors are discussed in Section 4.2. This is followed by an overview of the approach to examining multimorbidity as an outcome for this study and a detailed account of the variables examined in empirical analyses (Section 4.3). Results of the analyses are presented in Section 4.4 and these are discussed briefly in Section 4.5 and in more detail in Chapter 6.

4.2 Background and Context

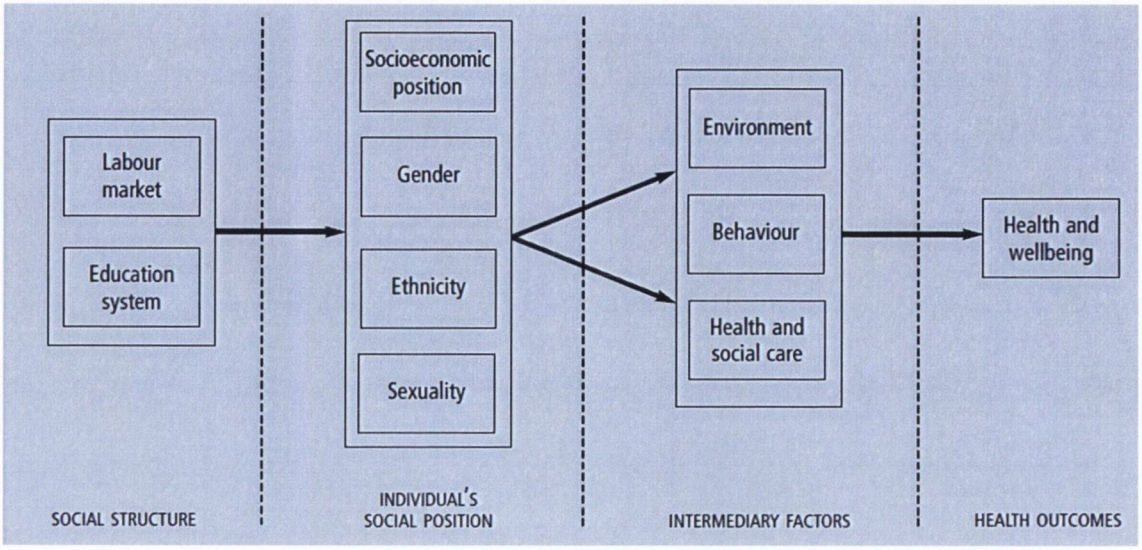
From the limited evidence to date, multimorbidity appears to be influenced by many of the same factors that influence the development of any one chronic condition and other general health measures. It is now well acknowledged that health and well-being are influenced by many modifiable and non-modifiable factors which include past and present behaviour, healthcare provision and wider determinants, including social, cultural and environmental (Wanless, 2004). The need to reorient public health approaches towards a broader understanding of risk factors was borne from consolidation of research evidence in the latter half of the 20th century which identified the important influence of social determinants on individual and population health. Dahlgren and Whitehead (1991) put forward a framework summarising the main determinants of health, represented as layers of influence (Figure 4.1).

Figure 4.1 Determinants of health (Dahlgren and Whitehead, 1991)



Age, sex and constitutional factors such as genetics are considered as non-modifiable risk factors, however other influences surrounding individuals in this framework are considered as modifiable through healthy public policy and individual lifestyle choices. Family and community influence on health behaviours and experiences are represented in the second layer and the wider influences on an individual's ability to maintain health is considered in the outer layer including living and working conditions, food supplies and access to essential goods and services including access to healthcare. Within this context, the inter-relationship of risk factors is considered as an important dynamic for health outcomes. Graham (2005) offers a useful framework (Figure 4.2) for examining the pathway of risk factors influencing health outcomes, paying particular attention to the social determinants of health. The pathway runs from the social structure to health and wellbeing. Graham highlights that determinants such as the education system impact on people's health and wellbeing via their social position and the intermediary factors associated with it. It is noteworthy that this framework provides one representation of a key set of pathways, and in this context it does not provide a complete picture.

Figure 4.2 Determinants of health pathways framework



Similar to general health status and singular conditions, multimorbidity has been linked with a range of socio-demographic factors including gender, age, educational status, income and deprivation (Schafer et al., 2012, Khanam et al., 2011, Agborsangaya et al., 2012, Marengoni et al., 2011, Walker, 2007, Barnett et al., 2012, Kirchberger et al., 2012). While few studies have examined the determinants of multimorbidity according to lifestyle risk factors, some studies point to the influence of increased BMI and low levels of physical activity on increased risk of multimorbidity (de Souza Santos Machado et al., 2012, Taylor et al., 2010, Nagel et al., 2008, Walker, 2007). The following sections of this thesis examine the factors associated with multimorbidity in previous research studies, including an assessment of the influence of social determinants on multimorbidity outcomes, however due to the cross-sectional nature of studies examined it is difficult to establish any evidence-base on causal pathways to multimorbidity.

4.2.1 Gender

Female gender was found to be associated with multimorbidity in cross-sectional studies of community samples, confirmed by longitudinal studies (Barnett et al., 2012, Cazale and Dumitru, 2008, Fuchs et al., 1998, Agborsangaya et al., 2012, Khanam et al., 2011) and this was generally found to be true across age groups in studies examining these trends. De Souza et al. (2012) also reported that multimorbidity was found to increase in women post-menopause (OR 4.4 CI 1.57-12.11) compared to pre-menopause in multivariate logistic regression analysis after controlling

for age effects. Marengoni et al. (2011) posit that women are more likely to be affected by non-fatal diseases such as osteoarthritis, compared to men, explaining some of the excess rates in multimorbidity between genders, however, this has not been adequately explored at a population level.

4.2.2 Age

The risk of multimorbidity is associated with increasing age (Gray et al., 2002, Boyd et al., 2007a, Britt et al., 2008, Marengoni et al., 2011, Schafer et al., 2012) and has been found to be especially prevalent in samples of very old persons (Kirchberger et al., 2012, Fuchs et al., 2012). However, recent evidence also points to substantial prevalence of multimorbidity in younger populations (Barnett et al., 2012, Taylor et al., 2010). Furthermore, crude analyses of multimorbidity prevalence indicate substantial heterogeneity in prevalence estimates and mean number of conditions according to age groups. Age however, in multivariate analyses, was generally modelled as a continuous variable, or analyses were stratified by age groups, and while these are valid approaches to examining age effects, this does make it difficult to delineate any differences in multimorbidity risk between age groups.

4.2.3 Family structure, living arrangement and social connectedness.

Multimorbidity prevalence has also been linked to family structure and living arrangement, mainly in studies with older samples; older persons living alone (Walker, 2007) and those not living with children aged 16 years and under were found to have an elevated risk of multimorbidity in multivariate analyses (Agborsangaya et al., 2012). Marital status was found to predict multimorbidity in a sample of rural-dwelling people in India (Khanam et al., 2011) and single individuals had a slightly higher risk of multimorbid compared to their married counterparts (OR 1.20 $p <= 0.001$). Living with family and having larger social networks were found to be protective of multimorbidity (Taylor et al., 2010, Marengoni et al., 2011), while individuals who were separated or divorced compared to those never married showed significantly higher odds of multimorbidity in multivariate analysis (Taylor et al., 2010).

4.2.4 Lifestyle risk factors

There is widespread consensus that behavioural risk factors contribute substantially to preventable chronic condition morbidity (Fine et al., 2004). Common chronic conditions are strongly associated with and causally related to four particular health behaviours: tobacco use, physical inactivity, unhealthy diet and harmful alcohol consumption. These four behaviours have been found to lead to four key metabolic/physiological changes: raised blood pressure, overweight/obesity, hyperglycemia and hyperlipidemia (Alwan, 2011). Lifestyle related factors have also been linked to an increased risk of multimorbidity for those reporting low physical activity (adjusted OR 2.7 CI 1.08-6.81) compared to those engaging in physical activity 3 or more times per week and for middle-aged smokers (OR 1.71 CI 1.02-2.86) compared to non-smokers. A substantially increased risk of multimorbidity has also been reported for obese compared to non-obese individuals (de Souza Santos Machado et al., 2012) and Taylor et al. (2010) found a significant relationship between multimorbidity and high waist circumference for younger and middle aged individuals. There was no effect found for alcohol consumption however in a study examining the issue (Taylor et al., 2010).

4.2.5 Social-determinants of multimorbidity

There is now substantial evidence documenting the powerful influence of a complex system of cultural, environmental, political, social, economic, behavioural and genetic factors on health status (Greene and Kreuter, 1991). Several studies have highlighted the role that socioeconomic status plays for health in later life (Walker et al., 2008 , Mackenbach et al., 1997, Bowling, 2004). The link between poverty and ill-health has been well documented and variations in life expectancy in developed countries have been attributed to income inequality and relative measures of poverty or deprivation compared to absolute measures of income or wealth (Wilkinson, 1996). Evidence suggests that at an individual level, the key determinants of health inequalities in later life are similar to those for other age groups and are mainly related to wealth and social position (Lloyd-Sherlock, 2000). Older people who are living in poverty demonstrate characteristics borne as a result of both lifecycle factors but also factors relating specifically to conditions in later life. Those who have experienced adverse social conditions earlier in life can experience the accumulation of these factors even more acutely in later life and may suffer reduced mobility, increased morbidity and premature mortality as a result (Farrell et al., 2008).

Research shows that older people in Ireland are at an increased risk of poverty in comparison to working adults (Prunty, 2007). This experience of poverty in later life has been found to be associated with increased risk of chronic conditions (Farrell et al., 2008). In addition, the quality of one's dwelling has an important direct role in influencing quality of life, morbidity and mortality (Smith and Kington, 1997, Fox and Goldblatt, 1982, Evandrou and Victor, 1989). Chronic condition prevalence is higher for people who have poor living conditions such as dampness and pollution; this is significant in that older people suffer high levels of housing deprivation in Ireland compared to other age groups (Prunty, 2007).

Additional to the impact of poor socioeconomic status on health, studies show that inequalities at a community level can also impact the health status of individuals, independently of individual socioeconomic status (Wilson, 1987). Poorer people benefit from sharing neighbourhoods with more affluent individuals linked to (i) better functioning institutions and better services in more affluent areas and (ii) learning from each other (Wilson, 1987). Kawachi and Berkman (2003) contend that the widening gulf between rich and poor individuals in society is mirrored by a growing divergence in their residential environments '*such that affluent people are increasingly living and interacting with other affluent people, while the poor increasingly live and interact with other poor people*'. It is argued that this residential segregation will continue to ensure that neighbourhoods remain relevant to addressing health disparities. MacIntyre and Ellaway (2003) argue that evidence is now pointing towards the importance of contextual factors. While '*who you are*' explains a lot of geographical variation in health outcomes, there is also an effect of '*where you are*'. The balance of evidence appears to be pointing to the characteristics of places where people live having an influence on the health independent of the characteristics of the people who reside in them.

Reflecting this established literature, multimorbidity prevalence was also found to be consistently higher in persons with lower socioeconomic status measured at an individual level for educational attainment (Marengoni, 2008, van den Akker et al., 1998b, Taylor et al., 2010), income (Agborsangaya et al., 2012, Cazale and Dumitru, 2008), public health insurance (van den Akker et al., 1998b, Glynn et al., 2011), unemployment, food insufficiency (Sharkey, 2003) and socioeconomic class (Uijen and van de Lisdonk, 2008).

The relationship between education and multimorbidity was attenuated in one study after controlling for income levels (Agborsangaya et al., 2012). The effect of education on multimorbidity was also attenuated in multivariate analysis in a recent study on a German

cohort (Nagel et al., 2008). Nagel et al. (2008) found that increased BMI and smoking status were intermediate factors in the association between education and multimorbidity. While Taylor et al. (2010) found multimorbidity to be inversely associated with income, especially in middle age groups; income was not independently significant in predicting multimorbidity in multivariate analysis. However other studies found that lifestyle risk factors for chronic conditions, could not fully explain the socioeconomic inequalities in multimorbidity measured by education levels, suggesting an independent effect of educational status on multimorbidity risk. This finding was attributed to a lack of awareness of healthy behaviours in less well-educated persons, a lower ability in those from poorer backgrounds to manage their own health and poorer access to preventative services. While this hypothesis has not been tested in a European context, literacy levels were found to be independently associated with multimorbidity in a study by Khanam et al. (2011) of people aged 60 years and older in rural Bangladesh. Modest differences were also found for socioeconomic status measured at an area level. Modest increases in multimorbidity prevalence in crude analysis were found for individuals living in more deprived areas in Scotland compared to more affluent areas (Barnett et al., 2012). However the relationship between deprivation and multimorbidity has not yet been explored in multivariate analysis.

Findings of a recent study indicated that even after controlling for current socioeconomic and demographic characteristics, childhood financial hardship was positively associated with a higher number of concurrent chronic conditions (Tucker-Seeley et al., 2011). Lifetime earnings were found to modify the relationship between financial hardship in childhood and multimorbidity.

4.2.6 Other factors associated with multimorbidity

Differences in crude prevalence rates were also found between a large urban area (Quebec) and those recorded for the rest of Canada (Cazale and Dumitru, 2008) suggesting higher rates of multimorbidity in urban populations, however no study identified in this review explore differences in multimorbidity risk between urban and rural areas in multivariate analysis. Multimorbidity was also found to be associated with nervousness and unfavourable self-assessed health, however the direction of effect of both nervousness and unfavourable self-assessment on multimorbidity has not yet been established and it is likely that these could also be presenting as a result of multimorbidity burden in individuals. A review of the causes of comorbidity conducted by Gijsen et al. (2001) identified four articles examining genetic and

familial associations as potential causes of co-occurring conditions; however this hypothesis was not confirmed by the studies under review.

4.3 Empirical analysis

4.3.1 Modelling multimorbidity

Bivariate and multivariate regressions were employed to analyse crude and adjusted associations between independent variables, grouped according to the factors outlined in the analytical framework (outlined in the following section), and a range of multimorbidity outcomes. Multimorbidity was conceptualised in two different ways in this study.

An initial analytical approach explored the factors associated with increasing levels of chronic conditions in a two-part modelling process. Tucker-Seeley et al. (2011) proposed that the factors associated with increasing numbers of concurrent conditions (i.e. levels of multimorbidity) may be substantively different from the factors associated with the presence or absence of morbidity. Therefore, a two-part process was employed which allowed for the testing of factors associated with morbidity distinct to the factors associated with increasing levels of multimorbidity.

A second analytical approach explored the factors associated with different types of multimorbidity; as indicated in earlier chapters, there are three types of multimorbidity investigated in this thesis. The first is what is generally defined as multimorbidity in the literature: ≥ 2 co-occurring conditions in an individual. However, considering physical and mental health conditions equally may be masking distinct processes and outcomes related to the co-occurrence of physical and mental health conditions. It has been suggested in the literature that multimorbidity with a mental health component is more prevalent in less affluent individuals (Barnett et al., 2012). Results presented in Chapter 3 indicate that this is also the case for people in Ireland. However, the factors that may be driving this difference have not yet been elucidated. A multinomial logistic regression model is employed to investigate the difference in independent variables predicting each category of the variable.

The main objective in model specification was to develop an explanatory model of exposures and confounders that are important influences on the outcome or dependent variable. In

advance of specifying statistical models an underlying analytical framework was developed (*see* Figure *4.3)*. This aided in identifying and refining explanatory variables to be included in the multivariate models. The analysis for all empirical models followed a general sequence. Descriptive and bivariate analyses were conducted for each outcome of interest. Initially, estimates of the dependent variables were cross-tabulated with each independent variable to investigate crude patterns in the data and detect cells with low numbers. Models for unadjusted associations between independent and dependent variables were then estimated in bivariate analysis in order to identify significant relationships between variables.

In the case of categorical explanatory variables, dummy variables were created to contrast different categories. For each categorical variable a baseline category was defined and all remaining categories were contrasted to the baseline. For k categories of a variable, $k-1$ dummy variables were created to investigate the differences in each category with respect to the dependent variable. Variables were examined individually at first in bivariate analysis for each outcome of interest. Groups of similar variables and alternative versions of the same variables were examined to assess the strength of association with each outcome of interest.

As the primary aim of regression analyses in this study was to develop an explanatory model of independent variables on outcomes, formal stepwise techniques were not applied as recommended by Kirkwood and Sterne (2003) and Hosmer and Lemeshow (2000). The selection procedure for explanatory variables in all multivariate models was based on a predefined analytical framework and purposeful selection of variables from bivariate analysis. Assessment of significance in bivariate models at more traditional levels such as 0.05 can fail to identify factors known to be important in predicting outcomes in health research, therefore as a general rule, measures that were significant at the p=0.10 bivariate level were considered for multivariate models to examine factors independently associated with outcomes (Bursac et al., 2008, Hosmer and Lemeshow, 2000). A general to specific method was employed for all models, starting with a complex model of all potential explanatory variables and progressively excluding variables that were found to be insignificant in the overall model (Greene 2008 & Campos 2005). Following the iterative process of variable selection, covariates were removed from the models if they were non-significant and not a confounder. Significance was evaluated at 0.10 alpha level and confounding was estimated as a change in any remaining parameter of greater than 20% compared to the full model.

All independent variables were tested for multicollinearity by examining their Variance Inflation Factor (VIF) and tolerance to assess the effect of potentially related dependent and independent variables in the presence of each other (for example house value and educational status). It was considered that poverty in childhood and more negative self-rated health in childhood could be correlated, with poverty in childhood a known predictor of poorer child health outcomes (Wood, 2003). This was not however confirmed in testing and both variables were retained for modelling in multivariate analyses.

As a model with few variables will have greater numerical stability and will be more easily generalisable (Hosmer and Lemeshow, 2000), the most parsimonious models were retained and presented in the results. Sex and age variables were retained in all models as they have been previously shown to demonstrate strong associations with multimorbidity (Marengoni et al., 2011). Estimates for all models are presented in their exponentiated form as either odds ratio's (ORs), incident rate ratios (IRRs) or relative risk ratios (RRRs). All estimates are presented with corresponding 95% confidence intervals to two decimal places, and P-values. P-values are presented as <0.001, <0.01 or corresponding value to two decimal places if significance level is higher than 0.01.

Three *a priori* interaction effects were examined for effects on morbidity and increasing levels of multimorbidity. It was hypothesised that the effect of increasing age on morbidity and multimorbidity levels could be moderated by sex, as females have been found to have a higher risk of multimorbidity. As Barnett et al. found increased levels of multimorbidity in younger deprived patients in Scotland; a second interaction was estimated between increasing age and levels of relative material deprivation. In addition, given that eligibility to the GMS is largely determined by income levels (i.e. as discussed in Section 3.1.1.3, assessment for a medical card is based on an income means test with nationally established income thresholds although a proportion of the population also qualify on the basis of particular health needs and participation in Government activation schemes (Nolan et al., 2007)), it was considered that the effect of income on morbidity and multimorbidity could be moderated by GMS status. However, as outlined in Section 2.10, data on income in TILDA was limited by a large amount of missing responses. Therefore two proxy measures of SES were employed to examine potential interaction effects with GMS in regression models; household value is examined as a proxy measure of wealth and the imported SAHRU deprivation variable also provides an area-based measure of socioeconomic status for all TILDA respondents.

Interaction effects were also examined in the multinomial multivariate analysis of multimorbidity. Recent findings from a large scale study in Scotland indicated a higher prevalence of multimorbidity in more deprived areas, occurring 10-15 years earlier in people from the most deprived compared to the most affluent areas. Prevalence of multimorbidity with a mental health component was also significantly higher in more deprived areas (Barnett et al., 2012). Therefore it was hypothesised in this study that indicators of poorer socioeconomic status would have a synergistic effect on both types of multimorbidity (i.e. with and without a mental health component in younger age groups). Given the inter-relationship between income and GMS as detailed above, interaction effects were also estimated between GMS and the two proxy variables for SES: house value and deprivation.

4.3.2 Data and variables

4.3.2.1 Dependent variables

Multimorbidity level is modelled as a count variable for increasing numbers of chronic conditions from 0 to ten or more. Multimorbidity type is not ordered and is characterised as a categorical variable with three independent categories. The first category contains anyone in the sample without multimorbidity (i.e. those with less than two of any of the 25 self-reported conditions examined). The second contains those who have two or more physical conditions, but no mental health condition. The third contains only those with two or more conditions, one of which is a mental health condition. The three categories of multimorbidity type are summarised as:

1. ≤ 1 chronic condition
2. the presence of multimorbidity without a mental health component
3. the presence of physical-mental health multimorbidity

4.3.2.2 Independent variables

An analytical framework for analysing the predictors of multimorbidity was developed based on the literature on multimorbidity and determinants of other measures of health status in mid-to-late life. This is illustrated in Figure 4.3. Measures include both modifiable and non-modifiable factors as outlined by the Dahlgren and Whitehead framework discussed above and variables included in the modelling were determined by the available data. It is proposed that

multimorbidity is determined by a range of factors that can be categorised under the following headings:

- Demographic factors
- Socioeconomic factors
- Lifestyle factors
- Childhood factors
- Social/psychosocial factors and
- Access to healthcare

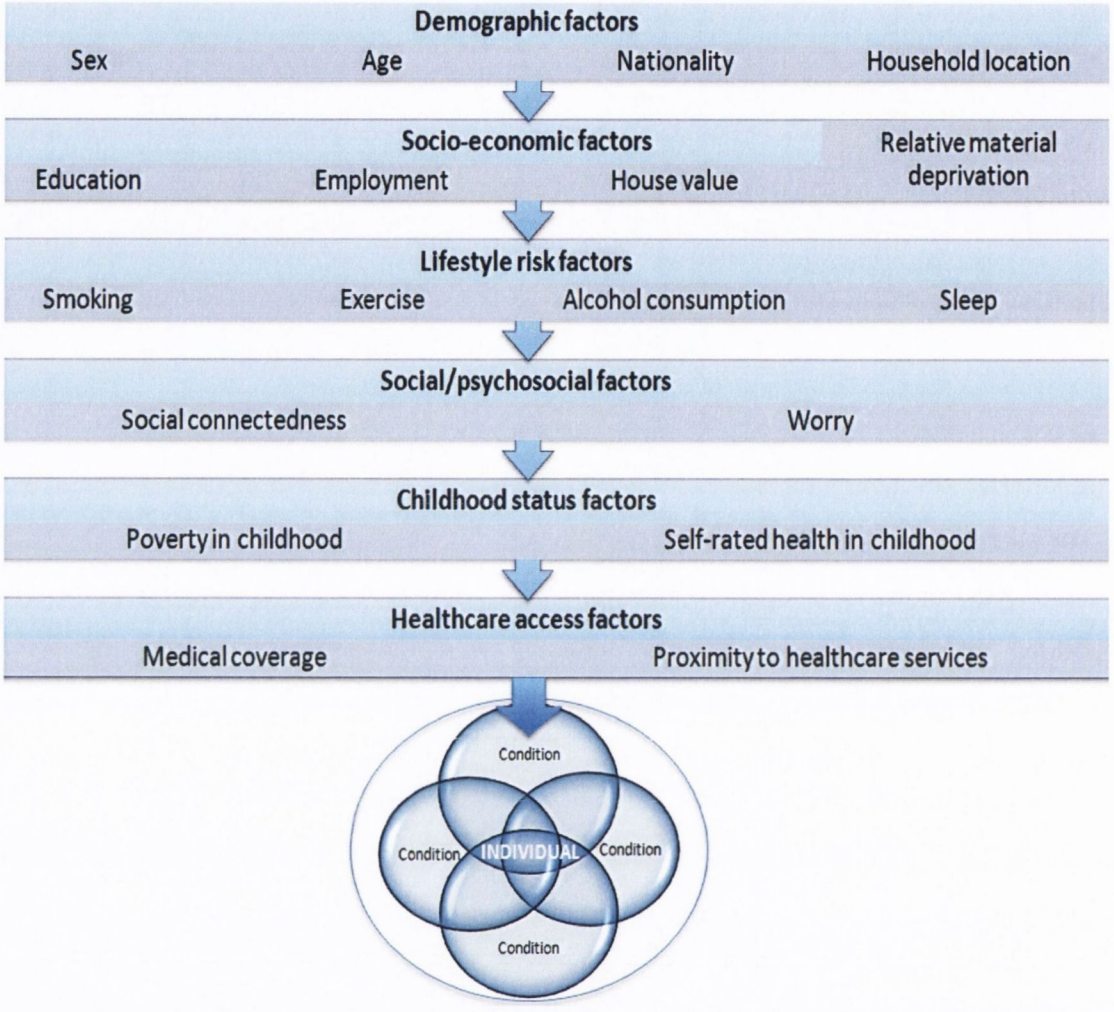
However, it is noted that due to the cross-sectional nature of analyses in this study that the causal mechanisms and direction of effect for independent variables cannot be determined and significant associations found in this study require further examination in longitudinal studies to determine the direction of effect. Furthermore, the lack of longitudinal analyses in this study precludes any examination of the pathways of factors influencing multimorbidity risk as described by Graham in Figure 4.2. However, it is acknowledged that factors examined in this study do not act independently on multimorbidity risk and that several pathways with inter-related factors may be influencing the accumulation of multimorbidity in this population. Future studies examining these factors in longitudinal analyses of TILDA data will provide a more insightful examination of such pathways of influence on multimorbidity risk.

The term risk is used here as an abbreviation of relative risk ratio associated with independent factors modelled in multivariate analyses and arrows in the analytical framework (Figure 4.3) denote steps in the analytical chain but not causality through the chain.

DEMOGRAPHIC FACTORS

Demographic factors were categorised as described in previous analysis in Chapter 3. These included nationality and household location. Age was categorised into 5-year age bands. A further binary variable examining the location of respondent's household was categorised as living in a rural or urban area. While it is likely that multimorbidity risk varies according to ethnicity, it was not possible to fully explore this due to the small number of non-Irish sampled in the TILDA study, therefore examination of ethnicity is limited to Irish, Northern Irish and British, with other nationalities grouped into one category due to low numbers (n=102).

Figure 4.3 Analytical framework adopted for modelling the factors associated with multimorbidity



SOCIOECONOMIC FACTORS

A large selection of variables was available in TILDA to measure economic factors including include education, income, assets and specific measures of social class and socioeconomic group. However, several of these indicators had a large proportion of missing data; therefore choice of economic variables in this analysis was limited. As in previous analysis house value was favoured over other measures of individual socioeconomic status and income and wealth variables as it was available for the full TILDA sample and previous research indicates the impact of housing deprivation on the health status of older individuals in Ireland (Prunty, 2007). A variable on area level relative material deprivation, derived from the SARHU index was also considered as an explanatory measure of socioeconomic status. This was categorised as described in Chapter 3. It was intended to model the deprivation measure merged into the TILDA dataset as an area level indicator of relative material deprivation. The data structure in

TILDA, sampled within a large number of electoral divisions did not allow for investigation of the hypothesis that multimorbidity is more pronounced in more deprived areas, even after controlling for the effects of individual level socioeconomic status indicators such as education and income. However, the structure of the data across areas sampled in TILDA was too diverse to allow for any meaningful analysis of an area level effect on multimorbidity risk. A single level modelling approach was then favored over a multi-level modelling approach and deprivation levels were modeled as a proxy indicator of individual deprivation status. This may explain the lack of discriminatory power in analyses.

Although it is likely that house value and the area measure of deprivation status are correlated, with area deprivation status likely predicting house value, it was decided to estimate the two variables at a bivariate level to assess the strongest association between variables and outcomes of interest. If both variables were significant at the bivariate level, they were both retained for multivariate modelling. However, in the case that both were significantly associated with a dependent variable in multivariate models, tests of multicollinearity were employed and deprivation status was favoured if evidence of multicollinearity was detected.

Education status is likely to impact on the risk of multimorbidity as described in Chapter 3 and has been found to predict multimorbidity in other studies. However, despite extensive evidence on the causal relationship between education and health outcomes in later life (Grossman, 1972), the relationship may be spurious for several reasons. Firstly, higher educated individuals have higher earning potential and hence, education may be acting as a proxy for an income effect. Secondly, the opportunity costs for poor health are more pronounced for more educated individuals. Nonetheless, the effect of educational status on multimorbidity due to issues of health literacy in later life (Berkman et al., 2011) may be important. Educational attainment is modelled as a categorical variable, classified into three categories from higher to lower levels of education (third level and above, secondary, primary or none). The discriminatory power of education as defined in the TILDA dataset is limited in multivariate analyses due to the change in access to education for older generations in Ireland detailed in Chapter 2.

Previous research points to the effect of unemployment on multimorbidity (Sharkey, 2003). Given the high prevalence of multimorbidity recorded for those who were permanently sick or disabled in earlier analyses and the low prevalence among those who were employed, particularly among the self-employed, employment status was coded according to eight response options including: retired, employed (including unpaid work in family business,

temporarily away from work or participating in apprenticeship or employment programme - such as Community Employment), self-employed (including farming), home-maker, permanently sick or disabled and unemployed (including those in education or training).

LIFESTYLE RISK FACTORS

The lifestyle risk factors assessed in TILDA include smoking, alcohol consumption, physical activity, sleep and BMI.

Smoking

Smoking was measured in a standard way using the following questions: '*Have you ever smoked cigarettes, cigars, cigarillos or a pipe daily for a period of at least one year?*' '*Do you smoke at the present time?*' '*How many cigarettes do/did you smoke on average per day?*' From this information, smoking status was aggregated into a five-category response variable indicating never smoker, past smoker, light smoker (1–9 cigarettes), moderate smoker (10–19 cigarettes), and heavy smoker (20 or more cigarettes).

Exercise

Exercise in TILDA was categorised according to the IPAQ short form questionnaire which has been validated in populations below and above 65 years of age (Craig et al., 2003, Tomioka et al., 2011). It was coded into a categorical variable with three categories:

- Low (category 1) - This is the lowest level of physical activity. Those individuals who do not meet criteria for categories 2 or 3 are considered inactive.
- Moderate (category 2) - Any one of the following 3 criteria:
    - 3 or more days of vigorous activity of at least 20 minutes per day; or
    - 5 or more days of moderate-intensity activity or walking of at least 30 minutes per day; or
    - 5 or more days of any combination of walking, moderate-intensity or vigorous-intensity activities achieving a minimum of at least 600 MET-min/week.
- High (category 3) - Any one of the following 2 criteria:
    - vigorous-intensity activity on at least 3 days and accumulating at least 1500 MET-minutes/week; or
    - 7 or more days of any combination of walking, moderate-intensity or vigorous-intensity activities achieving a minimum of at least 3000 MET-minutes/week.

Alcohol

Alcohol consumption is assessed in the TILDA Self-Completion Questionnaire where respondents are asked to rate their frequency of alcohol consumption, recorded on a scale from one (almost every day) to seven (not at all in the last 6 months). Intensity of alcohol use was measured according to a five-category variable indicating non-drinking or rarely drinking and increasing intensity of alcohol consumption per week.

BMI

BMI status was only measured for respondents attending for health assessment resulting in a large number of missing responses (n=2,286). However obtaining a valid objective measure was favoured over self-reported BMI status, and given the important well-documented association between BMI and health outcomes, it was decided to include BMI status in this study to assess its association with multimorbidity. Missing cases were assigned as a separate category of BMI status allowing for the inclusion of the variable in the multivariate analysis and analysis of the non-attenders grouping for BMI.

Sleep

The relationship between sleep and health status is emerging as an important issues in recent investigations (Gallicchio and Kalesan, 2009); however it is also acknowledged that the effect of sleep on multimorbidity may be circular in that individuals reporting multimorbidity may also report trouble sleeping as a result of pain, discomfort or linked to medication side-effects. Trouble sleeping was measured by the respondent indicating if they had trouble falling asleep: rarely or never; sometimes or always.

Childhood status factors

As discussed in previous sections, childhood financial hardship has been found to predict multimorbidity even after controlling for other socioeconomic indicators and demographic variables. A series of questions were asked in TILDA to assess the childhood experiences of respondents. A measure assessing the wealth of the respondent's family in childhood was classified into three categories: pretty well off financially, about average, poor.

Respondents were also asked to rate their general health when they were growing up. This was measured on a five-category likert scale: excellent, very good, good, fair, poor. This was dichotomised into favourable or unfavourable self-assessed health in childhood.

Social / psychosocial factors

Social connectedness

Two possible measures of social connectedness were considered as independent variables. Social connectedness was modelled as an ordinal variable with four levels (as defined in Chapter 5), from most integrated to most isolated based on Berkman's Social Networks Index (SNI) as a composite measure of four types of social connection: marital status (married versus not); sociability (number and frequency of contact with children, close relatives, and close friends); church group membership; and membership in other community organisations, used to assess the extent of the respondent's social network. These domains are not strongly correlated and each of these domains has been found to influence health through different mechanisms (Cohen, 2004). A further variable on marital status was considered and this was favored over a measure of living arrangement as it allows for the investigation of the high prevalence of multimorbidity in the separated/divorced grouping as reported in results for Chapter 3. As the social connectedness measure contains a component on marital status the two measures were highly correlated, therefore the measure on social connectedness was favored over marital status.

Worry

In addition, longitudinal investigations in the US suggest that high levels of worry may increase the risk of CHD (Kubzansky et al., 1997). Daily worry is related to low heart rate variability, a surrogate marker for autonomic dysfunction (Brosschot et al., 2007). This study includes a variable on worry that may act as an explanatory factor in predicting multimorbidity. It is measured using a question from the Penn State Worry Questionnaire (short-form), respondents were asked to rate the following statement "I have been a worrier all my life" and scores are recorded as a dichotomous variable indicating that the respondent is a worrier or not a worrier.

Access to healthcare

Healthcare coverage has been found to be significantly associated with levels of healthcare utilisation in Ireland and it is likely that those who have healthcare cover are more likely to attend services for preventative healthcare (Nolan, 2007). Healthcare coverage has been found to be significantly associated with levels of healthcare utilisation in Ireland, both in primary and acute care and a body of evidence also suggests the important role of healthcare services in diagnosing additional conditions, which may lead to increased reporting of multimorbidity compared to non-attenders at healthcare services. Therefore healthcare coverage was included in analyses to control for differences in opportunities for preventative care and also to account for potentially higher likelihood of diagnosis among those attending services more regularly. Two variables were available in TILDA to gauge access to healthcare services. These included GMS status and private health insurance status. As described in Section 3.2.1.7, GMS status is measured as a binary variable indicating full entitlement to a GMS medical card or non-entitlement. TILDA respondents were also asked to report if they had a health insurance policy at the time of survey, and what level of cover they had. For the purpose of this study, private health insurance was measured as a binary variable indicating presence or absence of a health insurance policy. Healthcare coverage is then modelled in analysis as a composite variable of GMS medical card entitlement and private health insurance coverage.

Variables on proximity to healthcare services were merged into the TILDA data, to provide information on proximity to the nearest healthcare services for each respondent in TILDA (variables are described in full in Chapter 2). A variable on nearest GP (in meters), compared to all GP practices in Ireland was included as an independent variable in models to control for the potential effects of proximity to healthcare services on use of preventative services and on increased diagnosing.

Table 4.1 Summary of dependent and independent variables examined in multivariate regression analyses

Dependent variables	
Multimorbidity Level	0 to 10+ co-occurring chronic conditions
Multimorbidity Type	1 = ≤ 1 condition, 1 = physical multimorbidity only, 3 = physical multimorbidity with at least one mental health condition
Independent variables	
Demographics	
Age group	0 = 50-54 years, 2 =55-59 years, 3=60-64 years, 4=65-69 years, 5=70-74 years, 6=75-80 years, 7=80+ years
Sex	0 = male, 1 = female
Nationality	0 = Irish, 1 = Northern Irish, 2 = British, 3 = other
Location	0 = urban, 1 = rural
Economic factors	
Educational status	0 = third level +, 1 = secondary, 2 = primary/none
Employment status	1 = employed, 2 = self-employed, 3 = retired, 4 = home-maker, 5 = in education or training, 6 = permanently sick or disabled, 7 = unemployed
House value	1 = >€560,001, 2 = €400,001-560,000, 3 = €240,001, 4 = €80,000-240,000, 5 = < 80,000
Relative material deprivation	1 to 10, from most affluent to least affluent
Lifestyle factors	
Smoking	0= never smoker, 1= past smoker, 2=light smoker (1–9 cigarettes), 3=moderate smoker (10–19 cigarettes), 4=heavy smoker (20 or more cigarettes).
Alcohol status	0 = none or rare, 1 = 1-2 days per week, 2 = 3-4 days per week, 3 = almost every day, 4 = unclassified
Exercise status	0 = high, 1 = moderate, 2 = low, 4 unclassed
Sleep	0 = rarely/never, 1 = sometimes, 2 = most of time
BMI	0 -= normal/underweight, 1 = overweight, 2 = obese, 3 = unclassified
Childhood factors	
Poor childhood	0= well off, 1 = average, 2 = poor
Unfavourable self-assessed health in childhood	0 = favourable, 1 = favourable.
Social/psychosocial factors	
Social Connectedness	0 = most integrated, 1 = moderately integrated, 2 = moderately isolated, 3 = most isolated, 4 = unclassified
Marital status	1 = married, 2 = =never married, 3 = separated/divorced, 4 = widowed
Worrier	0=yes 1=no
Healthcare access	
Medical coverage	0 = GMS and private insurance, 1 = private insurance only, 2 = GMS only, 3 = no additional cover
Minimum distance to GP	1 = closest 10%, 2 = next 20%, 3 = next 20%, 4 = next 20%, 5 = next 20%, 6 = furthest 10%

4.3.3 Data cleaning

There were no missing cases for the dependent variables. Several of the independent variables modelled in the analyses had missing cases. Frequencies and weighted percentages for all data

are presented in respective tables as well as numbers of missing cases. Where variables were missing fewer than 20 cases these were dropped in advance of analyses using listwise deletion. For variables with multiple categories and a large proportion of missing data, a separate "unclassified" category was created for the missing cases. For example, those who did not report BMI were assigned to an unclassified category.

4.4 Results

Sample size after dropping the small number of missing cases was restricted to 8,128 cases. The mean number of conditions in the full sample was 2.0 (sd 1.8). As presented in Chapter 3, mean number of conditions varied significantly and substantially according to different demographic characteristics. Descriptive statistics on the characteristics of respondents with multimorbidity and according to type of multimorbidity (i.e. physical only or physical and mental health multimorbidity) were also presented in Chapter 3. To examine the effect of each of the hypothesised factors listed above on multimorbidity outcomes, a series of bivariate analyses were completed. Only variables significant at the α = 0.10 level in bivariate models were retained for modelling in multivariate analyses. Bivariate analysis results are presented in Appendix 4.1 for all outcomes of interest.

4.4.1 Factors associated with morbidity and increasing levels of multimorbidity

It has been suggested that the factors associated with developing a chronic condition may be different than those driving the accumulation of additional chronic conditions (Tucker-Seeley et al., 2011). To test if any real differences exist between the factors associated with having one condition distinct from the accumulation of more than one condition (i.e. multimorbidity), analyses were performed in two-parts. An initial logistic regression model was employed to estimate the effect of independent variables on having one chronic condition. A zero-truncated model was then estimated for increasing levels of chronic conditions from 1 to 10 or more conditions. Formal tests indicated that the dependent variable (i.e. concurrent counts of chronic conditions) was over dispersed (Shapiro-Wilk test $z=13.4$ $p<0.001$) with a high proportion of respondents not experiencing any chronic condition (21.0 95% CI 20.1-21.9), supporting a zero-truncated negative binomial modelling approach (Vuong = 6.32 $p<0.001$). All independent variables significant at the α 0.10 level in bivariate models were considered in the multivariate

models. Those that were significant at the same level and were not acting as confounders were retained in the overall models. Formal tests indicated good fit for the logistic model (Hosmer and Lemeshow X^2 = 11.76 p=0.16) and for the zero-truncated negative binomial model (McFadden's adjusted R^2 = 0.05). Estimates for both models are presented in Table 4.2. The final logistic regression model was specified as:

$$Logit(\mathrm{Y}) = (\beta_1 sex + \beta_2 age5yrs_i + \beta_3 sex * age5years_i + \beta_4 Location + \beta_5 employ_i + \beta_6 smoke_i + \beta_7 alcohol_i + \beta_8 exercise + \beta_9 BMI_i + \beta_{10} sleep_i + \beta_{11} childhealth + \beta_{12} worry + \beta_{13} medcover_i$$

The final zero-truncated negative binomial model was specified as:

$$\mathrm{Y} = f(\beta_0 + \beta_1 sex + \beta_2 age5yrs_i + \beta_3 sex * age5years_i + \beta_4 employ_i + \beta_5 smoke_i + \beta_6 alcohol_i + \beta_7 exercise + \beta_8 BMI_i + \beta_9 sleep_i + \beta_{10} childhealth + \beta_{11} worry + \beta_{12} medcover_i$$

Table 4.2 Multivariate regression analyses – Two-part model estimating the factors associated with having one condition only (logistic model) and increasing levels of multimorbidity (zero-truncated negative binomial model)

	Multivariate logistic Model		Zero-truncated Multivariate Negative Binomial Model	
	Odds Ratio (95% C.I.)	P-value	Incident Rate Ratio (95% C.I.)	P-value
Demographic Factors				
Sex				
Male (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Female	1.0 (0.8-1.3)	0.81	1.3 (1.1-1.5)	<0.01
Age in 5 years				
50-54 (ref)	1 (1.0-1.0)	.	1 (1.0-1.0)	.
55-59	1.2 (0.9-1.5)	0.21	1.1 (1.0-1.2)	0.03
60-64	1.6 (1.2-2.0)	<0.01	1.1 (1.0-1.2)	<0.01
65-69	1.8 (1.3-2.4)	<0.001	1.3 (1.2-1.4)	<0.001
70-74	1.9 (1.3-2.7)	<0.001	1.2 (1.1-1.3)	<0.001
75-79	2.6 (1.7-3.9)	<0.001	1.3 (1.1-1.4)	<0.001
80-84	1.8 (1.1-3.0)	<0.01	1.3 (1.1-1.5)	<0.001
85+	3.3 (1.6-6.8)	<0.01	1.1 (1.0-1.3)	0.09
Sex*age interaction (female compared to male by age)				
50-54	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
55-59	1.4 (1.0-1.9)	0.05	1.0 (0.9-1.1)	0.92
60-64	1.3 (0.9-1.9)	0.13	1.0 (0.9-1.1)	0.98
65-69	2.1 (1.4-3.1)	<0.001	1.0 (0.9-1.1)	0.75
70-74	1.7 (1.1-2.6)	0.03	1.1 (1.0-1.2)	0.27
75-79	1.5 (0.8-2.5)	0.19	1.1 (1.0-1.3)	0.02
80-84	2.5 (1.2-5.2)	0.01	1.0 (0.9-1.1)	0.97
85+	0.7 (0.3-1.8)	0.52	1.3 (1.1-1.5)	<0.01
Household location				
Rural (ref)	1 (1.0-1.0)	.		
Urban	1.2 (1.1-1.4)	<0.01		

Economic factors				
Employment status				
Employed /self-employed	1.0 (1.0-1.0)		1.0 (1.0-1.0)	.
Retired	1.4 (1.1-1.6)	<0.01	1.1 (1.1-1.2)	<0.001
Home-maker	1.0 (0.8-1.2)	0.80	1.1 (1.1-1.2)	<0.001
Unemployed or in education/training	0.9 (0.7-1.2)	0.59	1.1 (1.0-1.2)	0.05
Permanently sick or disabled	5.4 (3.3-9.1)	<0.001	1.5 (1.4-1.6)	<0.001
Unclassified	1.4 (0.8-2.4)	0.22	1.2 (1.0-1.3)	0.01
Lifestyle factors				
Smoking status				
Never (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Past	1.2 (1.0-1.3)	0.02	1.1 (1.1-1.1)	<0.001
Light	1.3 (0.9-1.8)	0.17	1.0 (1.0-1.1)	0.29
Moderate	1.2 (0.9-1.5)	0.18	1.0 (1.0-1.1)	0.44
Heavy	0.9 (0.7-1.2)	0.56	1.1 (1.0-1.2)	<0.01
Alcohol status				
1-2 days p/w (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
None or rare	0.9 (0.8-1.1)	0.39	1.1 (1.0-1.1)	<0.01
3-4 days p/w	1.1 (0.9-1.3)	0.37	1.1 (1.0-1.1)	<0.01
Almost every day	1.3 (1.1-1.7)	0.02	1.1 (1.0-1.2)	<0.001
Unclassified	1.1 (0.8-1.6)	0.42	1.1 (1.0-1.2)	<0.01
Exercise status				
High (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Moderate	1.1 (1.0-1.3)	0.05	1.1 (1.0-1.1)	<0.001
Low	1.4 (1.2-1.7)	<0.001	1.2 (1.1-1.2)	<0.001
Unclassified	0.7 (0.4-1.2)	0.21	1.1 (0.9-1.2)	0.52
BMI				
Normal (and underweight)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Overweight	1.3 (1.1-1.5)	<0.01	1.1 (1.0-1.1)	0.01
Obese	2.0 (1.6-2.4)	<0.001	1.2 (1.1-1.3)	<0.001
Unclassified	1.0 (0.9-1.2)	0.75	1.0 (1.0-1.1)	0.87
Trouble sleeping				
Rarely/never (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Sometimes	1.5 (1.3-1.7)	<0.001	1.1 (1.1-1.1)	<0.001
Most of the time	2.0 (1.6-2.5)	<0.001	1.2 (1.2-1.3)	<0.001
Childhood factors				
Health in childhood				
Favourable	1 (1.0-1.0)	.	1 (1.0-1.0)	.
Unfavourable	2.7 (1.9-3.8)	<0.001	1.2 (1.1-1.3)	<0.001
Social/ Psychosocial Factors				
Worry				
Not a life worrier	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Life worrier	1.7 (1.3-2.2)	<0.001	1.2 (1.2-1.3)	<0.001
Unclassified	0.9 (0.6-1.1)	0.28	1.0 (1.0-1.1)	0.50
Access to Healthcare				
Healthcare coverage				
No additional coverage (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
GMS only	1.6 (1.3-1.9)	<0.001	1.2 (1.1-1.3)	<0.001
Insurance only	1.1 (0.9-1.3)	0.29	1.1 (1.0-1.1)	0.02
GMS * insurance	1.8 (1.4-2.3)	<0.001	1.2 (1.1-1.3)	<0.001
LR-sqr(dfres)	792.23 (43)		1,571.79 (42)	
N	8,126		6,404	
AIC	7,552.9		22,096.8	
BIC	7,861.0		22,394.5	

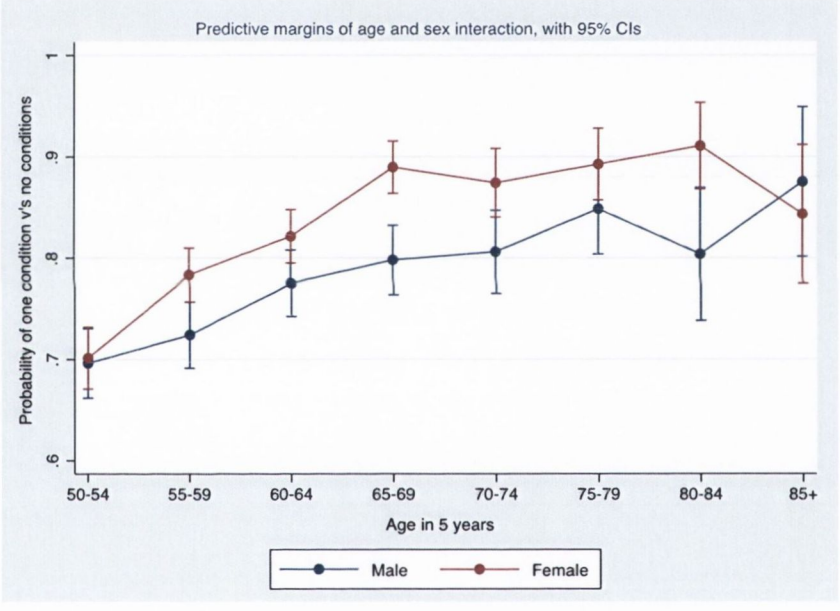
* All independent variables retained in the model were significant for both logistic and zero-truncated negative binomial regression analyses at the α 0.05 level.

Each factor associated with morbidity in the logistic model (Model A) are presented and discussed compared to those associated with increasing levels of multimorbidity in the zero truncated model (Model B). No effect was found for sex, on morbidity after controlling for all other factors, however being a female was associated with a 30% increased odds of increasing multimorbidity levels. Increasing age was associated with morbidity; increasing linearly up to age 75 to 79 years, however the odds of morbidity in those who were aged 80-84 was the same as those ten years younger (OR 1.9). The odds of morbidity rose again in the oldest age group, where a threefold increased odds was observed compared to those in the youngest age category. However, the effect of increasing age on concurrent levels of multimorbidity was small and did not appear to be linear. This was confirmed in a further test, where the overall effect of increasing age on multimorbidity levels was not significant ($p>0.10$). There was a small effect of household location on morbidity; those living in urban locations had a 20% increased odds, however, this variable was dropped for non-significance in the model on multimorbidity levels. Unsurprisingly, those who reported being permanently sick or disabled had the highest recorded odds of morbidity (OR 5.5). Furthermore, the hypothesis that they also have substantially higher multimorbidity was confirmed; compared to those in employment they were one and a half times as likely to report increasing multimorbidity.

Only past smoking status was associated with morbidity after controlling for other factors. Past and heavy smoking were associated with increased multimorbidity although the observed effects were small. Compared to moderate alcohol consumption, drinking alcohol every day was associated with a 30% increased odds of morbidity. Not consuming alcohol or only consuming it rarely as well as drinking more than 3 days a week had a slight increased odds of increasing multimorbidity, although the effect sizes were again small ($\leq$ 10%). Low levels of exercise and trouble sleeping were associated with both morbidity and increasing levels of multimorbidity. Obesity and being a worrier were associated with both increased odds of morbidity and increasing multimorbidity; although the effect size was small for increasing levels of multimorbidity (20% increased odds for each). Unfavourable self-assessed health in childhood was strongly associated with morbidity and had a 20% increased odds of increasing levels of multimorbidity. Finally, medical coverage was significantly associated with both acquiring morbidity and increasing levels of multimorbidity compared to those with no additional cover. Those with dual cover had a slightly higher increased odds for morbidity compared to those with only medical card coverage (OR 1.8 vs. 1.6).

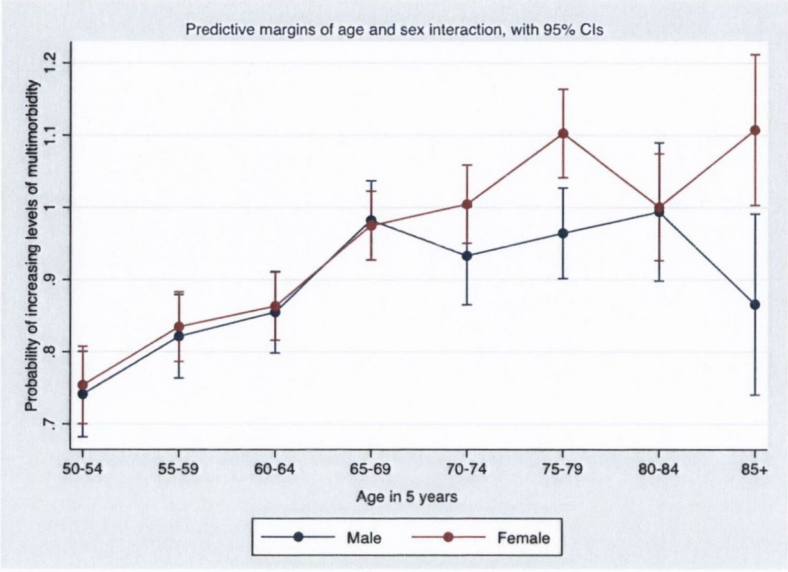
There was no evidence of an interaction effect between age and deprivation. The deprivation variable did not reach conventional significance levels in the main effects model and was subsequently dropped. However, the effect of increasing age on having one chronic condition was significantly modified by sex (χ^2=19.4 p<0.01). Figure 4.4 shows that the predicted probability of developing a chronic condition increases with increasing age, measured in five-year age groups and that this increase was more pronounced for women than for men. Women were 40% more likely to have a morbidity compared to men at age 55-59 (p<0.05), twice as likely at age 65-69 (p<0.001), 70% more likely at age 70-74 (p<0.05) and over two and a half times as likely at age 80-84 years. However there was no observed effect in those aged 85 years and over.

*Figure 4.4 Predicted probability of one condition vs. no conditions for the Sex*Age interaction for logit model presented in* Table *4.2*



The overall effect of increasing age on having more than one chronic condition was also significantly modified by sex (χ^2=16.2 p<0.05). The effect of increasing age on increased levels of multimorbidity also appears to be more pronounced for women than men (Figure 4.5). Women were 10% more likely to have a higher level of multimorbidity at 75-79 years (p<0.05) and a 30% higher level in the oldest age group (85+ years) (p<0.01) compared to their male counterparts.

*Figure 4.5 Predicted probability of increasing levels of multimorbidity for the Sex*Age interaction for the zero-truncated negative binomial model presented in* Table *4.2*



In addition, there was no evidence of an interaction effect between GMS and SES proxy variables in multivariate models. Neither house value or deprivation status reached conventional significance levels in the main effects models, these measures were subsequently dropped to estimate the parsimonious model for factors associated with multimorbidity.

4.4.2 Factors associated with different types of multimorbidity

Prevalence estimates in Chapter 3 suggest that the factors associated with developing multimorbidity may be different for those with two or more physical conditions compared to those with multimorbidity with a mental health dimension. To test if factors associated with physical only multimorbidity are similar to those associated with multimorbidity with a mental health dimension, a multinomial regression model was estimated with the dependent variable specified as k = 3 levels of the dependent variable as detailed in Table 4.1. Parameter estimates are examined relative to the reference groups specified in the models. Three sets of estimates are presented in Table 4.3. The estimates presented in the first two columns of Table 4.3 (Model A) examined both categories of multimorbidity (i.e. physical only and physical-mental) relative to the base category (≤ 1 condition). A further set of parameter estimates compared the factors associated with physical-mental health multimorbidity relative to those associated with physical only multimorbidity, presented in the last column of Table 4.3 (Model B). The empirical model was obtained by specifying the component in the vector χi of $v_{ij} = \chi_i \beta_j$. A constant term was included as well as all independent variables significant at the bivariate α = 0.10 level.

Table 4.3 Multivariate multinomial logistic regression analyses of Multimorbidity Type

	Multivariate Model A				Multivariate Model B	
	Estimates of physical multimorbidity only relative to ≤1 condition.		*Estimates of physical-mental multimorbidity relative to ≤1 condition*		*Estimates of physical-mental multimorbidity relative to physical only multimorbidity.*	
	Relative Risk Ratio (95% C.I.)	P-value	Relative Risk Ratio (95% C.I.)	P-value	Relative Risk Ratio (95% C.I.)	P-value
Demographic Factors						
Sex						
Male (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Female	1.2 (1.0-1.3)	0.019	1.1 (0.9-1.5)	0.30	0.9 (0.7-1.1)	0.35
Age in 5 years						
50-54 (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
55-59	1.7 (1.4-2.0)	<0.001	1.1 (0.8-1.6)	0.52	0.6 (0.4-0.8)	0.02
60-64	2.3 (1.9-2.8)	<0.001	1.5 (1.0-2.1)	0.03	0.6 (0.4-0.8)	<0.01
65-69	3.3 (2.7-4.0)	<0.001	1.9 (1.2-2.8)	<0.01	0.5 (0.3-0.8)	<0.01
70-74	3.2 (2.5-4.0)	<0.001	1.7 (1.1-2.6)	0.03	0.5 (0.2-0.5)	<0.01
75-79	4.3 (3.3-5.5)	<0.001	1.3 (0.8-2.3)	0.03	0.2 (0.1-0.4)	<0.001
80-84	3.7 (2.7-5.0)	<0.001	0.9 (0.4-1.7)	0.67	0.2 (0.1-0.4)	<0.001
85+	3.1 (2.2-4.4)	<0.001	0.6 (0.3-1.6)	0.34	0.2 (0.1-0.4)	<0.001
Household location						
Urban (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.		
Rural	1.2 (1.1-1.4)	<0.001	1.3 (1.1-1.6)	0.03		
Economic factors						
Employment status						
Employed /self-employed (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Retired	1.3 (1.1-1.5)	<0.001	2.0 (1.4-2.8)	<0.001	1.6 (1.2-2.3)	<0.01
Home-maker	1.2 (1.0-1.5)	<0.01	1.9 (1.3-2.7)	0.001	1.5 (1.1-2.2)	0.02
Unemployed or in education/training	0.9 (0.7-1.2)	0.78	1.6 (1.0-2.6)	0.05	1.8 (1.1-2.9)	0.02
Permanently sick or disabled	3.6 (2.0-3.4)	<0.001	7.0 (4.5-10.8)	<0.001	2.9 (1.9-4.3)	<0.001
Unclassified	1.0 (0.7-1.6)	0.86	3.0 (1.4-6.5)	<0.001	3.3 (1.6-6.8)	0.001
Lifestyle factors						
Smoking status						
Never (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.		
Past	1.2 (1.1-1.3)	<0.001	1.5 (1.2-1.9)	<0.01		
Light	1.3 (1.0-1.7)	0.11	1.6 (0.9-2.7)	0.09		
Moderate	1.0 (0.8-1.3)	0.93	1.2 (0.8-1.9)	0.36		
Heavy	0.9 (0.7-1.1)	0.69	1.9 (1.3-2.7)	<0.001		
Alcohol status						
None or rare (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
1-2 days p/w	1.1 (0.9-1.2)	0.33	1.7 (1.3-2.3)	<0.001	1.6 (1.2-2.2)	<0.01
3-4 days p/w	1.1 (0.9-1.3)	0.34	1.6 (1.0-2.4)	0.04	1.4 (0.9-2.2)	0.10
Almost every day	1.2 (1.0-1.5)	0.06	2.1 (1.4-3.2)	0.001	1.8 (1.2-2.7)	<0.01
Unclassified	1.1 (0.8-1.4)	0.62	1.9 (1.1-3.3)	0.02	1.9 (1.1-3.2)	0.03
Exercise status						
High (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.		
Moderate	1.2 (1.1-1.4)	<0.001	1.5 (1.1-2.0)	<0.01		
Low	1.6 (1.4-1.8)	<0.001	1.8 (1.4-2.4)	<0.001		
Unclassified	0.7 (0.4-1.2)	0.16	1.1 (0.4-3.3)	0.85		
Weight						

Normal (and underweight)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.		
Overweight	1.3 (1.1-1.5)	<0.01	1.2 (0.9-1.6)	0.35		
Obese	2.0 (1.7-2.3)	<0.001	2.2 (1.6-3.0)	<0.001		
Unclassified	1.1 (1.0-1.3)	0.13	0.9 (0.7-1.2)	0.57		
Trouble sleeping						
Rarely/never (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Sometimes	1.3 (1.2-1.5)	<0.001	1.7 (1.4-2.2)	<0.001	1.3 (1.1-1.6)	0.03
Most of the time	1.7 (1.4-2.0)	<0.001	3.1 (2.3-4.1)	<0.001	1.9 (1.5-2.5)	<0.001
Childhood factors						
Health in childhood						
Favourable	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Unfavourable	2.0 (1.6-2.5)	<0.001	2.4 (1.7-3.4)	<0.001	1.4 (1.0-1.8)	0.04
Social/ Psychosocial Factors						
Marital Status						
Married	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Widowed	0.9 (0.7-1.0)	0.10	1.3 (0.9-1.9)	0.12	1.5 (1.1-2.1)	0.01
Separated/divorced	0.9 (0.8-1.2)	0.58	2.1 (1.5-2.9)	<0.001	2.5 (1.8-3.4)	<0.001
Never married	1.2 (1.0-1.4)	0.05	1.4 (1.1-2.0)	0.02	1.3 (1.0-1.7)	0.12
Worry						
Non-worrier	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Worrier	1.2 (1.0-1.5)	<0.01	3.8 (2.8-5.2)	<0.001	3.3 (2.5-4.3)	<0.001
Unclassified	0.9 (0.7-1.1)	0.40	1.1 (0.7-1.8)	0.75	1.1 (0.7-1.7)	0.68
Access to Healthcare						
Healthcare coverage						
No additional coverage (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
GMS only	1.7 (1.4-2.1)	<0.001	2.3 (1.5-3.6)	<0.001	1.4 (0.9-2.2)	0.15
Insurance only	1.1 (0.9-1.3)	0.20	1.7 (1.1-2.7)	0.02	1.4 (1.0-2.3)	0.11
GMS * insurance	1.8 (1.4-2.2)	<0.001	3.4 (2.1-5.6)	<0.001	1.8 (1.1-3.0)	0.01
Model fit			LR-sqr (dfres)	1,491.9 (85)	LR-sqr (dfres)	1,323.07 (57)
			N	8,117	N	8,117
			AIC	12,575.9	AIC	1,2757.2
			BIC	13,206.1	BIC	1,3191.3

* All independent variables retained in the model were significant at the α 0.05 level.
†Empty cells indicate non-significance of independent variables in respective models. Non-significant variables were dropped to retain the most parsimonious models.

4.4.2.1 Factors associated with either physical-physical multimorbidity or physical-mental multimorbidity relative to no multimorbidity

Several factors were found to be significantly associated with the two types of multimorbidity examined here (i.e. with and without a mental health component) when compared to the baseline of no multimorbidity. The risk of physical multimorbidity was significantly higher for women compared to men (RRR 1.2 $p<0.05$). Increasing age was significantly associated with physical multimorbidity with the risk of physical multimorbidity appearing to increasing in a linear fashion up to age 70-79 years and decreasing slightly for those aged 80 years and over

(RRR 4.3 vs. 3.7 (age 80-85 years) and 3.1 (age 80+ years). The opposite was found for physical-mental multimorbidity. Older age appears to be protective for multimorbidity with a mental health component with the relative risk decreasing linearly after age 70. Living in a rural area was significantly associated with a slightly higher risk of both types of multimorbidity (RRR 1.2 for physical multimorbidity and 1.3 for physical-mental multimorbidity) compared to urban-dwelling.

Being either retired or a homemaker was associated with a slightly higher risk of physical multimorbidity (RRR 1.2 and 1.3 respectively) and a twofold increased risk of multimorbidity with a mental health component (RRR 2.0 and 1.9 respectively) compared to employment. Unemployment was associated with a 60% increased risk of multimorbidity with a mental health component compared to employees. While being permanently sick or disabled was associated with a substantially higher risk of both types of multimorbidity (RRR 3.6 for physical multimorbidity and 7.0 for physical-mental multimorbidity) compared to employees even after controlling for age and other covariates.

Former smokers had a significantly higher risk of both types of multimorbidity (RRR 1.2 for physical multimorbidity and 1.5 for physical-mental multimorbidity) compared to non-smokers. There was an almost doubling of the relative risk for multimorbidity with a mental health component for heavy smokers (RRR 1.9) compared to non-smokers. Compared to those who never consume alcohol or do so rarely, those who drank almost every day had a 20% increased risk of physical multimorbidity, while the risk of multimorbidity with a mental health component was substantially higher in those who consumed alcohol on a weekly basis, ranging from a 60% increased odds for those drinking 3-4 days per week to a doubling of the risk for those drinking almost every day. Low and moderate levels of exercise were associated with both types of multimorbidity (RRR 1.2 and 1.6 respectively for physical multimorbidity and 1.5 and 1.8 for multimorbidity with a mental health component). Being overweight was associated with a 30% increased risk, and double the risk for physical multimorbidity for those who were obese, compared to normal BMI status. A twofold increased risk was also found for multimorbidity with a mental health component for those who were obese.

An increased risk was also found for those who have trouble sleeping for physical multimorbidity ranging from RRR 1.3 for those who sometimes have trouble sleeping and 1.7 for those who often have trouble sleeping. The risk was more pronounced for multimorbidity with a mental health component with those who often have trouble sleeping having a threefold increased risk.

While there was a slight increased risk for physical multimorbidity for being a worrier (RRR 1.2), the risk of multimorbidity with a mental health component is almost fourfold for worriers compared to non-worriers (RRR 3.8). Confirming the findings of an increased observed prevalence of physical-mental health multimorbidity in those who were separated or divorced (findings presented in Chapter 3), they had a two and a half times increased risk of multimorbidity with a mental health component compared to those who were married after controlling for all other covariates. Poor health in childhood was associated with a doubling in the risk of both types of multimorbidity compared to those who had more favourable health in childhood.

GMS coverage was associated with an increased relative risk of both types of multimorbidity (RRR 1.7 for physical multimorbidity and 2.3 for physical-mental multimorbidity) compared to those with no additional coverage. Dual cover (i.e. GMS cover and insurance cover) was also associated with a significant increased risk of both types of multimorbidity (RRR 1.8 for physical multimorbidity and 3.4 for physical-mental multimorbidity).

A large significant effect was detected for both the unclassified employment type category and the unclassified alcohol consumption category for multimorbidity with a mental health component, indicating a bias in non-responders according to mental health status (RRR 3.0 ($p<0.001$) and 1.9 ($p<0.05$) respectively).

Interaction effects were examined in Model A to test the *a priori* hypothesis that indicators of poorer socioeconomic status have a synergistic effect on multimorbidity with a mental health component in younger age groups. However, there was no interaction effect detected for either house value or deprivation status by age groups. In addition, no interaction effects were detected for GMS and SES proxy variables. As neither variable were found to be independently significant in the multivariate models they were subsequently dropped to obtain the most parsimonious model.

4.4.2.2 Factors associated with physical-mental multimorbidity relative to physical multimorbidity

A final analysis was conducted to test for the differences in the factors associated with physical-mental multimorbidity relative to physical multimorbidity only (Model B Table 4.3). There was no observed difference between men and women. Increasing age was found to be protective of

multimorbidity with a mental health component. The relative risk of a co-occurring mental health condition with a physical condition decreased linearly with increasing age from RRR 0.6 for 55-59 years old to RRR 0.2 for those aged 85 years and above. Those who were retired, home-makers or unemployed all had significantly higher risk of physical-mental multimorbidity relative to those with physical only multimorbidity: effects ranged between RRR 1.5 and 1.8. A high relative risk of multimorbidity with a mental health component was observed for those who were permanently sick or disabled and the unclassified employment status grouping (RRR 2.9 and 3.3 respectively). Those who were widowed and separated or divorced individuals had a significantly higher risk of a mental health component compared to those who were married (RRR 1.5 and 2.5 respectively). The risk also increased linearly for increasing levels of alcohol consumption and again the greatest risk was observed in the unclassified alcohol status category (RRR 1.9). Trouble sleeping all the time was associated with a twofold increased risk and being a worrier with a threefold increased risk of multimorbidity with a mental health component. The difference in healthcare coverage for a mental health component relative to physical multimorbidity only was only significant for those with dual cover.

4.5 Discussion

Results demonstrate statistically significant associations between a wide variety of explanatory factors examined and the likelihood of having one chronic condition, increasing multimorbidity levels and different multimorbidity types. Overall, the findings indicate the need to take account of the difference between factors associated with one condition and those associated with increasing levels of multimorbidity supporting the theory that alternative factors may be influencing morbidity distinct from multimorbidity. There was an evident distinction between factors influencing physical multimorbidity and physical-mental health multimorbidity and this should also be considered in further studies investigating multimorbidity.

It is difficult to meaningfully compare results for the factors associated with multimorbidity due to the small number of studies examining this in multivariate analyses and methodological differences between studies. However, the findings are discussed here in relation to such studies and in relation to the factors hypothesised to be associated with multimorbidity from crude analysis in other prevalence studies.

4.5.1 Demographics

There was no effect of sex on having one condition but women were more likely to have increased levels of multimorbidity after controlling for covariates in multiple regression analyses. This is in contrast to the prevalence findings in Ireland by Glynn et al. (2011) although reflective of the wider literature (Marengoni et al., 2011). Women also had an increased risk of physical multimorbidity, however there was no difference detected between men and women for multimorbidity with a mental health component. There was a distinct age trend in the risk of having one chronic condition, which is strongly supported in the literature (Marengoni et al., 2011, Fortin et al., 2012, Britt et al., 2008). The odds of having one condition rose linearly up to age 80; interestingly, for those aged between 80-84 years the odds were similar to those aged 70-74 years however, those in the eldest age category (85 years +) had the highest odds of morbidity, again perhaps reflecting a survivor effect.

Notably, however, there appears to be a smaller effect of age on increasing levels of multimorbidity. Compared to those in the youngest age category (50-55 years), those aged below 65 years had a 10% increased risk of increasing multimorbidity levels, while those aged 65 years and over had between a 20% and 30% increased risk which did not appear to be linear as age increased. Findings from other studies report an increasing risk of multimorbidity for increasing age, however the different age effects found in this study between having one condition and accumulating multiple conditions is an important distinction. This may indicate an effect of increased condition susceptibility after developing one condition, although this is likely to be different for different conditions and examination of the risks associated with specific clusters of conditions would advance an important understanding of this issue. The risk of having a chronic condition and having multiple chronic conditions for increasing age was more pronounced for women compared to men, indicating the need to design interventions to target women for prevention and in multimorbidity interventions. This was especially evident for women aged between 80-84 years for one condition and those in the eldest age category for increasing levels of multimorbidity, likely also reflecting a survivor effect supporting the theory put forward by Marengoni et al. (2009a) that women may be living longer with more debilitating, but less fatal conditions. The risk of a mental health component was greater in younger people with multimorbidity after controlling for all other factors this was reflective of the findings by Ajmera et al. in a large U.S study (2012).

Unlike findings from Taylor et al. (2010), nationality was not found to be associated with multimorbidity levels or type in analyses, although examination of nationality was limited by the low numbers of 'other nationality' groupings. Given the high risk of multimorbidity found for Irish and British living in Australia, there may be important differences between nationalities and these should be investigated in further analysis. A small increased risk of one condition was found for those living in an urban area similar to findings by Cazale et al. (2008), although this was not significant for increasing levels of multimorbidity, a small but significant effect was also observed for urban dwelling and risk of multimorbidity with and without a mental health component.

4.5.2 Socioeconomic factors

Notwithstanding the powerful influence of socioeconomic factors associated with poor status for other health outcomes, there was no social-gradient for multimorbidity evident in this study after controlling for need factors and other covariates. As socioeconomic indicators in TILDA were limited due to high levels of non-response, this study applied two other measures to examine a socioeconomic effect on multimorbidity, using house value and a measure of relative material deprivation. However neither of these factors were found to be associated with multimorbidity in analyses after controlling for all other factors. These observations may be accounted for by the inclusion of the GMS eligibility indicator in multivariate analyses, which has been shown to be in many ways the most robust measure of income in Ireland as it is based on rigorous means testing (Kelleher et al., 2003), although for the reasons explained earlier, GMS status is not likely to have discriminatory power in people aged 70 years an older in Ireland given the universal access granted and subsequently restricted in the last decade. Healthcare coverage was significantly associated with all types of multimorbidity compared to those with no additional cover. Interestingly, having dual cover was associated with increased likelihood of multimorbidity with a mental health component this may be explained by the increased access to diagnosis inflating the rate compared to those who have lower access. The crude association with education observed in Chapter 3 on multimorbidity levels was also not supported in multivariate analyses and again, this may be to the lack of discriminatory power of education for older people in Ireland given that free second level education became universally available in 1978. Nonetheless, higher levels of education were associated with multimorbidity with a mental health component.

Unsurprisingly, being permanently sick or disabled was significantly associated with having one condition, but it was also strongly associated with all multimorbidity outcomes. The effect was most pronounced for multimorbidity with a mental health component, with such individuals having a seven fold increased risk compared to no multimorbidity and a threefold increased risk compared to physical only multimorbidity. These findings have not been reported in other studies, however they indicate a substantial increased vulnerability of individuals in Ireland with permanent sickness and disability status. This finding highlights the need to target secondary prevention and multimorbidity interventions towards this group as *a priori*ty. Being a home-maker was also significantly associated with multimorbidity with a mental health component although the opposite was found in a U.S. sample (Andrade et al., 2010). Being unemployed and retired were also significantly associated with multimorbidity with a mental health component again highlighting the need for intervention in these population sub-groups. Contrary to findings in crude analyses in Chapter 3, supported by multivariate analysis by Andrade et al. (2010) in the U.S., there was no significant association found for the effect of being *separated/divorced* on multimorbidity risk after accounting for other factors.

4.5.3 Lifestyle and psychological/social risk factors

The association between lifestyle risk factors and multimorbidity are complex and it was not possible to compare results between studies due to the low numbers of studies examining this issue. Lower levels of exercise and trouble sleeping were associated with both morbidity and increasing multimorbidity, although this may be a circular effect, where multimorbid patients are less likely to exercise due to activity restrictions or pain and are also more likely to have trouble sleeping. Trouble sleeping was associated with all multimorbidity outcomes examined although it was especially pronounced for multimorbidity with a mental health component. Similar to trouble sleeping, being a worrier was associated with all multimorbidity outcomes, but was especially pronounced for multimorbidity with a mental health component.

In addition, increased alcohol consumption and being a worrier predicted multimorbidity with a mental health component compared to multimorbidity with only a physical component. Heavy smoking was associated with an increased likelihood of higher levels of multimorbidity similar to findings reported by Taylor et al. (2010) and an almost doubling of the risk of multimorbidity with a mental health component. Well-established research points to specific health benefits of giving up smoking after a number of years including reduced cancer and heart disease risk (Doll

et al., 2004). While the temporal relationship between time of giving up smoking and development of multimorbidity is not known in this study, findings suggest that former smoking is associated with both morbidity and all types of multimorbidity. Further Investigation is required to establish the true health benefits of giving up smoking on the accumulation of multiple conditions rather than specific conditions. In contrast to findings reported by Taylor et al, drinking alcohol everyday was associated with an increased risk of morbidity, while not drinking at all or drinking only rarely as well as drinking on 3 days a week or more was found to be associated with an increased risk of higher multimorbidity levels. The risk of multimorbidity with a mental health component was substantially higher for those who consumed alcohol on a weekly basis, reflecting a general evidence-base on the negative effects of heavy drinking on health related outcomes.

Reflecting findings by de Souza et al. (2012) and Taylor et al. (2010), lower levels of exercise and to a lesser extent moderate exercise was associated with both morbidity and increasing multimorbidity and with both types of multimorbidity and obesity was associated with morbidity and increasing multimorbidity levels, although the effect size is small for the latter, as well as a doubling of the risk for both types of multimorbidity.

4.5.4 Childhood status factors

Unfavourable self-assessed health in childhood was strongly associated with having a chronic condition and had a small effect on increasing multimorbidity level, as well as a doubling of the risk of both types of multimorbidity, more pronounced again for multimorbidity with a mental health component. This supports the impact of lifecourse factors on later life multimorbidity reported by Tucker-Seeley et al. (2011). However, in contrast to their findings, there was no effect found for early life poverty on multimorbidity risk in people aged 50 years and over in Ireland.

4.5.5 Strengths and limitations

A major strength of this study is the large sample size and variety of indicators available to explain multimorbidity outcomes. It is acknowledged that due to the cross-sectional nature of the data, causal relationships cannot be inferred from the results. Nonetheless this is one of the first studies to examine the factors associated with multimorbidity in a nationally representative

sample and learning from these analyses is important to inform future investigations using further waves of TILDA to examine the causal mechanisms underlying multimorbidity incidence.

Several variables had missing data that were categorised as unclassified groups in respective variables. Lifestyle and socioeconomic factors in particular required classification of missing data categories compared to other measures. It is noteworthy that BMI status had a large number of missing responses, substantially reducing the sample size for estimation. However, the inclusion of an unclassified category for BMI allowed for estimation of the effect of a valid objective measure of BMI on multimorbidity outcomes. There was no bias observed for the unclassified categories for BMI, exercise or worry. However, estimates for the unclassified categories of employment status and alcohol consumption were significantly associated with multimorbidity with a mental health component indicating a bias in non-response for individuals living in the community with a mental health condition.

While effects were detected at the bivariate level, indicators of socioeconomic status did not perform well in the multivariate models, after controlling for other covariates. Improved quality of income and asset data in future waves of TILDA would allow for more detailed examination of the question of socioeconomic inequalities related to multimorbidity and other health related outcomes. Given the availability of data in TILDA on early life disadvantage (poverty) and parental socioeconomic status it would be possible to extend analysis to examine cumulative disadvantage over the lifecourse. A single level modelling approach was employed to model deprivation levels as a proxy indicator of individual deprivation status owing to the structure of the TILDA data. However, this does not take account of the hierarchical structure inherent in area level indicators and may explain the lack of discriminatory power in analyses.

Finally, given the cross-sectional nature of the data examined, it is not possible to establish the direction of the effects. In particular, findings relating to difficulty sleeping and low levels of exercise may be circular, in that increased pain as a result of multimorbidity may be diminishing the individual's ability to sleep and exercise.

4.6 Conclusion

In general, effect sizes for increasing levels of multimorbidity after the initial acquisition of a chronic condition were small, ranging in the magnitude of 1.1-1.5. Factors associated with

increasing levels of multimorbidity were not well elucidated in the estimated model. It is likely that other factors in the development of multimorbidity have not been accounted for in the modelling process such as the impact of having one condition on likelihood of developing further conditions, prescribing cascades and potential biological risk factors. Further research is required to untangle the specific effects of individual and area level predictors of multimorbidity and other factors influencing the accumulation of multiple conditions in an individual.

Chapter 5. The Health and Social Care Burden of Multimorbidity in the Community-dwelling Population aged 50 years and over in Ireland.

5.1 Introduction

Recipients of healthcare have attracted increasing attention at a policy level as healthcare expenditure is expected to escalate rapidly with the demographic shift towards an ageing population. The significant cost associated with chronic condition management has led to many developed countries re-examining the fit between the needs of their population and the design of their healthcare systems. Nonetheless, healthcare policy and practice continue to focus on disease-specific approaches to chronic care management, overlooking the import of increasing multimorbidity prevalence and burden in patients. The delayed response of healthcare systems to reorient services towards multimorbidity care may in part be linked to the paucity of research identifying the independent effect of multimorbidity on healthcare utilisation and outcomes supporting the need for multimorbidity appropriate healthcare. Challenges identified in establishing a strong evidence-base on the association between multimorbidity and healthcare utilisation and costs are similar to those outlined for multimorbidity prevalence estimates and include varying approaches to data collection, sample size and sample structure, as well as numbers and types of conditions, data abstraction and weighting of multimorbidity (Lehnert et al., 2011, Hodek et al., 2011). Some further considerations for healthcare evaluation include country-specific health care systems, variation in types and costs of services and time of assessment (Hodek et al., 2011).

The drivers of health and social care use have been examined extensively both nationally and internationally, although investigations into the independent contribution of multimorbidity is in its infancy. However, adopting a focus on multimorbidity and the increasing availability of studies based on community-dwelling samples generalisable to the population allows for the impact of multimorbidity burden to be measured at a healthcare systems level rather than within narrowly defined comorbidity groupings or clinical subgroups. Several considerations arise when examining the role of multimorbidity on health and social care utilisation at a health system level. The per-capita effect of multimorbidity on health service use and its contribution to patient complexity is increasingly recognised in healthcare. With the projected increase in the older population, a further consideration comes to the fore: what is the population effect of

multimorbidity burden on service use? If multimorbidity is concentrated among a small number of highly complex patients the impact of multimorbidity on health systems will be manageable. Conversely, if a large proportion of the population are presenting to health services as a result of multimorbidity this is likely to place a substantial burden on service provision with considerable implications for resourcing healthcare systems. Applying resource rankings for chronic conditions, Rapoport et al. (2004) found that healthcare utilisation is driven by the number of people who have a condition i.e. the overall prevalence, rather than the per capita effect of chronic conditions. This finding suggests a substantial burden of multimorbidity driven by the sheer increase in the proportion of the population with multimorbidity in years to come.

Evidence points to increased complexity of healthcare for multimorbid patients (Guthrie, 2011, Xakellis, 2005, Shah et al., 2008, Boyd et al., 2005). Multimorbid individuals are more likely to have multiple healthcare appointments and see more physicians from both primary care and specialist care leading to complex self-management regimes. It is also likely that certain combinations of conditions may in turn promote disability or frailty in vulnerable individuals, leading to increased patient complexity and dependency in the community. In addition to the physical dimension of multimorbidity, prevalence estimates in Chapter 3, highlight that 7.5% of the Irish population aged 50 years and over experience multimorbidity with a mental health component. This added dimension of complexity could also be influencing the use of or need for health and social care services in Ireland.

Few studies have examined the independent impact of multimorbidity on healthcare utilisation and the effects of multimorbidity on social care are unknown. It is also not yet known if the impact of multimorbidity is more pronounced for certain types of healthcare. To my knowledge no study to date has examined the independent effect of multimorbidity, in all its forms relative to other gerontological constructs (i.e. disability and frailty) and other determinants of utilisation from a population perspective adopting a whole healthcare systems approach. To address this in an Irish context, the empirical analyses presented in this Chapter are concerned with the impact of multimorbidity on health and social care utilisation in Ireland's community-dwelling population aged 50 years and over. Acknowledging the significant effect of population ageing on the efficiency, quality and cost of a healthcare, this study aims to disentangle the particular effect of multimorbidity on health and social care utilisation and quality of care, controlling for a wide variety of indicators including age, healthcare availability and socio-economic indicators. The Anderson's Healthcare Framework is employed as an analytical framework to guide the empirical analysis of health and social care utilisation. A two-part process is undertaken where

relevant to examine the propensity to use a service, distinct from the intensity of service use. This allows for a distinction between the drivers of one-time use of service and regular service use. It should be noted that intensity of service use is defined in this context as recurrent use of the health care services examined and it does not include any qualification of quality of services provided or assessment of clustering of consultations at time of increased need among service users with multimorbidity.

The evidence-base on the burden of multimorbidity on healthcare services is presented in Section 5.2. This includes a discussion of the current literature on the effects of multimorbidity on the healthcare utilisation in a national and international context. The context of the Irish healthcare system is of particular relevance to this study and evidence on current healthcare delivery practices and utilisation in Ireland is examined in detail in Section 5.2.3. The empirical analysis approach adopted to inform the objectives of this study is discussed in detail in Section 5.3 and results are presented in Section 5.4. As in previous chapters, a brief discussion of the findings is provided in Section 5.5 and results are discussed in more detail in Chapter 6.

5.2 Background and context

5.2.1 Multimorbidity and healthcare utilisation

High healthcare use was identified for individuals with multimorbidity across a range of studies and health service indicators examined in the literature. Evidence of the impact on healthcare utilisation to date suggests that multimorbidity in and of itself is likely to lead to higher use of a range of healthcare services with associated adverse outcomes such as polypharmacy and the risk of inappropriate prescribing contributing further to patient complexity (Guthrie, 2011). Mainly based on U.S. and Canadian data, studies suggests that multimorbidity is linked to high utilisation in both primary and secondary care (Condelius et al., 2008, Ionescu-Ittu et al., 2007, Landi et al., 2004, Librero et al., 1999, Schneider et al., 2009, Bianca et al., 2010, Fortin et al., 2005a, Starfleld et al., 2005, Marengoni et al., 2013, Rochon et al., 1996). Evidence to date suggests that increasing numbers of concurrent chronic conditions are associated with an incremental increase in healthcare utilisation even after controlling for typical confounders of healthcare service (Lehnert et al., 2011). This was found to be true for primary care use (Rapoport et al., 2004, Hessel et al., 2000, Martin et al., 2006, Linden et al., 1997, Glynn et al., 2011, Van Den Bussche et al., 2011b, Taylor et al., 2010), hospital use including admissions and

length of stay (Rapoport et al., 2004, Landi et al., 2004, Chan et al., 2002, Wolff et al., 2002, Schneider, 2006, Condelius et al., 2008, Byles et al., 2005, Friedman et al., 2006, Putnam et al., 2002), emergency admissions and hospital readmissions (Shah et al., 2008, Librero et al., 1999, Marcantonio et al., 1999, Agborsangaya et al., 2013), preventable complications while hospitalised (Wolff et al., 2002), number of prescriptions and polypharmacy (Linden et al., 1997, Laux et al., 2008, Hessel et al., 2000, Ramage-Morin, 2009, Taylor et al., 2010, Nobili et al., 2011), number of care referrals and satisfaction with care (Laux et al., 2008). Few studies explicitly report the nature of the relationship between increasing numbers of concurrent conditions (i.e. multimorbidity levels) and outcomes. However, from the limited evidence presented it appears that the impact of additional conditions after incidence of an initial condition have a linear relationship with outcomes investigated to date (Lehnert et al., 2011).

When limited to community-dwelling populations multimorbidity was found to be independently associated with a wide range of health services (Taylor et al., 2010, Rapoport et al., 2004) and polypharmacy in a large Australian sample (Taylor et al., 2010). A crude incremental increase for increasing levels of multimorbidity was also found for physician home healthcare visits (Partnership for Solutions, 2004), general practice, specialist consultations and one or more nights spent in hospital (Cazale and Dumitru, 2008). Moreover, increasing numbers of concurrent chronic conditions significantly predicted healthcare utilisation in younger (< 60 years) and older persons (≥ 60 years) in a large U.S. study (Rapoport et al., 2004). Substantial impacts of multimorbidity with an activity limitation on a range of healthcare utilisation indicators were also found to increase with increasing number of concurrent conditions with activity limitations suggesting a possible synergistic effect of multiple need factors.

5.2.2 Multimorbidity and care complexity

Wolff et al. (2002) examined the risk of hospitalisations considered to be preventable with adequate ambulatory care and found that patients with four or more chronic conditions had a ninety times greater odds of incurring potentially preventable hospital admissions compared to those with no chronic conditions. They were also more likely to have preventable complications once hospitalised. Complex prescribing regimes for patients with multiple conditions have been shown to result in adverse drug events and increased likelihood of potentially preventable admissions to hospital (Wolff et al., 2002, Gilbert et al., 2011). Multimorbidity is closely associated with polypharmacy, commonly defined as concurrent use of five or more medications

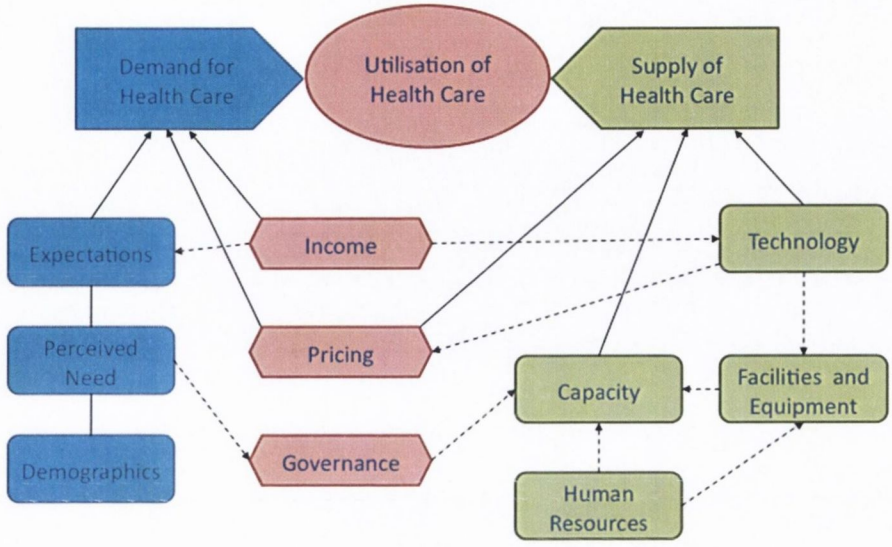
(Fulton and Riley Allen, 2005). Extensive prescription drug use is common and recommended for treatment of certain chronic conditions such as diabetes and cardiovascular disease (Boyd et al., 2005, Tinetti et al., 2004). However, as older people and people with multimorbidity are generally excluded from drug trials (Hilmer and Gnjidic, 2008), there is limited evidence of efficacious drug use for multimorbid older patients. There are a limited number of studies with an explicit focus on the association between polypharmacy and multimorbidity. Nonetheless, polypharmacy has been shown to be associated not only with increasing number of conditions, but also with specific multimorbidity patterns (Nobili et al., 2011, Vyas et al., 2012). Vyas et al. (2012) also found increased rates of polypharmacy for increasing levels of multimorbidity in a nationally representative sample in the U.S.

5.2.3 Healthcare utilisation and entitlement in Ireland

Healthcare utilisation in Ireland is driven by a complex interplay of factors illustrated in Figure 5.1. Determinants are roughly divided into 'demand' factors including health status and perceived need, demographic factors and expectations and supply factor determinants including capacity, facilities, resources and governance. Need factors measured by different constructs such as self-rated health status and disability and proxies such as age have been shown to be important determinants of healthcare across all areas of usage in Ireland (Layte et al., 2009). Researchers have highlighted as a limitation the absence of appropriate measures of need in Irish healthcare utilisation studies (Nolan et al., 2007) and the independent effects of multimorbidity relative to other need factors has yet to be elucidated for healthcare utilisation in Ireland and internationally.

The current structuring of the Irish healthcare system is likely to have direct implications for the quality of care and management of multimorbid patients in the Ireland. Furthermore, the higher prevalence of multimorbidity among those with GMS cards, observed in this study (Chapter 3) and in a previous study conducted by Glynn et al (2011), may be reflecting increased diagnosis among frequent attenders at medical services enabled by greater health care access. Therefore any consideration of the impact of multimorbidity on healthcare services requires delineation of the important influence of healthcare access on multimorbidity related healthcare outcomes. Disentangling the particular effects of healthcare access on healthcare outcomes however is complicated by the complex structure of service provision and entitlements underlying the Irish healthcare services.

Figure 5.1 The complex drivers of health care utilisation (adopted from Layte et al., 2009)



The Irish health care system is a mix of a tax-based public health service and a fee-based private system (Thomas et al., 2006, Nolan et al., 2007) and provides a complicated mix of public, private and voluntary care, which often charges at the point of access, depending on services. About half of the total population contribute to private health insurance schemes. Private health insurance provides access to a number of private hospitals around the country and coverage also enables faster access to the public hospital system. Unlike other tax-funded systems there is no universal entitlement to free care and no universal access (Thomas and Burke, 2011), however a basic entitlement to subsidised services is available for a proportion of the population.

Entitlement to subsidised services is however also complex. Table 5.1 provides a summary of healthcare entitlements in Ireland, valid at the time of the TILDA survey. The population can be categorized into four entitlement groups: medical card holders with a sub-category group entitled to GP visit coverage only; privately insured; individuals with both medical card and private health insurance (dual cover) and individuals with neither medical card nor private health insurance 'no additional cover'[4] (Smith, 2007). Eligibility to public health services is determined by medical card status. As detailed in Section 3.1.1.3, assessment for a GMS medical card is based on an income means test with nationally established income thresholds; a

[4] For ease of presentation, the four groups are referred to in the text as medical card holders, GP only card holders, privately insured, dual cover, and no additional cover.

proportion of the population also qualify on the basis of particular long-term health needs and participation in Government activation schemes and (Nolan et al., 2007). Universal entitlement to GMS for people aged 70 years and over was withdrawn in 2009; nonetheless a high proportion of older people in Ireland continue to hold GMS cards.

Table 5.1 Entitlements to health care in Ireland by healthcare coverage categories (valid at date of survey - 2010)

Eligibility category	General Practitioner	Prescription medications	Public Hospital care	
			Acute outpatient (including ED visits)	Acute inpatient
Full Medical Card	Free unconditional consultations	€0.50 per item	Free unconditional public care	Free public care
GP only card holders	Free unconditional consultations	Free after €120 out-of-pocket payment per month. Free for specific medications to Long-term illness card holders.	Free with referral	€75 per night subject to annual limit
No additional cover	Approximately €40-€60 per visit. Free maternity, infant and palliative care and some vaccinations provided free of charge.	Free after €120 out-of-pocket payment per month. Free for specific medications to Long-term illness card holders.	Free with referral	€75 per night subject to annual limit
Privately insured	Charge conditional, fixed by provider	Free after €120 out-of-pocket payment per month. Free for specific medications to Long-term illness card holders.	Free with referral	Charge partially covered
Duplicate cover	Free unconditional consultations	€0.50 per item	Free unconditional public care	Free public care

A further proportion of the population are eligible for GP visit cards providing GP care free-of charge but this excludes costs of prescriptions and other primary care services. All Irish citizens are eligible for public hospital care at a maximum cost of €700-750 per year and medical card holders are entitled to public hospital and GP care without charge (Burke, 2009). Persons not eligible for a medical card pay substantial out-of-pocket expenses for primary care; between €40 and €60 per GP visit. Private health insurers have introduced new plans that provide subsidised cover for primary healthcare expenses (Layer et al., 2007). Medical card holders are were entitled to prescribed medicines subject to a 50 cent per item charge on prescriptions in 2010 and some auxiliary care services such as optical and aural services. Private patients are eligible for tax relief on certain medications at their marginal rate of tax, subject to reaching an annual

threshold payment of €125 per annum (Nolan et al., 2007). While prescribed drugs are subsidised through the Drugs Payment Scheme, non-medical card holders also pay a large proportion out-of-pocket for prescription medicines (Burke, 2009). Some services are provided universally, such as public health nurse visits to new-borns, vaccinations and palliative care, however these have come under increasing pressure in recent years, despite an ageing population with an increasing burden of chronic conditions (Burke and Considine, 2012).

5.2.4 Equity in health care provision in Ireland

While the principle of equity is embedded in Irish health policy documents such as *Shaping a Healthier Future* (1994), *Quality and Fairness – a health system for you* (2001), the primary care strategy *Primary Care- a new direction* (2001) and the Department of Health's *Statement of Strategy 2011-2014*, many argue that the system is not provided on need alone, but that personal circumstances and resources may well determine the extent to which individuals access treatment and the speed of that access (Layte, 2007, Burke, 2009, Wren, 2003). Differential pricing structures and entitlements for different parts of the Irish healthcare system as documented in Table 5.1, has resulted in a complicated mix of egalitarian and libertarian principles, which are at odds with the stated goals of healthcare policy in Ireland (Smith, 2009).

Previous research has highlighted the poorer health status of lower income groups in Ireland, indicating their higher level of healthcare service need (Layte, 2007). However, there is little systematic evidence available to assess the equitable provision of services to those with a higher level of need in the Irish health care system. Nonetheless, some conclusions can be drawn from the literature. Utilisation of services has been shown to vary significantly according to a range of socio-demographic characteristics including location (People, 1998, Morrissey et al., 2003), distance to hospital services (Smith, 2007), income distribution (Layte, 2007) and healthcare entitlements (Nolan et al., 2007). When limited to examination of healthcare utilisation, a study conducted by Layte et al in 2007 found that after standardising for a range of socio-demographic characteristics, including age, sex, location and need, those on lower incomes had a higher level of usage of GP services and prescribing. This could largely be explained by the need factors included in analyses, however it is acknowledged that the measure of need included in analyses was limited, based on presence of a chronic illness, limitation by illness and self-rated health. Of note, however was that inpatient and outpatient hospital services were neutral in their distribution across income groups indicating unequal distribution of hospital services in Ireland

across socio-economic groupings, inverse to care need (Layte et al., 1999, Layte, 2007). This finding is consistent with international evidence of an inverse care law (Tudor Hart, 1971). However, interestingly, this study did not control for GMS status. Medical card holders show an increased use of GP care visits and hospital length of stay whereas privately insured show an increased use of outpatient visits (Layte, 2007), therefore these findings are likely confounded by the complex patterns of healthcare coverage in the Irish services. Further studies on equitable provision of care would benefit from including a measure of health care cover including GMS and private health insurance to elucidate the particular effects of entitlements on equity in health service provision.

It has been suggested previously that health care provider behaviour can be influenced by payment incentives within the Irish system (Layte, 2007). GPs are independent professionals providing a variety of diagnostic and medical treatments in the community setting (Nolan et al., 2007). GPs are generally the first point of contact for individuals seeking health care and they play an important gatekeeping role for secondary care in Ireland. The capitation method of payment used to refund GPs treating GMS patients means that GPs have an incentive to see more private patients. Similarly in the hospital context, receiving a direct payment fee for treating private patients (either through out-of pocket or private health insurance payments) rather than the prospective budget allotted from State funding for GMS patients may well influence service provision behaviour. Such payment mechanisms may well account for large differences between the delivery and subsequent utilisation of health care services for those in different parts of the income distribution.

There is evidence to suggest differential treatment between GMS and non-GMS patients in primary care and hospital services which extends beyond the quantity of services accessed to quality of services received (Fadden, 2003, Wren, 2003). One study suggests that GP services were restricted to certain hours of the day for GMS patients and that regular GP check-ups were not being provided to GMS patients (Fadden 2003). It has also been argued that more GMS patients are on hospital waiting lists and that hospital care for public patients is less effective than that provided to private patients, the latter being given more time in hospital, more attention and a greater range of tests (Wren, 2003), thereby indicating an unmet need in lower socio-economic groups despite entitlement to services provided through the medical card system.

The two-tier health system in operation in Ireland has been well documented as perpetuating health inequalities, resulting in delayed access to hospital services for public patients even though these patients tend to be older, sicker and poorer than private patients Tussing and Wren (2006). Furthermore, patients with no additional healthcare cover may be less inclined to seek medical care in the context of substantial out-of-pocket costs and poorer quality of care in a public system compared to their subsidised privately insured counterparts and medical card holders.

In addition, poor integration at the policy and operational level has been highlighted as affecting timely access to appropriate services, particularly for people requiring multiple supports (McDaid et al., 2009). It has also been noted that the financing of primary and secondary care in Ireland encourages a shift away from primary care towards the more expensive secondary care service, and is said to be *...exactly the opposite of what way an efficient financing system would work* (Brennan et al., 2000). Two main points of admission to hospital are in operation in the Irish health system; these are as an emergency patient through the Emergency Department in public hospitals and as an elective case referred by a GP or another hospital doctor for specialised treatment. Smith (2007) found a high prevalence of frequent attenders (defined as ≥ 3 visits in previous year) in four large teaching hospitals in Dublin. There is growing debate on the appropriateness of many ED attendances; the lack of a comprehensive out-of-hours GP service in certain areas means that for many patients, an ED visit is the only option. The odds of frequent attendance were higher for unemployed, retired and those in receipt of medical cards, again indicating possible unmet need in primary care services among these population sub-groups in Ireland. This issue has gained substantial attention as efficiency in the hospital sector has come under scrutiny in response to an increase in State spending on healthcare in recent years (Gannon, 2007), however efforts to address this should incorporate an equitable approach to service provision throughout the healthcare system.

Previous research also points to inequity in the Irish healthcare service arising from the geographical distribution of services with areas of disadvantage both within urban and rural regions under-served by GP's (Sinclair et al., 1997), although policy incentives in the intervening years to attract GP's to establish practices in more deprived areas appear to have made gains (Teljeur et al., 2010).

5.2.5 Multimorbidity and healthcare utilisation in the older Irish population

Two previous studies have examined the impact of multimorbidity on healthcare utilisation indicators in Ireland. Glynn et al. (2011) examined a wide range of healthcare utilisation indicators and costs using nationally representative primary care data and Naughton et al. (2006) examined prescription claims and costs from the Irish HSE–Primary care reimbursement services (HSE–PCRS), a pharmacy claims database representative of GMS patients. Naughton et al. (2006) found that multimorbidity was significantly associated with polypharmacy (i.e. 4 or more prescriptions) in older Irish people (aged ≥70years) and also found an incremental increase in prescription costs with increasing numbers of concurrent conditions.

Increasing numbers of chronic conditions were also independently associated with an increase in healthcare utilisation for primary care consultations, hospital out-patient visits, hospital admissions, and total healthcare costs even after adjustment for known confounders including sex, age, GMS eligibility and practice clusters (Glynn et al., 2011). Evaluation of healthcare utilisation in an Irish context is limited by the lack of a unique patient identifier as discussed in Chapter 2, making it difficult to accurately assess the global picture of healthcare utilisation in Ireland. It is likely that while the methodological approach adopted by Glynn et al. provides a valid measure of primary care utilisation, it may be substantially under-estimating healthcare received in the acute sector not captured in GP practice records, especially emergency hospital care. Self-reports of healthcare utilisation may be subject to recall bias but are likely better able to capture the full pattern of healthcare use by community-dwelling older people in Ireland. Nonetheless, evidence to date suggests that multimorbidity is placing a considerable strain on healthcare resource use in Ireland. Further examination of the impact of multimorbidity prevalence and patterns from a population impact perspective could add valuable insight into the influence of multimorbidity on healthcare burden in Ireland.

5.2.6 Objectives

To date, the impact of increasing patient complexity across a broad range of healthcare services as a result of multimorbidity remains poorly understood, despite recent efforts to examine the issue in international literature. Studies examining multimorbidity and healthcare utilisation are generally restricted to particular populations determined by age range, data source or service types such as primary care (Glynn et al., 2011), hospital admissions (Condelius et al., 2008) or length of stay (Librero et al., 1999, Rochon et al., 1996). Studies have been limited to older, more

frail (Landi et al., 2004) clinical populations based on a limited number of high profile conditions. Evidence of the impact of multimorbidity on health and social care in an Irish context is also limited. It is proposed in this study that need factors are the primary determinants of healthcare utilisation in people aged 50 years and over in Ireland, and it is hypothesised that multimorbidity acts independently of other need factors and covariates in driving healthcare use across a range of indicators. Analyses of the impact of multimorbidity on healthcare utilisation outcomes in multivariate analysis controlling for a range of other need factors and covariates is important to advance our understanding of the independent impact of multimorbidity on healthcare burden, acknowledging the impact of varying constructs of multimorbidity including physical and mental health multimorbidity.

The effect of multimorbidity on health and social care burden is examined from two main perspectives in this study. Firstly, the impact of increasing levels of multimorbidity on a range of health and social care services is examined. The nature of the impact of acquiring additional chronic conditions on health and social care utilisation is of particular interest. The question is posed: is there a significant additional effect or is there a diminishing effect of the accumulation of additional conditions on service use. To expand on this further, if the acquisition of additional chronic conditions in an individual does not imply increased health or social care utilisation the utility of investing in multimorbidity prevention and management is less a question of economics and more a question of quality of life for those experiencing multimorbidity. If however, increasing multimorbidity leads to significant increases in healthcare utilisation, investment in primary and secondary prevention of multimorbidity is justified in order to reduce the burden on health care services. Secondly, the effect of different types of multimorbidity are examined across the same range of health and social care services. Multimorbidity type is modelled as described in early chapters as multimorbidity with and without a mental health component.

This chapter examines the impact of multimorbidity on health and social care utilisation relative to a wide range of factors that may also be driving utilisation in Ireland organised according to three broad enquiries:

1. The impact of multimorbidity levels and type on healthcare utilisation, measured by three indicators: GP visits, outpatient visits and total number of nights spent in hospital.
2. The impact of multimorbidity levels and type on quality of care for multimorbid patients, measured by two proxy indicators of quality care including propensity and intensity of use of Emergency Department services and polypharmacy.

3. The impact of multimorbidity levels and type on care received in the home, measured by two indicators: Public Health nurse (PHN) visits and formal care support in the home.

Examining a wide range of service outcomes allows for the identification of the relative contribution of multimorbidity to health and social service use in Ireland.

Several factors were controlled for in analyses, including other gerontological constructs. Disability, frailty and negative self-rated health were all modelled in multivariate analysis to control for additional elements of complexity, independent of multimorbidity. The Anderson Phase-3 model of healthcare utilisation is employed as an analytical framework allowing to the assessment of a wide range of covariates including socio-economic indicators such as education and employment status. While it is beyond the scope of this study to examine equity in the Irish healthcare services in any detail, a measure of medical cover is included in analyses to control for entitlement to services. Further to the interplay of need factors, detangling the independent effect of multimorbidity relative to age is of particular interest in this study.

5.3 Empirical analysis approach

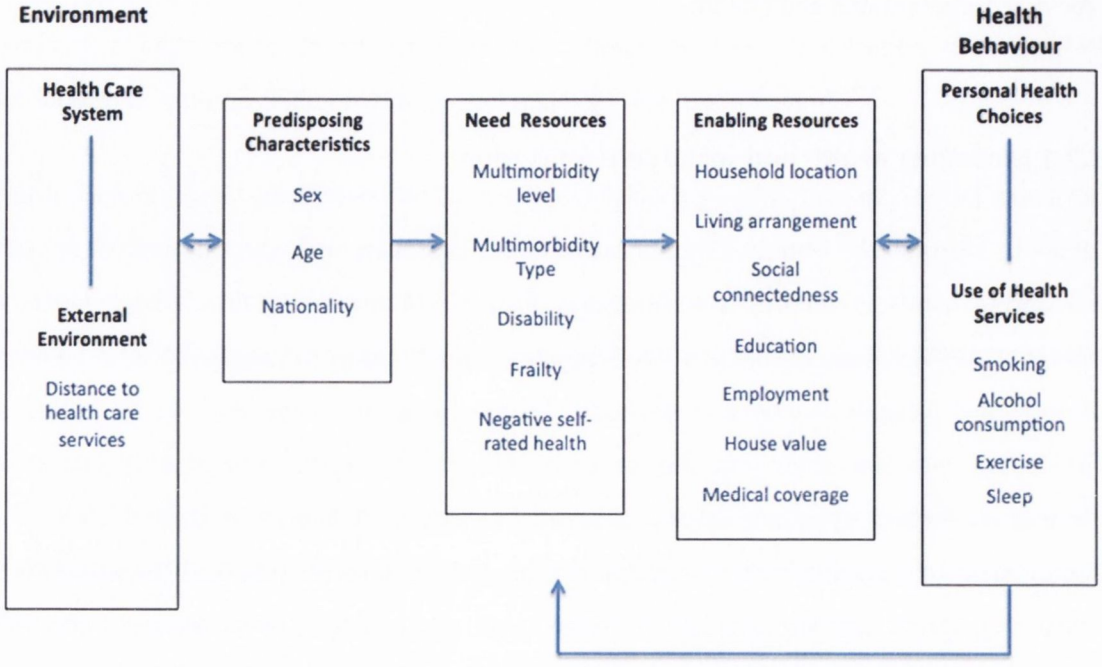
Availability of data on secondary outcomes of interest, namely measures of health and social care utilisation, was a further consideration in the development of empirical analysis in this thesis. Acknowledging the significant effect of population ageing on the efficiency, quality and cost of healthcare (as described in Chapter 2), a second objective of this thesis is to disentangle the particular effect of multimorbidity on health and social care utilisation, controlling for a wide variety of indicators. Comprehensive data on the use of health and social care services in Ireland are difficult to obtain for the reasons outlined in Chapter 2. Mainly due to the lack of a unique patient identifier administration data in Ireland are limited to single episodes of hospital activity, while TILDA captures data on respondent's use of a variety of health care services including visits to GPs, Emergency Departments, and episodes of hospital care as an inpatient or outpatient. Data are also collected on the usage of social care services including PHN visits, Home Help and formal personal care services. Availability of a comprehensive set of variables on health and social care utilisation in Ireland allows for detailed analysis of the impact of multimorbidity burden on health and social care services in Ireland, while data on a wider range of socio-demographic characteristics of respondents allows for controlling of potential confounders in multivariate regression analysis. Data are captured on current socio-demographic characteristics

including gender, age, nationality, marital status, living arrangement, location of household, educational attainment, employment and socio-economic status as well as childhood measures of socio-economic status and health.

5.3.1 Modelling health and social care utilisation

In order to examine the impact of multimorbidity on healthcare utilisation controlling for other need and extraneous factors, the Anderson Phase-3 Model of Health Service Utilisation (Anderson, 1995) is applied in this study (Figure 5.2) to inform the analytical framework. Indicators are integrated into a testable model assessing correlates that either impede or facilitate health service utilisation. This particular adaptation includes contextual factors as well as individual factors hypothesised to influence healthcare utilisation in Ireland. The model proposes that an individual's access to, and use of, services is a function of three components: predisposing characteristics, enabling resources, and need factors. Need refers to the direct health status of the individual that may prompt health service use. Predisposing characteristics are defined as socio-cultural characteristics of the individual that exist prior to the illness or disability that identify the propensity of the individual to use healthcare services. Enabling resources are described as the means available to individuals to use services and include logistical aspects of obtaining care. Anderson et al. (1973) hypothesised that each component would vary in their independent contribution to the prediction of health service utilisation. It was further hypothesised that need factors would be the primary predictors of non-discretionary behaviour (i.e. behaviour that was dictated by the seriousness of the health status or dictated by a healthcare provider), while predisposing and enabling factors would be more predictive of discretionary behaviour (i.e. behaviour that largely depends on the individual's own decision to seek care).

Figure 5.2 Anderson's Phase-3 Model of Health Service Utilisation as applied in this study (based on adaptation from Phillips et al. 1998)



Multimorbidity was added to the model as a need factor to assess its contribution to a range of healthcare utilisation outcomes relative to other need factors and covariates. Previously established determinants of healthcare utilisation in Ireland are incorporated into the Framework to control for the influence of additional determinants of healthcare utilisation in Ireland. Given the multidimensional nature of measures captured in TILDA, a wide range of variables were available for consideration as enabling and predisposing factors in the model, described in the following section. Indicators influencing healthcare supply in Ireland were also incorporated into analyses including variables indicating levels of healthcare coverage and geographical proximity to healthcare services.

It was hypothesised that other need factors such as disability and frailty may have a synergistic effect on health and social care utilisation. Therefore *a priori* interaction effects between multimorbidity and other need factors are tested in empirical analysis. Given the well-documented relationship between age and healthcare utilisation possible interactions between age and multimorbidity were tested for in all health and social care outcomes. *A priori* interactions were also tested for multimorbidity and socio-economic status measured by education and relative material deprivation levels.

Figure 5.3 Analytical Framework of health and social careutilisation



5.3.2 Data and variables

5.3.1.1 Dependent variables

A large selection of variables were available in TILDA to measure healthcare utilisation across a wide range of services including primary and secondary care services as well as social care services, based on self-reported intensity of healthcare utilisation in the preceding year of the survey date. Four commonly used variables were selected to examine the intensity of healthcare utilisation in primary and secondary care. These included:

1. the number of visits made to a GP in the preceding year of the survey date;
2. the number of outpatient visits for a substantial procedure in the preceding year of the survey date;
3. the number of overnight stays in hospital in the preceding year of the survey date.

Two further variables were selected as proxy measures of quality of care. As discussed, both polypharmacy and excess attendance at Emergency Departments may indicate poor quality of care. In keeping with the common definition in the literature (Fulton and Riley Allen, 2005), polypharmacy was defined in this study as the concurrent use of five or more prescribed medicines in an individual, based on self-reported use of prescribed medications. A dichotomous variable was generated to indicate the presence or absence of polypharmacy. Emergency department visits were examined as a dichotomous variable in descriptive analyses indicating greater or less than three visits to an Emergency department in the preceding year, and as a count variable based on the number of visits an individual had in the preceding 12 months.

A dichotomous variable was also generated for Public Health nurse visits indicating none or at least one visit in the preceding 12 months. This study examines formal social care only, i.e. that provided by the State. Previous reports do however point to the high proportion of community-dwelling older people in Ireland who receive social care from private (for profit) or not-for-profit sector as well as from older people themselves. The bulk of social care for older in Ireland is provided by family caregivers, primarily spouses and adult children, especially daughters (Kamiya et al., 2012). A significant minority of TILDA respondents reported using formal social care services; therefore meaningful analysis was not possible for some indicators of service use, due

to small cell numbers. Three variables were selected as indicators of health and social care use in the community including:

1. if a respondent had received the services of a PHN in the preceding year of the survey date;
2. if a respondent had received formal support in the form of either home help services in the preceding year of the survey date;
3. if a respondent had received formal care assistance in the preceding year of the survey date;

Each variable was coded as a dichotomous variable indicating use or non-use of the service. Due to small numbers, two of the variables were recoded into a single dichotomous variable indicating the use of either home help or a personal care attendant in the past year.

All dependent variables are listed and described as coded in Table 5.2.

Table 5.2. Description of dependent variables

Healthcare	
General practitioner visits	Count of visits from 0 to 150
Outpatient visits	Count of visits from 0 to 156
Number of nights in hospital	Count of nights spent in hospital from 0 to 196
Quality of care	
Emergency department visits	Count of visits from 0 to 50
Polypharmacy	0 = not polypharmacy, 1 = polypharmacy
Social care	
PHN visit	0 = no PHN visit, 1 = at least one PHN visit
Formal care assistance	0 = no formal care assistance, 1 = formal care assistance

5.3.1.2 Independent variables

In keeping with the Phase-3 Model of Health Service Utilisation proposed by Anderson (1995), multivariate regression models were adjusted for need factors, factors that predispose individuals to healthcare use and factors that enable individuals to utilise healthcare services as well as health behaviours and health system factors.

Key independent variables: Multimorbidity Level and Multimorbidity Type

The general definition of multimorbidity as two or more conditions was thought too restrictive for analyses in this study. The level of multimorbidity is therefore modelled as a concurrent count of conditions, from no condition to six or more conditions from the list of 25 conditions as outlined in Chapter 3. Multimorbidity type is modelled as a categorical variable with three categories indicating no multimorbidity, physical-physical multimorbidity and physical-mental health multimorbidity.

Notwithstanding the growing body of evidence on the impact of multimorbidity on patient complexity in later life, several other need factors are hypothesised to contribute to complexity. Drawing on the gerontological constructs defined in Chapter 1, two further objective need factors, disability and frailty, are included as need factors in analyses. Negative self-rated health may also contribute to higher levels of healthcare use independent of objective measures of health need (Miilunpalo et al., 1997). Self-rated health was also then considered as a need factor and added to the modelling Framework (Figure 5.2): All need factor variables were defined as per Chapter 3. To account for the large number of missing data (n=2,468), a fourth category was included in the frailty variable as an unclassified category. A summary of the coding of independent variables is presented in Table 5.3.

PREDISPOSING CHARACTERISTICS

Health and social care utilisation has been found to vary substantially by age and sex; therefore these factors are included in the model as predisposing factors. International and national studies have consistently shown that women are more frequent and more intensive users of healthcare than men (Mustard et al., 1998, Verbrugge and Wingard, 1987, Gijsbers van Wijk et al., 1992, Office, August 2011). Increasing age has also been found to be associated with higher utilisation of health and social care services. Age has consistently been found to be an important determinant of GP care, hospitalisations and nights in hospital (Rochon et al., 1996) and this holds true for Ireland (Layte et al., 2009). Older age is also strongly associated with increased use of prescription medications (Bennette et al., 2009). Age is however correlated with a number of factors potentially driving health and social care in Ireland including disability, frailty and the onset of chronic conditions, which are generally also associated with high rates of utilisation. In multivariate analyses, the effects of age on healthcare utilisation appear to be attenuated by other 'demand' or 'need' factors (Terner et al., 2011). Therefore age is included in multivariate

analysis as a potential confounder. Age was entered as a categorical variable in bands of ten years.

Nationality

Differences in healthcare utilisation according to ethnicity have been found in other developed countries (Willis et al., 2013) however, there is no evidence of an ethnicity or migrant effect in health and social care utilisation in Ireland. It could be however that Northern Irish individuals have a greater healthcare need based on higher reported levels of disability, which could not be explained by levels of multimorbidity in Northern Irish adults compared to adults in the Republic of Ireland (McDaid et al., 2013). Respondent's nationality was assessed as an open-ended response. Only a small proportion of respondents were born outside the ROI (< 10%) many of whom reported Northern Irish or British nationality. Given the small numbers of international respondents in the sample meaningful analysis by these nationality groupings were limited and they were aggregated into one 'other' category. Nationality was entered as a categorical variable with four categories: Irish, Northern Irish, British and other.

ENABLING CHARACTERISTICS

Several Irish studies have highlighted inequity in the Irish healthcare system and this has been accounted for in the modelling framework using 'house value' a proxy indicator of wealth (as described in detail in Chapter 4) and other structural indicators of inequalities in healthcare utilisation are accounted for in the models by controlling for location of household (either rural or urban), distance to services including the minimum distance to a General Practice Surgery and minimum distance to either a community or general hospital. As discussed, healthcare coverage has been found to be significantly associated with levels of healthcare utilisation in Ireland, both in primary and acute care. Healthcare coverage is modelled in the framework as an enabling factor based on a composite variable of GMS medical card entitlement and private health insurance coverage. For examination of frequent attendance at Emergency Departments, healthcare coverage is modelled as GMS coverage only.

Location of household

Location of household was categorised as a three-response measure including: in Dublin city or county, a city or town in the ROI other than Dublin, in a rural part of the country. This was aggregated into two categories indicating rural or urban location.

Social connectedness

Marital status, living arrangement and level of social integration including religiosity, church attendance and volunteering have previously been found to impact on levels of health and social care utilisation (Inouye et al., 2008, Willis et al., 2013, Layte et al., 2009). Three indicators were available to measure different aspects of social connectedness in TILDA. These included marital status, household composition and a third variable was based on the well-validated Berkman-Syme Social Network Index (SNI). It was initially decided to enter both household composition (measured as a three category variable indicating if person lives alone, if respondent lives with a spouse or if the respondent lives with other persons not a spouse) and social connectedness (measured as an four category ordinal scale from most integrated to most isolated) in analyses. However formal tests indicated multicollinearity between these variables. Social connectedness was subsequently dropped from all models and household composition was retained for analyses coded as a categorical variable indicating if respondent lived with a spouse, another individual or lived alone.

Education

The effects of educational status on healthcare utilisation manifest in many ways. Individuals with higher levels of educational attainment are likely to have a greater knowledge of health conditions and treatment regimes, have better self-management skills and are more proactive in primary prevention (Higgins et al., 2008). As previously discussed in Chapter 4, poor health literacy is closely related to educational attainment and is associated with higher healthcare costs, rates of hospitalisation and use of healthcare services in general (McCray, 2005). For the purpose of analysis, educational attainment categories were aggregated into three categories: completion of primary level or lower, completion or part-completion of secondary level and third level or higher (as per Chapter 3.).

Employment status

Labour market participation is independently associated with more regular health visits even after controlling for other factors (Institut de Recherche et Documentation en Economie de la Santé, December 2010). Employment status was coded according to eight response options including: retired, employed (including unpaid work in family business, temporarily away from work, or participating in apprenticeship or employment programme - such as Community Employment), self-employed (including farming), homemaker, in education or training, permanently sick or disabled, unemployed.

Table 5.3 Description of Independent variables

Need factors	
Multimorbidity level	0 to 6+ co-occurring chronic conditions
Multimorbidity type	1 = ≤ 1 condition, 1 = 2 physical conditions, 3 = 1 physical and 1 mental health condition
Disability	0 = no ADL or IADL disability, 1 = ADL or IADL disability
Frailty	0 = not frail, 1 = pre-frail, 2 = frail, 3 = unclassified
Self-rated health	0 = excellent or v.good or good, 1 = fair or poor
Predisposing factors	
Age group	0 = 50-59 years, 1 = 60-69 years, 2 = 70-79 years, 3 = 80+ years
Sex	0 = male, 1 = female
Nationality	0 = Irish, 1 = Northern Irish, 2 = British, 3 = other
Enabling factors	
Location	0 = urban, 1 = rural
Household composition	0 = lives with other persons, 1 = lives with spouse only, 2 = lives alone
Social Connectedness	0 = most integrated, 1 = moderately integrated, 2 = moderately isolated, 3 = most isolated, 4 = unclassified
Educational status	0 = third level +, 1 = secondary, 2 = primary/none
Employment status	1 = employed, 2 = self-employed, 3 = retired, 4 = home-maker, 5 = in education or training, 6 = permanently sick or disabled, 7 = unemployed
House value	1 = >€560,001, 2 = €400,001-560,000, 3 = €240,001, 4 = €80,000-240,000, 5 = < 80,000
Medical coverage	0 = GMS and private insurance, 1 = private insurance only, 2 = GMS only, 3 = no additional cover
Medical card status only	0 = no GMS, 1 = full GMS
Environmental factors	
Minimum distance to GP	1 = closest 10%, 2 = next 20%, 3 = next 20%, 4 = next 20%, 5 = next 20%, 6 = furthest 10%
Minimum distance to the nearest Community or General Hospital	1 = closest 10%, 2 = next 20%, 3 = next 20%, 4 = next 20%, 5 = next 20%, 6 = furthest 10%
Health behaviours	
Smoking status	0 = never, 1 = past, 2 = light, 3 = moderate, 4 = heavy
Alcohol consumption status	0 = none or rare, 1 = 1-2 days per week, 2 = 3-4 days per week, 3 = almost every day, 4 = unclassified
Exercise status	0 = high, 1 = moderate, 2 = low, 3 = Unclassified
Sleep	0 = rarely/never, 1 = sometimes, 2 = most of time

Proximity to health services

Variables on proximity to healthcare services were merged into the TILDA data, to provide information on proximity to the nearest healthcare services for each respondent in TILDA (variables are described in full in Chapter 4). Two variables were used in the empirical analysis for this chapter depending on outcome of interest. For example, a variable on nearest GP (in

meters), compared to all GP practices in Ireland was included as an independent variable for the GP utilisation models. The variable on nearest hospital (in meters), compared to all community OR general acute hospitals was entered into the model on outpatient use and nights spent in hospital.

HEALTH BEHAVIOUR FACTORS

Four health behaviour variables are included in analyses these are: exercise status, alcohol consumption, smoking status and sleep. All health behaviours are classified as detailed in Chapter 4.

5.3.3 Statistical analyses of healthcare utilisation

5.3.3.1 Descriptive statistics

Descriptive statistics were calculated for all indicators of healthcare utilisation and hypothesised determinants of healthcare utilisation (Table 5.4 and 5.5). The mean number of healthcare utilisation episodes was calculated for levels of multimorbidity, multimorbidity type and according to other outcomes of interest. These are presented with their standard deviation. In the case of non-normally distributed data, differences between means were tested using the Mann-Whitney test for dichotomous variables and the Kruskal-Wallis test for categorical variables. Chi-square tests were used to assess significant differences in proportions between multimorbidity categories as well as other categorical variables and the health outcomes for frequent Emergency Department use (defined as 3+ visits in the past year), polypharmacy (defined as 5 or more medications), use of a PHN in the previous year and use of formal care assistance in the previous year. Bivariate and multivariate regressions were used to analyse the crude and adjusted associations between independent variables, grouped according to need, predisposing, enabling and health behaviour factors and each dependent outcome for healthcare utilisation. Estimates are presented as odds ratios (ORs) or incident rate ratios (IRRs) with 95% confidence intervals and P-value.

5.3.3.2 Regression Models

Bivariate and multivariate logistic and negative binomial regression models were employed to test for associations between independent and dependent variables, guided by the nature of the data. The objective of the statistical modelling approach was to identify the model best able to explain observed patterns of outcome for each empirical enquiry. Multivariate regression models were developed for each empirical enquiry presented in this study. The main objective in model specification was to develop an explanatory model of exposures and confounders that are important influences on the outcome or dependent variable. While inclusion of all exposure variables associated with the dependent variable is recommended for multiple linear regression this is not the case for generalized linear models, for example, inclusion of extraneous variables in logistic regression models tends to increase the standard error of the estimated exposure effect (Hosmer and Lemeshow, 2000). However, sufficient attention must be paid to all potential confounders in logistic regression models as failure to do so can lead to a biased estimate of the effect (Hosmer and Lemeshow, 2000). Furthermore, in considering which potential confounders to include in multivariate analysis, careful consideration was afforded to the hierarchical relationships between exposures and confounders. Acknowledging the importance of confounders as well as exposure variables, a modelling strategy was developed based on the underlying conceptual framework for each research question. This aided in identifying and refining explanatory variables to be included in each model as potential effect modifiers or *a priori* confounders. Tests were two-tailed with α adopted at the less conservative 0.10 significance level.

The analysis for all empirical models followed a general sequence. Separate analysis was conducted for each health and social care outcome of interest. Initially, estimates of the dependent health and social care variables were cross-tabulated with each independent variable to investigate crude patterns in the data and detect cells with low numbers. Models for unadjusted associations between independent and dependent variables were estimated in bivariate analysis. Separate models were estimated for each health and social care outcome of interest, in order to identify significant relationships between variables. The distribution of outcome variables was examined for normality using the Shapiro-Wilk test for normality. In cases were the data was over dispersed, an alternative model fit was examined and tested using the Vuong test statistic to assess model preference.

Logistic regression analysis was conducted to estimate the impact of having one condition and multimorbidity type on propensity to use services and quality of care outcomes. A two-part

model was estimated. This is an appealing approach to modelling healthcare as it explicitly acknowledges the different contextual, decision and need processes at play depending on different stages of healthcare utilisation. This approach helps to identify the differential impact of multimorbidity on initiation and intensity of service use. The two-part modelling approach was favoured here when tests indicated over dispersion and an excess of zero's in the data.

There were potential concerns for multicollinearity between need factors entered in the models for all types of healthcare utilisation outcomes. However, given the conceptual framework of complex patients underlying analyses, the models needed to control for the potential confounding effect of measures of need including disability, negative self-rated health and frailty in addition to multimorbidity or the association between multimorbidity and outcomes of interest could be over-estimated. Furthermore, there was concern that multicollinearity may have been present between variables measuring different processes of socio-economic status, for example household value and education. Where evidence of multicollinearity was present (indicated by VIF values ≥ 5 and tolerance values ≤ 0.20) one of the variables was dropped and if no evidence of multicollinearity was indicated both dependent variables were retained in the overall model. The overall models were also examined for mean VIF and variance levels. Graphic displays and the Breusch-Pagan test were used to detect the presence of heteroskedasticity.

5.3.3.3 Model Fit

Sensitivity analyses were undertaken to examine the robustness of the specified model results and data structure. The Hosmer and Lemeshow χ^2 goodness-of -fit test is generally a good indicator of the fit of a model, suitable for models with potentially large numbers of covariate patterns, and has also been updated to account for complex survey design in the most recent release of STATA12 using the SVYSET command to take account of the TILDA multistaged stratified random sample design. Non-significance value at the conventional 0.10 alpha level indicated that the model was a good fit for the data. However, goodness of fit was not the main criterion for rejecting the models. For multivariate logistic models, non-significant variables at a 0.10 alpha level were subsequently omitted in the modelling process until a satisfactory model was obtained. McFadden's adjusted R^2 was used to assess model fit for the zero-truncated part of the model. Preliminary main effect models are presented for each outcome of interest along with goodness of fit statistics. Coefficients are presented as ORs or IRRs along with 95% CI's and P-values.

5.3.3.4 Normality, multicollinearity, homoskedasticity and influential observations in multivariate models.

Graphic displays of data indicated that all dependent variables modelled as count data violated the normality assumption for OLS, confirmed by the Shapiro-Wilk test for normality: GP visits ($z = 19.879$, $p<0.000$); outpatient visits ($z=20.963$, $p<0.000$), nights in hospital ($z = 20.312$, $p<0.000$) and Emergency Department visits ($z=19.88$ $p<0.000$). Formal tests for over dispersion and excess zeros indicated that a zero-inflated regression model was favoured over either a Poisson or negative binomial model for all outcomes: GP visits (Vuong = 5.22 $p<0.001$); outpatient visits (Vuong = 2.84 $p<0.001$) hospital nights (Vuong = 8.73 $p<0.001$) and Emergency Department visits (Vuong = 3.476 $p<0.001$). In all cases a two-part hurdle model was favoured over the zero-inflated regression model for its ability to estimate the propensity to use services separate to the intensity of use. Propensity to use service was modelled as a logit model indicating use or non-use of services and intensity of use was modelled using a zero truncated negative binomial model. The remaining three outcomes of interest were modelled as dichotomous variables indicating the presence or absence of polypharmacy and the use or non-use of PHN visits and formal social care assistance in the previous twelve months.

Sex and age variables were retained in all analyses as they have been previously shown to demonstrate strong associations with healthcare outcomes, unless they indicated collinearity with other variables. There was concern that multicollinearity may have been present between variables measuring different processes of socio-economic status, for example Household value and education. Where evidence of multicollinearity was present (indicated by VIF values ≥ 5 and tolerance values ≤ 0.20) one of the variables was dropped and if no evidence of collinearity was indicated both dependent variables were retained in the overall model. The overall models were also examined for mean VIF and variance levels. Graphic displays and the Breusch-Pagan test were used to detect the presence of heteroskedasticity.

Multivariate models were examined for issues of multicollinearity for each dependent outcome for both models examining multimorbidity levels and multimorbidity type. There were no issues of multicollinearity detected for GP visits (mean VIF for multimorbidity level was 1.45 and the mean VIF for the multimorbidity type model was 1.42); outpatient visits (mean VIF for the model e multimorbidity levels was 1.45 and the mean VIF for the multimorbidity type model was 1.42); nights in hospital (mean VIF for the multimorbidity levels model was 1.45 and 1.42 for multimorbidity type model); Emergency Department visits (mean VIF for the multimorbidity levels model was 1.44 and 1.41 for multimorbidity type model); polypharmacy (mean VIF for the

multimorbidity levels model was 1.40 and 1.36 for multimorbidity type model); PHN visits (mean VIF for the multimorbidity levels model and the multimorbidity type model was 1.58 and 1.57 respectively) or for care assistance (mean VIF for the overall multimorbidity levels model was 1.64 and 1.64 for multimorbidity type model).

The Breusch-Pagan test for heteroskedasticity indicated that the null hypothesis should be rejected for all dependent variables: GP (χ^2 = 7834.78, p<0.001); outpatient visits (χ^2 = 49113.98, p<0.001); nights in hospital (χ^2=13628, p<0.001); Emergency Department visits (χ^2 =4211.46, p<0.01); polypharmacy (χ^2 =1831.25, p<0.001); PHN visits (χ^2 = 6921.87, p<0.001) and care assistance (χ^2 =13877.06, p<0.001). Heteroskedasticity was corrected for by estimating robust standard errors in all models.

All variables were inspected to assess potential outliers or influential observations in the data. Four cases were observed as potential outliers for hospital nights in hospital >100 days in hospital in previous year. Respondent characteristics were then examined to ascertain if need factors indicated a potential long stay in hospital and all respondents had a limiting long-term illness and either physical or mental health multimorbidity therefore the suspected outliers were retained in the data.

5.3.3.5 Multivariate modelling sequence

Modelling followed a general sequence. For all outcomes of interest, two overall models were estimated. The first modelled *multimorbidity levels* from 0 to 6 plus conditions as the primary independent variable of interest and the second modelled *multimorbidity type* as a categorical variable as the primary variable of interest. In the case of count data that were over-dispersed each of two models described were examined using a two-part zero-truncated model, leading to four sets of estimated results. In the case of dichotomised dependent variables, logistic regression model results are presented for each of the two models as described (i.e. multimorbidity levels and multimorbidity type).

Only variables significant at the α = 0.10 level in bivariate models were retained for modelling in multivariate analyses. Bivariate analysis results are presented in Appendix 5.1 for all outcomes of interest. Other independent need variables (i.e. disability, frailty and self-rated health) significant at the bivariate level were entered into the model after the primary variables of

interest had been entered followed by predisposing, enabling and behavioural factors. In order to retain the most parsimonious models, variables indicating non-significance at the α = 0.10 level were also dropped from multivariate models after checking for evidence of a confounding effect on other variables. Model fit was compared between the null model, and model iterations after adding additional groups of variables separately according to the factors outlined in the Anderson Healthcare Framework: need, predisposing, enabling and behavioural factors. Likelihood ratio tests were used to compare fit between model iterations for all logistic and zero-truncated negative binomial models. Likelihood ratio tests for all models favoured the final models presented in the results with χ^2 significant at the p<0.001 level. Overall goodness of fit was assessed by the Hosmer and Lemeshow χ^2 test for logistic models and McFaddens adjusted R^2 for the zero-truncated negative binomial models.

Where the overall effect for increasing levels of multimorbidity on service use was significant in multivariate models, predicted probabilities for the impact of increasing multimorbidity levels on propensity to use a service and intensity of service use were estimated after adjusting for all covariates. Results are graphed along with a further graph displaying the predictive margins for the probability of service use between adjacent levels of multimorbidity averaging across all values of the covariates.

5.3.3.6 Multivariate model specification

General Practitioner visits

For the multivariate analysis of GP utilisation, the dependent variable was specified as count data and the final two-part model for multimorbidity level was specified as:

Part 1. Logistic regression model

$$Logit(\mathrm{Y}) = \beta_1 multimorbiditylevel_i + \beta_2 disability + \beta_3 frail_i + \beta_4 SRH$$
$$+\beta_5 agegroup_i + \beta_6 sex + \beta_7 nationality_i + \beta_8 medcover_i + \beta_9 livingstatus_i$$
$$+\beta_{10} employment_i + \beta_{11} exercise_i + \beta_{12} sleep_i$$

Part 2. Zero-truncated negative binomial regression model:

$$Y = f(\beta_0 + \beta_1 multimorbiditylevel_i + \beta_2 disability + \beta_3 frail_i + \beta_4 SRH + \beta_5 agegroup_i + \beta_6 sex + \beta_7 nationality_i + \beta_8 medcover_i + \beta_9 livingstatus_i + \beta_{10} employment_i + \beta_{11} exercise_i + \beta_{12} sleep_i)$$

The final two-part model for multimorbidity type was specified as above with

$\beta_i multimorbiditylevel_i$ replaced by $\beta_i multimorbiditytype_i$ in each model.

The most parsimonious model for multimorbidity levels indicated good fit for the logit model (χ^2 = 11.19 p=0.19) and the zero-truncated negative binomial model (ztnb) (McFadden's Adjusted R^2 = 0.063). The most parsimonious model for multimorbidity type also indicated good fit for the logit model (χ^2 = 5.93 p=0.65) and the ztnb model (McFadden's Adjusted R^2 = 0.06).

Outpatient visits

For the multivariate analysis of OP utilisation, the dependent variable was specified as count data and the final two-part model for multimorbidity level was specified as:

Part 1. Logistic regression model

$$Logit(Y) = \beta_1 multimorbiditylevel_i + \beta_2 disability + \beta_3 frail_i + \beta_4 SRH + \beta_5 sex + \beta_6 agegroup_i + \beta_7 nationality_i + \beta_8 livingstatus_i + \beta_9 reversemedcover_i + \beta_{10} education_i + \beta_{11} employment_i + \beta_{12} alcohol_i + \beta_{13} smoke_i$$

Part 2. Zero-truncated negative binomial regression model:

$$Y = f(\beta_0 + \beta_1 multimorbiditylevel_i + \beta_2 disability + \beta_3 frail_i + \beta_4 SRH + \beta_5 sex + \beta_6 agegroup_i + \beta_7 nationality_l + \beta_8 livingstatus_i + \beta_9 reversemedcover_i + \beta_{10} education_i + \beta_{11} employment_i + \beta_{12} alcohol_i + \beta_{13} smoke_i)$$

The final two-part model for multimorbidity type was specified as above with

$\beta_i multimorbiditylevel_i$ replaced by $\beta_i multimorbiditytype_i$ in each model.

The most parsimonious model for multimorbidity levels indicated good fit for the logit model (χ^2 = 7.23 p=0.51) and the ztnb model (McFadden's Adjusted R^2 = 0.058). The most parsimonious model for multimorbidity type also indicated good fit for the logit model (χ^2 = 5.20 p=0.73) and the ztnb model (McFadden's Adjusted R^2 = 0.052).

Hospital nights

For the multivariate analysis of GP utilisation, the dependent variable was specified as count data and the final two-part model for multimorbidity level was specified as:

Part 1. Logistic regression model

$$Logit(\mathrm{Y}) = \beta_1 multimorbiditylevel_i + \beta_2 disability + \beta_3 frail_i + \beta_4 SRH + \beta_5 agegroup_i + \beta_6 sex + \beta_7 revmedcover_i + \beta_8 reveducation_i + \beta_9 employment_i + \beta_{10} exercise_i + \beta_{11} smoke_i$$

Part 2. Zero-truncated negative binomial regression model:

$$\mathrm{Y} = f(\beta_0 + \beta_1 multimorbiditylevel_i + \beta_2 disability + \beta_3 frail_i + \beta_4 SRH + \beta_5 agegroup_i + \beta_6 sex + \beta_7 revmedcover_i + \beta_8 reveducation_i + \beta_9 employment_i + \beta_{10} exercise_i + \beta_{11} smoke_i)$$

The final two-part model for multimorbidity type was specified as above with

$\beta_i multimorbiditylevel_i$ replaced by $\beta_i multimorbiditytype_i$ in each model.

The most parsimonious model for multimorbidity levels indicated good fit for the logit model (χ^2 = 1.79 p=0.98) and the ztnb model (McFadden's Adjusted R^2 = 0.022). The most parsimonious model for multimorbidity type also indicated good fit for the logit model (χ^2 = 727 p=0.51) and the ztnb model (McFadden's Adjusted R^2 = 0.025).

Emergency Department visits

For the multivariate analysis of Emergency Department utilisation, the dependent variable was specified as count data and the final two-part model for multimorbidity level was specified as:

Part 1. Logistic regression model

$$Logit(\mathrm{Y}) = \beta_1 multimorbiditylevel_i + \beta_2 disability + \beta_3 SRH$$
$$+\beta_4 revagegroup_i + \beta_5 sex + \beta_6 medcard_i + \beta_7 employment_i + \beta_8 frail_i$$

Part 2. Zero-truncated negative binomial regression model:

$$\mathrm{Y} = f(\beta_0 + \beta_1 multimorbiditylevel_i + \beta_2 disability + \beta_3 SRH$$
$$+\beta_4 revagegroup_i + \beta_5 sex + \beta_6 medcard_i + \beta_7 employment_i)$$

The final two-part model for multimorbidity type was specified as above with

$\beta_i multimorbiditylevel_i$ replaced by $\beta_i multimorbiditytype_i$ in each model and frailty included as an independent dummy variable $\beta_8 frail_i$.

The most parsimonious logit model for multimorbidity levels was significant at the α 0.05 level, indicating poor model fit (χ^2 = 6.53 p=0.02), although the ztnb model indicated good fit (McFadden's Adjusted R^2 = 0.022). The most parsimonious model for multimorbidity type indicated good fit for the logit model (χ^2 = 2.97 p=0.94) and the ztnb model (McFadden's Adjusted R^2 = 0.026).

Polypharmacy

Both sex and medical cover were reverse coded in the multivariate regression models. The final logistic regression model for polypharmacy was specified as:

$$Logit(\mathrm{Y}) = \beta_1 multimorbiditylevel_i + \beta_2 disability + \beta_3 frail_i + \beta_4 SRH$$
$$+\beta_5 agegroup_i + \beta_6 revsex + \beta_7 revmed\mathrm{cover}_i + \beta_8 employment_i$$
$$+\beta_9 smoke_i + \beta_{10} alcohol_i + \beta_{11} exercise_i$$

The final logistic regression model for multimorbidity type was specified as above with

$\beta_i multimorbiditylevel_i$ replaced by $\beta_i multimorbiditytype_i$ in each model.

The most parsimonious model for multimorbidity levels indicated moderate fit for the logit model (χ^2 = 13.96 p=0.08) and the most parsimonious model for multimorbidity type also indicated moderate fit for the logit model (χ^2 = 15.41 p=0.60).

PHN visits

Distance to nearest General Practice was reverse coded and retained in the multivariate regression models for PHN visits. For the multivariate analysis of PHN utilisation, the logistic regression model was specified as:

$$Logit(\mathrm{Y}) = \beta_1 multimorbiditylevel_i + \beta_2 disability + \beta_3 frail_i + \beta_4 SRH + \beta_5 agegroup_i + \beta_6 sex + \beta_7 Lives_i + \beta_8 revmedcover_i + \beta_8 employment_i + \beta_9 revGPdistance_i + \beta_{10} exercise_i + \beta_{11} smoke_i + \beta_{12} sleep_i$$

The final logit model for multimorbidity type analysis was specified as above with

$\beta_i multimorbiditylevel_i$ replaced by $\beta_i multimorbiditytype_i$.

The most parsimonious model for multimorbidity levels logit model indicated good fit (χ^2 = 2.05 p=0.98) as well as the logit model for multimorbidity type (χ^2 = 6.50 p=0.59).

Formal care assistance

For the multivariate analysis of PHN utilisation, the logistic regression model was specified as:

$$Logit(\mathrm{Y}) = \beta_1 multimorbiditylevel_i + \beta_2 disability + \beta_3 frail_i + \beta_4 SRH + \beta_5 agegroup_i + \beta_6 sex + \beta_7 Lives_i + \beta_8 revmedcover_i + \beta_8 employment_i + \beta_9 exercise_i$$

The final logit model for multimorbidity type analysis was specified as above with

$\beta_i multimorbiditylevel_i$ replaced by $\beta_i multimorbiditytype_i$.

The most parsimonious model for multimorbidity levels logit model indicated good fit (χ^2 = 6.76 p=0.56) as well as the logit model for multimorbidity type (χ^2 = 9.71 p=0.28).

5.3.4 Data cleaning

Several variables modelled in the analyses presented in this chapter had missing data. Frequencies and weighted percentages for all data are presented in respective tables as well as missing data. In the case of data missing for dependent variables, all missing cases were dropped

before multivariate analysis (GP visits n=10, outpatient visits n=7, nights in hospital n=3, Emergency Department visits n=7 polypharmacy n=81). Independent variables were also examined for missing cases and sensitivity analyses were conducted to establish any effect of exclusion of missing data from independent variables. For variables with multiple categories and a large proportion of missing data, a separate 'unclassified' category was created for the missing data. For example, those who did not report frailty were assigned to an unclassified category. In the case of low numbers of missing data, models were run omitting the missing data (sex n=3, age=12, nationality n=6, education n=3, GMS medical card n=8, private medical insurance n=5, house location n=12).

5.4 Results

5.4.1 Descriptive analysis

A large proportion of middle to older age people had accessed some form of healthcare in the previous year (88.4%). A high proportion had accessed General Practitioner services (87.5%, n=7,141) while smaller numbers had attended hospital as an outpatient (17.2%, n=1,451) and had at least one overnight stay in hospital (12.7%, n=1,042). The mean number of GP consultations for the full TILDA sample was 4.0 (± 5.4). The mean number of outpatient visits was 0.4 (±2.5) and the mean number of nights in hospital was 1.2 (±6.3) nights.

5.4.1.1 Chronic conditions

Healthcare utilisation rates varied substantially according to chronic conditions and across healthcare utilisation type (Appendix 5.1-5.3). Highest mean GP utilisation was recorded for persons with vision impairment, memory disorder, Parkinson's disease, stroke/TIA and other mental health condition (not anxiety or depression). Highest mean outpatient visits was recorded for cirrhosis, cancer, stroke/TIA, heart failure and heart murmur. Highest mean number of nights in hospital was observed for persons with memory disorder, stroke/TIA, Parkinson's disease, vision impairment and heart failure. Individuals with heart failure had the highest rate of both frequent Emergency Department visits (≥3 visits in the previous year) (10.5%) and polypharmacy (76.4%). Those with memory disorders were the second most frequent attenders at Emergency Departments compared to any other of the 25 conditions

examined and the sixth highest levels of polypharmacy. Individuals with stroke/TIA also had high rates of frequent attendance at EDs and had a high rate of polypharmacy. Those with sensory impairments also had a high rate of frequent attendance at EDs as well as individuals with anxiety or depression, respiratory conditions, an abnormal heart rhythm and angina or heart attack.

The highest proportion of PHN visits was found for persons with Parkinson's disease, this was double the recorded rate for memory disorders (46.8% vs. 26.4% respectively). Individuals with sensory impairments as well as those with varicose ulcers, angina or heart attack or incontinence also recorded a high use of PHNs. Again Parkinson's disease was found to have the highest rate of formal care assistance, double that for the next most prevalent condition for use of care assistance: vision impairment (34 % vs. 15%). Individuals with stroke/TIA, memory disorders, varicose ulcers or incontinence were also among the top ranking users of formal care assistance compared to other conditions.

5.4.1.2 Descriptive results for outcomes of interest and all independent variables.

Tables 5.4 and 5.5 present descriptive analysis between each of the outcomes of interest and all independent variables considered as potential predictors of healthcare utilisation as described. Further to the observed differences in utilisation by condition type, distinct patterns of use were evident when examined across need, predisposing, enabling and behavioural factors.

Multimorbidity and other need factors

The distribution of need factors in the overall TILDA sample was examined to investigate the proportion of respondents with need factors and any combination of need factors. 53.4% of respondents in the TILDA sample had threshold multimorbidity, 12% reported difficulty with at least one ADL or IADL (i.e. disability) and 2% were frail[5]. Of the total sample, 10% (n=814) had multimorbidity with a disability, 1.8% (n=146) had multimorbidity with frailty and 1.2% had disability with frailty (n=100) (Figure 5.4). A small proportion (1.2%, n=94) of respondents had all three need factors (i.e. threshold multimorbidity, disability and frailty).

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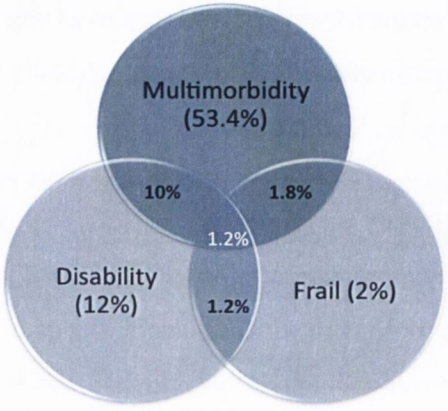
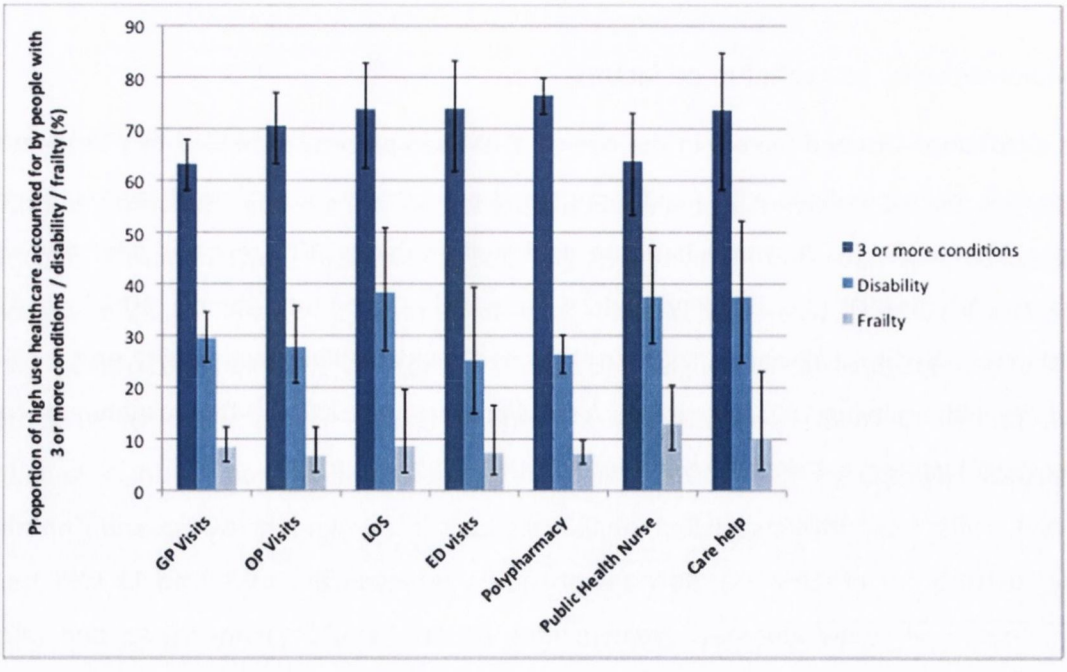
[5] Frailty is likely underestimated in TILDA due to the absence of institutionalised older people and cognitively impaired in the study.

Figure 5.4 Distribution of need factors in the TILDA sample



The proportions of high health and social care use accounted for by each of the three need factors is presented in Figure 5.5. Individuals with ≥ 3 co-occurring conditions accounted for a high level of utilisation across all health and social care indicators. 63.2% of those classified as high users of GP service (defined as ≥7 visits in the previous year) had ≥ 3 co-occurring conditions. The proportion of high health care use accounted for by multimorbidity varied slightly across health service use but a substantially higher proportion of high users had multimorbidity compared to the other need factors.

Figure 5.5 Proportion of high use of healthcare services accounted for by multimorbidity, disability and frailty.



Substantial and significant differences in GP visiting rates were observed for persons with increasing multimorbidity (Table 5.4). Persons with six or more conditions recorded a fourfold increase in 8.9 average visits per year compared to 1.8 visits for people reporting no chronic condition ($p<0.001$). There was also an evident increase in utilisation rates for people with physical and mental health multimorbidity. Respondents reporting the presence of both a physical and mental health condition, had an average 6.6 visits to the GP in the previous year compared to 2.6 for those without multimorbidity and 5.1 for those with two or more physical conditions only ($p<0.001$). An observed higher number of visits was also true for persons with more than one mental health condition; 6.8 visits compared to 3.9 visits for persons without mental health multimorbidity ($p<0.001$). Those who were frail recorded the highest mean number of GP visits compared to any other category of need factor (10.0 ± 12.4) and high average use was also recorded for those reporting a disability; 7.6 compared to 3.5 for those without ($p<0.001$). Those reporting negative self-rated health also indicate high use of GP services compared to those reporting more favourable self-assessed health (7.2 vs. 3.0) ($p<0.001$).

Outpatient visits (Table 5.4) increased incrementally for increasing levels of multimorbidity ($p<0.001$). Those with six or more co-occurring conditions had an elevenfold increased mean number of outpatient visits in the previous year compared to those with no conditions and a fourfold increase compared to those with one condition. A small difference in outpatient visits was found for those with at least one physical and at least one mental health condition compared to multimorbid individuals with no co-occurring mental health condition. Individuals reporting negative self-rated health had almost four times the average outpatient visits compared to those with more positive self-assessed health ($p<0.001$), while those with a disability had twice the average compared to those without and more frail individuals also had five times higher average visits compared to their counterparts ($p<0.001$ in all cases).

Those with higher levels of multimorbidity also recorded significantly higher number of nights in hospital as an inpatient; 4.6 nights for six plus conditions compared to 0.3 for those with no chronic condition ($p<0.001$) (Table 5.4). Those with physical-mental health multimorbidity averaged double the nights compared to those with no co-occurring mental health condition ($p<0.001$). Persons reporting a disability had twice the average nights in hospital compared to those without a disability (1.2 vs. 2.3, $p<0.001$); those reporting more negative health status had almost six times the average compared to those reporting more favourable health (3.2 vs. 0.6,

p<0.001), while those who were frail had an almost fourteen times higher average number of nights spent in hospital compared to those who were not (0.5 vs. 6.9, p<0.001).

5.4.1.3 Descriptive results for outcomes of interest predisposing and enabling factors

Women had slightly higher average GP visits compared to their male counterparts (3.9 vs. 4.1 p<0.001) although no significant difference was detected for outpatient visits or nights in hospital (Table 5.5). GP visits increased incrementally according to ten years age bands (3.3 for age 50-59, 3.9 for age 60-69, 4.9 for age 70-79 and 5.8 for age 80 plus, p<0.001). Higher average number of outpatient visits and LOS were also recorded for increasing age groups (p<0.001 in all cases). Significant differences were also recorded by nationality, with a higher average GP use recorded for British nationals (4.1) compared to other groups, slightly in excess of that for Irish nationals (4.0). Lowest use was recorded for 'other nationals' (2.6) (p<0.001). Those on medical cards had substantially higher mean GP visits than any other category of medical cover (5.8) p<0.000. Use for those with health insurance was similar to that for those with no additional cover (2.6 vs. 2.5), although those who did not have additional medical cover recorded the lowest mean GP use compared to any other category examined. A similar pattern was observed for outpatient visits and nights in hospital, although for both, a slightly higher average use was recorded for those with dual cover (both GMS and private insurance) (p<0.001 in all cases).

Those living alone and those who are most isolated also recorded high levels of GP (4.9 and 5.0 respectively, p<0.001), outpatient (0.8 and 0.9 respectively, p<0.01) and nights in hospital (1.5 and 1.4 respectively, p<0.001) (Table 5.5). Respondents with lower levels of education completed recorded higher levels of GP use (5.2 for primary level or none vs. 3.1 for third level p<0.001) and average nights in hospital (1.7 for primary level or none vs. 0.9 for third level p<0.02). However, this pattern was reversed for outpatient use, where those who had third level education were on average more frequent users of outpatient services (0.8 for primary level or none vs. 0.9 for third level p<0.01). Permanently sick and disabled individuals had substantially higher attendance at GPs compared to any other employment category including unemployed and retired (9.3 vs. 3.6 and 4.4 respectively, p<0.001). They also had on average higher outpatient visits and nights spent in hospital compared to other employment groups (2.1 and 4.6 respectively p<0.001 in all cases). GP use also increased incrementally for decreasing house value with those living in properties valued at less than €80,000 averaging almost twice as many GP visits in the previous year compared to those in the highest value category (p<0.001). This

also held true for number of nights in hospital ($p<0.1$), however, this pattern was not observed for outpatient visits.

Table 5.4 Descriptive analysis of need factors for health and social care variables

Variable (n=missing)	Categories	n	Weighted % (95% CI)	Mean GP visits (+SD)	Mean OP visits (+SD)	Mean LOS (+SD)	Frequent ED user (3+)	Polypharmacy (5+ meds)	PHN visit	Social care visits
N (missing)		8,128		8,118 (10)	8,128	8, 125 (3)	8,128	8,047 (81)	8,128	8,128
n (weighted %)				7,099 (88.7%)	1446 (18.5%)	1,039 (12.4%)	131 (1.5%)	1,672 (21.9%)	480 (4.6)	273 (2.5)
				4.0 ± 5.4	0.8 ± 4.0	1.2 ± 6.3				
Need Factors										
Number of conditions	0	1,723	21.0 (20.0-21.9)	1.8±3.5	0.2±0.9	0.3±2.2	0.5 (0.3-1.0)	1.6 (1.0-2.3)	1.3 (0.8-2.0)	1.2 (0.7-2.0)
	1	2066	25.2 (24.2-26.2)	3.1±4.8	0.5±2.6	0.6±3.9	0.8 (0.5-1.3)	6.9 (5.8-8.2)	3.5 (2.7-4.6)	1.4 (1.0-2.1)
	2	1723	21.0 (20.1-22.0)	4.1±4.6	0.9±5.0	1.0±3.9	0.8 (0.4-1.4)	16.2 (14.4-18.1)	6.5 (5.2-8.0)	3.3 (2.4-4.6)
	3	1148	14.1 (13.3-14.9)	4.9±4.4	1.0±3.5	1.8±9.0	2.1 (1.4-3.2)	32.7 (29.9-35.7)	7.6 (6.0-9.5)	4.8 (3.6-6.5)
	4	693	8.8 (8.2-9.5)	5.9±6.7	1.3±4.8	1.8±7.2	3.5 (2.3-5.3)	52.4 (48.3-56.4)	11.2 (8.9-14.0)	8.5 (6.3-11.5)
	5	378	4.7 (4.2-5.2)	6.8±5.9	1.4±4.4	3.2±12.1	3.2 (1.8-5.8)	59.7 (54.3-64.9)	15.8 (12.2-20.4)	7.1 (4.8-10.4)
	6+	397	5.2 (4.6-5.7)	8.9±10.4	2.2±6.8	4.6±12.5	8.5 (6.0-11.8)	74.5 (69.5-78.9)	24.9 (20.6-29.7)	16.0 (12.4-20.5)
				p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001
Multimorbidity	≤ 1 condition	3,992	47.3 (45.6-49.0)	2.6±4.4	0.3±2.1	0.4±.4.8	0.9 (0.5-1.4)	4.5 (3.6-5.8)	1.7 (1.1-2.6)	0.9 (0.4-1.9)
	2 Physical conditions	3,664	46.0 (44.3-47.7)	5.1±5.9	1.1±4.9	0.9±.7.2	1.7 (1.2-2.5)	35.8 (33.2-38.5)	7.2 (5.7-9.0)	4.0 (2.9-5.6)
	2 conditions one of which is mental	472	6.7 (5.8-7.6)	6.6±6.4	1.3±4.3	1.6±.10.7	3.8 (1.9-7.3)	49.0 (42.0-55.9)	8.1 (5.1-12.6)	3.8 (1.9-7.4)
				p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001
Disability	No disability	7,150	88.5 (87.2-89.3)	3.9±5.4	1.4±4.4	1.2±6.1	0.7±3.7	20.2 (19.2-21.2)	6.3 (5.8-7.0)	3.8 (3.4-4.4)
	Disability	978	11.5 (10.2-12.7)	6.3±6.1	2.6±4.8	2.3±8.5	1.5±4.6	43.9 (38.7-49.3)	11.5 (8.5-15.4)	5.3 (3.3-8.3)

				p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p=0.04	p=0.12
Frailty	Not frail	3,853	45.0 (43.9-46.2)	3.0±3.7	1.1±2.7	0.5±4.3	0.5±2.1	13.1 (12.0-14.3)	2.2 (1.7-2.7)	0.7 (0.4-1.1)
	Pre-frail	1,651	20.8 (19.8-21.7)	4.9±5.4	2.1±5.0	1.6±6.2	1.1±3.9	32.9 (30.5-35.4)	9.7 (8.2-11.5)	6.4 (5.2-7.9)
	Frail	163	2.6 (1.8-2.5)	10.0±12.4	4.4±13.8	6.9±13.9	2.7±13.3	61.7 (52.8-70.0)	36.5 (28.8-44.8)	25.6 (18.5-34.2)
	Unclassified	2,461	32.1 (31.0-33.2)	4.5±6.5	1.6±5.0	1.7±7.7	0.8±4.3	22.9 (21.1-24.7)	8.8 (7.6-10.1)	5.4 (4.4-6.5)
				p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001
Negative Self-rated Health	Favourable	6,239	74.9 (73.8-75.9)	3.0±3.6	1.0±3.1	0.6±3.6	0.5±2.5	12.9 (12.0-13.8)	3.9 (3.4-4.5)	2.2 (1.8-2.7)
	Poor	1,889	25.1 (24.1-26.2)	7.2±8.5	3.2±7.1	3.2±11.0	1.8±6.3	46.9 (44.5-49.3)	14.5 (12.8-16.3)	8.9 (7.6-10.5)
				p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001

Table 5.5 Descriptive analysis of predisposing, enabling and behavioural factors for health and social care variables

Variable (n=missing)	Categories	n	Weighted % (95% CI)	Mean GP visits (+SD)	Mean OP visits (+SD)	Mean LOS (+SD)	Frequent ED user (3+)	Polypharmacy (5+ meds)	PHN visit	Social care visits
Predisposing										
Sex	Male	3,722	48 .0 (46.8-49.2)	3.9±5.7	0.9±4.7	1.3±6.5	1.4 (0.9-2.1)	20.4 (18.4-22.5)	4.1 (3.0-5.4)	1.8 (1.1-3.1)
	Female	4,406	52.0 (50.8 -53.2)	4.1±5.2	0.7±2.8	1.1±6.1	1.6 (1.1-2.2)	23.2 (21.1-25.5)	5.1 (4.0-.6)	3.1 (2.2-4.4)
				p<0.001	p=0.60	p=0.60	p=0.65	p=0.06	p=0.22	p=0.09
Age groups	50-59	3,257	40.4 (39.3-41.6)	3.3 ±4.8	0.6±2.9	0.8±5.5	1.8 (1.3-2.6)	10.4 (9.0-11.9)	1.7 (1.2-2.3)	0.4 (0.1-0.9)
	60-69	2,580	31.0 (29.9-32.1)	3.9±5.9	0.9±3.9	1.1±5.0	1.4 (0.9-2.3)	21.7 (19.5-24.0)	3.1 (2.3-4.3)	0.7 (0.4-1.4)
	70-79	1,669	19.9 (19.0-20.8)	4.9±4.9	0.9±3.8	1.9±8.0	1.0 (0.5-2.1)	38.2 (33.8-42.7)	7.8 (5.5-11.0)	4.6 (2.9-7.2)
	80+	622	8.7 (8.0-9.5)	5.8±6.7	0.6±6.4	2.0±8.6	1.4 (0.4-4.4)	46.2 (36.5-56.3)	22.6 (15.3-32.0)	20.6 (13.4-30.2)
				p<0.001	p<0.001	p<0.001	p=0.47	p<0.001	p<0.001	p<0.001
Nationality	Irish	7,374	92.0 (91.4-92.6)	4.0±5.5	0.8±3.9	1.2±6.4	1.5 (1.1-2.0)	21.6 (20.0-23.2)	4.8 (4.0-5.8)	2.6 (2.0-3.5)
	Northern Irish	347	3.7 (3.3-4.2)	3.6±5.6	0.7±2.5	1.0±3.7	1.8 (0.7-4.8)	23.7 (08.1-30.3)	2.0 (0.9-4.7)	1.4 (0.5-4.0)
	British	305	3.2 (2.8-3.6)	4.1±4.5	0.9±3.3	1.0±3.8	0.8 (0.2-3.4)	31.5 (23.4-40.8)	2.7 (1.1-6.6)	1.5 (0.2-9.7)
	Other nationality	102	1.1 (0.9-1.3)	2.6±2.8	0.4±1.5	1.0±9.8	0	15.8 (7.8-29.4)	3.5 (0.5-20.7)	0
				p<0.001	p=0.14	p=0.44	p=0.66	p=0.04	p=0.24	p=0.53
Enabling										
Medical cover	Dual cover	1,360	15.2 (14.4-16.0)	5.0±6.2	1.0±4.0	1.9±8.8	2.6 (1.6-4.2)	36.0 (31.9-40.3)	8.2 (5.9-11.3)	6.5 (4.4-9.5)
	Insurance only	3,327	37.7 (36.6-38.8)	2.6±3.5	0.6±3.1	0.7±3.5	0.5 (0.3-0.8)	10.1 (8.9-11.5)	1.2 (0.8-1.8)	0.5 (0.3-1.0)
	GMS only	2,522	35.0 (33.9-36.2)	5.8±6.8	0.9±4.9	1.8±8.1	2.3 (1.5-3.5)	33.6 (30.2-37.2)	8.9 (6.8-11.4)	3.8 (2.4-6.0)
	No additional cover	919	12.0 (11.3-12.8)	2.5±3.4	0.4±1.8	0.4±2.2	0.8 (0.3-1.8)	11.6 (8.9-15.1)	0.5 (0.2-1.5)	0
				p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001
Location of Household	Urban	4,240	57.6 (56.4-58.8)	3.9±5.6	0.8±3.7	1.2±6.0	1.9 (1.3-2.6)	23.1 (21.2-25.2)	5.9 (4.7-7.4)	2.6 (1.8-3.7)
	Rural	3,910	42.4 (41.2-43.6)	4.1±5.2	0.7±3.9	1.2±6.5	1.1 (0.7-1.6)	20.6 (18.4-22.9)	3.3 (2.4-4.5)	2.4 (1.5-3.8)
				p=0.31	p=0.33	p=0.85	p=0.03	p=0.10	p<0.01	p=0.79

Living status	With spouse	3,100	38.8 (37.2-40.4)	4.0±5.4	0.9±3.9	1.2±6.6	1.2 (0.8-1.9)	26.0 (23.7-28.4)	4.4 (3.3-5.8)	1.5 (0.9-2.7)
	Other persons	3,226	36.7 (35.6-37.8)	3.4±4.3	0.6±2.7	1.0±5.8	1.6 (1.1-2.4)	44.0 (12.5-16.6)	3.3 (2.3-4.7)	1.0 (0.5-2.3)
	Living alone	1,802	24.4 (23.4-25.5)	4.9±6.9	0.8±5.0	1.5±6.3	1.8 (1.0-3.1)	27.7 (23.9-31.9)	7.4 (5.2-10.4)	6.8 (4.7-9.7)
				p<0.001	p<0.01	p<0.001	p=0.51	p<0.001	p<0.01	p<0.001
Educational attainment (3)	Third level	2,392	18.5 (17.8-19.3)	3.1±4.5	3.1±4.5	0.9±4.4	1.4 (0.9-2.1)	15.4 (13.7-17.2)	2.5 (1.8-3.5)	1.0 (0.6-1.6)
	Secondary	3,248	43.2 (42.1-44.4)	3.7±4.7	3.7±4.7	1.1±5.1	1.6 (1.1-2.4)	16.5 (14.9-18.3)	3.8 (3.0-4.8)	2.0 (1.4-2.8)
	Primary/no formal education	2,488	38.2 (37.1-39.4)	5.2±6.8	5.2±6.8	1.7±8.6	1.4 (0.8-2.3)	31.5 (28.3-34.9)	6.6 (4.9-8.9)	3.9 (2.5-6.0)
				p<0.001	p<0.001	p=0.02	p=0.72	p<0.001	p<0.001	p<0.001
Employment status (105)	Employed	2,038	24.7 (23.7-25.7)	2.6±3.1	2.6±3.1	0.4±1.8	1.1 (0.6-1.8)	7.8 (6.3-9.6)	1.0 (0.6-1.8)	0.2 (0.0-0.6)
	Self-employed	883	11.2 (10.5-12.0)	2.5±3.2	2.5±3.2	0.7±3.6	0.8 (0.3-2.1)	7.1 (5.2-9.7)	1.2 (0.5-2.7)	0
	Retired	3,026	36.6 (35.5-37.7)	4.6±5.4	4.6±5.4	1.6±6.9	1.3 (0.8-2.1)	31.7 (28.9-34.6)	8.7 (6.8-11.1)	5.4 (3.9-7.5)
	Home-maker	1,268	16.0 (15.1-16.8)	4.4±5.2	4.4±5.2	1.0±4.9	1.0 (0.5-2.1)	27.4 (23.0-32.3)	3.8 (2.5-5.8)	1.8 (0.8-4.0)
	In education/training	43	0.4 (0.3-0.6)	3.4±4.3	3.4±4.3	0.5±2.2	2.9 (0.4-18.2)	5.5 (1.7-16.3)	2.9 (0.4-18.2)	0
	Permanently sick/disabled	377	5.5 (4.9-6.0)	9.3±12.8	9.3±12.8	4.6±15.7	8.9 (5.2-14.7)	50.9 (43.2-58.6)	7.6 (4.4-12.8)	3.0 (1.2-7.3)
	Unemployed	388	5.6 (5.0-6.1)	3.6±3.9	3.6±3.9	1.1±8.0	0.4 (0.1-3.0)	11.8 (8.0-17.2)	2.1 (0.8-5.5)	0
				p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001
House value in thousands (583)	≥ €560,001	633	6.7 (6.2-7.3)	2.8±3.4	2.8±3.4	0.7±3.5	0.5 (0.2-1.3)	16.5 (13.6-20.0)	2.4 (1.4-4.1)	1.1 (0.4-3.1)
	€400,001-560,000	667	7.5 (7.0-8.1)	2.9±2.9	2.9±2.9	0.9±5.2	1.1 (0.5-2.8)	18.0 (15.0-21.6)	4.1 (2.6-6.2)	1.9 (1.0-3.6)
	€240,001-400,000	2,500	30.0 (28.9-31.0)	3.5±4.2	3.5±4.2	1.1±5.1	1.3 (0.9-1.9)	19.9 (18.2-21.6)	5.0 (4.1-6.1)	3.1 (2.4-4.0)
	€80,000-240,000	2,419	29.9 (28.9-31.0)	4.4±6.4	4.4±6.4	1.2±6.2	1.9 (1.4-2.6)	22.1 (20.4-23.9)	6.8 (5.8-8.0)	3.2 (2.5-4.1)
	≤ €80,000	1,441	20.2 (19.3-21.2)	4.9±6.2	4.9±6.2	1.8±8.8	2.3 (1.6-3.3)	25.5 (23.2-28.0)	10.4 (8.8-12.3)	7.2 (5.8-9.0)
	Unclassified	468	5.5 (5.0-6.1)	4.6±7.0	4.6±7.0	1.4±6.6	2.0 (1.0-3.8)	20.2 (16.6-24.4)	8.6 (6.0-12.2)	6.3 (4.2-9.3)
				p<0.001	p<0.001	p=0.10	p<0.01	p<0.001	p<0.001	p<0.001
Behaviour										
Smoking status	Never	3,550	42.4 (41.2-43.5)	3.8±5.6	0.6±2.6	0.8±5.8	1.2 (0.9-1.6)	19.2 (17.8-20.7)	5.8 (5.0-6.8)	4.0 (3.3-4.9)
	Past	3,190	38.9 (37.8-40.0)	4.2±5.3	0.9±4.0	1.4±6.6	2.2 (1.7-2.8)	24.6 (23.1-26.3)	7.1 (6.2-8.2)	3.6 (2.9-4.4)

	Light	280	3.7 (3.2-4.1)	4.2±4.8	1.5±10.1	1.3±5.1	0.5 (0.1-2.1)	21.0 (16.2-26.6)	9.6 (6.6-13.7)	5.3 (3.0-9.1)
	Moderate	488	6.5 (5.9-7.1)	4.1±5.0	0.6±3.7	1.4±6.4	1.3 (0.5-3.0)	20.1 (16.5-24.1)	8.1 (5.6-11.5)	4.4 (2.8-6.8)
	Heavy	620	8.6 (7.9-9.3)	4.1±5.5	0.7±3.5	1.4±7.1	2.6 (1.5-4.2)	18.1 (15.1-21.5)	5.6 (3.9-7.9)	3.9 (3.4-4.4)
				p<0.001	p<0.001	p=0.14	p<0.01	p<0.001	p=0.06	p=0.60
Alcohol status	None or rare	3,335	40.8 (39.7-42.0)	4.3±5.4	0.7±3.1	1.3±6.7	2.2 (1.7-2.7)	26.1 (24.5-27.8)	8.0 (7.0-9.1)	5.6 (4.7-6.6)
	1-2 days p/w	1,931	23.5 (22.6-24.5)	3.4±5.6	0.7±3.4	0.6±2.8	0.9 (0.6-1.5)	15.5 (13.9-17.3)	3.1 (2.4-4.0)	1.5 (1.0-2.2)
	3-4 days p/w	797	9.5 (8.8-10.2)	3.4±6.5	0.7±2.1	1.0±4.5	1.4 (0.8-2.6)	14.7 (12.2-17.6)	3.8 (2.6-5.5)	0.7 (0.3-2.0)
	Almost every day	680	7.6 (7.7-8.2)	3.7±6.0	0.8±2.7	1.1±5.4	1.4 (0.7-2.9)	20.9 (17.9-24.4)	4.9 (3.4-7.0)	2.0 (1.2-3.5)
	Unclassified	1,385	18.5 (17.6-19.5)	4.4±5.5	1.0±6.2	1.9±9.2	1.8 (1.2-2.8)	21.8 (19.5-24.3)	10.1 (8.5-12.1)	5.7 (4.5-7.3)
				p<0.001	p=0.02	p<0.01	p=0.02	p=0.02	p<0.001	p<0.001
Exercise (79)	High	2,702	32.8 (31.8-33.9)	3.0±3.5	0.5±2.6	0.6±3.6	1.2 (0.8-1.7)	12.5 (11.2-13.8)	2.8 (2.1-3.5)	1.0 (0.6-1.5)
	Moderate	2,764	33.4 (32.3-34.5)	3.9±4.7	0.7±3.3	1.0±5.3	1.3 (0.9-1.8)	21.1 (19.5-22.8)	5.0 (4.1-6.0)	2.1 (1.6-2.8)
	Low	2,584	32.7 (31.6-33.8)	5.1±7.3	1.1±5.1	2.1±8.9	2.5 (2.0-3.3)	30.9 (29.0-32.9)	12.2 (10.9-13.7)	8.8 (7.6-10.2)
	Unclassified	78	1.1 (0.8-1.3)	4.0±7.8	0.3±0.8	0.3±1.9	3.2 (0.8-11.8)	13.7 (7.5-23.7)	3.0 (0.9-9.8)	1.4 (0.4-5.6)
				p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001
BMI	Normal/underweight	1,335	15.5 (14.7-16.4)	3.3±4.8	1.4±3.9	1.0±5.2	1.6 (1.0-2.5)	16.8 (14.7-19.2)	6.4 (5.0-8.2)	3.6 (2.6-4.9)
	Overweight	2,508	30.0 (28.9-31.0)	3.4±3.8	1.4±4.7	1.0±6.5	1.0 (0.6-1.5)	17.9 (16.4-19.6)	4.8 (3.9-5.8)	2.6 (1.9-3.4)
	Obese	1,999	24.6 (23.6-25.6)	4.6±6.4	1.7±3.9	1.1±4.4	2.3 (1.7-3.1)	27.2 (25.2-29.4)	6.6 (5.5-7.9)	4.7 (3.7-6.0)
	Unclassified	2,286	29.9 (28.9-31.0)	4.4±6.2	1.5±4.9	1.6±7.7	1.9 (1.4-2.6)	22.2 (20.4-24.2)	8.5 (7.3-9.9)	4.8 (3.9-5.9)
				p<0.001	p<0.001	p<0.01	p<0.01	p<0.001	p<0.001	p<0.01
Sleep	Rarely	5,255	64.1 (63.0-65.2)	3.5±4.8	0.7 ±3.3	1.1±5.8	1.3 (1.0-1.6)	18.1 (17.0-19.3)	6.1 (5.4-6.8)	3.4 (2.8-4.1)
	Never	1,996	24.6 (23.6-25.6)	4.5±5.7	0.8±4.9	1.2±5.8	1.8 (1.3-2.6)	24.5 (22.5-26.6)	7.0 (5.8-8.4)	4.5 (3.6-5.7)
	Most of the time	877	11.3 (10.6-12.1)	5.8±7.4	1.2±4.0	1.9±9.2	3.7 (2.6-5.3)	32.9 (29.7-36.3)	8.9 (7.0-11.2)	5.4 (4.0-7.3)
				p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p=0.02	p=0.01

5.4.1.3 Descriptive results for outcomes of interest and health behaviours

Slightly higher GP use was observed according to smoking intensity (4.1 for heavy smokers compared to 3.8 for never smokers $p<0.001$) and for outpatient visits (0.7 for heavy smokers compared to 0.6 for never smokers $p<0.001$) although no significant difference was observed for either outpatient visits or nights in hospital. Moderate alcohol consumption appeared to have a protective effect on GP utilisation (3.4 for drinking between 1-4 days per week compared to 4.3 for those who consume less alcohol and 3.7 for those who drink regularly) as well as exercise; those reporting higher exercise levels had on average one less visits to a GP in the previous year. Similar patterns were also observed for moderate alcohol consumption ($p<0.01$) and regular exercise ($p<0.001$) on nights in hospital. However, an increase in average outpatients visits was observed for heavy smokers only and there was no observed protective effect for moderate drinking on outpatient visits. Those who reported that they have trouble with sleeping on a regular basis had significantly higher average GP use (5.8 vs. 3.5 for those reporting no problems with sleeping), outpatient visits (1.2 vs. 0.7 for those reporting no problems with sleeping) and nights in hospital (1.9 vs. 1.1 for those reporting no problems with sleeping).

5.4.2 Outcomes of multivariate regression modelling

5.4.2.1 General practitioner visits

Increasing levels of multimorbidity were significantly associated with both propensity to use GP services and increasing use of GP services after initial visit. The odds of visiting a GP for those with six or more conditions was over eight times greater (OR 8.6) compared to those with no chronic conditions while intensity of use increased substantially for increasing levels of multimorbidity and multimorbidity type, after adjusting for all covariates. The impact of other need factors including disability and frailty were attenuated for propensity to visit a GP after controlling for multimorbidity indicators in the respective multivariate analysis although they were associated with increased risk of higher GP use. Negative self-rated health was significantly associated with increased odds for initial GP visit and increased incident ratios for intensity of GP use.

The effect of increasing age is significantly associated with propensity to use GP services although again the effect of age on intensity of use is attenuated after controlling for

multimorbidity and other factors. Reflecting the increased use of GP services for GMS patients observed in crude analyses, there was a significant increased rate of GP usage among GMS patients observed in multivariate models after controlling for predisposing need factors and all other covariates. Those with GMS entitlement combined with private health insurance cover were most likely to visit a GP (OR 3.1) compared to those with any other coverage level, and it is noteworthy that the likelihood of visiting a GP was higher in the group with GMS cards only (OR 2.6) compared to those with only private health insurance (OR 1.4). Individuals with GMS medical cover were also significantly more likely to attend a GP more frequently than those with no additional cover. While those with private medical insurance had a significantly higher propensity to visit a GP, there was no association found for intensity of GP use among those with private health insurance.

Permanently sick and disabled persons were significantly more likely to have a higher intensity of use compared to those in employment. Exercise was found to have a slight protective effect on GP use. Those reporting low exercise had a 20% increased odds of using a GP and a 10% increased risk of higher GP use compared to those who exercise regularly. Those reporting trouble with sleeping were also found to have significant 10% higher risk for GP intensity compared to those who do not.

Table 5.6 Adjusted two-part models for Multimorbidity Levels and Multimorbidity Type for GP utilisation

	Multimorbidity Levels 2-part model				Multimorbidity Type 2-part model			
GP visits	**Adjusted OR (95% CI) P-value**		**Adjusted IRR (95% CI) P-value**		**Adjusted OR (95% CI) P-value**		**Adjusted IRR (95% CI) P-value**	
Need Factors								
Multimorbidity								
0 (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.				
1	2.0 (1.7-2.4)	<0.001	1.4 (1.2-1.6)	<0.001				
2	3.6 (2.9-4.4)	<0.001	1.6 (1.4-1.8)	<0.001				
3	7.4 (5.2-10.4)	<0.001	1.7 (1.5-2.0)	<0.001				
4	7.5 (4.6-12.2)	<0.001	1.9 (1.6-2.2)	<0.001				
5	7.2 (3.6-14.4)	<0.001	2.1 (1.7-2.4)	<0.001				
6	8.6 (3.8-19.7)	<0.001	2.2 (1.8-2.6)	<0.001				
Multimorbidity type								
< 1 condition (ref)					1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Physical					3.3 (2.7-3.9)	<0.001	1.4 (1.3-1.5)	<0.001
Physical + mental					4.6 (2.6-8.1)	<0.001	1.5 (1.3-1.6)	<0.001
Disability								
No ADL (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.

ADL	1.2 (0.8-1.7)	0.32	1.2 (1.1-1.3)	<0.001	1.3 (0.9-1.9)	0.116	1.3 (1.1-1.4)	<0.001
Frailty								
Not frail (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Prefrail	1.2 (1.0-1.6)	0.07	1.1 (1.1-1.2)	<0.001	1.3 (1.0-1.6)	0.025	1.2 (1.1-1.2)	<0.001
Frail	1.1 (0.3-3.8)	0.84	1.4 (1.2-1.7)	0.001	1.2 (0.4-4.0)	0.757	1.4 (1.2-1.7)	<0.001
Unclassified	0.9 (0.7-1.0)	0.13	1.2 (1.1-1.2)	<0.001	0.9 (0.7-1.0)	0.063	1.1 (1.1-1.2)	<0.001
Self-rated Health								
Favourable (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Unfavourable	1.8 (1.3-2.3)	<0.001	1.5 (1.4-1.6)	<0.001	2.0 (1.5-2.6)	<0.001	1.6 (1.5-1.7)	<0.001
Sex								
Male (ref)								
Female	1.1 (1.0-1.3)	0.17	0.9 (0.9-1.0)	0.01	1.2 (1.0-1.4)	0.07	0.9 (0.9-1.0)	<0.01
Age								
50-59 (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
60-69	1.2 (1.0-1.4)	0.03	1.0 (0.9-1.1)	0.461	1.3 (1.1-1.5)	<0.01	1.0 (0.9-1.1)	0.61
70-79	1.5 (1.1-1.9)	0.01	0.9 (0.8-1.0)	0.06	1.6 (1.2-2.1)	<0.001	0.9 (0.9-1.0)	0.21
80+	1.6 (1.0-2.6)	0.04	1.0 (0.9-1.1)	0.768	1.8 (1.1-2.8)	0.02	1.0 (0.9-1.1)	0.80
Nationality								
Irish (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Northern Irish	0.7 (0.5-1.0)	0.03	0.9 (0.8-1.1)	0.262	0.7 (0.5-0.9)	0.02	0.9 (0.8-1.1)	0.29
British	0.7 (0.5-1.0)	0.06	0.9 (0.8-1.1)	0.242	0.7 (0.5-1.0)	0.06	0.9 (0.8-1.1)	0.29
Other	0.6 (0.4-1.0)	0.05	0.7 (0.6-1.0)	0.023	0.6 (0.4-1.0)	0.07	0.7 (0.6-1.0)	0.02
Enabling Factors								
Living arrangement								
With other persons	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
With spouse	1.2 (1.0-1.4)	0.04	1.1 (1.0-1.2)	0.024	1.2 (1.0-1.5)	0.02	1.1 (1.0-1.2)	0.02
Living alone	1.0 (0.8-1.3)	0.81	1.1 (1.0-1.2)	<0.01	1.1 (0.9-1.3)	0.62	1.1 (1.0-1.2)	0.00
Healthcare coverage								
No additional	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
GMS only	2.6 (2.0-3.3)	<0.001	1.6 (1.4-1.8)	<0.001	2.6 (2.0-3.3)	<0.001	1.6 (1.5-1.8)	0.00
Insurance only	1.4 (1.1-1.7)	<0.01	1.0 (0.9-1.1)	0.66	1.4 (1.1-1.7)	<0.001	1.0 (0.9-1.2)	0.65
GMS * insurance	3.1 (2.2-4.4)	<0.01	1.5 (1.3-1.7)	<0.001	3.2 (2.3-4.5)	<0.001	1.5 (1.3-1.7)	0.00
Employment status								
Employed	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Retired	0.8 (0.7-1.0)	0.03	0.9 (0.8-1.0)	0.09	0.8 (0.7-1.0)	0.03	0.9 (0.8-1.0)	0.13
Home-maker	0.8 (0.6-1.0)	0.07	1.1 (1.0-1.1)	0.08	0.8 (0.6-1.0)	0.06	1.1 (1.0-1.1)	0.11
Unemployed	0.7 (0.5-0.9)	0.02	1.0 (0.9-1.1)	0.96	0.7 (0.5-0.9)	0.01	1.0 (0.9-1.1)	0.97
Permanently sick or	1.4 (0.8-2.7)	0.27	1.4 (1.2-1.6)	<0.001	1.6 (0.8-3.0)	0.15	1.4 (1.2-1.6)	<0.001
Unclassified	1.9 (0.8-4.5)	0.16	1.1 (0.9-1.4)	0.26	2.0 (0.8-4.7)	0.13	1.1 (0.9-1.4)	0.24
Health behaviours								
Exercise status								
High (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Moderate	1.2 (1.0-1.5)	0.01	1.1 (1.0-1.2)	0.01	1.2 (1.1-1.5)	<0.001	1.1 (1.0-1.2)	<0.01
Low	1.2 (1.0-1.5)	0.04	1.1 (1.0-1.2)	0.01	1.2 (1.0-1.5)	<0.001	1.1 (1.0-1.2)	<0.01
Unclassified	0.6 (0.4-1.1)	0.12	1.0 (0.8-1.4)	0.77	0.6 (0.4-1.1)	0.12	1.1 (0.8-1.4)	0.66
Trouble sleeping								

Rarely/never (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Sometimes	1.2 (1.0-1.5)	0.03	1.1 (1.0-1.2)	0.01	1.3 (1.1-1.5)	0.01	1.1 (1.0-1.2)	<0.001
Most of the time	1.2 (0.9-1.6)	0.34	1.1 (1.0-1.2)	<0.01	1.2 (0.9-1.6)	0.17	1.2 (1.1-1.2)	<0.001
Disability compared to no disability by multimorbidity level								
0 (ref)			1.1 (1.0-1.0)	<0.001				
1			1.5 (1.2-1.8)	<0.001				
2			1.5 (1.3-1.6)	<0.001				
3			1.5 (1.4-1.7)	<0.001				
4			1.6 (1.4-1.8)	<0.001				
5			1.5 (1.3-1.7)	<0.001				
6			1.8 (1.6-1.9)	<0.001				
LR-sqr (dfres)	1012.74 (33)		1466.268		631.959(29)		1379.666(29	
N	8118		7099		8118		7099	
AIC	5196.4		31928.2		5293.2		32046.1	
BIC	5434.5		32168.6		5503.3		32259.1	

Differences for the probability of a GP visit were significant up to three co-occurring conditions (χ^2 = 274.02 p<0.001) however, after three conditions, the effect is no longer significant (Figure 5.6 and 5.7).

Figure 5.6 Predicted probability for propensity to visit a GP by increasing levels of multimorbidity.

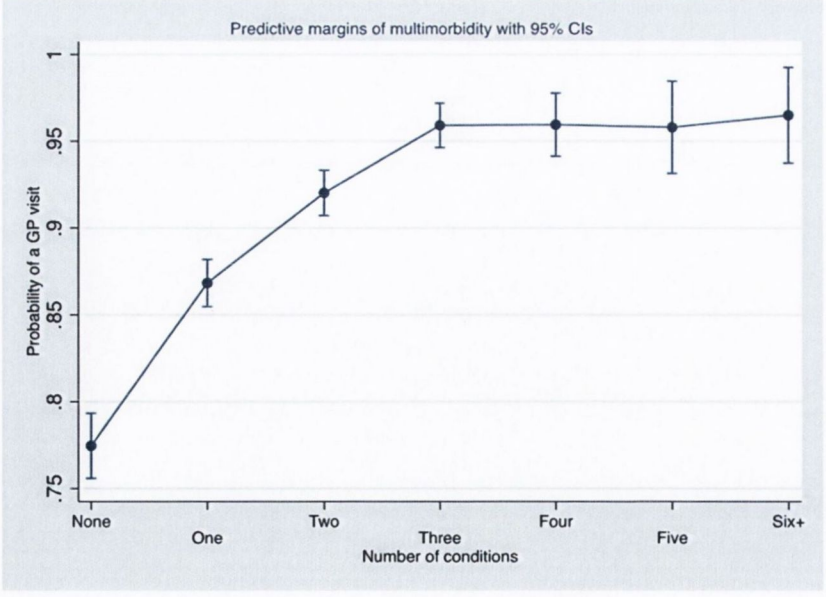
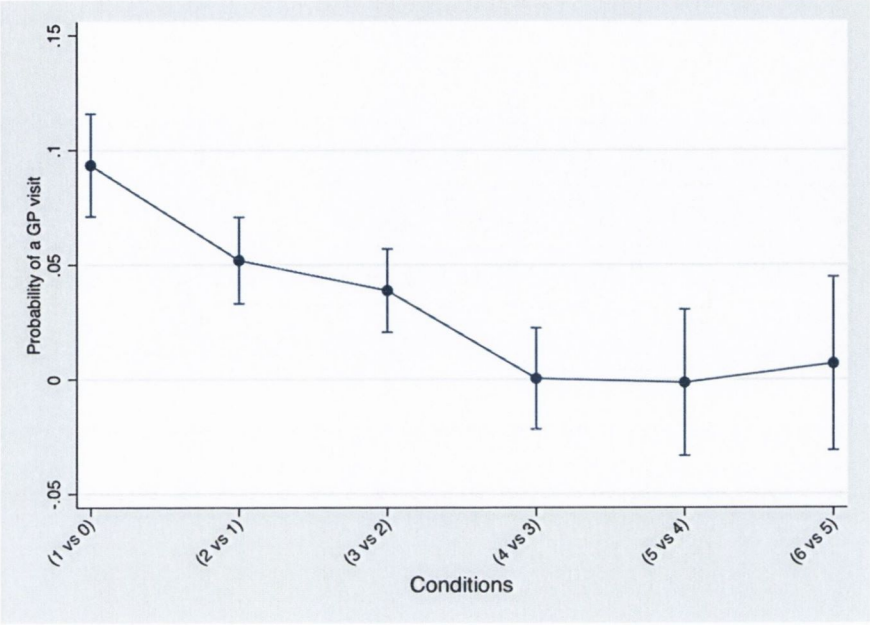


Figure 5.7 Predicted changes in probability for propensity to visit a GP by increasing levels of multimorbidity.



However, for the impact of multimorbidity levels on intensity of GP use, a significant effect is detected when increasing from no condition to one condition and from one condition to two conditions (χ^2 = 135.16 p<0.001). The effect of further additional co-occurring conditions is not significant at the conventional level (Figure 5.8 and 5.9).

Figure 5.8 Predicted probability for intensity of GP use by increasing levels of multimorbidity.

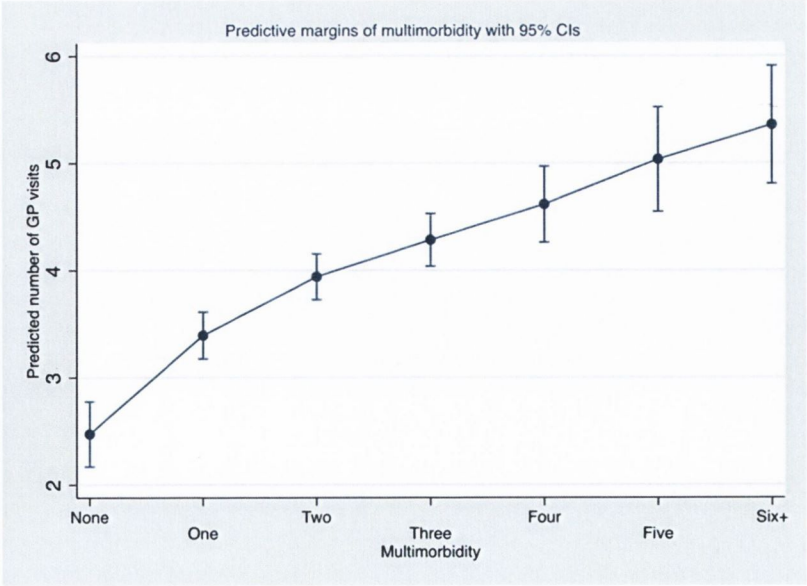
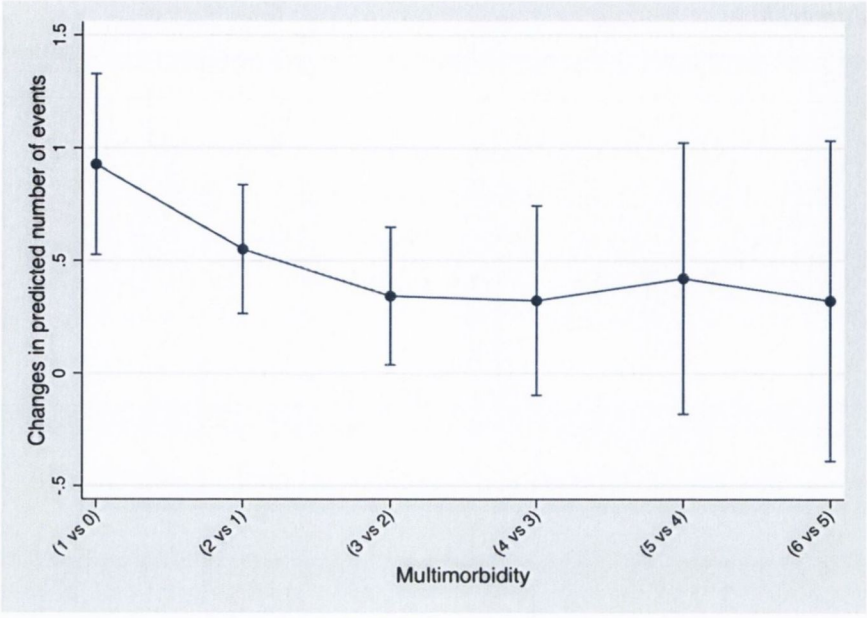


Figure 5.9 Predicted changes in probability of intensity of GP use for increasing levels of multimorbidity.



The predicted log IRR of intensity of GP use was found to increase with increasing levels of multimorbidity and this increase appears to be stronger for individuals with a disability, significant for one versus no conditions, however the effect does not reach conventional significance levels after the acquisition of one condition (χ^2 = 12.2 p=0.57) (Figure 5.10 and 5.11).

Figure 5.10 Predicted log IRR of intensity of GP use by interaction of Multimorbidity Levels and disability.

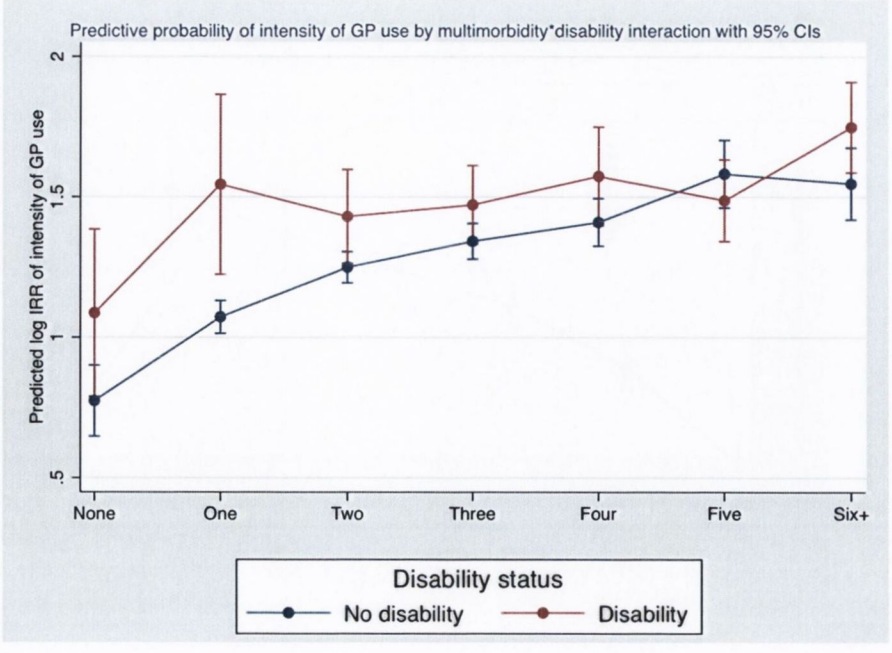
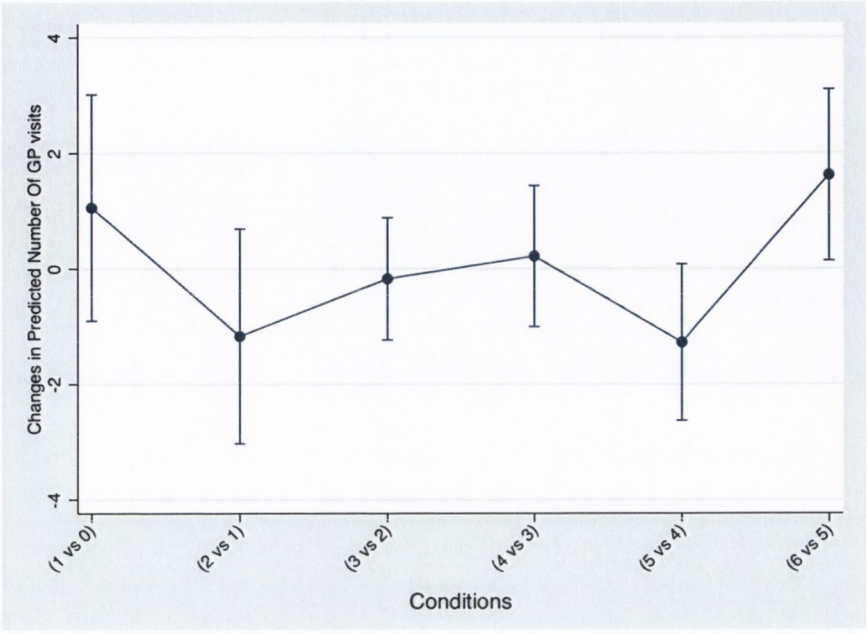


Figure 5.11 Predicted change in probability of intensity of GP use for interaction of Multimorbidity Levels and disability.



5.4.2.2 Hospital outpatient visits

Increasing levels of multimorbidity were significantly associated with both propensity to use outpatient services and intensity of their use in multivariate models (Table 5.7). The odds of one visit for persons with six or more chronic conditions was over four times that (OR 4.5) for individuals with no chronic condition. A higher intensity of use was also more likely in those with higher levels of multimorbidity. Both physical multimorbidity and physical-mental health multimorbidity were associated with increased odds of use compared to those without multimorbidity, however there was no difference detected in the propensity to use services, while those with at least two physical conditions did appear to use services more intensely compared to those with at least one physical and mental health condition (IRR 2.1 vs. 1.8). Having a disability was associated with a 30% higher increase in the odds of an outpatient visit as well as with a 70% increased intensity of use compared to those without. An increased use of outpatient services for more frail persons was detected for intensity of use only while negative self-rated health was associated with increased odds of both initial use (OR 1.8) and intensity of use (IRR 1.5).

While no significant differences were observed for propensity to use the services between males and females, females were found to have a lower intensity of use compared to their male counterparts. Interestingly, propensity to use outpatient services reduces for increasing age

groups, with persons in the oldest age group (80 years plus) half as likely to attend outpatient services compared to the youngest group sampled (age 50 -59 years). British and other nationalities were found to have a significantly lower intensity of outpatient use compared to the Irish. No significant differences in intensity of use were detected for Northern Irish.

Those living alone also had a significantly higher rate of intensity of use for outpatient services. Persons with private health insurance and dual cover are significantly more likely to use outpatient services although the observed increase in propensity to use outpatient services is mainly accounted for by those with private health insurance, with no significant effect found for those with GMS cards only. However when recurrent use of outpatient services is considered, only patients with dual cover were found to have significantly higher levels of use (IRR 2.1) compared to those with no additional coverage.

Higher levels of education were also found to be associated with increased propensity to use outpatient services and intensity of service use. The unemployed were significantly less likely to use outpatient services compared to their employed counterparts; however there was no difference detected for permanently sick and disabled persons who have been shown to have high healthcare needs.

The association between smoking and outpatient services use is complex, with past and light smokers showing an increased propensity to use services compared to never smokers. However there was no significant difference detected in use for heavy smokers. A significant difference in propensity to use OP services was detected for those drinking alcohol between 3 to 4 days per week only, compared to those who do not drink at all or who drink only rarely.

Table 5.7 Adjusted two-part models for Multimorbidity Levels and Multimorbidity Type for outpatient utilisation

	Two-part model for Multimorbidity Levels				Two part model for Multimorbidity Type			
OP visits	**Adjusted OR (95% CI)**	**P-value**	**Adjusted IRR (95% CI)**	**P-value**	**Adjusted OR (95% CI)**	**P-value**	**Adjusted IRR (95% CI)**	**P-value**
Need Factors								
Primary independent variables of interest								
Multimorbidity								
0 (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)					
1	1.9 (1.5-2.3)	<0.001	1.4 (0.6-3.1)	0.38				
2	2.9 (2.3-3.6)	<0.001	2.4 (1.2-4.8)	0.01				
3	3.0 (2.3-3.8)	<0.001	2.3 (1.1-4.7)	0.03				
4	3.3 (2.5-4.4)	<0.001	3.1 (1.4-6.8)	<0.01				
5	4.3 (3.2-5.9)	<0.001	2.1 (1.0-4.5)	0.05				

6	4.5 (3.3-6.2)	<0.001	2.5 (1.1-5.7)	0.03				
Multimorbidity type								
< 1 condition (ref)					1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Physical multimorbidity					2.1 (1.9-2.5)	<0.001	2.1 (1.4-3.0)	<0.001
Physical + mental multimorbidity					2.1 (17-26)	<0.001	1.8 (1.1-3.1)	0.05
Other Need Factors								
Disability								
No disability (ref)								
Disability	1.3 (1.1-1.5)	0.01	1.7 (1.2-2.5)	<0.01	1.3 (1.1-1.6)	<0.01	1.5 (1.0-2.4)	0.05
Frailty								
Not frail (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)		1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Prefrail	1.2 (1.0-1.4)	0.01	1.4 (0.9-2.0)	0.11	1.2 (1.0-1.4)	0.04	1.4 (0.9-2.3)	0.12
Frail	1.1 (0.8-1.7)	0.52	2.4 (0.9-6.6)	0.08	1.1 (0.8-1.6)	0.66	2.7 (0.6-	0.20
Unclassified	0.9 (0.8-1.0)	0.12	1.5 (0.9-2.3)	0.09	0.8 (0.7-1.0)	0.08	1.3 (0.8-2.1)	0.01
Self-rated Health								
Unfavourable								
Favourable	1.8 (1.6-2.1)	<0.001	1.5 (1.1-2.1)	0.01	2.0 (1.7-2.3)	<0.001	1.6 (1.1-2.3)	0.01
Predisposing Factors								
Sex								
Male (ref)								
Female	1.0 (0.9-1.1)	0.71	0.5 (0.3-0.7)	<0.00	1.0 (0.9-1.2)	0.93	0.5 (0.3-0.7)	<0.01
Age								
50-59 (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)					
60-69	1.0 (0.9-1.2)	0.98	1.1 (0.7-1.6)	0.63				
70-79	0.9 (0.7-1.1)	0.15	0.7 (0.4-1.2)	0.26				
80+	0.5 (0.4-0.7)	<0.001	0.5 (0.2-1.2)	0.11				
Nationality								
Irish (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)		1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Northern Irish	1.0 (0.7-1.3)	0.84	0.8 (0.4-1.5)	0.46	1.0 (0.7-1.3)	0.89	1.0 (0.5-2.0)	0.94
British	1.0 (0.8-1.4)	0.84	0.4 (0.2-0.8)	<0.01	1.0 (0.8-1.4)	0.86	0.6 (0.3-1.1)	0.09
Other	0.5 (0.3-1.0)	0.06	0.3 (0.1-1.3)	0.1	0.5 (0.3-1.0)	0.08	0.4 (1.0-1.9)	0.23
Enabling Factors								
Living arrangement								
With other persons (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)					
With spouse	1.1 (0.9-1.2)	0.31	1.4 (1.0-2.0)	0.08				
Living alone	1.0 (0.8-1.2)	0.82	1.6 (1.0-2.6)	0.04				
Healthcare coverage								
No additional coverage	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)		1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
GMS only	1.0 (0.8-1.3)	0.98	1.7 (0.9-3.3)	0.12	0.9 (0.7-1.1)	0.40	1.7 (0.8-3.6)	0.13
Insurance only	1.3 (1.0-1.6)	0.02	1.5 (0.7-3.0)	0.28	1.4 (1.1-1.8)	<0.01	1.8 (0.8-3.7)	0.14
GMS * insurance (ref)	1.3 (1.0-1.8)	0.03	2.1 (1.0-4.4)	0.05	1.3 (1.1-1.7)	0.04	2.2 (1.1-4.8)	0.04
Educational Status (3)								
Primary or none	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)					
Secondary level	1.1 (0.9-1.3)	0.31	1.5 (1.0-2.1)	0.06				
Third level +	1.3 (1.1-1.6)	<0.001	1.6 (1.0-2.5)	0.04				
Employment status								
Employed or in education/training (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)		1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Retired	1.0 (0.8-1.3)	0.82	1.1 (0.5-2.4)	0.73	1.0 (0.8-1.3)	0.88	1.3 (0.6-3.1)	0.49

Home-maker	0.9 (0.8-1.1)	0.35	1.3 (0.9-2.0)	0.29	0.9 (0.8-1.1)	0.17	1.3 (0.8-2.3)	0.28
Unemployed	1.1 (0.8-1.5)	0.50	0.3 (0.2-0.7)	<0.01	1.1 (0.8-1.5)	0.38	0.4 (0.2-0.7)	<0.01
Permanently sick or disabled	1.2 (0.9-1.6)	0.21	0.9 (0.5-1.6)	0.8	1.3 (1.0-1.7)	0.03	0.9 (0.5-1.6)	0.77
Unclassified	1.2 (0.7-1.9)	0.48	0.2 (0.0-0.8)	0.02	1.3 (0.7-2.0)	0.36	0.2 (0.0-0.6)	<0.01
Health behaviours								
Smoking status								
Never (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)		1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Past	1.2 (1.0-1.3)	<0.001	1.4 (1.0-2.0)	0.09	1.2 (1.0-1.4)	<0.01	1.4 (1.0-2.0)	0.09
Light	1.2 (0.9-1.7)	0.26	3.2 (1.2-8.9)	0.03	1.2 (0.9-1.7)	0.25	3.2 (1.2-9.0)	0.02
Moderate	0.8 (0.6-1.0)	0.10	0.5 (0.2-1.1)	0.08	0.8 (0.6-1.1)	0.11	0.5 (0.2-1.2)	0.10
Heavy	0.8 (0.6-1.0)	0.08	0.5 (0.3-0.8)	<0.01	0.8 (0.6-1.0)	0.11	0.5 (0.3-0.8)	<0.01
Alcohol status								
None or rare (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)		1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
1-2 days p/w	1.0 (0.8-1.2)	0.86	1.0 (0.7-1.6)	0.86	1.0 (0.8-1.2)	0.87	1.1 (0.7-1.7)	0.76
3-4 days p/w	1.2 (1.0-1.5)	0.06	0.8 (0.4-1.5)	0.48	1.2 (1.0-1.5)	0.03	0.9 (0.4-1.9)	0.78
Almost every day	1.1 (0.9-1.3)	0.52	0.7 (0.4-1.2)	0.22	1.1 (0.9-1.4)	0.4	0.7 (0.4-1.3)	0.3
Unclassified	1.0 (0.8-1.2)	0.97	1.4 (0.9-2.2)	0.15	1.0 (0.8-1.2)	0.87	1.5 (0.9-2.4)	0.13
LR-sqr (dfres)	148.831 (38)				427.61 (31)			
N	8,121				8121			
AIC	3569.9				7219.9			
BIC	3781				77388.0			

Examining the predictive margins for the probability of an OP visit between adjacent levels of multimorbidity averaging across all values of the covariates, differences between increasing numbers of conditions are significant for one vs. no condition, two vs. one condition and five vs. four conditions (χ^2 = 141.91 p<0.001). The overall effect of increasing multimorbidity levels on OP intensity was not significant at the conventional level (χ^2 = 8.35 p=0.21) (Figure 5.12 and 5.13).

Figure 5.12 Predicted probability for propensity to use outpatient services by increasing levels of multimorbidity

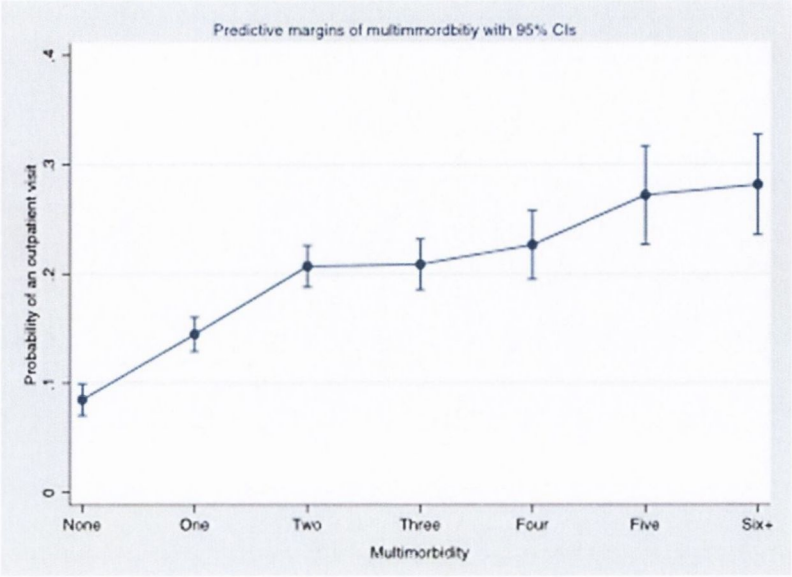
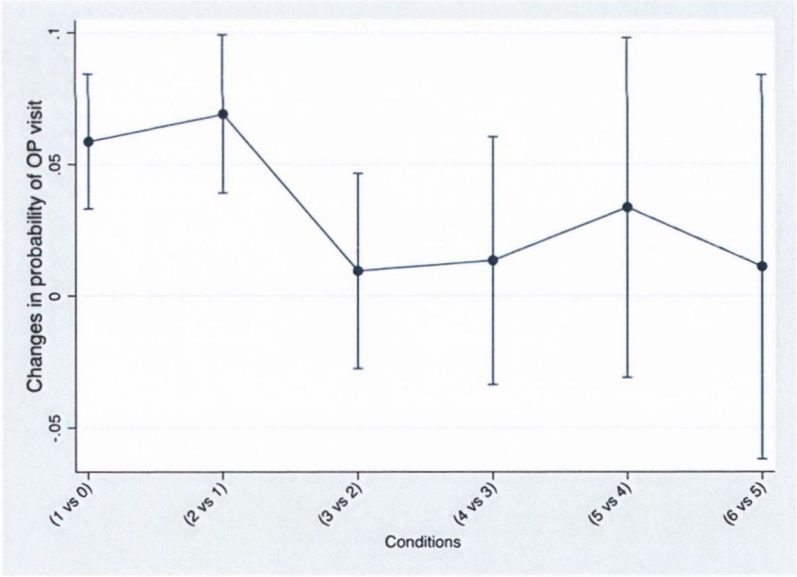


Figure 5.13 Changes in predicted probability for propensity to use outpatient services by increasing levels of multimorbidity (with 95% CI's)



5.4.2.3 Hospital Stays

Increasing levels of multimorbidity were strongly associated with propensity for an overnight stay in hospital (Table 5.8). The odds of an overnight stay was threefold for those with six or more conditions compared to those with no conditions. However, there was no significant effect detected on nights spent in hospital for increasing levels of multimorbidity. There was also no

significant effect for type of multimorbidity on hospital stays. Other need factors were however significantly associated with number of nights spent in hospital. Those who were frail had a twofold increased odds of a hospital stay and intensity of use and poor self-rated health was also found to significantly increase the propensity to require hospitalisation and the nights spent in hospital. The effect of disability on nights spent in hospital is less pronounced.

Table 5.8 Adjusted two-part models for Multimorbidity Levels and Multimorbidity Type for hospital overnight stays

	Two-part model Multimorbidity Levels				**Two-part model Multimorbidity Type**			
LOS	**Adjusted OR (95% CI) P-value**		**Adjusted IRR (95% CI) P-value**		**Adjusted OR (95% CI) P-value**		**Adjusted IRR (95% CI) P-value**	
Need Factors								
Primary independent variables of interest								
Multimorbidity								
0 (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.				
1	1.6 (1.2-2.1)	<0.01	1.1 (0.7-1.5)	0.75				
2	2.5 (1.9-3.3)	<0.001	0.9 (0.7-1.3)	0.66				
3	2.8 (2.1-3.8)	<0.001	1.2 (0.8-1.7)	0.4				
4	3.3 (2.4-4.6)	<0.001	1.1 (0.7-1.6)	0.75				
5	4.2 (2.8-6.2)	<0.001	0.8 (0.5-1.2)	0.21				
6 +	3.7 (2.4-5.5)	<0.001	1.4 (0.9-2.2)	0.12				
Multimorbidity type								
< 1 condition (ref)					1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Physical multimorbidity					1.8 (0.7-4.6)	0.20	0.7 (0.3-1.7)	0.49
Physical + mental multimorbidity					1.1 (0.4-2.8)	0.86	1.3 (0.5-3.2)	0.60
Other Need Factors								
Disability								
No ADL (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
ADL	1.2 (1.0-1.4)	0.11	1.04 (1.1-1.8)	<0.01	5.0 (2.2-11.2)	<0.001	1.0 (0.6-1.9)	0.93
Frailty								
Not frail (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Prefrail	1.4 (1.2-1.8)	<0.001	1.3 (1.1-1.7)	0.02	1.5 (1.2-1.8)	<0.001	1.4 (1.1-1.7)	<0.01
Frail	2.3 (1.6-3.5)	<0.001	2.2 (1.5-3.3)	<0.001	2.4 (1.6-3.6)	<0.001	2.4 (1.6-3.5)	<0.001
Unclassified	1.3 (1.1-1.6)	<0.01	1.6 (1.3-2.1)	<0.001	1.3 (1.1-1.6)	<0.01	1.7 (1.3-2.1)	<0.001
Predisposing Factors								
Self-rated Health								
Not negative self-rated health	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Negative self-rated health	2.0 (1.7-2.3)	<0.001	1.45 (1.2-1.8)	<0.001	1.9 (1.6-2.3)	<0.001	1.4 (1.2-1.7)	<0.001
Sex								
Male (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Female	0.9 (0.8-1.0)	0.13	0.9 (0.8-1.1)	0.45	0.9 (0.8-1.0)	0.12	0.9 (0.8-1.1)	0.33
Age								
50-59 (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
60-69	1.0 (0.9-1.2)	0.68	1.0 (0.8-1.3)	0.86	1.0 (0.8-1.2)	0.90	1.1 (0.9-1.4)	0.28
70-79	1.0 (0.8-1.3)	0.81	1.3 (0.9-1.7)	0.09	1.0 (0.8-1.2)	0.82	1.3 (1.0-1.8)	0.03

80+	0.8 (0.6-1.1)	0.21	1.4 (0.9-2.0)	0.12	0.8 (0.6-1.0)	0.07	1.5 (1.0-2.1)	0.05
Enabling Factors								
Healthcare coverage								
No additional coverage (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
GMS only	1.8 (1.3-2.4)	<0.001	1.4 (0.9-2.1)	0.13	1.8 (1.3-2.4)	<0.001	1.3 (0.9-2.0)	0.19
Insurance only	1.7 (1.2-2.2)	<0.01	1.3 (0.9-1.9)	0.15	1.7 (1.2-2.2)	<0.01	1.2 (0.8-1.8)	0.28
GMS * insurance	2.1 (1.5-2.9)	<0.001	1.5 (1.0-2.4)	0.06	2.1 (1.5-3.0)	<0.001	1.4 (0.9-2.3)	0.10
Educational Status (3)								
Third level + (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Secondary level	1.2 (1.0-1.4)	0.07	0.9 (0.7-1.1)	0.39	1.2 (1.0-1.4)	0.06	0.9 (0.7-1.2)	0.51
Primary or none	1.2 (1.0-1.5)	0.03	0.8 (0.6-1.1)	0.21	1.3 (1.0-1.6)	0.02	0.9 (0.7-1.1)	0.3
Employment status								
Employed	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Retired	1.2 (1.0-1.6)	0.10	1.2 (0.9-1.7)	0.27	1.2 (0.9-1.6)	0.12	1.3 (0.9-1.8)	0.18
Home-maker	1.0 (0.8-1.2)	0.73	1.0 (0.7-1.2)	0.74	1.0 (0.8-1.2)	0.73	1.0 (0.7-1.3)	0.82
Unemployed	0.9 (0.7-1.4)	0.75	1.5 (0.7-3.1)	0.34	1.0 (0.7-1.4)	0.84	1.2 (0.6-2.4)	0.59
Permanently sick or disabled	1.3 (1.0-1.7)	0.1	1.7 (1.1-2.5)	0.01	1.3 (1.0-1.8)	0.05	1.6 (1.1-2.2)	0.01
Unclassified	1.6 (1.0-2.6)	0.07	0.5 (0.3-0.8)	<0.01	1.7 (1.0-2.8)	0.03	0.4 (0.3-0.7)	<0.01
Health behaviours								
Smoking status								
Never (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Past	1.0 (0.8-1.1)	0.86	1.2 (1.0-1.5)	0.05	1.0 (0.8-1.1)	0.83	1.2 (1.0-1.5)	0.04
Light	1.1 (0.8-1.6)	0.55	1.0 (0.6-1.6)	0.95	1.1 (0.8-1.6)	0.49	1.0 (0.6-1.6)	0.94
Moderate	0.9 (0.7-1.2)	0.52	1.1 (0.7-1.7)	0.62	0.9 (0.7-1.2)	0.52	1.1 (0.8-1.7)	0.55
Heavy	0.9 (0.6-1.1)	0.31	1.0 (0.7-1.4)	0.90	0.9 (0.7-1.2)	0.52	0.9 (0.6-1.2)	0.4
Exercise status								
High (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Moderate	1.1 (1.0-1.4)	0.15	1.2 (0.9-1.5)	0.15	1.1 (0.9-1.4)	0.17	1.2 (0.9-1.5)	0.16
Low	1.3 (1.1-1.6)	<0.01	1.3 (1.0-1.7)	0.02	1.3 (1.1-1.5)	0.01	1.3 (1.0-1.6)	0.02
Unclassified	0.4 (0.1-1.2)	0.10	0.9 (0.2-3.2)	0.85	0.4 (0.1-1.2)	0.1	0.9 (0.2-3.3)	0.89
LR-sqr (dfres)			269.227 (32)		519.799 (28)			
N			1039.0		8137.0			
AIC			6329.3		5750.5			
BIC			6497.4		5953.7			

After adjusting for all other covariates, the effect of age on the propensity to stay in hospital overnight was attenuated. However significant effect was observed for those in the age 70-79 years group for nights in hospital, where they were observed to have a 30% increased rate of nights spent in hospital compared to those in the lowest age group. Similar to outpatient visits, any additional level of medical cover was significantly associated with propensity to stay in hospital overnight although only dual cover was associated with a higher number of nights in hospital. Those with dual cover were twice as likely to have an overnight stay and 1.5 times as likely to have an increased number of nights in hospital compared to those with no additional cover.

Lower educated were slightly more likely (OR 1.2) to have a hospital stay but there was no difference detected for nights in hospital compared to those with a higher education after controlling for all other factors. Those who were permanently sick or disabled had slightly greater odds of being hospitalised and having a higher number of nights in hospital compared to those who were employed. Those who reported lower exercise status also had increased odds of hospitalisation and number of nights spent in hospital, while past smokers were found to have a significantly higher rate of nights in hospital compared to non-smokers.

Examining the predicted probability of an overnight stay in hospital between adjacent levels of multimorbidity averaging across all values of the covariates, differences between increasing numbers of conditions are significant for one vs. no condition, two vs. one condition and five vs. four conditions (χ^2 = 79.19 p<0.001). The overall effect of increasing multimorbidity levels on intensity of hospital overnight stays was not significant at the conventional level (χ^2 = 6.51 p=0.37) (Figure 5.14 and 5.15)

Figure 5.14 Predicted probability for an overnight stay in hospital by increasing levels of multimorbidity.

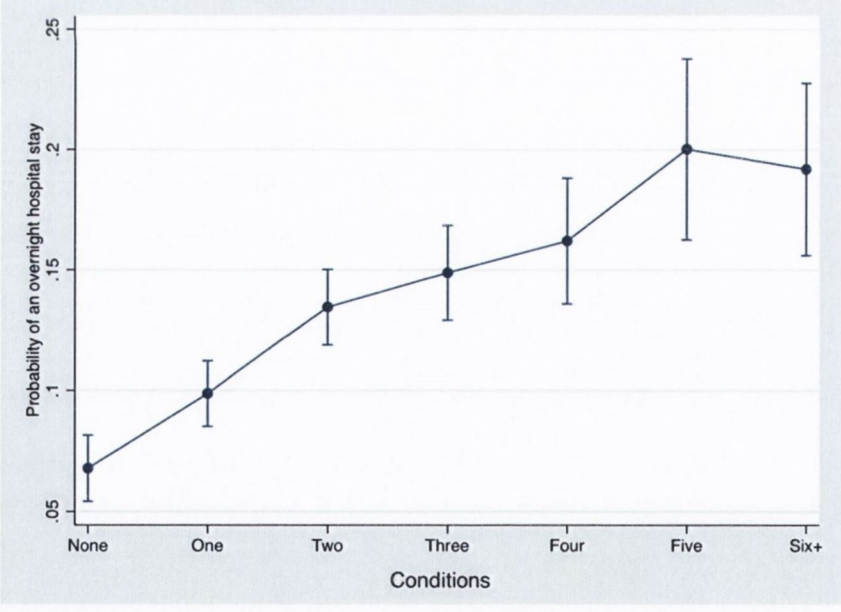
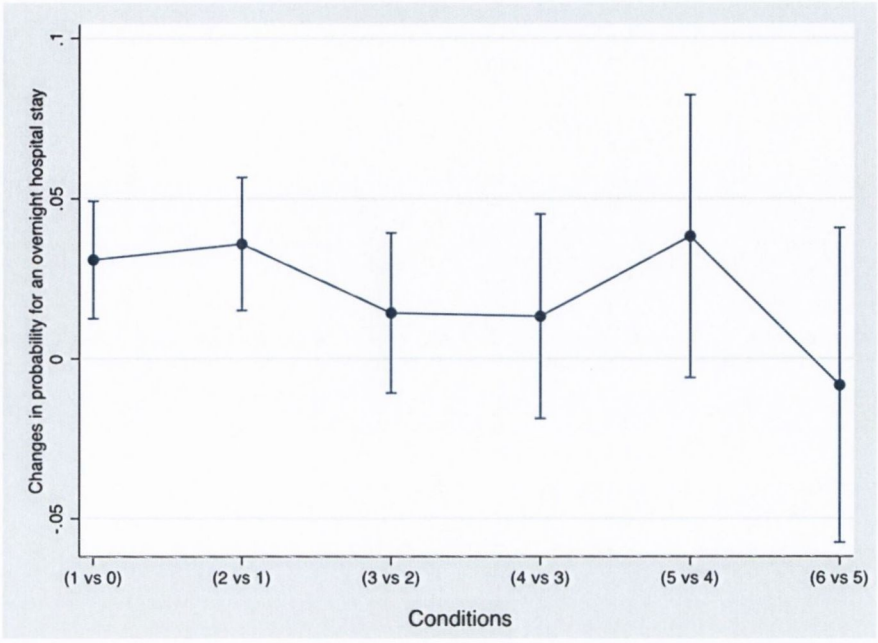


Figure 5.15 Changes in predicted probability for an overnight stay in hospital by increasing levels of multimorbidity.



5.4.2.4 Multivariate analysis of Emergency Department visits

Two proxy indicators were employed to investigate quality of care for individuals with multimorbidity. In descriptive analysis, ED visits are examined for frequent attenders, however, again for multivariate regression analyses this variable is modelled as a count variable, in a two-part model to examine propensity to use emergency care and intensity of use. Medication use is examined as a dichotomous variable to examine polypharmacy for individuals taking five or more prescription medications.

Increasing levels of multimorbidity were strongly associated with at least one visit to an ED in the previous year (Table 5.9). The odds of an ED visit were threefold for those with six or more conditions compared to those with no conditions. However, there was no significant effect detected for intensity of ED use for increasing levels of multimorbidity. While a significant increased propensity to use emergency care was observed for those with physical multimorbidity and for those with physical and mental health multimorbidity compared to those with only one condition or less, there was no significant effect detected between multimorbidity type for intensity of ED use. Disability was significantly associated with an increased intensity of emergency care use, although did not show an effect for propensity to use emergency care. Other need factors were however significantly associated with use. Those who were frail had a 70% increased odds of attending an Emergency Department in the previous year and 90% increased odds of higher use. Disability was also associated with a slight increased odds of use

and intensity of use. Poor self-rated health was associated with an increased propensity to use emergency care, although there was no effect observed for intensity of use.

There was no observed effect of age on the propensity to use or intensity of use of emergency care. Medical cover was modelled as a dichotomous variable indicating if individuals have a medical card or not. GMS entitlement was found to be significantly associated with intensity of ED use (IRR 1.7), but not with propensity to visit an ED.

Those who were unemployed had a 70% reduced rate, while those who were permanently sick or disabled had almost a three times greater rate of intensity of ED use. Homemakers had a significantly reduced propensity to use emergency care. There was no effect found for health behaviours or distance to services at the bivariate level.

Table 5.9 Multivariate logistic regression results for Emergency Department visits

	Two-part model for Multimorbidity Levels				Two-part model for Multimorbidity Type			
Emergency Department visits	**Adjusted OR (95% CI) P-value**		**Adjusted IRR (95% CI) P-value**		**Adjusted OR (95% CI) P-value**		**Adjusted IRR (95% CI) P-value**	
Need Factors								
Multimorbidity								
0 (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.				
1	1.5 (1.2-1.9)	0.000	0.7 (0.3-1.8)	0.51				
2	1.9 (1.5-2.3)	0.000	0.8 (0.3-2.1)	0.67				
3	2.2 (1.7-2.8)	0.000	0.8 (0.3-1.9)	0.61				
4	2.4 (1.8-3.2)	0.000	1.1 (0.4-2.8)	0.87				
5	3.0 (2.2-4.2)	0.000	0.8 (0.3-2.3)	0.69				
6	3.4 (2.4-4.6)	0.000	1.1 (0.5-2.8)	0.79				
Multimorbidity type								
< 1 condition (ref)					1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Physical multimorbidity					1.7 (1.4-1.9)	<0.000	1.1 (0.6-1.9)	0.72
Physical + mental multimorbidity					1.8 (1.4-2.3)	<0.000	0.9 (0.4-1.9)	0.78
Other Need Factors								
Disability								
No ADL (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
ADL	1.2 (1.0-1.4)	0.12	1.5 (1.0-2.2)	0.07	1.3 (1.0-1.5)	0.02	1.5 (1.0-2.1)	0.06
Frailty								
Not frail (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Prefrail	1.2 (1.0-1.5)	<0.01	1.4 (0.9-2.3)	0.12	1.3 (1.1-1.5)	<0.01	1.5 (0.9-2.5)	0.14
Frail	1.7 (1.2-2.5)	<0.01	1.9 (0.9-3.9)	0.03	1.8 (1.2-2.7)	0.00	2.1 (1.0-4.3)	0.04
Unclassified	1.1 (0.9-1.3)	0.31	1.5 (0.9-2.6)	0.04	1.1 (0.9-1.3)	0.40	1.7 (1.0-2.9)	0.05
Self-rated Health								
No NegSRH (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
NegSRH	1.8 (1.6-2.1)	<0.001	0.7 (0.5-1.1)	0.15	2.0 (1.7-2.3)	<0.000	0.7 (0.4-1.1)	0.10
Predisposing Factors								
Sex								
Male (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.				
Female	1.0 (0.9-1.1)	0.92	0.8 (0.5-1.2)	0.24	1.0 (0.9-1.2)	0.80	0.8 (0.5-1.1)	0.18
Age	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
80+ (ref)	1.1 (0.9-1.4)	0.45	0.6 (0.3-1.3)	0.20	1.1 (0.9-1.4)	0.43	0.8 (0.4-1.6)	0.46
70-79	1.3 (1.0-1.6)	0.11	0.8 (0.4-1.8)	0.58	1.2 (0.9-1.6)	0.15	1.0 (0.5-2.1)	0.97
60-69	1.3 (1.0-1.8)	0.05	1.2 (0.5-2.8)	0.63	1.3 (1.0-1.7)	0.10	1.8 (0.8-4.2)	0.14

50-59	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.				
Enabling Factors								
Medical card coverage								
No GMS medical card (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
GMS medical card	1.1 (0.9-1.3)	0.37	1.7 (1.0-3.0)	0.04	1.1 (0.9-1.3)	0.27	1.9 (1.1-3.2)	0.01
Employment status								
Employed	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Retired	0.8 (0.6-1.0)	0.10	1.5 (0.6-3.5)	0.39	0.8 (0.6-1.0)	0.09	1.3 (0.6-3.0)	0.47
Home-maker	0.8 (0.7-1.0)	0.06	1.3 (0.7-2.3)	0.47	0.8 (0.7-1.0)	0.05	1.2 (0.7-2.3)	0.51
Unemployed	1.0 (0.7-1.3)	0.88	0.3 (0.1-0.6)	<0.000	1.0 (0.7-1.3)	0.88	0.3 (0.1-0.6)	<0.000
Permanently sick or disabled	1.2 (0.9-1.5)	0.22	2.7 (1.0-7.0)	0.04	1.2 (0.9-1.6)	0.12	2.2 (0.9-5.2)	0.09
Unclassified	1.2 (0.7-1.9)	0.56	0.6 (0.2-1.4)	0.20	1.2 (0.7-1.9)	0.56	0.5 (0.2-1.3)	0.17
LR-sqr (dfres)	384.479 (21)				354.285 (17)			
N	8118				8118			
AIC	6541.6				6568.1			
BIC	6695.7				6694.1			

Examining the predictive margins for the probability of an ED visit between adjacent levels of multimorbidity averaging across all values of the covariates, differences between increasing numbers of conditions are significant for one vs. no condition at the α 0.05 level and for two vs. one condition at the α 0.10 level only (χ^2 = 80.96 p<0.001). The overall effect of increasing multimorbidity levels on intensity of ED use was not significant at the conventional level (Figure 5.16 and 5.17).

Figure 5.16 Predicted probability for the impact of increasing levels of multimorbidity on propensity to use ED services.

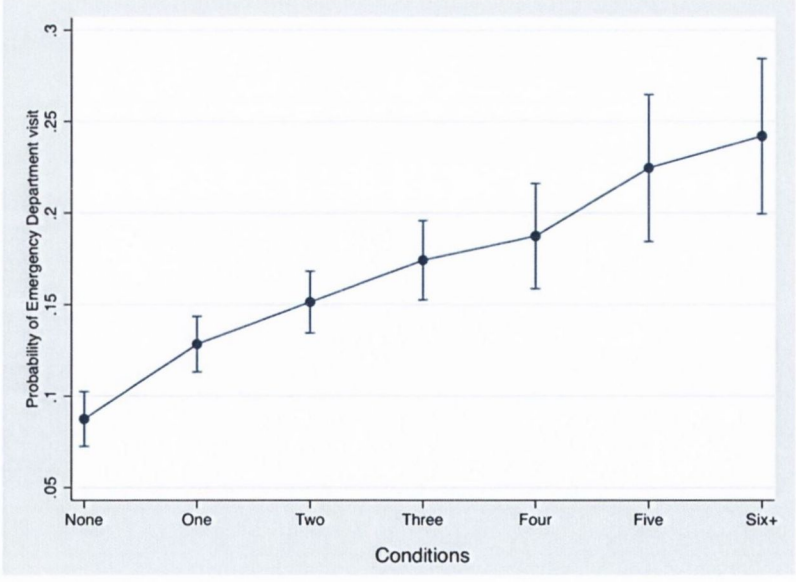
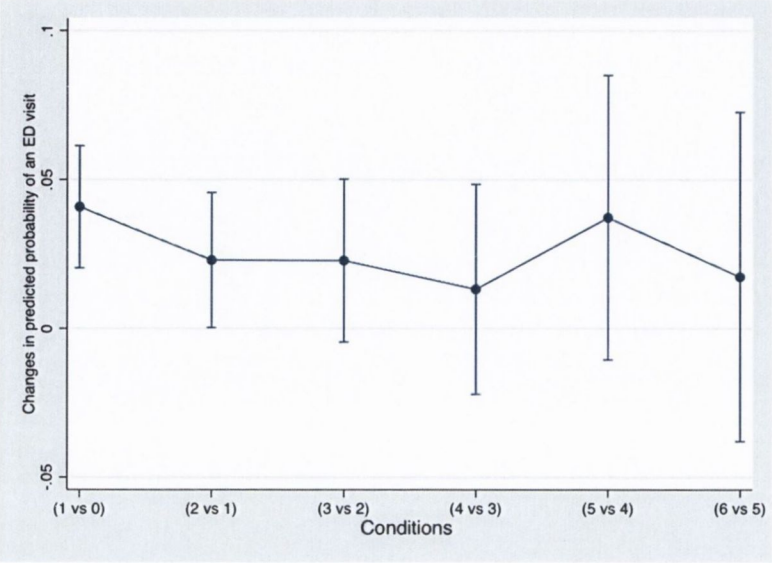


Figure 5.17 Changes in predicted probability for the impact of increasing levels of multimorbidity on propensity to use ED services.



5.4.2.5 Polypharmacy

Increasing levels of multimorbidity were strongly associated with polypharmacy (Table 5.10). Compared to those with no conditions, individuals with six or more conditions had a 67 times greater odds of reporting polypharmacy. The odds of polypharmacy for six or more conditions is almost double that of the odds for those with five conditions (OR 67.4 vs. OR 36.1). The odds of polypharmacy were also significantly higher for those with physical multimorbidity (OR 6.3) and for those with physical-mental health multimorbidity (OR 7.2) compared to those with one condition or less. Those reporting unfavourable self-assessed health had a 2.5 fold increased odds of polypharmacy, while individuals with a disability had a 30% increased odds ad those who were frail had a 70% increased odds of polypharmacy compared to their non-disabled and non-frail counterparts. Males had slightly higher increased odds (20%) of polypharmacy compared to females. Even after controlling for need factors, increasing age was found to be significantly associated with polypharmacy. Living alone was also associated with increased odds of polypharmacy. GMS entitlement was significantly associated with the odds of taking five or more medications compared to those with no GMS card (OR 1.4) after controlling across all covariates including need factors indicated by multimorbidity, self-rated health, disability and frailty. Permanently sick and disabled individuals also indicated higher odds of polypharmacy compared to their employed counterparts, even after controlling for age and other need factors. Past smokers showed slight increased odds of polypharmacy (10%) and those who reported that they

consume alcohol, at any level, showed decreased odds of polypharmacy. Those who recorded lower levels of exercise also had increased odds of polypharmacy.

Table 5.10 Multivariate logistic regression results for polypharmacy

Polypharmacy	Adjusted OR (95% CI)		P-value	Adjusted OR (95% CI)		P-value
Need Factors						
Primary independent variables of interest						
Multimorbidity						
0 (ref)	1	(1.0-1.0)	.			
1	3.4	(2.2-5.2)	<0.000			
2	7.1	(4.7-10.7)	<0.000			
3	15.7	(10.4-23.8)	<0.000			
4	31.2	(20.3-47.8)	<0.000			
5	36.1	(22.7-57.2)	<0.000			
6	67.4	(42.1-107.9)	<0.000			
Multimorbidity type						
< 1 condition (ref)				1	(1.0-1.0)	.
Physical multimorbidity				6.3	(5.2-7.5)	<0.000
Physical + mental multimorbidity				7.2	(5.6-9.2)	<0.000
Other Need Factors						
Self-rated Health						
No Negsrh (ref)						
NegSRH	2.5	(2.2-3.0)	<0.000	3.1	(2.7-3.6)	0
Disability						
No ADL (ref)						
ADL	1.3	(1.1-1.6)	0.01	1.6	(1.4-1.9)	<0.000
Frailty						
Not frail (ref)	1	(1.0-1.0)	.	1	(1.0-1.0)	.
Prefrail	1.5	(1.2-1.8)	<0.000	1.6	(1.3-1.9)	<0.000
Frail	1.6	(1.0-2.5)	0.04	1.9	(1.3-2.9)	<0.000
Unclassified	1.2	(1.0-1.4)	0.03	1.1	(0.9-1.3)	0.17
Predisposing Factors						
Sex						
Female (ref)	1	(1.0-1.0)	.	1	(1.0-1.0)	.
Male	1.2	(1.0-1.4)	0.02	1.1	(0.9-1.2)	0.5
Age						
50-59 (ref)	1	(1.0-1.0)	.	1	(1.0-1.0)	.
60-69	1.5	(1.3-1.8)	<0.000	1.6	(1.4-2.0)	<0.000
70-79	2.2	(1.8-2.8)	0.000	2.5	(2.0-3.1)	<0.000
80+	2.7	(2.0-3.7)	0.000	3	(2.2-4.0)	<0.000
Enabling Factors						
Living arrangement						
With other persons (ref)	1	(1.0-1.0)	.	1	(1.0-1.0)	.
With spouse	1.4	(1.2-1.7)	<0.000	1.3	(1.1-1.6)	<0.000
Living alone	1.2	(1.0-1.5)	0.04	1.2	(1.0-1.5)	0.02
Medical card coverage						
No GMS medical card (ref)	1	(1.0-1.0)	.	1	(1.0-1.0)	.
GMS medical card	1.4	(1.1-1.6)	<0.000	1.4	(1.2-1.7)	<0.000
Employment status						
Employed (ref)	1	(1.0-1.0)	.	1	(1.0-1.0)	.
Retired	0.8	(0.6-1.0)	0.07	0.7	(0.6-1.0)	0.04
Home-maker	1	(0.8-1.2)	0.81	1	(0.8-1.2)	1
Unemployed	0.8	(0.5-1.1)	0.17	0.8	(0.5-1.1)	0.2
Permanently sick or disabled	1.8	(1.3-2.4)	<0.000	2.1	(1.6-2.7)	<0.000
Unclassified	1.1	(0.6-2.0)	0.66	1.2	(0.7-2.2)	0.54
Health behaviours						
Smoking status						
Never (ref)	1	(1.0-1.0)	.	1	(1.0-1.0)	.
Past	1.1	(1.0-1.3)	0.08	1.3	(1.1-1.5)	<0.000
Light	0.8	(0.5-1.2)	0.22	0.8	(0.5-1.1)	0.18
Moderate	0.9	(0.7-1.3)	0.62	0.9	(0.7-1.3)	0.74
Heavy	0.7	(0.5-0.9)	0.02	0.8	(0.6-1.0)	0.09
Alcohol status						
None or rare (ref)	1	(1.0-1.0)	.	1	(1.0-1.0)	.
1-2 days p/w	0.8	(0.7-1.0)	0.07	0.8	(0.7-1.0)	0.06

3-4 days p/w	0.7	(0.5-0.9)	<0.000	0.8	(0.6-1.0)	0.03
Almost every day	0.9	(0.7-1.2)	0.50	1	(0.8-1.3)	0.95
Unclassified	0.7	(0.6-0.9)	<0.000	0.8	(0.6-0.9)	0.01
Exercise status						
High (ref)	1	(1.0-1.0)	.	1	(1.0-1.0)	.
Moderate	1.2	(1.0-1.5)	0.02	1.3	(1.1-1.5)	<0.01
Low	1.2	(1.0-1.4)	0.05	1.2	(1.0-1.5)	<0.01
Unclassified	1	(0.4-2.4)	0.99	1.2	(0.5-2.6)	0.65
R-sqr (dfres)		1,696.042	(34)		1,612.019	(30)
N		8,047.0			8,047.0	
AIC		5,500.4			5,865.6	
BIC		5,745.1			6,082.4	

Examining the predictive margins for the probability of polypharmacy between adjacent levels of multimorbidity averaging across all values of the covariates, differences between increasing numbers of conditions are significant for increasing levels of multimorbidity, except for five vs. four conditions (χ^2 = 715.72 p<0.001) (Figure 5.18 and 5.19).

Figure 5.18 Predicted probability for the impact of increasing levels of multimorbidity on polypharmacy

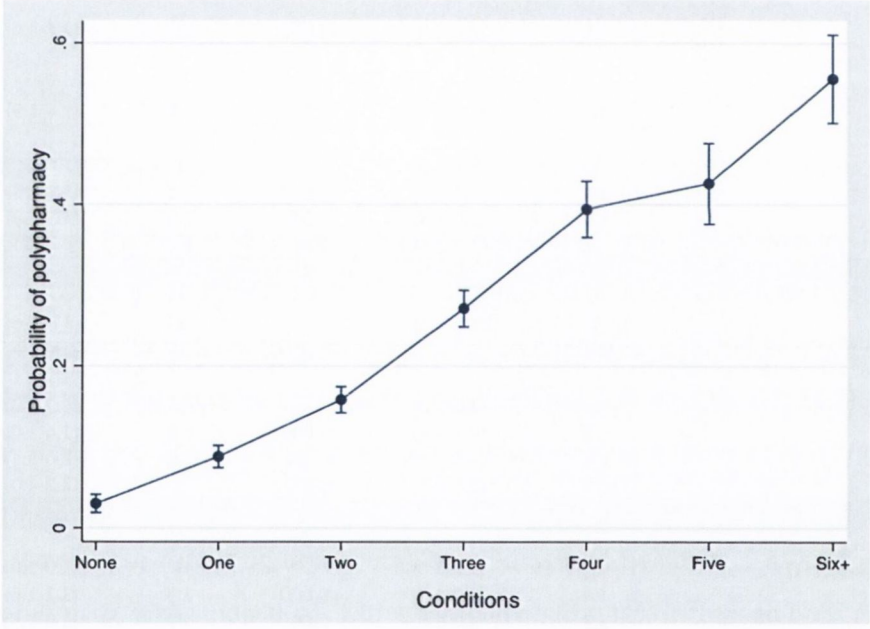
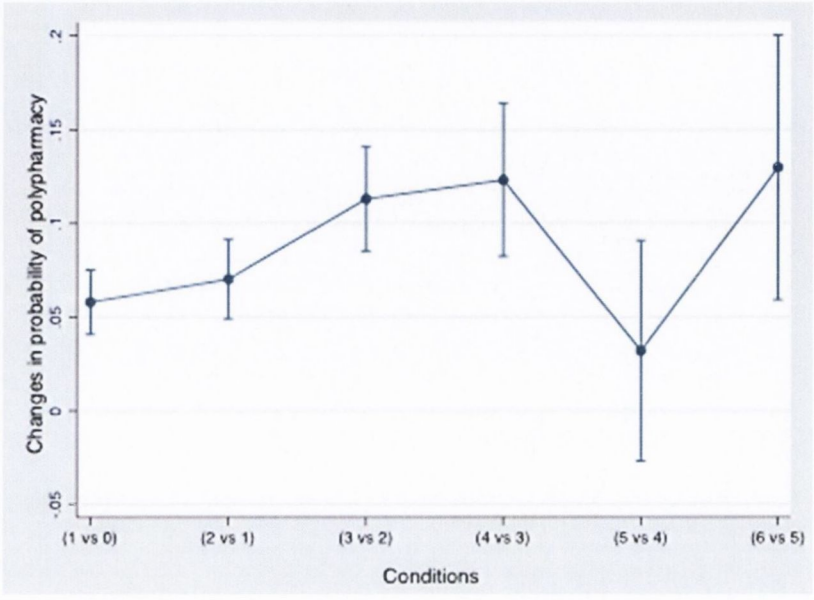


Figure 5.19 Changes in predicted probability for the impact of increasing levels of multimorbidity on polypharmacy



5.3.2.6 PHN Visits

Even after controlling for other need factors, increasing levels of multimorbidity were strongly associated with PHN visits (Table 5.11). Compared to those with no conditions, individuals with six or more conditions had a 5 times greater odds of a PHN visit in the previous year. The odds of a PHN visit were also slightly higher for those with physical multimorbidity and for those with physical-mental health multimorbidity compared to those with one condition or less (OR 2.1 and OR 1.9 respectively). Use of PHN was also significantly higher for those who were frail and for those with a disability. Use increased significantly with increasing age, and there was no gender difference. After controlling across all other covariates, the likelihood of using a PHN was significantly and substantially higher for those with increased access to PHN services indicated by medical coverage and proximity to GP services. Those with GMS entitlement had fourfold increased odds (OR 4.2) of a PHN visit compared to those without any additional medical coverage. Permanently sick and disabled individuals also indicated higher odds of PHN use. Low exercise also appears to be associated with PHN visits.

Table 5.11 Multivariate logistic regression results for PHN visits

PHN	Multimorbidity level		Multimorbidity type	
	Adjusted OR (95% CI)	P-value	Adjusted OR (95% CI)	P-value
Need Factors				
Primary independent variables of interest				
Multimorbidity				
0 (ref)	1.0 (1.0-1.0)	.		
1	1.8 (1.1-3.0)	0.030		
2	2.4 (1.5-4.1)	0.001		
3	2.4 (1.4-4.0)	0.001		
4	3.0 (1.7-5.1)	0.000		
5	3.6 (2.0-6.3)	0.000		
6	5.1 (3.0-8.9)	0.000		
Multimorbidity type				
< 1 condition (ref)			1.0 (1.0-1.0)	.
Physical multimorbidity			1.9 (1.4-2.5)	<0.000
Physical + mental multimorbidity			2.1 (1.4-3.2)	<0.00
Other Need Factors				
Self-rated Health				
Not negative SRH (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Negative SRH	1.4 (1.1-1.8)	0.002	1.6 (1.3-2.0)	<0.000
Disability				
No ADL (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
ADL	2.2 (1.7-2.8)	0.000	2.4 (1.9-3.1)	<0.000
Frailty				
Not frail (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Prefrail	1.6 (1.2-2.2)	0.002	1.7 (1.2-2.4)	<0.000
Frail	2.8 (1.8-4.5)	0.000	3.2 (1.9-5.2)	<0.000
Unclassified	1.5 (1.1-2.1)	0.005	1.5 (1.1-2.1)	<0.00
Predisposing Factors				
Sex				
Male (ref)	1.0 (1.0-1.0)	.		
Female	1.0 (0.8-1.3)	0.693	1.1 (0.9-1.4)	0.31
Age				
50-59 (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
60-69	1.3 (0.9-1.9)	0.163	1.3 (0.9-1.9)	0.17
70-79	2.2 (1.5-3.1)	0.000	2.2 (1.5-3.3)	<0.000
80+	3.8 (2.5-5.7)	0.000	3.7 (2.4-5.6)	<0.000
Enabling Factors				
Living arrangement				
With other persons (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
With spouse	0.8 (0.6-1.1)	0.233	0.8 (0.6-1.1)	0.22
Living alone	1.3 (1.0-1.7)	0.038	1.3 (1.0-1.8)	0.03
Healthcare coverage				
No additional coverage (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
GMS only	4.2 (2.1-8.5)	0.000	4.5 (2.2-9.1)	<0.000
Insurance only	0.9 (0.4-1.9)	0.791	1.0 (0.5-2.0)	0.91
GMS and insurance	3.2 (1.5-6.6)	0.002	3.5 (1.7-7.3)	<0.01
Employment status				
Employed (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Retired	1.0 (0.6-1.8)	0.976	1.0 (0.6-1.8)	1.00
Home-maker	1.0 (0.7-1.3)	0.766	1.0 (0.7-1.3)	0.97

Unemployed	0.4 (0.1-1.0)	0.043	0.4 (0.2-1.0)	0.05
Permanently sick or disabled	1.5 (1.0-2.2)	0.035	1.7 (1.1-2.5)	<0.01
Unclassified	1.0 (0.4-2.2)	0.966	0.9 (0.4-2.1)	0.74
Distance to GP (in meters)				
Furthest 10% (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Rest of 4th quintile	1.7 (1.1-2.6)	0.03	1.6 (1.0-2.5)	0.04
3rd quintile	1.4 (0.9-2.1)	0.09	1.3 (0.9-2.0)	0.15
2nd quintile	1.3 (0.9-2.0)	0.18	1.3 (0.9-2.0)	0.21
rest of 1st quintile	1.6 (1.0-2.4)	0.05	1.5 (1.0-2.3)	0.06
Closest 10%	1.9 (1.2-3.1)	<0.01	1.5 (1.2-3.0)	<0.01
Health behaviours				
Exercise status				
High (ref)	1.0 (1.0-1.0)	.	1.9 (1.2-3.0)	<0.01
Moderate	1.2 (0.8-1.6)	0.364	1.0 (1.0-1.0)	.
Low	1.6 (1.2-2.1)	0.004	1.9 (1.2-3.0)	<0.01
Unclassified	1.2 (0.3-4.0)	0.787	1.0 (1.0-1.0)	.
R-sqr (dfres)	741.656 (39)		738.070 (35)	
N	8128		81128	
AIC	2749.7		2770.2	
BIC	3029.9		3022.3	

Examining the predictive margins for the probability of PHN use between adjacent levels of multimorbidity averaging across all values of the covariates, differences between increasing numbers of conditions are significant for increasing levels of multimorbidity for one vs. no condition ($p<0.05$) and for two vs. one conditions and six or more conditions vs. five conditions at the less conservative $p<0.10$ level ($\chi^2 = 43.70$ $p<0.001$) (Figure 5.20 and 5.21).

Figure 5.20 Predicted probability for the impact of increasing levels of multimorbidity on PHN visits

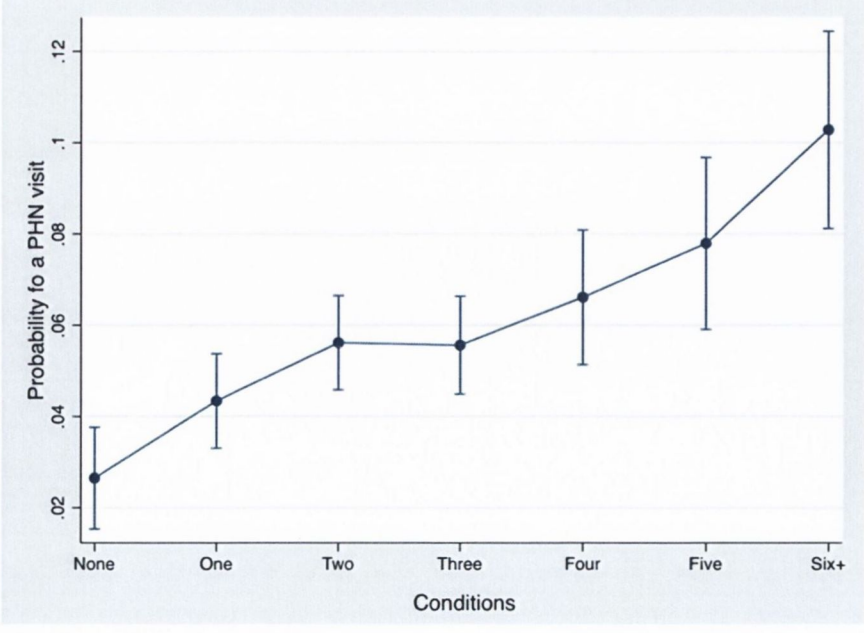
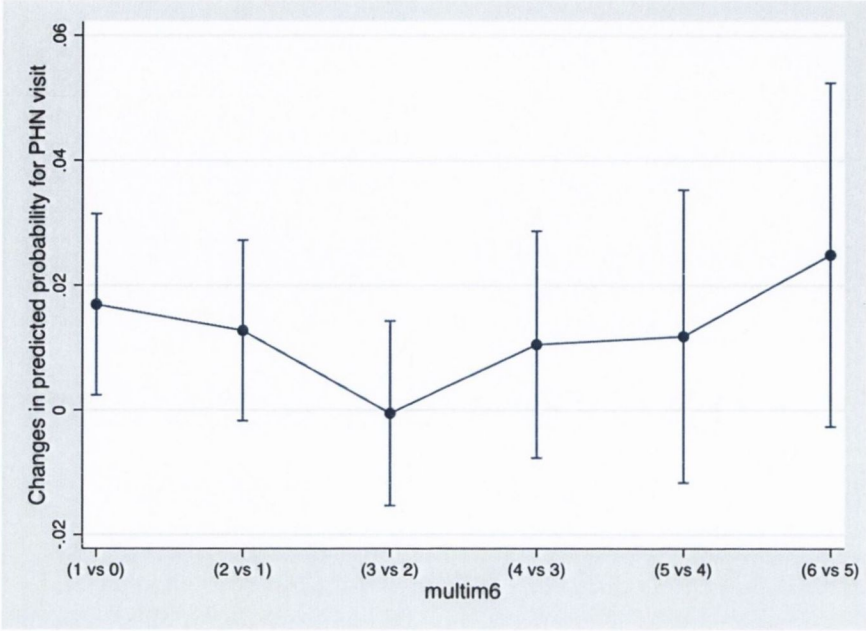


Figure 5.21 Changes in predicted probability for the impact of increasing levels of multimorbidity on PHN visits



5.3.2.7 Formal Care Assistance

Increasing levels of multimorbidity were strongly associated with receipt of formal care assistance, although this was at a lower magnitude than associations with other dependent variables (Table 5.12). Compared to those with no conditions, individuals with six or more conditions had an 80% increased odds of utilisation. The odds of utilisation were also significantly higher for those with physical multimorbidity (OR 1.4) and for those with physical-mental health multimorbidity (OR 2.0) compared to those with one condition or less. Those reporting unfavourable self-assessed health had a 80% increased odds of utilisation, while individuals with a disability had an almost threefold increased odds and those who were frail had just over a threefold increased odds of utilisation compared to their non-disabled and non-frail counterparts. Even after controlling for need factors, increasing age was found to be significantly and substantially associated with receipt of formal care support in the community. Those in the oldest age category (age 80 years +) had a fourteenfold increased likelihood of formal care assistance compared to their youngest counterparts (age 50-59 years). Those living alone had threefold increased odds of assistance. Individuals eligible for medical cards had substantially increased odds of formal care assistance (OR 3.9) even after controlling for age and predisposing need factors. Permanently sick and disabled individuals also indicated higher likelihood of formal care assistance compared to their employed counterparts and homemakers also had reduced

odds of formal care assistance. Those who recorded low exercise status had increased odds for receipt of formal care assistance.

Table 5.12 Multivariate logistic regression results for formal care assistance

Formal Care Assistance	Multimorbidity Levels		Multimorbidity Type	
	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value
Need Factors				
Primary independent variables of interest				
Multimorbidity				
0 (ref)	1.0 (1.0-1.0)	.		
1	0.8 (0.4-1.4)	0.40		
2	1.1 (0.6-2.0)	0.80		
3	1.1 (0.6-2.0)	0.86		
4	1.4 (0.7-2.6)	0.32		
5	1.0 (0.5-2.1)	0.92		
6	1.8 (0.9-3.5)	0.09		
Multimorbidity type				
< 1 condition (ref)			1.0 (1.0-1.0)	.
Physical multimorbidity			1.4 (1.0-2.1)	0.07
Physical + mental multimorbidity			2.0 (1.2-3.3)	0.01
Other Need Factors				
Self-rated Health				
Not negative self-rated health (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Negative self-rated health	1.8 (1.3-2.5)	<0.000	1.8 (1.3-2.5)	<0.000
Disability				
No ADL (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
ADL	2.7 (1.9-3.7)	<0.000	2.7 (2.0-3.7)	<0.000
Frailty				
Not frail (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Prefrail	2.6 (1.6-4.3)	<0.000	2.6 (1.6-4.2)	<0.000
Frail	3.3 (1.6-6.5)	<0.01	3.4 (1.7-6.7)	<0.000
Unclassified	1.9 (1.2-3.1)	0.01	1.9 (1.1-3.1)	0.01
Predisposing Factors				
Sex				
Male (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Female	1.4 (1.0-2.0)	0.05	1.4 (1.0-2.0)	0.044
Age				
50-59 (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
60-69	2.0 (1.0-3.9)	0.05	2.0 (1.0-4.0)	0.04
70-79	5.4 (2.7-10.8)	<0.000	5.7 (2.8-11.5)	<0.000
80+	14.6 (7.2-	<0.000	15.2 (7.4-31.2)	<0.000
Enabling Factors				
Living arrangement				
With other persons (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
With spouse	1.2 (0.7-1.9)	0.471	1.2 (0.7-1.9)	0.49
Living alone	3.3 (2.2-4.9)	<0.000	3.2 (2.2-4.8)	<0.000

Healthcare coverage				
No additional coverage (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
GMS only	3.9 (0.9-17.0)	0.07	4.0 (0.9-17.1)	0.07
Insurance only	1.7 (0.4-7.6)	0.50	1.7 (0.4-7.6)	0.49
GMS and insurance	3.9 (0.9-17.3)	0.07	3.9 (0.9-17.1)	0.07
Employment status				
Employed	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Retired	0.5 (0.2-1.5)	0.23	0.5 (0.2-1.5)	0.22
Home-maker	0.7 (0.5-1.0)	0.07	0.7 (0.5-1.0)	0.08
Unemployed	0.7 (0.2-3.2)	0.64	0.7 (0.2-3.2)	0.63
Permanently sick or disabled	2.2 (1.2-3.9)	0.01	2.2 (1.2-3.9)	0.01
Unclassified	1.6 (0.6-4.5)	0.36	1.5 (0.5-4.3)	0.44
Health behaviours				
Exercise status				
High (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Moderate	1.0 (0.6-1.7)	0.89	1.0 (0.6-1.8)	0.86
Low	2.2 (1.3-3.5)	0.00	2.2 (1.4-3.6)	0.00
Unclassified	1.9 (0.3-11.4)	0.48	2.1 (0.4-12.1)	0.41
R-sqr (dfres)	670.365 (24)		546.857 (20)	
N	8112		8112	
AIC	1582.7		1463.3	
BIC	1757.8		1597.9	

The predicted probability for the impact of increasing multimorbidity levels on formal care assistance were estimated after adjusting for all other covariates. The overall effect of multimorbidity levels on formal care assistance was not significant (χ^2 = 10.6 p=0.11).

5.5 Discussion

5.5.1 Healthcare utilisation

A large proportion of TILDA respondents had accessed some form of healthcare in the previous year (88.4%). The mean number of GP consultations for the full TILDA sample was 4.0 (± 5.4). The mean number of outpatient visits was 0.4 (±2.5) 18.5% and the mean number of nights in hospital was 1.2 (±6.3) nights for the full sample, although only 18.5% and 12.5% respectively of the full sample had accessed outpatient care and had a hospital stay. Utilisation rates varied substantially according to chronic conditions and across healthcare utilisation type. This is the first study to my knowledge to examine the impact of multimorbidity on a wide range of healthcare services controlling for other factors that could be driving complexity for individuals in this age group including disability, frailty and a subjective measures of general health status.

Even after controlling for other need factors and covariates increasing levels of multimorbidity was significantly associated with both propensity to use GP services, outpatient visits and overnight stays in hospital as well as with increased intensity of GP and outpatient visits and nights in hospital.

A high proportion of the population use GP services and increasing levels of multimorbidity were significantly associated with both propensity to use GP services and increasing use of GP services after an initial visit similar to previous findings from national and international studies (Rapoport et al., 2004, Hessel et al., 2000, Martin et al., 2006, Linden et al., 1997, Glynn et al., 2011, Schafer et al., 2010, Taylor et al., 2010), The odds of visiting a GP for those with six or more conditions was over eight times greater (OR 8.6) than those with no chronic conditions. Intensity of use increased substantially for increasing levels of multimorbidity and multimorbidity type, after adjusting for all covariates. The impact of other need factors including disability and frailty were attenuated for propensity to visit a GP after controlling for multimorbidity indicators in the respective multivariate analysis although they were associated with increased risk of higher GP use. The impact of accumulating additional chronic conditions on the propensity to visit a GP is significant up to three conditions however, there is no significant effect detected for increasing multimorbidity levels on propensity to visit a GP after three conditions. For intensity of GP use, multimorbidity levels are significant up to two conditions but not after two conditions, indicating that once individuals have at least two conditions, they are regular visitors at GP surgeries regardless of level of multimorbidity. Furthermore, confirming the *a priori* hypothesis that the interplay of need factors is contributing to greater utilisation, the effect of increasing multimorbidity levels on intensity of GP use appears to be more pronounced for individuals with a disability confirming the higher use of healthcare services for individuals with multimorbidity and activity limitations that was also observed in a large U.S. study (Partnerships for Solutions 2004). This underlines the need to invest in secondary prevention to reduce the debilitating effects of increasing condition co-occurrence on individuals in the community.

Increasing levels of multimorbidity were significantly associated with both propensity to use outpatient services and intensity of their use after controlling for all other factors and covariates again reflecting international evidence of increased use of specialist and ambulatory services (Nie et al., 2010, Van Den Bussche et al., 2011b). The likelihood of an outpatient procedure for individuals with six or more chronic conditions was over four times that (OR 4.5) for individuals with no chronic condition. Those with higher levels of multimorbidity were also more likely to use outpatient services more intensely although this effect was not found to be linear. The

independent effect of increasing multimorbidity levels on propensity to use services was significant up to two conditions; it flattens out after two conditions but is significantly different again for five vs. four conditions.

Increasing levels of multimorbidity were strongly associated with propensity for an overnight stay in hospital however, there was no significant effect detected on number of nights in hospital for increasing levels of multimorbidity which is in direct contrast to findings in the international literature (Byles et al., 2005; Chan et al., 2002; Condelius et al., 2008; Friedman et al., 2006; Landi et al., 2004; Putnam et al., 2002; Rapoport et al., 2004; Schneider 2006; Wolff, Starfield, and Anderson 2002). This is likely due to the modelling approach adopted in this study; no other study has examined the distinction between morbidity and increasing multimorbidity levels for nights spent in hospital controlling for other need factors. The independent effect of increasing multimorbidity levels on propensity to be hospitalised overnight reflected that for outpatient use. It was significant up to two conditions, flattens out after two conditions but is significantly different again for five vs. four conditions.

Multimorbid individuals with a mental health condition were significantly more likely to use GP services compared to those with physical-only multimorbidity or without morbidity. Both physical multimorbidity and physical-mental health multimorbidity were associated with increased odds of outpatient use and intensity of use compared to those without multimorbidity. Those with at least two physical conditions did appear to use services a little more intensely compared to those with at least one physical and mental health condition (IRR 2.1 vs. 1.8). There was no effect detected for multimorbidity with or without a mental health component for propensity to be hospitalized or total number of nights in hospital. Other need factors were significantly associated with intensity of hospital stays. Frailty, disability and poor self-rated health were all independently associated with higher number of nights spent in hospital, although the effect of disability on number of hospital nights is less pronounced.

5.5.2 Indicators of quality of care

Further to the impact of multimorbidity on healthcare utilisation, multimorbid individuals are more likely to attend hospital Emergency Departments and are at a substantial and significantly higher risk of polypharmacy highlighting potential issues with quality of care for community-dwelling individuals with multimorbidity in Ireland. Increasing levels of multimorbidity were strongly associated with at least one visit to an Emergency Department in the previous year

reflective of findings in other studies (Agborsangaya et al., 2012, Librero et al., 1999, Marcantonio et al., 1999). The odds of an ED visit were threefold for those with six or more conditions compared to those with no conditions. However, no significant effect was detected for intensity of ED use for increasing levels of multimorbidity. The independent effect of increasing multimorbidity levels on propensity to visit an ED was significant up to two conditions only reflecting the nature of the relationship found for increasing multimorbidity on other healthcare utilisation outcomes. The effect of multimorbidity on propensity to attend an ED in the preceding year was slightly higher for those with a mental health component. However again this was not significant on intensity of ED use. Disability and frailty were independently associated with intensity of ED use. In particular, frailty had a twofold increase on intensity of use. This indicates potential issues with quality of care for more disabled and frail individuals.

Similar to other studies (Hilmer and Gnjidic, 2008, Naughton et al., 2006), increasing levels of multimorbidity were strongly associated with polypharmacy. Compared to those with no conditions, individuals with six or more conditions had a 67 times greater odds of reporting polypharmacy. The odds of polypharmacy for six or more conditions was almost double that of the odds for those with five conditions (OR 67.4 vs. OR 36.1), this may be due to the cut off definition used in the polypharmacy measure (i.e. 5 or more medications). The odds of polypharmacy were also significantly higher for those with physical-mental health multimorbidity (OR 7.2) and those with physical multimorbidity alone (OR 6.3) compared to no conditions. The independent effect of increasing multimorbidity levels on polypharmacy was significant for all levels of multimorbidity except between four and five conditions. Multimorbidity is a strong independent predictor of polypharmacy in this age group. While this is to be expected due to the need for extensive prescription drug treatment for a wide range of chronic conditions, nonetheless issues with poor medication coordination and prescribing cascades have been shown to impact negatively on individuals, likely leading to increased complexity and reduced quality of life as well as high rates of readmission to hospital (Wolff et al., 2002, Roughead et al., 2011).

5.5.3 Indicators of health and social care in the home

While the effects of multimorbidity on healthcare utilisation have received some attention in international and national studies, no study to date has examined its impact on health and social care in the home. Even after controlling for other need factors, increasing levels of multimorbidity were strongly associated with PHN visits. Compared to those with no conditions,

individuals with six or more conditions had a 5 times greater odds of a PNH visit in the previous year. The independent effect of increasing multimorbidity levels on a PHN visit was significant up to two conditions and flattened out after that up to five conditions when the odds of a PHN visit rose sharply again, again reflecting the general nature of the effect of increasing levels of multimorbidity on healthcare utilisation. Odds of a visit were also slightly higher for those with physical-mental health multimorbidity compared to physical multimorbidity alone (OR 2.1 and OR 1.9 respectively). Use of a PHN was also independently associated with frailty and disability.

The low use of primary and social care services by older people in Ireland has previously been identified and debated by McGee et al. (2005). Increasing levels of multimorbidity were also independently associated with receipt of formal care assistance, although this was at a lower magnitude compared to associations with other healthcare outcome variables. The independent effect of increasing multimorbidity levels was only significant after six conditions. The independent effects of disability and frailty were more pronounced compared to the effect for increasing multimorbidity levels. Those reporting a disability had an almost threefold increased odds of care assistance and those who were frail had just over threefold increased odds of utilisation compared to their non-disabled and non-frail counterparts.

5.5.4 Other factors associated with health and social care outcomes after controlling for need factors

In contrast to previous findings based on the same age group in a primary care sample in Ireland (Glynn et al., 2011), there was no significant effect of gender or age groups on healthcare utilisation in multivariate analysis. Women did however have a slightly higher odds of polypharmacy (OR 1.2) compared to men and they were also more likely to be in receipt of formal care assistance (OR 1.4). While age was a significant predictor of healthcare utilisation in univariate analysis this effect was attenuated when multimorbidity was introduced into the multivariate models. The impact of age on healthcare services, while significant in bivariate models is attenuated after controlling for need factors indicating that age, *per se* is less of a driver of healthcare in Ireland than multimorbidity and other need factors such as disability, although it is acknowledged that age and multimorbidity are correlated and the risk of multimorbidity increases with age. This finding does not however hold true for other outcomes. Age is more strongly associated with the use of care support in the home. Even after controlling for need factors, increasing age was found to be significantly and substantially associated with a PHN visit and receipt of formal care support in the community. It is acknowledged that factors

associated with social care are more difficult to elucidate than those associated with healthcare utilisation. This may in part be related to the strong age effect on need for social care. Those in the oldest age category (80 years +) had a fourteenfold increased likelihood of formal care assistance compared to their youngest counterparts (50-59 years).

The association between increased educational status and propensity to use and level of outpatient service use independent of need factors and level of healthcare coverage is interesting. It may be reflecting a greater ability of those with a third level qualification to negotiate the healthcare system and access increased specialist care. This finding may also be related to poorer recall in less well-educated individuals although it warrants further investigation.

While specific examination of the equity of healthcare services was beyond the scope of this study, the documented inequity evidenced in care provision previously in Ireland (Wren, 2003, Layte, 2007, Smith, 2009) may have important implications for the care of multimorbid patients. Considering the higher prevalence of multimorbidity in poorer, more deprived individuals highlighted in Chapter 4, healthcare itself may be acting as a determinant of health for multimorbid patients in Ireland. A recent study suggests that the inverse care law, observed as: *the availability of good medical care tends to vary inversely with the need for it in the population*, is a key influence on multimorbidity related outcomes for patients in Scotland (Mercer et al., 2012). It has been highlighted that poor access to health services in general can contribute to inequalities in health and that appropriate provision of primary care services can alleviate health inequalities (Mackenbach et al., 1996, Starfield, 2007) and play an important role in managing multimorbid patients (Guthrie, 2011, Mercer et al., 2012, Starfield, 2011, Starfield et al., 2003).

Findings in this study indicate that increased entitlement to healthcare services, through the provision of medical cards is associated with an increased use in GP services, even after controlling for a range of need factors including multimorbidity. This held true for both propensity to visit a GP and recurrent number of GP visits. This finding is in keeping with previous studies where GMS entitlement was found to be an important influence on health care utilisation in Ireland (Layte, 2007, Smith, 2009). This finding contributes a greater understanding of the pattern of GP use among medical card holders in Ireland and indicates equity in the provision of GP services for those in lower income bands with GMS cards. However, this analysis only provides assessment of the quantity of care provided to such patients and cannot provide insight on the quality of that care provision, which has been documented in other studies as poor for GMS patients compared to private patients (Wren, 2003, Fadden, 2003). Studies of

multimorbid patients attending primary care in Scotland (Mercer et al., 2012, O'Brien et al., 2011) highlight the important role of GP care quality as well as frequency of consultations on outcomes for multimorbid patients, found to be particularly important in more deprived patients with high levels of multimorbidity. Further investigations are required in an Irish context to establish the influence of GP care quality on multimorbidity outcomes for poorer patients.

While having health insurance also increased the likelihood and number of GP visits, the effect of private health insurance was relatively small compared GMS eligibility. Having dual cover (i.e. both GMS and private health insurance) indicated the highest level of use; mainly accounted for by GMS entitlement. Those without any additional cover had the lowest level of GP use compared to any other category. It is likely that this group of patients comprises those who are slightly above the GMS entitlement threshold and as such are on lower incomes and unable to pay for GP care, indicating potential limited access to services among this group of patients who are required to pay for GP services out-of-pocket. This may have important implications for multimorbid patients as previous research found that individuals with multimorbidity were at greatest risk of out-of pocket healthcare costs and were at particular risk of being under-insured in the United States healthcare system (Hoffman et al., 1996, Schoenberg et al., 2007). Further research to uncover the particular service needs of multimorbid patients with no additional cover is required in an Irish context.

The findings of increased propensity and recurrent use of outpatient services for privately insured patients, after controlling for need factors including multimorbidity, self-rated health, frailty and disability, are congruent with findings reported by Layte et al. (2007) and indicates some level of inequity in the provision of outpatient services in Ireland.

Any additional healthcare cover was associated with an increased likelihood of an overnight stay in hospital, however only those with dual coverage had an increased rate of stay compared to those with no additional cover after controlling for all other covariates. It is unclear what is driving this increased likelihood for extended hospital stays for those with dual cover, however it is unlikely related to healthcare need factors as a wide range of need factors were controlled for in multivariate analyses. This finding is again in keeping with previous findings reporting inequitable distribution of hospital services across income groups in Ireland (Layte, 2007).

While GMS coverage was not associated with propensity to visit an Emergency Department, it was associated with an almost doubling of the intensity of use. This may be reflecting the high

healthcare need in this category and other issues facing those with GMS cards for example lengthy waiting lists for specialist care and a poor out-of-hours GP service.

GMS coverage was also associated with a 40% increased odds of polypharmacy after controlling for a wide range need factors and other covariates in multivariate analysis, including number of chronic conditions. This finding is likely explained by a difference in prescribing practices in Ireland between GMS and non-GMS patients, which was previously highlighted by Fadden (2003). Further studies examining patterns of prescribing in different patient groups are required to investigate this in more detail, however, this finding has one major implication for multimorbidity studies. Several studies examining multimorbidity assess chronic condition prevalence based on prescribing data rather than self-reported survey data or administrative data. Studies attempting to measure multimorbidity based on prescription data in Ireland should take cognisance of potential bias introduced by differential prescribing practices between GMS and non-GMS patients.

GMS entitlement in and of itself or with private health insurance was strongly associated with PHN visits and formal care support, even after controlling for need factors, while no effect was found for those with private health insurance only. This may be reflecting increased access to these services for patients with a medical card compared to those without and again, findings may indicate reduced access to healthcare services for those with lower incomes that exceed the GMS threshold, who are required to pay out-of-pocket for care assistance. This may be particularly important for multimorbid patients who are not entitled to a medical card but who have substantial social care need, however this requires further investigation.

Those who were permanently sick or disabled also had a slightly higher likelihood of health service use and intensity of use for GPs and nights in hospital. They also had a slight increased rick of polypharmacy and had slightly higher odds of an outpatient visit and a PHN visit. They were substantially more likely to attend Emergency Departments compared to their employed counterparts (OR 2.7) and to use formal care assistance (2.2). Those living alone had a substantially higher odds of formal care assistance (OR 3.3) and slightly higher odds of polypharmacy and a PHN visit. Higher odds of PHN use was also observed for populations living closest to a GP, reflecting potential inequity in the provision of public health nursing care in Ireland.

Trouble with sleeping was associated with a slightly elevated risk of GP use. The association between smoking status and healthcare use is complex, and may be explained in part by

controlling for need factors in the models. Past smoking status was associated with higher levels of outpatient visits, hospital nights and polypharmacy compared to non-smokers. There was however no effect found for current levels of smoking except that heavy smoking appears to be slightly inversely associated with polypharmacy. Those who drank alcohol 3 to 4 days per week had a slight elevated odds of an outpatient visit compared to those who drink rarely or never drink. Increased alcohol consumption appears to be slightly inversely associated with polypharmacy. Exercise had a slight protective effect on GP use and intensity of use, polypharmacy, PHN visits and formal care support.

5.5.5 Strengths and limitations

A significant strength of this analysis was the large population based sample generalisable to the population aged 50 years and over in Ireland. To date few studies have examined the role of multimorbidity in predicting health and social care outcomes in a large population samples; studies are generally restricted to certain healthcare populations and analysis on one or two healthcare service types. A major strength of this study is the wide range of measures available in TILDA allowed for a comprehensive analysis of multimorbidity across primary, ambulatory and inpatient care as well as for social care outcomes including public health nurse visits and formal care assistance. While there is strong evidence of polypharmacy in older multimorbid patients, this also allowed for examination of the effect of multimorbidity on polypharmacy on community-dwelling individuals in mid-to-later life. This is the first time that the impact of multimorbidity has been assessed across such a variety of healthcare services in a national context. Moreover, the inclusion of valid measures of frailty and disability as well as several other covariates in the TILDA survey enabled a thorough investigation of the independent effect of multimorbidity on outcomes. Population level data on the effects of multimorbidity on healthcare utilisation are particularly useful as they provide generalisable estimates and contribute valuable data to inform healthcare policy and planning. The large sample size of the TILDA study provided a useful source of data on healthcare use generalisable to the Irish population aged 50 years and over. Population based surveys are particularly important in Ireland for measuring healthcare utilisation due to the lack of a unique patient identifier system.

A notable limitation of this study is the examination of healthcare utilisation based on self-reported data. Self-reported healthcare utilisation data may be biased in several ways. Firstly, recall accuracy may be compromised by cognitive impairment, illness or disability. All of which are more likely to affect older population groups in TILDA. Older age has generally been found to

be associated with under-reporting of usage (Bhandari and Wagner, 2006). For adults, age is less important than the respondent's cognitive competency, although both may be correlated. There is a well-documented association between increased utilisation of services and under-reporting (Bhandari and Wagner, 2006). Methodological factors including questionnaire design, mode of data collection and question prompts and aid probes have also been found to influence recall accuracy. Efforts to minimise recall bias were incorporated into the TILDA study design including the use of probes in the questionnaire interview and asking for specific counts of visits and episodes rather than providing categorical response options. Inaccuracy increases with length of recall period, although accuracy was found not to diminish over a one-year period in an urban population in Spain (Bellon et al., 2000). Recall for health service utilisation in the TILDA study was limited to a one-year period. Nonetheless, it should be noted that healthcare utilisation in this study may be under-reported for older individuals and those with cognitive impairment and increased healthcare utilisation which is likely to result in under-reporting in complex multimorbid patients.

More general limitations have been described in Chapter 2 however some further limitations should also be noted. Observed trends on the impact of multimorbidity on healthcare utilisation, measured by counts of conditions, may be masking underlying synergistic effects of certain combinations of conditions. It is also likely that effects of combinations of conditions on healthcare utilisation are subject to severity of individual conditions measured within the cluster. Diagnosis of conditions may not be randomly distributed throughout the population; diagnosis of conditions may be biased towards those already receiving chronic care (Berkson, 1946). Reference groups for those with lower access to care for example, those without additional medical care cover, were included in models to control for this potential bias.

Length of GP visit and physician empathy have previously been established as important influencing factors on the quality of care for multimorbid patients in more deprived areas. It was not possible to control for these factors in this study. Furthermore, it was not possible to measure the burden of unmet need for those living with multimorbidity in Ireland.

Research in the US has pointed out that even among high earners, those who are uninsured have significantly lower use of healthcare services (Ross et al., 2006). However, it was not possible to examine the effect of income on healthcare use in this study due to the lack of available data.

Ethnicity has been found to have an association with healthcare utilisation in the UK (Willis et al., 2013) however, the numbers of non-nationals included in the TILDA study precluded meaningful analysis of ethnicity in this study.

Finally, while *a priori* interaction effects were examined in all models between multimorbidity and other need factors only one interaction effect was found to be significant. While some interacted variables indicated a synergistic effect, these were not significant at α 0.10 and are therefore not reported in the findings. Further studies based on a larger sample size may be able to detect interaction effects that were not evident in these analyses.

5.6 Conclusion

Overall, this picture indicates a substantial burden of care for those with multimorbidity and highlights the role of multimorbidity as a significant driver of healthcare in Ireland, across all healthcare services examined, even after controlling for age effects and other gerontological constructs such as disability and frailty. Findings from this study provide support for the theoretical framework on patient complexity developed by Shanick et al. (2012) discussed in detail in Chapter 1. This necessitates an increased awareness and focus on the impact of multimorbidity on healthcare use in Ireland distinct from other need factors. The effect of accumulating multimorbidity on healthcare utilisation is more than the sum of its parts up to three conditions for GP use and up to at least two conditions for other types of care. Acquisition of additional concurrent conditions at high levels of multimorbidity is also important in predicting outpatient and hospital use. However, the effect is weaker than for other need factors for formal care assistance in the home. Having mental health as a component of multimorbidity was found to be associated with a higher use of social care services, and polypharmacy. GMS entitlement was found to have an important influence on care utilisation, particularly for primary care services and formal care assistance, reflecting some level of equitable care provision in primary care in Ireland. However, it is noteworthy that those who exceed the GMS income threshold, but do not have private health insurance, may have reduced access to care due to inability to pay out-of-pocket for important healthcare services. Those with dual cover have the highest level of use across healthcare services, although this is not reflected in social care services. The implications for policy and practice as a result of the findings of this study are discussed further in Chapter 6.

Chapter 6. General Discussion and Conclusions

6.1 Re-configuring multimorbidity research towards a population health approach

Multimorbidity is associated with many adverse health outcomes, placing a heavy burden on the individual as well as on society in general. It has clear implications for current healthcare provision and with the associated increase in chronic conditions prevalence it presents substantial challenges for future healthcare policy and planning. Evidence of the epidemiology and implications of multimorbidity at a population level, is however, limited. Few studies have examined prevalence and non-random patterning of multimorbidity in nationally representative samples. The factors driving multimorbidity prevalence are poorly understood and appropriate responses have yet to be integrated into population health planning and service delivery. A greater understanding of multimorbidity in nationally representative community-dwelling populations would enable a more informed assessment of the burden it presents and allow for a more comprehensive approach to its prevention and management.

The definition and measurement of co-occurring conditions has, to date, been largely driven by a clinical focus on comorbidity, unsuitable for examination of the health and healthcare burden of the phenomenon from a population perspective. Furthermore, a wide variety of operational definitions have emerged in the literature, mainly as a result of different methodological approaches to studying the phenomenon in the last two decades. Owing to the complexity of these definitions and measurement approaches, a primary objective of this thesis was to develop an approach to the definition and measurement of multimorbidity, suitable for application in population-based studies of the general population, distinct from clinical sub-groups. The term *multimorbidity* is applied in this thesis as an overarching global term referring to *all* conceptualisations of co-occurring conditions within an individual, allowing for a more complete assessment of the burden of multimorbidity at a population level. Operational definitions and constructs have been explicitly defined with the aim of enhancing the precision and generalisability of research findings, enabling improved understanding and comparison of outcomes in future research into multimorbidity in Ireland and across international studies.

Noting the considerable influence that non-conventional conditions may exert on the health status and health and social care utilisation of people in mid-to-later life, a wide range of chronic conditions were considered for inclusion in the multimorbidity measure, adopting a broad nosological approach to multimorbidity and a taxonomy of *chronic conditions* rather than

chronic diseases allowing for the inclusion of gerontological constructs such as falls and incontinence as well as mental health conditions, physical impairments and conventional diseases. The high level of multimorbidity burden found to be associated with impairments and mental health conditions in analyses justifies this approach. Quantifying the burden of multimorbidity using a comprehensive measure of multimorbidity as well as qualifying the relationships between conditions and the overall pattern at a population level is important for the development of policy and healthcare interventions to address the substantial challenge posed by multimorbidity now and in the future.

6.2 Discussion of the principle findings

6.2.1 Multimorbidity prevalence

From a population health perspective this thesis offers a unique insight into the prevalence and patterns of multimorbidity in the community-dwelling Irish population aged 50 years and over. It provides national estimates of the multimorbidity burden in Ireland from the wide range of perspectives presented including the conventionally defined threshold multimorbidity, complex multimorbidity, increasing multimorbidity levels and multimorbidity with and without a mental health component. There was a high multimorbidity prevalence and burden recorded for the community-dwelling population aged 50 years and over in Ireland, and while it is not possible to meaningfully compare prevalence between studies, estimates generally reflected international findings. 53.8% had threshold multimorbidity (≥ 2 conditions), 32.8% had complex multimorbidity (≥ 3 conditions), 7.5% had physical-mental health multimorbidity and 3.3% had mental health multimorbidity. A small but significant proportion of the total population in this age group had six or more conditions (5%). Results demonstrate statistically significant associations between a wide variety of explanatory factors examined and the likelihood of having one chronic condition, increasing multimorbidity levels and different multimorbidity types. Several factors influencing multimorbidity at a population level have been identified in analyses; however effect sizes for increasing levels of multimorbidity after the initial acquisition of a chronic condition were small.

Overall, the findings indicate the need to take account of the difference between factors associated with one condition and those associated with increasing levels of multimorbidity, supporting the theory proposed by Tucker-Seeley et al. (2011) that alternative factors may be

influencing morbidity distinct from multimorbidity. Furthermore, building on international findings of a higher prevalence of physical-mental health multimorbidity in some demographic groupings (Barnett et al., 2012, Andrade et al., 2010, Ajmera et al., 2012) indicate an independent association for several factors including alcohol consumption and trouble sleeping on the relative risk of multimorbidity with a mental health component. Moreover there was an evident distinction between factors independently associated with physical only multimorbidity and physical-mental health multimorbidity in multivariate regression analyses in this thesis. In particular there was a distinct effect of alcohol and trouble sleeping on multimorbidity with a mental health component. This finding supports the need to consider different dimensions of multimorbidity in future investigations.

6.2.2 At-risk population sub-groups

Several at-risk population sub-groups were identified from crude analyses of prevalence rates, further confirmed in multivariate analyses in Chapter 4. In keeping with international evidence, women were found to be particularly vulnerable to multimorbidity, especially in older age groups. Previous studies examining gender differences in self-reported health have shown that women are not simply more likely to report morbidities than men (Macintyre et al., 1999, Malmusi et al., 2011); however they are more likely to attend health services introducing potential bias in condition diagnosis. It is difficult then to ascertain if this finding is reflecting a true gender effect in multimorbidity prevalence. The association between multimorbidity and age appears to be more complex than previously reported in the international literature. Previous studies reported a steep increased risk with rising age (Barnett et al., 2012, Marengoni et al., 2011). Results of this thesis indicate that while the risk of multimorbidity increases with increasing age in general, the patterns are more complex. There appears to be a vulnerable group acquiring multimorbidity in younger old age, this appears to stabilise in mid old age and is again more pronounced in the oldest old. This may be indicating a survival effect in some older people where the average accumulation process for multimorbidity is deferred into late old life. This highlights the need for greater understanding of the complex interactions between ageing, disease susceptibility and the effects of chronic disease management.

Mental health conditions were more prevalent for increasing levels of multimorbidity and multimorbidity with a mental health component was found to concentrate among younger multimorbid individuals, similar to findings reported in Scotland (Barnett et al., 2012). This finding should be interpreted with some caution as research indicates a degree of under-

reporting of depression and other mental health conditions in older people, who are also less likely to recognise their own mental health symptoms (Stek, 2004). Nonetheless, the substantial burden of co-occurring mental and physical conditions is likely impacting negatively on quality of life and other health outcomes for affected individuals and findings from this study indicate the need for intervention in younger age groups. Future multimorbidity research would benefit from incorporating more objective measures of mental health conditions to reduce the potential bias associated with self-reported doctor diagnosis.

In keeping with findings reported by Barnett et al. (2012), women had a disproportionately higher prevalence of multimorbidity with a mental health component; however this was attenuated after controlling for other factors in multivariate analyses. Again supporting findings from the Barnett study, a social gradient was found for all multimorbidity in crude analyses and was more pronounced for multimorbidity with a mental health component. However, this gradient was not confirmed in multivariate analyses, although this may relate to the quality of the indicators of socio-economic status used in this study.

Although permanently sick and disabled individuals account for only a small proportion of the population (approximately 4% in the TILDA sample) they are particularly vulnerable to all types of multimorbidity, increasing multimorbidity burden and show an inordinate burden of multimorbidity with a mental health component. Being unemployed, retired or a homemaker was also significantly associated with multimorbidity with a mental health component again highlighting the need for intervention in these population sub-groups. Contrary to findings in crude analyses in Chapter 3, supported by multivariate analysis by Andrade et al. (2010) in the U.S., there was no significant association found for the effect of being *separated/divorced* on multimorbidity after accounting for other factors. However the small numbers of this group in TILDA may have precluded the detection of a significant effect in multivariate models and this association requires further research.

A small but significant effect for morbidity was found for those living in rural areas; however, there was no effect of household location for increasing levels of multimorbidity, although the opposite was found for the likelihood of having either type of multimorbidity; urban-dwelling was associated with both types of multimorbidity, with and without a mental health component. Previous investigations of healthcare utilisation in Ireland point to the influence of healthcare access and availability as determinants of morbidity and the observed increased relative risk among the urban-dwelling population observed in this thesis may be reflecting a higher degree of access to medical services. Examination of multimorbidity risk according to healthcare

coverage indicates a positive association for any level of extra coverage compared to those with no additional cover reflecting a previously documented increased need among those eligible for medical cards (Nolan et al., 2007), but also likely reflecting increased access to GP care and opportunity for diagnosis. Interestingly, having dual cover (including public cover and private health insurance) was positively associated with multimorbidity with a mental health component, likely also reflecting increased opportunity for diagnosing in this grouping, but also perhaps the higher level of mental health multimorbidity in higher educated groups observed in crude analysis in Chapter 3.

6.2.3 Lifestyle risk factors

The association between lifestyle risk factors and multimorbidity are complex and the low number and diverse methodologies of studies examining the issue precluded meaningful comparison of results between studies. Nonetheless findings largely reflect the broader evidence-base on risk factors for singular conditions and some interesting conclusions can be drawn. Heavy smoking was associated with an increased likelihood of increasing multimorbidity and an almost doubling of the risk of multimorbidity with a mental health component. Former smoking was also associated with an increased risk of multimorbidity compared to never smoking. Although evidence points to the health benefits of giving up smoking for singular conditions the implications for multimorbidity risk has not yet been established. Results for alcohol consumption are complex. A higher risk was detected for non-drinkers and those who drink only rarely and for those who drink very regularly compared to those who reported moderate drinking for increasing levels of multimorbidity. The risk of multimorbidity with a mental health component was substantially higher for those who consumed alcohol on a daily basis, reflecting a general evidence-base on the negative effects of heavy drinking on health related outcomes. Lower levels of exercise and, to a lesser extent, moderate exercise was also associated with higher levels of multimorbidity. The potential health benefits of moderate alcohol consumption for multimorbidity would be an interesting area for further work. Obesity was also associated with multimorbidity and increasing multimorbidity burden. Trouble sleeping and being a worrier were independently associated with all multimorbidity outcomes examined and effects were especially pronounced for multimorbidity with a mental health component. While these effects may be circular, as discussed earlier, the balance of evidence points to the important influence of exercise, sleep patterns and worry on mental and physical health outcomes.

Physical activity has been found to play a particularly important role in maintaining general health and reducing the risk of several chronic conditions and premature mortality (Warburton et al., 2006). Furthermore, the important role of exercise in reducing depression, anxiety and enhancing cognitive functioning and well-being in general is now also well established (Callaghan, 2004). A burgeoning body of literature now also points to the modifiable role of sleep patterns on specific chronic conditions, general wellbeing and mortality risk (Gallicchio and Kalesan, 2009). Specifically, studies show that sleep duration has an effect on mortality risk; short sleepers have an elevated risk of a number of adverse health conditions including CHD and diabetes, conversely long-sleepers have an elevated risk of chronic conditions and mortality. Sleep is a commonly under-recognised public health issue and is become increasingly problematic in developed countries with a trend towards fewer hours of sleep on a nightly basis due in the most part to longer work schedules and a greater allotment of time to leisure activities (Akerstedt and Nilsson, 2003). If findings from this study hold true in further longitudinal studies, the trend towards increasingly unhealthy sleeping patterns may substantially impact on multimorbidity risk in future populations. Worry has also been found to negatively influence a range of health related outcomes independent of other factors (Brosschot et al., 2002, Brosschot et al., 2007, Gerin et al., 2001, Glynn et al., 2002). In particular, studies have shown the effect of worry on prolonging the cognitive representation of stress. Preliminary studies found a mediating role of worry on prolonged activity related to stress and anxiety and identified worry as a co-determinant in cardiovascular risk (Brosschot et al., 2007). In multimorbid patients worry may be exacerbated by increased health concerns and volume and complexity of treatment regimes. In addition, worry and unhealthy sleeping behaviour are inextricably linked (Jansson and Linton, 2006). Unfavourable self-assessed health in childhood was strongly associated with having a chronic condition in later life and had a small effect on increasing multimorbidity levels, as well as a doubling of the risk of both types of multimorbidity, more pronounced again for multimorbidity with a mental health component. This supports the need for a lifecourse approach to multimorbidity prevention as well as intervention to address the mental health effects of having a chronic condition.

6.2.4 Multimorbidity patterns

Knowledge of non-random patterns of multimorbidity at a population level may provide insight into underlying pathophysiological mechanisms thereby allowing for the prediction of subsequent morbidity incidence in an individual and the identification of at-risk groups in society. This is particularly important for the development of targeted interventions for primary

and secondary prevention of multimorbidity. Cluster analysis allowed for the identification of non-random patterning of the 28 conditions examined in this thesis, generalisable to the national Irish population aged 50 years and over. The analysis examined how individual chronic conditions are associated with each other without *a priori* hypothesis and provides insight into where particular condition combinations of interest occur in the overall pattern. Nine associative multimorbidity clusters in the older Irish population were identified. Five robust pairwise combinations reflecting some well-established pathophysiological associations were identified, however, in general clusters varied when they were compared by sex, age group and deprivation status, indicating the need to examine patterns of multimorbidity and tailor healthcare interventions according to socio-demographic characteristics.

It is noteworthy however, that several multimorbidity clusters do not neatly reflect conventional clinical care specialisms. For example, diabetes and cancer are discordant in terms of clinical care programmes although they appear to cluster at a population level, although they may have underlying shared risk factors. Moreover, geriatric syndromes such as falls and incontinence and impairments such as hearing and vision cluster closely with physical health conditions in all demographic groups, not only in older age groups. Discordant clusters identified in the solutions require further analysis to establish mechanisms for their association. These may be as a result of common genetic or lifestyle risk factors, underlying pathophysiological mechanism or discordant treatment regimes. These findings have two important implications. Firstly, classification of conditions used in multimorbidity measurement according to disease systems may be overlooking important patterns in multimorbidity. Secondly, this finding challenges the current organisation of clinical care; healthcare in many developed countries is organised according to well-established organ system specialisms. This model of organisation is likely overlooking important patterns of concurrent chronic conditions in the general population and may be resulting in adverse outcomes and poor care quality not only for individuals with higher levels of multimorbidity but also for those presenting to the health services with discordant patterns of multimorbidity. Furthermore, healthcare for older people organised around chronic physical diseases is likely ignoring the burden of geriatric syndromes, sensory impairments and mental health on clinical outcomes in treatment programmes.

While the patterning of mental health conditions is found to be independent in cluster analyses, this is likely to be due to the strong association between mental health conditions. Nonetheless the high prevalence of physical-mental health multimorbidity observed in other analyses underscores the importance of consideration of both mental health and physical health in

healthcare provision. Concurrent depression and chronic physical conditions have been shown to impact negatively on healthcare management (Katon, 2011) and specialist healthcare systems continue to treat physical and mental health as discordant conditions to the detriment of patient's quality of care (Ajmera et al., 2012).

6.2.5 Healthcare utilisation

There appears to be a marked transition from being a 'well' individual to being a 'sick' individual with the acquisition of a first chronic condition, however what being a 'multimorbid' patient entails is a complex question and requires further examination. Overall, acquisition of a first chronic condition has an impact on healthcare utilisation, however for each additional chronic condition acquired there is an incremental increase on the risk of numbers of GP visits, outpatient visits and propensity to have a hospital overnight stay, although no effect was detected for number of nights spent in hospital. Building on previous findings by Glynn et al. (2011) for healthcare use in Ireland, multimorbidity was found to act independently of age, sex and socio-economic status in this study but also a wide range of other covariates including lifestyle risk factors and access to services. This study also provides support for the theoretical framework on patient complexity developed by Shanick et al. (2012) discussed in detail in Chapter 1; multimorbidity was found to act independently from other need factors, including disability and frailty, in predicting healthcare utilisation. Furthermore it also had an independent effect from self-rated health status. This necessitates an increased awareness and focus on the impact of multimorbidity on healthcare use in Ireland distinct from other need factors.

Results for the impact of multimorbidity on healthcare use are similar to those found internationally (Lehnert et al., 2011). Healthcare use increased significantly with each additional condition and reflecting findings from other studies controlling for predisposing and enabling factors, multimorbidity had a far stronger impact on outcomes compared to any other factor. This thesis offers a further qualification of the important influence of multimorbidity on healthcare use even after controlling for other need factors not accounted for in other research. Multimorbidity and also reflect findings on the impact of increasing multimorbidity on healthcare costs; although Hodek et al. (2011) conclude that consistent results cannot be deduced from existing studies for greater than three levels of multimorbidity. It appears that the effect of accumulating multimorbidity on healthcare utilisation is more than the sum of its parts up to three conditions for GP use and up to at least two conditions for other types of healthcare. It is more difficult to deduce a clear pattern for increasing numbers of concurrent conditions

after this, although it appears that acquisition of additional concurrent conditions at high levels of multimorbidity may also be important in predicting outpatient and hospital use. These findings also indicate that multimorbidity independently predicts PHN visits and formal social care in Ireland. The effect is however weaker than for other need factors for formal care assistance in the home, reflecting the more prominent social care needs of some community-dwelling individuals. The different dimensions of multimorbidity, i.e. individuals with or without a mental health condition as an aspect of their multimorbidity also appear to lead to differential use of social care services, and a higher risk of polypharmacy; only slight differences were detected for healthcare utilisation. Nonetheless, the presence of multiple chronic conditions is often compounded with psychosocial challenges and inequity in healthcare, which in turn increases the complexity of responding to patients with multimorbidity.

Overall, this picture indicates a substantial burden of care for those with multimorbidity and highlights the role of multimorbidity as a significant driver of healthcare in Ireland, across all healthcare services examined, even after controlling for age effects and other gerontological constructs such as disability and frailty. Previous research indicates that the impact of individual conditions on healthcare outcomes is driven by the overall prevalence of conditions at a population level rather than the per-capita effect of conditions. While it was beyond the scope of this research to examine this in an Irish context, this has important implications for monitoring and evaluating multimorbidity burden at a population level in Ireland. Although it has been gaining increased attention in recent years, the impact of multimorbidity on healthcare utilisation is under-researched and much remains to be done to establish an evidence-base on the burden of multimorbidity at a population level sufficient to capture the attention of policy makers.

Moreover, while evidence is available from international studies investigating unmet care need for multimorbid patients (O'Brien et al., 2011, Mercer et al., 2007, Mercer et al., 2012), this requires further investigation in an Irish context. Findings from this study indicate that those with increased healthcare coverage have the highest level of service use although the pattern of use varies between services and primary care services appear to be more equitable compared to hospital services. However, those with no additional medical care coverage have been shown to have the lowest use of healthcare services, which may be reflecting inadequate care access in those above the GMS entitlement threshold but who are unable to afford private health insurance. This may have important implications for multimorbid patients without any additional healthcare coverage. While this study provided some useful insights into the level of

healthcare utilisation in Ireland, it was beyond the scope of this study to examine quality of care provision for multimorbid patients in Ireland. One previous study from a GP and pharmacist perspective conducted in Dublin (Smith et al., 2010), highlighted several issues of potential concern for multimorbid patients in Ireland including low levels of awareness of multimorbidity care needs among practitioners. It is recommended that future studies are required to fully untangle the particular experiences of multimorbid patients in the Irish health care context.

6.3 Implications for Policy and Practice

6.3.1 Adopting a population health approach to multimorbidity

Improved data on condition patterns in community-dwelling populations allows for a more comprehensive examination of multimorbidity from a population health perspective. The demographic shift towards population ageing and more effective treatment of conditions has resulted in a higher proportion of community-dwelling populations living with multiple chronic conditions. The high level of multimorbidity evidenced in the community-dwelling population aged 50 years and over in this study highlights that the burden of multimorbidity is no longer limited to older clinical sub-populations. It therefore requires a substantial population health response to manage the burden this presents for individuals and society in general. Adopting a population health approach to multimorbidity would allow for the development of primary and secondary prevention strategies with particular attention paid to at-risk population sub-groups. Furthermore, the identified burden of physical-mental health multimorbidity present in the community-dwelling population in Ireland necessitates a parity approach to addressing multimorbidity in population health.

6.3.1.1 A focus on at-risk population subgroups

Several at-risk population sub-groups were identified in analyses. Women had a substantially higher burden of multimorbidity in this study warranting investigation into the factors driving this increased prevalence. This may be as a result of a survivor effect, namely the reduced life expectancy in men compared to women in Ireland. Men appear to be dying earlier of more fatal conditions while women appear to be living longer with increased multimorbidity. Future longitudinal investigations may shed some light on the sex differences of multimorbidity and the patterns of conditions driving mortality in an Irish context. Nevertheless the observed higher

burden of multimorbidity in women requires particular attention in population health interventions. The substantially higher prevalence of multimorbidity for those who are permanently sick or disabled also warrants particular attention. Designing effective prevention and intervention strategies for this group is important as the complex health needs of this group occur in mid-life and are likely to be long lasting requiring significant healthcare investment.

While age is associated with multimorbidity, the particular effect of aging was not clear on the risk of increasing levels of multimorbidity in this thesis. Nonetheless, a higher prevalence of multimorbidity has been found in this study and internationally for older age groups. Findings in this study then support the need to address multimorbidity in younger age groups as well as in older community-dwelling individuals identified in other studies (Taylor et al., 2010, Barnett et al., 2012, Mercer et al., 2009). Crude prevalence rates indicate a higher burden of multimorbidity in those from poorer socio-economic backgrounds in Ireland similar to findings in Scotland (Barnett et al., 2012), although this was not supported in multivariate analyses; this may be due to the limited nature of the indicators used and the adjustment of models for risk factors which are known to be more concentrated in more deprived individuals rather than a true null effect. The balance of evidence does support the need for a focused primary and secondary prevention approach to multimorbidity in more deprived populations.

6.3.1.2 Primary, secondary and tertiary prevention of multimorbidity

In general this study shows a need for improved lifestyles to maintain health throughout mid-to-later life. The healthier one is entering later years, the less likely one will be to require health services. The important role of secondary prevention programmes in alleviating the burden of increasing multimorbidity on individuals and on health systems has been highlighted previously (Starfield and Shi, 2005). Primary and secondary prevention strategies are documented as a core component of the Irish Chronic Illness Framework (Health Servce Executive, July 2008), with the primary aim of preventing chronic illness where possible and minimising and managing the impact of chronic illness on individuals and the population.

Although findings in this thesis suggest that lifestyle risk factors for multimorbidity are similar to the well-documented factors associated with singular chronic conditions and interventions to address these factors in the population are also likely to entail a reduction in multimorbidity prevalence, there is no evidence-base on effective strategies to prevent the incidence of multimorbidity or to reduce further incidence in morbid individuals (Smith et al., 2009). Findings

in this study highlight the important influence of tobacco, alcohol, physical activity and obesity related policies and interventions for physical multimorbidity as well as for multimorbidity with a mental health component, and further research is required to investigate the particular effects of addressing these factors for multimorbidity outcomes.

In particular, interventions to improve physical activity in healthy and more morbid individuals may prove beneficial in reducing the risk of all types of multimorbidity. Evidence supports improved outcomes associated with increased physical activity in healthy individuals (Callaghan, 2004) and in those with mental health problems (Petruzzello et al., 1991). However considerable uncertainty remains for the effectiveness of exercise referral schemes for increasing physical activity and improving health indicators in individuals with chronic conditions (Pavey, 2011). If, as findings in this thesis indicate, lower levels of exercise predict not only morbidity, but increased multimorbidity levels in an individual, effective interventions to improve physical activity in unhealthy individuals may be important for secondary prevention of all types of multimorbidity including increasingly complex multimorbidity.

The role of sleep disorders on health is particularly under-researched and findings in this thesis underscore the potentially important influence of trouble sleeping on multimorbidity outcomes. The Institute of Ageing in the United States recently highlighted the need for increased awareness and improved diagnosis and treatment of sleep disorders and improved public health approaches to monitoring and surveillance of sleep disorders (Medicine, 2006). A similar approach in an Irish context could improve the negative impact of unhealthy sleep on multimorbid individuals and increased data on sleep patterns could provide a further contribution to our understanding of the factors associated with multimorbidity burden.

Cognitive Behavioural Therapy is showing some promising outcomes in the treatment of pathological worry in patients with generalised anxiety disorder (Covin R, 2008), while mindfulness-based stress reduction therapy has been found to show small effects on several aspects of mental health of adults with chronic conditions (Bohlmeijer et al., 2010). Such interventions may have important effects on the development and management of multimorbidity in later life. Improved physical activity may also have an important role in moderating the effect of worry in later life (Petruzzello et al., 1991, Penedo and Dahn, 2005) and would likely lead to reduced incidence and improved outcomes for multimorbid patients especially for those with co-occurring physical and mental health conditions.

It is now well recognised that secondary prevention can improve longevity, enhance quality of life, and reduce medical expenses nonetheless, previous research indicates that people rarely make positive changes in lifestyle behaviours after they have been diagnosed with a chronic condition (Newsom et al., 2012). Furthermore the likelihood of improved health behaviours varies according to specific conditions considered. Research into secondary prevention of multimorbidity is in its infancy and a recent review of interventions found studies were mainly limited to older populations and care provision (Smith et al., 2009). Overall findings indicate that interventions focusing on particular risk factors or functional difficulties in multimorbid patients may be more effective. Further research into effective secondary prevention interventions is required to reduce the burden and negative effects of multimorbidity in an Irish context and achieve the aims of the Chronic Illness Framework.

Tertiary prevention of multimorbidity necessitates an improved focus on medical care for chronically ill patients. To date, however, there is limited evidence on tertiary prevention for chronic conditions in general and the evidence-base is particularly in the context of multimorbidity. Nonetheless, Emmanuel (2012) identifies some potentially effective tertiary approaches such as systematic use of electronic health records and reduced use of specialists and provision of non-conventional care services including email and wireless monitoring of medication use that would likely minimise adverse events in chronically ill patients and reduce healthcare spending through fewer hospitalisations, Emergency Department visits, and lower use of specialist services. These interventions might also prove beneficial for multimorbid patients. Persons with multimorbidity require a longitudinal approach to healthcare, involving multi-disciplinary input across a range of services. While certain aspects of chronic care management are working well in Ireland, the absence of effective clinical information systems in the Irish healthcare system has been identified as a key challenge in caring for patients with chronic disease (Darker et al., 2011). Despite acknowledgement of the importance of such systems in delivering integrated care to respond to the growing burden of chronic illness in national policy documents (Health Servce Executive, July 2008, Department of Health, 2004) they remain underdeveloped. In particular, it could be expected that widespread adoption of electronic health records (EHRs) would facilitate sharing of clinical information across multi-disciplinary boundaries of community and acute healthcare settings and while a large proportion of GP's in Ireland use EHRs (Mc Hugh et al., 2009) this is not reflected in the acute sector.

6.3.1.3 Parity in population health

There is a strong bi-directional association between mental and physical health. Poor mental health is associated with a greater risk of physical health problems, and poor physical health is associated with a greater risk of mental health problems (National Institute for Health and Clinical Excellence, 2010). Recent publications in the U.K. (Royal College of Psychiatrists, 2010, Royal College of Psychiatrists in Scotland, March 2013) and enacted legislation in the U.S. in 2008 (Mental Health Parity and Addiction Equity Act) points to the need to address the parity of mental and physical health within a population health framework. The Academy of Medical Royal Colleges (February 2013) have recently advocated for a 'whole person' approach to public health strategies in the UK, highlighting opportunities for working across health and social care in order to consider the wider determinants of mental wellbeing. Planning for parity means a move away from mental health/physical health silos; with equal priority afforded to mental health as well as physical health. This is particularly important for multimorbid individuals as evidenced by the significant burden of physical-mental health multimorbidity in the community-dwelling population found in this study. Future public health policy, strategy and practice in Ireland must ensure that mental health and wellbeing are integral with physical health to reduce the burden of physical-mental health multimorbidity in Irish society.

The particular experience of multimorbidity with a mental health component was more pronounced in younger age groups and more socio-economically deprived persons as well as those who were permanently sick or disabled, unemployed, retired or homemakers. This highlights a distinct role for population health strategy to address the co-occurrence of mental and physical health conditions in these population sub-groups. Furthermore, higher multimorbidity burden was associated with an increased risk of a mental health component underscoring the need for secondary intervention to alleviate the mental health effects of increasing multimorbidity.

6.3.2 Reorienting the Irish healthcare system to care for multimorbid patients

Using population level data, this thesis found a significant independent effect of multimorbidity on a range of healthcare outcomes in the Irish population aged 50 years and over. Moreover, it also found that use of health care services was mainly driven by multimorbidity, even after controlling for other need factors generally associated with poor health status in later life, including disability, poor self-rated health and frailty. This affirms the need to plan for

multimorbidity in healthcare policy and to address the substantial heterogeneity of patients attending healthcare services in Ireland.

Like many other countries, Ireland is faced with the question of how best to organise and deliver healthcare services in the context of new and emerging challenges such as population ageing and increasing chronicity in a difficult economic environment. Allocating scarce resources efficiently and working towards a healthier society is a challenging task at any time, but most especially in times of economic austerity. Nonetheless, the balance of evidence points to the high use of healthcare services by multimorbid patients in Ireland and the substantial economic costs associated with it in the Irish healthcare system (Glynn et al., 2011). Given the significant burden on healthcare, independent of other need factors, found in this thesis and the impact of increasing levels of multimorbidity on quality of care indicators including Emergency Department use and polypharmacy, maintaining the current system of care will fall substantially short of the healthcare needs of the population. Furthermore, the potential savings attached to providing appropriate care for a population who are generally characterised by multimorbidity rather than silos of conditions makes economic sense (Emanuel, 2012).

It is likely that the projected increase in multimorbidity as a result of population ageing in the years ahead will present an ever increasing challenge to Ireland's healthcare system. The current approach to chronic care management, rooted in a single disease framework is ill-equipped to address the likely burden of multimorbidity in years to come, not least at times of healthcare resource rationing. The adoption of healthcare management models more appropriately reflecting population healthcare needs would reduce the impact of this potential burden. Poor population level data on the prevalence of multimorbidity has precluded examination of the population burden of multimorbidity and its relevance to healthcare in an Irish context. Poor acknowledgement of the role of multimorbidity in patient complexity and its direct and indirect association with health and social care utilisation is however impeding the development of a comprehensive policy approach to address chronic conditions at a health system level in Ireland. The strong independent effect of multimorbidity on healthcare utilisation, as well as the strong associations between multimorbidity and proxy indicators for quality of care found in this thesis, reflects the growing consensus on the need to reorient care systems towards more person centred care appropriate to multimorbid individuals (Guthrie, 2011, Boyd et al., 2007a).

Starfield, Shi et al. (2005) highlight that a strong primary care service is associated with a more equitable distribution of health in populations, in contrast to speciality care dominated systems. People who have greater access to primary care services and who report better quality of

primary care report better health outcomes and are generally healthier overall, compared with those who don't (Starfleld et al., 2005). However, findings in this thesis suggest unequal access to primary healthcare in the current healthcare system in Ireland and primary care remains under-developed in Ireland despite commitments from Government to strengthen it *(Government of Ireland, 2011)*. From a clinical perspective, effective management of patients requires careful consideration of the myriad of factors driving complexity in patients. The current acute sector dominated healthcare system in Ireland, organised according to silos of chronic condition specialisms, is ill-equipped to manage the documented complexity associated with multimorbid individuals in this thesis. This organisational approach to healthcare in Ireland is likely contributing to more fragmented care for multimorbid patients. Increased fragmentation of care involving multiple clinicians between primary care and secondary care may lead to inappropriate prescribing and an increased risk of adverse effects in multimorbid patients (Stange, 2009, Townsend et al., 2003, Smith et al., 2010). The high levels of polypharmacy in multimorbid patients observed in this study may be an indicator of poor quality of care for multimorbid patients in the Irish healthcare system.

The finding that healthcare increases with need as distinct from age challenges the dominant political discourse summarised by Walker (2012) as the assumption that older people are a '*homogeneous mass of financially secure, but unhealthy citizens, who are the only generations to use health and social care services*'. Furthermore it challenges the current organisation of healthcare in Ireland on the basis of age rather than need. A generalist approach to condition management reduces the likelihood of overlooking discordant conditions and is likely to lead to improved patient management in general. In essence however, the HSE in Ireland has yet to recognise the value of the more generalist health care approach for multimorbid patients espoused in international research (Boyd et al., 2005, Salisbury, 2012, Guthrie, 2011). Although limited to date, recent policy developments under the HSE Chronic Care Programme indicate a move towards more generalist care in Ireland. However, this generalist care is provided exclusively to those aged 65 years and over. Care for adults under 65 years will be organised into sixteen Chronic Care Programmes based on the most prevalent chronic condition silo's with little account for the substantial challenges posed by multimorbidity. This thesis however points to a significant burden of multimorbidity in younger patients requiring health care management. The growing evidence of multimorbidity in younger patients is of significant concern. There is a clear need to develop models of care appropriate to multimorbid patients across mid-to-late life.

It is now an opportune time in Ireland, to reorient healthcare towards the health needs of the population. Recent policy moves to establish a stronger primary care system in Ireland offers potential to deliver a healthcare system that is both proactive in identifying those at risk of multimorbidity and responsive to those who are already affected. However, meeting the healthcare needs of Ireland's population is increasingly challenged in the absence of universal healthcare and a dominant specialist acute sector. Espoused developments of primary care services outlined in the Programme for Government and the Strategic Framework for Reform of the Health Service 2012 – 2015 (Department of Health, November 2012) have not yet been delivered and reorienting care towards appropriate models for multimorbid patients will require significant political will.

6.5 Recommendations for future research

Areas for future research have been highlighted throughout the discussion however some particularly relevant areas for future research are also described here in order to highlight priority areas for attention in future studies. First and foremost there is limited longitudinal data allowing for the examination of multimorbidity incidence and outcomes at a population level. The exploratory nature of this thesis allowed for the generation of a baseline to develop future multimorbidity investigations in an Irish context. However it should be noted that while this thesis offers a refinement in the approach to multimorbidity measurement in community-dwelling populations using survey data it was limited by the lack of appropriate indicators of condition severity and objective measures of health status. Furthermore, examination of condition clusters at a population level requires substantially larger datasets in order to qualify determinants of clusters and clustering effects. Large-scale longitudinal studies designed with a multimorbidity focus would provide useful insights into the patterns and factors associated with multimorbidity highlighted in this thesis.

Factors associated with increasing levels of multimorbidity were not well elucidated in the estimated model in Chapter 4. It is likely that other factors in the development of multimorbidity have not been accounted for in the modelling process such as the impact of having one condition on likelihood of developing further conditions. Future research should focus on additional factors that may be promote multimorbidity such as prescribing cascades and potential biological risk factors. In addition, further longitudinal analyses are required to unearth the particular effect of ageing on multimorbidity risk. If as suggested in this thesis,

multimorbidity susceptibility expresses itself at an earlier stage in a vulnerable sub-set of the population and it is deferred in some more resilient individuals, future research may be able to discern the factors driving this difference. It should also be noted that estimates in this thesis are limited by the particular effect of survival bias inherent in cross-sectional data analyses. Examination of multimorbidity from a longitudinal perspective would allow for the investigation of mortality risk in multimorbid individuals and a more objective evaluation of burden in survivors.

It is likely that certain combinations of conditions may be contributing a synergistic effect on multimorbidity related outcomes and health care use. Condition clusters may be anchored within different disease specialisms or gerontological constructs, treated within different clinical care pathways. Previous authors highlighted the need to integrate multimorbidity into care planning at a structural level and examine the utility of combinations of conditions for predicting clinical care utilisation and outcomes (Valderas et al., 2007, Marengoni and Fratiglioni, 2011). A logical follow on from this study would be an examination of healthcare use according to prevalent clusters and potentially synergistic combinations of conditions at a population level. Of particular interest is the impact of discordant combinations of conditions on health and social care use and quality of care for multimorbid individuals treated within a chronic care management system organised around disease specialism silos.

One limitation of hierarchical cluster analysis is its inability to assign conditions to more than one cluster. Evidently, some conditions may be expected to be part of more than one pattern and conditions in one cluster may have important associations with conditions in another cluster (Cornell et al., 2007, Garcia-Olmos et al., 2012). Garcia-Olmos et al. (2012) employed correspondence analysis; an exploratory, multivariate technique that converts a data matrix into a scatter plot, to depict relationships between conditions in overlapping categories. This allows for a more comprehensive assessment of multimorbidity patterning at a population level and its potential for use should be explored in further research. However, this study aimed to investigate the overall pattern of conditions in the general older population in Ireland and in socio-demographic subgroups to establish associative multimorbidity in the older Irish population. This broad approach to multimorbidity patterning is useful to identify unknown pathophysiological associations and guide population health measures and clinical care for an ageing population.

While this thesis provides some evidence of the impact of component elements of complexity on health and social care utilisation, further research is required to investigate how complexity

manifests in multimorbid patients and appropriate responses to manage complexity in multimorbid patients.

Further research is required to gain a more comprehensive understanding of the risk factors for multimorbidity and the factors associated with particular clusters of multimorbidity in an Irish context and internationally. The direction of the effects of the health behaviours observed to be associated with multimorbidity should be more clearly elucidated in future research, in particular longitudinal research into the influence of physical activity levels, poor sleeping patterns and worry may confirm the importance of maintaining healthy behaviours to avoid multimorbidity risk. Other factors that were not included in analyses in this thesis such as self-efficacy and resiliency should also be explored in the context of their potential influence on multimorbidity and related outcomes.

Furthermore, risk factors were included in analyses in this thesis as separate factors potentially influencing multimorbidity risk however, the multimorbidity implications of risk factor clusters have not yet been explored. Risk factors occur in individuals and populations in different combinations and these combinations may show additive or multiplicative effects on health outcomes (Lawder et al., 2010). In particular, clusters of negative health behaviours are more prevalent in women and in more socially disadvantaged groups (Lawder et al., 2010, Poortinga, 2007, Stringhini et al., 2010). One previous study identified similar patterns of risk factor clustering in the Irish population with unhealthy patterns more pronounced in individuals with poor mental health (Conry et al., 2011). Clustering of unhealthy behaviours may then have a more pronounced effect on multimorbidity risk and may explain in part the increased burden observed in certain sub-groups of the Irish population identified in this study. While it was beyond the scope of this thesis, further research to examine the role of risk factor clusters on multimorbidity in an Irish context could add substantial value to the evidence-base and aid in the development of interventions to reduce multimorbidity burden in later life. The inter-connected nature of mental health and behaviour patterns requires particular attention in elucidating the impact of risk factors on multimorbidity with a mental health component.

While effects were detected at the bivariate level, indicators of socio-economic status did not perform well in the multivariate models, after controlling for other covariates. Improved quality of income and asset data in future waves of TILDA would allow for more detailed examination of the question of socio-economic inequalities related to multimorbidity and other health related outcomes. Given the availability of data in TILDA on early life disadvantage and parental socio-economic status it would be possible to extend analysis to examine cumulative disadvantage

over the lifecourse.

The low numbers of certain demographic groups in TILDA precluded meaningful analyses of potential high-risk sub-groups. As there was a low number of 'other nationalities' represented within the data, it was not possible to meaningfully consider multimorbidity in immigrant groups although prevalence in this category indicated a lower prevalence of multimorbidity in general. Although data was not available in TILDA, consideration of multimorbidity in the Travelling community would be an interesting question for further studies as members of the Travelling community have considerably reduced life-expectancy in Ireland compared to the settled population. Further studies should focus on the prevalence of multimorbidity in separated and divorced individuals as they have been found to have a high level of multimorbidity in crude analyses although this was not supported in multivariate analysis in this thesis, contrary to findings in a large Australian study. The low numbers of self-employed in TILDA did not allow for meaningful analysis of the apparent protective effect of self-employment on multimorbidity, particularly with a mental health component observed in crude analyses and this should be explored in future research.

Finally, the methodological approach developed in this thesis based on data comparable to other nationally representative longitudinal studies on ageing, such as ELSA in the UK and the HRS in the U.S., presents an opportunity to develop meaningful international comparisons of multimorbidity prevalence and related outcomes based on similar measurement approaches in large-scale ageing cohort studies which has been limited to date.

6.6 Concluding Remarks

Overall, this picture indicates a substantial burden of multimorbidity in the Irish population aged 50 years and over and highlights the role of multimorbidity as a significant driver of healthcare in Ireland, across all healthcare services examined, even after controlling for age effects and other gerontological constructs such as disability and frailty, although the effect of multimorbidity was less pronounced for formal social care utilisation. Several factors influencing multimorbidity at a population level have been identified in analyses; however effect sizes for increasing levels of multimorbidity after the initial acquisition of a chronic condition were small. There was a clear distinction between factors associated with multimorbidity with and without a mental health component. Given the inextricable link between physical and mental health conditions observed

in this thesis and its corresponding impact on subsequent health and social care use, there is a need to adopt a parity approach in population health and healthcare policy in Ireland.

Further research is required to gain a more comprehensive understanding of the risk factors for increasing levels of multimorbidity and the factors associated with particular clusters of multimorbidity in an Irish context and internationally. As population health and healthcare systems evolve to address demographic changes, existing vertical approaches to chronic disease prevention and management will need to reorient towards primary, secondary and tertiary prevention of multimorbidity and improvements in the management of complex patients with several co-existing conditions. Population based studies of multimorbidity are particularly useful as they provide generalisable estimates and contribute valuable data to inform population health and healthcare policy and planning. Current healthcare policy and organisation fall considerable short of meeting the healthcare need of the significant proportion of the Irish population with multimorbidity. Moves towards a strengthened primary care sector will likely lead to some improvements, however a concerted effort is required to reorient the current healthcare system away from specialism silos towards a generalist managed care approach to cater for the significant needs of multimorbid patients in Ireland.

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Appendices

Appendix 3.1 Variables for all chronic conditions in TILDA considered in multimorbidity measure.

TILDA Questions		**All Chronic Condition Variables**				**Chronic Condition Variables Considered for the Multimorbidity Prevalence Measure**			
Question	Further question specifications	Conditions	Frequency = yes (missing)	Variable codes	Population prevalence (weighted % CI)	Conditions	Variable codes	Prevalence n	Weighted prevalence (95% CI)
PHYSICAL CONDITIONS									
TILDA (PH201) We are interested in finding out more information about heart problems people may suffer from: Has a doctor ever told you that you have any of the following conditions? (yes/no)		Angina	447 (0)	Ang	5.74 (5.19-6.29)	Angina or heart attack	HAang = V1	671	8.61 (7.95-9.27)
		A heart attack (including myocardial infarction or coronary thrombosis)	377 (0)	HA	4.78 (4.28-5.28)				
		Congestive heart failure	87 (0)	HF	1.06 (0.82-1.29)	Congestive heart failure	HF = v2	87	1.06 (0.82-1.29)
		A stroke (cerebrovascular disease)	133 (0)	ST	1.65 (1.36-1.95)	Stroke or TIA	STIA = v3	291	3.60 (3.16-4.04)
		A mini stroke or TIA	174 (0)	TIA	2.14 (1.79-2.48)				
		A heart murmur	387 (0)	HM	4.54 (4.07-5.01)	A heart murmur	HM = v4	388	4.54 (4.07-5.01)
		An abnormal heart rhythm	586 (0)	HR	7.01 (6.41-7.59)	An abnormal heart rhythm	HR = v5	588	7.01 (6.41-7.59)
		Diabetes	632 (0)	Diab	8.12 (7.47-8.75)	Diabetes	Diab = v6	634	8.12 (7.47-8.75)

	TILDA (PH202) Has condition and currently taking medication:	High blood pressure or hypertension	2585 (0)	HBP	32.45 (31.36-33.56)	High blood pressure	HBp= v7	2591	32.45 (31.36-33.56)
	TILDA (PH225) Has condition and currently taking medication:	High cholesterol	2030 (0)	Chol	24.73 (23.73-25.73)	High cholesterol	Chol = v8	2032	24.73 (23.73-25.73)
TILDA (PH401) How many times have you fallen in the past year?	TILDA (PH404) Two or more times	Recurrent Falls	586 (2)	Fall	7.44 (6.82-8.07)	Falls or fractures	FF = v9	1416	17.76 (16.86-18.66)
TILDA (PH414) Have you ever fractured your hip or wrist?	Yes to either	Fractures	1125 (0)	Frac	14.33 (13.50-15.16)				
TILDA (PH601) During the past 12 months have you lost any amount of urine beyond your control?	TILDA (PH602) More than once in a month	Incontinence	764 (24)	Incon	9.29 (8.64-10.00)	Incontinence	Incon = v10	765	9.29 (8.64-10.00)
TILDA (PH102) Is your eyesight?	Poor or registered or legally blind	Vision impairment	146 (0)	Vis	2.10 (1.78-2.51)	Vision impairment	Vis = v11	147	2.10 (1.78-2.51)

TILDA (PH108) Is your hearing?	Poor	Hearing impairment	193 (0)	Hear	2.70 (2.37-3.19)	Hearing impairment	Hear = v12	194	2.70 (2.37-3.19)
TILDA (PH301) Has a doctor ever told you that you have any of the following conditions? (yes/no)		Chronic lung disease such as chronic bronchitis or emphysema	329 (0)	LD	4.24 (3.77-4.71)	Chronic respiratory condition	CRC = v13	988	12.31 (11.55-13.08)
		Asthma	750 (0)	Ast	9.29 (8.62-9.96)				
	TILDA (PH304) What type of arthritis (including osteoarthritis or rheumatism) do you have?	Osteoarthritis	1041 (0)	Oart	12.20 (11.45-12.96)	Arthritis	ART = v14	2255	27.78 (26.73-28.83)
		Rheumatoid arthritis	682 (0)	Rart	8.76 (8.09-9.43)				
		Unclassified arthritis	562 (0)	OTart	7.23 (6.61-7.85)				
		Osteoporosis	786 (0)	Ostp	9.36 (8.68-10.05)	Osteoporosis	Ostp = v15	786	9.36 (8.68-10.05)
		Cancer or a malignant tumour (including leukaemia or lymphoma but	512 (0)	Can	6.21 (5.65-6.76)	Cancer	Can = v16	512	6.21 (5.65-6.76)
		Parkinson's disease	43 (0)	Park	0.52 (0.36-0.70)	Parkinson's disease	Park = v17	43	0.52 (0.36-0.70)
		Stomach ulcers	571 (0)	STUL	7.27 (6.65-7.88)	Stomach ulcers	STUL = v18	572	7.27 (6.65-7.88)
		Varicose ulcers	271	VUL	3.42 (2.99-3.85)	Varicose ulcers	VUL = v19	271	3.42 (2.99-3.85)
		Cirrhosis, or serious liver damage	46 (0)	Liv	0.56 (0.39 – 0.73)	Liver disease	Liv = v20	46	0.56 (0.39 – 0.73)

MENTAL								
	Alzheimer's disease	8 (0)	Alz	0.09 (0.02-0.16)	Memory disorder	Mem = v21	51	0.64 (0.46-0.83)
	Dementia	8 (0)	Dem	0.11 (0.03-0.20)				
	Serious memory impairment	39 (0)	MemIMP	0.49 (0.33-0.65)				
	Alcohol or substance abuse	131	Abuse	1.76 (1.44-2.07)	Alcohol or substance abuse	Abuse = v22	131	1.76 (1.44-2.07)
	Any emotional, nervous or psychiatric problems, such as anxiety or depression	693 (0)		8.35 (7.72-8.98)				
TILDA (PH316) What type of emotional, nervous or psychiatric problems do/did you have?	Anxiety	388	Anx	4.66 (4.18-5.14)	Anxiety	Anx = v23	388	4.65 (4.18-5.14)
	Depression	437	Dep	5.24 (4.74-5.75)	Depression	Dep = v24	437	5.24 (4.74-5.75)
	Emotional problems	93	Omen	1.23 (0.97-1.49)	Other mental health conditions	OMen = v25	192	2.43 (2.07-2.78)
	Mood swings	89		1.11 (0.87- 1.35)				
	Manic depression	32		0.37 (0.24-0.51)				
	Hallucinations	10		0.12 (0.04-0.20)				
	Schizophrenia	9		0.11 (0.03-0.18)				
	Psychosis	8		0.10 (0.02-0.17)				
	Something else	21		0.25 (0.14-0.37)				

Appendix 3.2 Selection of studies including specific chronic condition in multimorbidity measurement

Chronic conditions in TILDA	Studies including specific chronic condition in multimorbidity measurement
Angina/Heart attack	Bayliss et al., Byles et al., Crabtree et al., Fan et al. , Glattacker et al., Greenfield et al., Groll et al., Incalzi et al., Kaplan and Feinstein, McGee et al., Newmann et al., Rozzini et al., Sangha et al., Shwartz et al., Tooth et al., Von Korff et al.
Arthritis	Bayliss et al., Byles et al., Crabtree et al., Fan et al., Groll et al., Newmann et al., Shwartz et al., Sangha et al., Tooth et al., von Korff et al.
Asthma	Bayliss et al., Crabtree et al., George et al., Groll et al., Shwartz et al., Tooth et al., Von Korff et al.
Cancer	Bayliss et al.(in last 5 years), Byles et al., Fan et al., Glattacker et al., Groll et al., Sangha et al., Tooth et al., Von Korff et al.
Diabetes	Bayliss et al., Byles et al., Charlson et al., Crabtree et al., Fan et al., George et al., Glattacker et al. , Glattacker et al., Greenfield et al., Groll et al., Incalzi et al., Newmann et al., Sangha et al., Tooth et al., Von Korff et al.
Incontinence	Tooth et al., Grimby and Svanborg, Higashi et al., Min
Fall/fracture	Crabtree et al., Tooth et al.
Heart failure	Bayliss et al., Byles et al., Charlson et all., Fan et al.., Greenfield et al., Groll et al. McGee et al.
Hearing impairment	Bayliss et al.Byles et al., Crabtree et al., Groll et al. o
Heart rhythm	Greenfield et al., Holman et al.
High Blood Pressure	Byles et al., Sangha et al., Verbrugge et al., Grimby and Svanborg, Marengoni et al.
High cholesterol	Bayliss et al, Von Korff et al.
Liver disease	Byles et al., Charlson et al., Fan et al., George et al., Glattacker et al., Groll et al., Incalzi et al., Sangha et al.
Lung disease	Byles et al., Fan et al., Newmann et al., Sangha et al., Crabtree et al., Glattacker et al., Greenfield et al., Incalzi et al., Kaplan and Feinstein, Von Korff et al.
Memory disorders	Charlson et al., George et al., Glattacker et al., Groll et al., Incalzi et al.
Mental health condition	Byles et al., Crabtree et al., Fan et al., Glattacker et al., Groll et al, Sangha et al., Newmann et al.
Osteoporosis	Bayliss et al., Crabtree et al., Fan et al., Groll et al., Tooth et al.
Parkinson's	Crabtree et al., George et al., Incalzi et al. Rozzini et al., Von Korff et al.
Stomach Ulcer	Charlson et al., George et al., Fan et al., Incalzi et al., Sangha et al., Von Korff et al
Stroke/TIA	Bayliss et al., Byles et al., Fan et al.., Glattacker et al., Groll et al., Incalzi et al., McGee et al., Rozzini et al., Tooth et al.
Varicose Ulcer	CDC, Guralnik et al., Verbrugge et al.
Vision impairment	Byles et al., Fan et al., Incalzi et al.

Appendix 3.3 Multivariate logistic regression analyses of health sequalae for each condition (1-25) in TILDA.

POOR SELF-RATED HEALTH

	Angina/heart attack		Heart failure		Stroke/TIA		Heart murmur		Abnormal heart rhythm	
	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value
Condition 1-5	3.2 (2.7-3.8)	p<0.001	6.0 (3.7-9.8)	p<0.001	2.8 (2.2-3.6)	p<0.001	2.0 (1.6-2.5)	p<0.001	2.8 (2.3-3.4)	p<0.001
Male (Ref)	*1*		*1*		*1*		*1*		*1*	
Female	1.0 (0.9-1.1)	0.95	0.9 (0.8-1.1)	0.35	0.9 (0.8-1.0)	0.23	0.9 (0.8-1.0)	0.15	1.0 (0.8-1.1)	0.39
50-59 years (Ref)	*1*		*1*		*1*		*1*		*1*	
60-69 years	1.0 (0.9-1.1)	0.88	1.0 (0.9-1.2)	0.57	1.0 (0.9-1.2)	0.75	1.0 (0.9-1.2)	0.58	1.0 (0.9-1.2)	0.88
70-79 years	0.7 (0.6-0.9)	p<0.001	0.8 (0.7-1.0)	0.02	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-1.0)	0.03	0.8 (0.6-0.9)	p<0.01
80+ years	0.6 (0.5-0.7)	p<0.001	0.7 (0.5-0.9)	p<0.01	0.6 (0.5-0.8)	p<0.001	0.7 (0.5-0.8)	p<0.01	0.6 (0.5-0.8)	p<0.001
3rd Level + (Ref)	*1*		*1*		*1*		*1*		*1*	
Secondary	1.1 (0.9-1.3)	0.22	1.1 (1.0-1.3)	0.15	1.1 (1.0-1.3)	0.14	1.1 (1.0-1.3)	0.16	1.1 (1.0-1.3)	0.15
Primary/none	1.9 (1.7-2.3)	p<0.001	2.0 (1.7-2.4)	p<0.001	2.0 (1.7-2.4)	p<0.001	2.0 (1.7-2.4)	p<0.001	2.1 (1.7-2.4)	p<0.001
No GMS (Ref)	*1*		*1*		*1*		*1*		*1*	
Full GMS	2.5 (2.1-2.8)	p<0.001	2.6 (2.2-3.0)	p<0.001	2.5 (2.2-2.9)	p<0.001	2.6 (2.2-2.9)	p<0.001	2.5 (2.2-2.9)	p<0.001
≤€80,000 (Ref)	*1*		*1*		*1*		*1.0 (1.0-1.0)*		*1.0 (1.0-1.0)*	
€80,001-160,000	0.9 (0.8-1.1)	0.36	0.9 (0.8-1.1)	0.34	0.9 (0.8-1.1)	0.34	0.9 (0.8-1.1)	0.22	0.9 (0.8-1.1)	0.22
€160,001-240,000	0.8 (0.6-1.0)	0.02	0.8 (0.6-0.9)	0.01	0.8 (0.6-0.9)	0.01	0.8 (0.6-0.9)	p<0.01	0.8 (0.6-0.9)	p<0.01
€240,001-320,000	0.9 (0.7-1.0)	0.08	0.9 (0.7-1.0)	0.08	0.9 (0.7-1.0)	0.06	0.8 (0.7-1.0)	0.03	0.8 (0.7-1.0)	0.03
€320,001-400,000	0.6 (0.4-0.8)	p<0.001	0.6 (0.4-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.4-0.8)	p<0.001
€400,001-480,001	0.7 (0.5-1.1)	0.15	0.7 (0.5-1.1)	0.16	0.7 (0.5-1.2)	0.20	0.7 (0.5-1.1)	0.14	0.7 (0.4-1.1)	0.11
€480,001-560,000	0.6 (0.4-0.8)	p<0.001	0.6 (0.4-0.8)	p<0.01	0.6 (0.4-0.8)	p<0.001	0.6 (0.4-0.8)	p<0.001	0.6 (0.4-0.8)	p<0.001
≥€560,000	0.5 (0.4-0.7)	p<0.001	0.6 (0.4-0.7)	p<0.001	0.5 (0.4-0.7)	p<0.001	0.5 (0.4-0.7)	p<0.001	0.5 (0.4-0.7)	p<0.001
R-sqr 3(dfres)	755.429 (15)		654.715 (15)		660.493 (15)		630.684 (15)		707.973 (15)	
N	7570		7570		7570		7570		7570	
AIC	7445.8		7546.5		7540.7		7570.5		7493.3	
BIC	7556.7		7657.4		7651.7		7681.5		7604.2	

POOR SELF-RATED HEALTH

	Diabetes		High blood pressure		High cholesterol		Falls/fracture		Incontinence	
	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value
Condition 6-10	3.3 (2.7-3.9)	p<0.001	2.1 (1.9-2.4)	p<0.001	2.0 (1.8-2.2)	p<0.001	1.8 (1.6-2.1)	p<0.001	2.1 (1.8-2.5)	p<0.001
Male (Ref)	*1*		*1*		*1*		*1*		*1*	
Female	1.0 (0.9-1.1)	0.72	0.9 (0.8-1.0)	0.11	0.9 (0.8-1.0)	0.10	0.9 (0.8-1.0)	0.17	0.9 (0.8-1.0)	0.01
50-59 years (Ref)	*1*		*1*		*1*		*1*		*1*	
60-69 years	1.0 (0.9-1.2)	0.93	0.9 (0.8-1.1)	0.44	1.0 (0.8-1.1)	0.63	1.0 (0.9-1.2)	0.57	1.0 (0.9-1.2)	0.60
70-79 years	0.8 (0.7-0.9)	p<0.01	0.7 (0.6-0.8)	p<0.001	0.8 (0.6-0.9)	p<0.01	0.8 (0.7-1.0)	0.01	0.8 (0.7-1.0)	0.02
80+ years	0.7 (0.5-0.8)	p<0.001	0.6 (0.5-0.7)	p<0.001	0.7 (0.5-0.8)	p<0.001	0.7 (0.5-0.9)	p<0.01	0.6 (0.5-0.8)	p<0.001
3rd Level + (Ref)	*1*		*1*		*1*		*1*		*1*	
Secondary	1.1 (0.9-1.3)	0.23	1.1 (1.0-1.3)	0.19	1.1 (1.0-1.3)	0.13	1.1 (1.0-1.3)	0.18	1.1 (1.0-1.3)	0.17
Primary/none	2.0 (1.7-2.3)	p<0.001	1.9 (1.7-2.3)	p<0.001	2.0 (1.7-2.4)	p<0.001	2.0 (1.7-2.4)	p<0.001	2.0 (1.7-2.3)	p<0.001
No GMS (Ref)	*1*		*1*		*1*		*1*		*1*	
Full GMS	2.5 (2.2-2.9)	p<0.001	2.5 (2.1-2.9)	p<0.001	2.5 (2.2-2.9)	p<0.001	2.6 (2.2-3.0)	p<0.001	2.5 (2.2-2.9)	p<0.001
≤€80,000 (Ref)	*1*		*1*		*1*		*1*		*1*	
€80,001-160,000	0.9 (0.8-1.1)	0.37	0.9 (0.8-1.1)	0.27	0.9 (0.8-1.1)	0.20	0.9 (0.8-1.1)	0.36	0.9 (0.8-1.1)	0.34
€160,001-240,000	0.8 (0.6-0.9)	0.01	0.8 (0.6-0.9)	p<0.01	0.8 (0.6-0.9)	p<0.01	0.8 (0.6-1.0)	0.01	0.8 (0.6-0.9)	p<0.01
€240,001-320,000	0.8 (0.7-1.0)	0.04	0.8 (0.7-1.0)	0.03	0.8 (0.7-1.0)	0.02	0.9 (0.7-1.0)	0.08	0.9 (0.7-1.0)	0.06
€320,001-400,000	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.4-0.7)	p<0.001	0.6 (0.5-0.8)	0	0.6 (0.5-0.8)	p<0.001
€400,001-480,001	0.7 (0.5-1.1)	0.12	0.7 (0.5-1.1)	0.17	0.7 (0.4-1.0)	0.08	0.7 (0.5-1.1)	0.17	0.7 (0.5-1.1)	0.12
€480,001-560,000	0.6 (0.4-0.8)	p<0.001	0.6 (0.4-0.8)	p<0.001	0.5 (0.4-0.7)	p<0.001	0.6 (0.4-0.8)	0.001	0.6 (0.4-0.8)	p<0.01
≥€560,000	0.5 (0.4-0.7)	p<0.001	0.5 (0.4-0.7)	p<0.001	0.5 (0.4-0.7)	p<0.001	0.6 (0.4-0.7)	p<0.001	0.5 (0.4-0.7)	p<0.001
R-sqr(dfres)	758.722 (15)		749.152 (15)		716.006 (15)		672.481 (15)		666.440 (15)	
N	7570		7570		7570		7570		7570	
AIC	7442.5		7452.1		7485.2		7528.8		7534.8	
BIC	7553.4		7563		7596.1		7639.7		7645.7	

POOR SELF-RATED HEALTH

	Vision impairment		Hearing impairment		Chronic respiratory		Arthritis		Osteoporosis	
	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value
Condition 11-15	5.1 (3.5-7.5)	p<0.001	3.0 (2.2-4.0)	p<0.001	2.9 (2.5-3.3)	p<0.001	2.3 (2.0-2.6)	p<0.001	2.1 (1.8-2.5)	p<0.001
Male (Ref)	*1*		*1*		*1*		*1*		*1*	
Female	0.9 (0.8-1.0)	0.15	0.9 (0.8-1.1)	0.36	0.9 (0.8-1.0)	0.06	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-0.9)	p<0.01
50-59 years (Ref)	*1*		*1*		*1*		*1*		*1*	
60-69 years	1.1 (0.9-1.2)	0.44	1.1 (0.9-1.2)	0.49	1.1 (0.9-1.2)	0.46	0.9 (0.8-1.1)	0.36	1.0 (0.9-1.1)	0.98
70-79 years	0.8 (0.7-1.0)	0.03	0.8 (0.7-1.0)	0.02	0.9 (0.7-1.0)	0.07	0.7 (0.6-0.8)	p<0.001	0.8 (0.7-0.9)	p<0.01
80+ years	0.7 (0.5-0.8)	p<0.01	0.7 (0.5-0.8)	p<0.01	0.7 (0.6-0.9)	p<0.01	0.6 (0.4-0.7)	p<0.001	0.6 (0.5-0.8)	p<0.001
3rd Level + (Ref)	*1*		*1*		*1*		*1*		*1*	
Secondary	1.1 (0.9-1.3)	0.195	1.1 (0.9-1.3)	0.21	1.1 (1.0-1.3)	0.15	1.1 (1.0-1.3)	0.11	1.1 (1.0-1.3)	0.15
Primary/none	1.9 (1.6-2.3)	p<0.001	1.9 (1.6-2.3)	p<0.001	2.0 (1.7-2.3)	p<0.001	2.0 (1.7-2.4)	p<0.001	2.0 (1.7-2.4)	p<0.001
No GMS (Ref)	*1*		*1*		*1*		*1*		*1*	
Full GMS	2.5 (2.2-2.9)	p<0.001	2.6 (2.2-3.0)	p<0.001	2.5 (2.2-2.9)	p<0.001	2.5 (2.2-2.9)	p<0.001	2.6 (2.2-3.0)	p<0.001
≤€80,000 (Ref)	*1.0 (1.0-1.0)*		*1.0 (1.0-1.0)*		*(1.0-1.0)*		*1.0 (1.0-1.0)*		*1.0 (1.0-1.0)*	
€80,001-160,000	0.9 (0.8-1.1)	0.42	0.9 (0.8-1.1)	0.317	0.9 (0.8-1.1)	0.38	0.9 (0.8-1.1)	0.28	0.9 (0.8-1.1)	0.25
€160,001-240,000	0.8 (0.6-0.9)	0.01	0.8 (0.6-0.9)	p<0.01	0.8 (0.6-0.9)	p<0.01	0.8 (0.6-0.9)	p<0.01	0.8 (0.6-0.9)	p<0.01
€240,001-320,000	0.9 (0.7-1.0)	0.07	0.9 (0.7-1.0)	0.05	0.9 (0.7-1.0)	0.08	0.8 (0.7-1.0)	0.05	0.8 (0.7-1.0)	0.05
€320,001-400,000	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	0	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001
€400,001-480,001	0.7 (0.5-1.1)	0.17	0.7 (0.5-1.1)	0.15	0.7 (0.5-1.1)	0.17	0.8 (0.5-1.2)	0.21	0.7 (0.5-1.1)	0.17
€480,001-560,000	0.6 (0.4-0.8)	p<0.001	0.6 (0.4-0.8)	p<0.001	0.6 (0.4-0.8)	p<0.001	0.6 (0.4-0.8)	p<0.001	0.6 (0.4-0.8)	p<0.001
≥€560,000	0.5 (0.4-0.7)	p<0.001	0.5 (0.4-0.7)	p<0.001	0.5 (0.4-0.7)	p<0.001	0.5 (0.4-0.7)	p<0.001	0.5 (0.4-0.7)	p<0.001
R-sqr(dfres)	674.920 (15)		644.725 (15)		776.001 (15)		775.074 (15)		665.166 (15)	
N	7570		7570		7570		7570		7570	
AIC	7526.3		7556.5		7425.2		7426.2		7536.1	
BIC	7637.2		7667.4		7536.1		7537.1		7647	

POOR SELF-RATED HEALTH

	Cancer		Parkinson's disease		Stomach ulcer		Varicose ulcer		Liver disease	
	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value
Condition 11-15	1.8 (1.4-2.2)	p<0.001	15.0 (6.7-33.7)	p<0.001	2.0 (1.6-2.4)	p<0.001	1.5 (1.1-2.0)	p<0.01	3.0 (1.6-5.6)	p<0.01
Male (Ref)	*1*		*1*		*1*		*1*		*1*	
Female	0.9 (0.8-1.0)	0.16	0.9 (0.8-1.0)	0.23	0.9 (0.8-1.1)	0.32	0.9 (0.8-1.0)	0.14	0.9 (0.8-1.0)	0.21
50-59 years (Ref)	*1*		*1*		*1*		*1*		*1*	
60-69 years	1.0 (0.9-1.2)	0.68	1.0 (0.9-1.2)	0.66	1.1 (0.9-1.2)	0.44	1.0 (0.9-1.2)	0.56	1.0 (0.9-1.2)	0.53
70-79 years	0.8 (0.7-1.0)	0.02	0.8 (0.7-1.0)	0.01	0.8 (0.7-1.0)	0.06	0.8 (0.7-1.0)	0.02	0.8 (0.7-1.0)	0.03
80+ years	0.7 (0.5-0.9)	p<0.01	0.7 (0.5-0.8)	p<0.001	0.7 (0.6-0.9)	p<0.01	0.7 (0.5-0.8)	p<0.01	0.7 (0.6-0.9)	p<0.01
3rd Level + (Ref)	*1*		*1*		*1*		*1*		*1*	
Secondary	1.1 (1.0-1.3)	0.15	1.1 (1.0-1.3)	0.15	1.1 (1.0-1.3)	0.15	1.1 (1.0-1.3)	0.17	1.1 (1.0-1.3)	0.16
Primary/none	2.0 (1.7-2.4)	p<0.001	2.0 (1.7-2.4)	p<0.001	2.0 (1.7-2.3)	p<0.001	2.0 (1.7-2.3)	p<0.001	2.0 (1.7-2.4)	p<0.001
No GMS (Ref)	*1*		*1*		*1*		*1*		*1*	
Full GMS	2.5 (2.2-2.9)	p<0.001	2.6 (2.3-3.0)	p<0.001	2.6 (2.2-2.9)	p<0.001	2.6 (2.2-3.0)	p<0.001	2.6 (2.2-3.0)	p<0.001
≤€80,000 (Ref)	*1*		*1*		*1*		*1*		*1*	
€80,001-160,000	0.9 (0.8-1.1)	0.24	0.9 (0.8-1.1)	0.26	0.9 (0.8-1.1)	0.29	0.9 (0.8-1.1)	0.27	0.9 (0.8-1.1)	0.32
€160,001-240,000	0.8 (0.6-0.9)	p<0.01	0.8 (0.6-0.9)	0.01	0.8 (0.6-0.9)	p<0.01	0.8 (0.6-0.9)	p<0.01	0.8 (0.6-0.9)	0.01
€240,001-320,000	0.8 (0.7-1.0)	0.03	0.9 (0.7-1.0)	0.07	0.8 (0.7-1.0)	0.05	0.8 (0.7-1.0)	0.05	0.9 (0.7-1.0)	0.07
€320,001-400,000	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001
€400,001-480,001	0.7 (0.5-1.1)	0.14	0.8 (0.5-1.2)	0.20	0.7 (0.5-1.1)	0.15	0.7 (0.5-1.1)	0.17	0.7 (0.5-1.1)	0.17
€480,001-560,000	0.6 (0.4-0.8)	p<0.001	0.6 (0.4-0.8)	p<0.01	0.6 (0.4-0.8)	p<0.001	0.6 (0.4-0.8)	p<0.001	0.6 (0.4-0.8)	p<0.001
≥€560,000	0.5 (0.4-0.7)	p<0.001	0.5 (0.4-0.7)	p<0.001	0.5 (0.4-0.7)	p<0.001	0.5 (0.4-0.7)	p<0.001	0.6 (0.4-0.7)	p<0.001
R-sqr(dfres)	627.668 (15)		656.239 (15)		644.956 (15)		606.821 (15)		611.115 (15)	
N	7570		7570		7570		7570		7570	
AIC	7573.6		7545		7556.3		7594.4		7590.1	
BIC	7684.5		7655.9		7667.2		7705.3		7701	

POOR SELF-RATED HEALTH

	Memory disorders		Alcohol / substance abuse		Anxiety		Depression		Other mental health conditions	
	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value
Conditions 16-21	2.6 (1.4-4.7)	p<0.01	2.1 (1.4-3.1)	p<0.001	2.0 (1.6-2.5)	p<0.001	2.2 (1.8-2.7)	p<0.001	2.6 (1.9-3.5)	p<0.001
Male (Ref)	*1*		*1*		*1*		*1*		*1*	
Female	0.9 (0.8-1.0)	0.21	1.0 (0.8-1.1)	0.38	0.9 (0.8-1.0)	0.09	0.9 (0.8-1.0)	0.13	0.9 (0.8-1.0)	0.14
50-59 years (Ref)	*1*	.	*1*	.	*1*	.	*1*	.	*1*	.
60-69 years	1.0 (0.9-1.2)	0.54	1.0 (0.9-1.2)	0.50	1.1 (0.9-1.2)	0.42	1.1 (0.9-1.2)	0.41	1.1 (0.9-1.2)	0.37
70-79 years	0.8 (0.7-1.0)	0.03	0.8 (0.7-1.0)	0.04	0.9 (0.7-1.0)	0.07	0.9 (0.7-1.0)	0.10	0.9 (0.7-1.0)	0.09
80+ years	0.7 (0.5-0.9)	p<0.01	0.7 (0.6-0.9)	p<0.01	0.7 (0.6-0.9)	p<0.01	0.7 (0.6-0.9)	p<0.01	0.7 (0.6-0.9)	p<0.01
3rd Level + (Ref)	*1*	.	*1*	.	*1*	.	*1*	.	*1*	.
Secondary	1.1 (1.0-1.3)	0.15	1.1 (1.0-1.3)	0.14	1.1 (1.0-1.3)	0.13	1.1 (1.0-1.3)	0.10	1.1 (1.0-1.3)	0.13
Primary/none	2.0 (1.7-2.3)	p<0.001	2.0 (1.7-2.4)	p<0.001	2.0 (1.7-2.4)	p<0.001	2.0 (1.7-2.4)	p<0.001	2.0 (1.7-2.3)	p<0.001
No GMS (Ref)	*1*		*1*		*1*		*1*		*1*	
Full GMS	2.6 (2.2-3.0)	p<0.001	2.6 (2.2-2.9)	p<0.001	2.5 (2.2-2.9)	p<0.001	2.5 (2.2-2.9)	p<0.001	2.5 (2.2-2.9)	p<0.001
≤€80,000 (Ref)	*1*	.	*1*	.	*1*	.	*1*	.	*1*	.
€80,001-160,000	0.9 (0.8-1.1)	0.31	0.9 (0.8-1.1)	0.34	0.9 (0.8-1.1)	0.36	0.9 (0.8-1.1)	0.38	0.9 (0.8-1.1)	0.42
€160,001-240,000	0.8 (0.6-0.9)	0.01	0.8 (0.6-0.9)	0.01	0.8 (0.6-0.9)	p<0.01	0.8 (0.6-0.9)	0.01	0.8 (0.6-0.9)	0.01
€240,001-320,000	0.9 (0.7-1.0)	0.06	0.9 (0.7-1.0)	0.07	0.9 (0.7-1.0)	0.07	0.9 (0.7-1.0)	0.09	0.9 (0.7-1.0)	0.08
€320,001-400,000	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	0	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001
€400,001-480,001	0.7 (0.5-1.1)	0.17	0.7 (0.5-1.1)	0.18	0.7 (0.5-1.1)	0.17	0.7 (0.5-1.1)	0.16	0.7 (0.5-1.1)	0.17
€480,001-560,000	0.6 (0.4-0.8)	p<0.001	0.6 (0.4-0.8)	p<0.001	0.6 (0.4-0.8)	p<0.001	0.6 (0.4-0.8)	p<0.001	0.6 (0.4-0.8)	p<0.01
≥€560,000	0.5 (0.4-0.7)	p<0.001	0.6 (0.4-0.7)	p<0.001	0.5 (0.4-0.7)	p<0.001	0.5 (0.4-0.7)	p<0.001	0.5 (0.4-0.7)	p<0.001
R-sqr(dfres)	608.633 (15)		613.342 (15)		629.844 (15)		644.916 (15)		632.783 (15)	
N	7570		7570		7570		7570		7570	
AIC	7592.6		7587.9		7571.4		7556.3		7568.4	
BIC	7703.5		7698.8		7682.3		7667.2		7679.4	

DISABILITY

	Angina/heart attack		Heart failure		Stroke/TIA		Heart murmur		Abnormal heart rhythm	
	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value
Condition 1-5	1.8 (1.4-2.2)	p<0.001	1.7 (1.0-2.9)	0.07	3.1 (2.4-4.1)	p<0.001	1.7 (1.3-2.2)	p<0.001	2.1 (1.7-2.6)	p<0.001
Male (Ref)	*1*		*1*		*1*		*1*		*1*	
Female	1.2 (1.0-1.4)	0.01	1.2 (1.0-1.4)	0.04	1.2 (1.0-1.4)	0.03	1.2 (1.0-1.3)	0.05	1.2 (1.0-1.4)	0.02
50-59 years (Ref)	*1*		*1*		*1*		*1*		*1*	
60-69 years	1.1 (0.9-1.4)	0.18	1.2 (1.0-1.4)	0.11	1.1 (0.9-1.4)	0.19	1.2 (1.0-1.4)	0.12	1.1 (0.9-1.4)	0.17
70-79 years	1.4 (1.2-1.8)	p<0.01	1.5 (1.2-1.9)	p<0.001	1.4 (1.2-1.8)	p<0.01	1.5 (1.2-1.9)	p<0.001	1.5 (1.2-1.8)	p<0.01
80+ years	2.9 (2.3-3.7)	p<0.001	3.1 (2.4-3.9)	p<0.001	2.9 (2.3-3.7)	p<0.001	3.0 (2.4-3.9)	p<0.001	2.9 (2.2-3.7)	p<0.001
3rd Level + (Ref)	*1*		*1*		*1*		*1*		*1*	
Secondary	0.9 (0.8-1.1)	0.53	0.9 (0.8-1.2)	0.58	0.9 (0.8-1.2)	0.62	0.9 (0.8-1.2)	0.60	0.9 (0.8-1.2)	0.61
Primary/none	1.3 (1.1-1.7)	p<0.01	1.4 (1.1-1.7)	p<0.01	1.4 (1.1-1.7)	p<0.01	1.4 (1.1-1.7)	p<0.01	1.4 (1.1-1.7)	p<0.01
No GMS (Ref)	*1*		*1*		*1*		*1*		*1*	
Full GMS	2.1 (1.7-2.6)	p<0.001	2.2 (1.8-2.7)	p<0.001	2.1 (1.7-2.6)	p<0.001	2.2 (1.8-2.6)	p<0.001	2.1 (1.8-2.6)	p<0.001
≤€80,000 (Ref)	*1*		*1*		*1*		*1*		*1*	
€80,001-160,000	0.8 (0.6-1.0)	0.02	0.8 (0.6-1.0)	0.01	0.8 (0.6-1.0)	0.02	0.8 (0.6-0.9)	0.01	0.8 (0.6-0.9)	0.01
€160,001-240,000	0.8 (0.7-1.1)	0.18	0.8 (0.7-1.1)	0.16	0.8 (0.7-1.1)	0.18	0.8 (0.7-1.1)	0.15	0.8 (0.6-1.1)	0.13
€240,001-320,000	0.7 (0.5-0.8)	p<0.001	0.7 (0.5-0.8)	p<0.001	0.7 (0.5-0.8)	p<0.001	0.7 (0.5-0.8)	p<0.001	0.7 (0.5-0.8)	p<0.001
€320,001-400,000	0.7 (0.5-1.0)	0.02	0.7 (0.5-1.0)	0.03	0.7 (0.5-0.9)	0.02	0.7 (0.5-0.9)	0.02	0.7 (0.5-0.9)	0.02
€400,001-480,001	0.9 (0.6-1.6)	0.84	1.0 (0.6-1.6)	0.85	1.0 (0.6-1.7)	0.95	0.9 (0.6-1.6)	0.81	0.9 (0.5-1.6)	0.76
€480,001-560,000	0.6 (0.4-0.9)	p<0.01	0.6 (0.4-0.9)	p<0.01	0.6 (0.4-0.9)	p<0.01	0.6 (0.4-0.8)	p<0.01	0.6 (0.4-0.8)	p<0.01
≥€560,000	0.6 (0.5-0.9)	0.02	0.7 (0.5-0.9)	0.02	0.7 (0.5-0.9)	0.02	0.6 (0.4-0.9)	0.01	0.6 (0.5-0.9)	0.02
R-sqr(dfres)	456.234 (15)		433.808 (15)		490.398 (15)		442.907 (15)		468.000 (15)	
N	7570		7570		7570		7570		7570	
AIC	5101.5		5123.9		5067.3		5114.8		5089.7	
BIC	5212.4		5234.8		5178.2		5225.7		5200.6	

DISABILITY

	Diabetes		High blood pressure		High cholesterol		Falls/fracture		Incontinence	
	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value
Condition 6-10	1.8 (1.5-2.3)	p<0.001	1.5 (1.3-1.8)	p<0.001	1.4 (1.2-1.7)	p<0.001	2.0 (1.7-2.3)	p<0.001	3.2 (2.7-3.9)	p<0.001
Male (Ref)	*1*		*1*		*1*		*1*		*1*	
Female	1.2 (1.0-1.4)	0.02	1.1 (1.0-1.3)	0.07	1.1 (1.0-1.3)	0.07	1.1 (1.0-1.3)	0.07	1.0 (0.9-1.2)	0.93
50-59 years (Ref)	*1*		*1*		*1*		*1*		*1*	
60-69 years	1.2 (0.9-1.4)	0.16	1.1 (0.9-1.4)	0.30	1.1 (0.9-1.4)	0.23	1.2 (1.0-1.4)	0.12	1.2 (1.0-1.4)	0.14
70-79 years	1.5 (1.2-1.9)	p<0.001	1.4 (1.1-1.7)	p<0.01	1.5 (1.2-1.8)	p<0.01	1.5 (1.2-1.9)	p<0.001	1.5 (1.2-1.9)	p<0.001
80+ years	3.0 (2.4-3.9)	p<0.001	2.8 (2.2-3.6)	p<0.001	3.0 (2.4-3.9)	p<0.001	3.1 (2.4-4.0)	p<0.001	2.9 (2.3-3.8)	p<0.001
3rd Level + (Ref)	*1*		*1*		*1*		*1*		*1*	
Secondary	0.9 (0.8-1.1)	0.51	0.9 (0.8-1.2)	0.56	1.0 (0.8-1.2)	0.62	0.9 (0.8-1.2)	0.55	0.9 (0.8-1.2)	0.55
Primary/none	1.4 (1.1-1.7)	p<0.01	1.4 (1.1-1.7)	p<0.01	1.4 (1.1-1.7)	p<0.01	1.4 (1.1-1.7)	p<0.01	1.4 (1.1-1.7)	p<0.01
No GMS (Ref)	*1*		*1*		*1*		*1*		*1*	
Full GMS	2.1 (1.8-2.6)	p<0.001	2.1 (1.7-2.6)	p<0.001	2.1 (1.8-2.6)	p<0.001	2.2 (1.8-2.6)	p<0.001	2.1 (1.7-2.5)	p<0.001
≤€80,000 (Ref)	*1*		*1*		*1*		*1*		*1*	
€80,001-160,000	0.8 (0.6-1.0)	0.02	0.8 (0.6-0.9)	0.01	0.8 (0.6-0.9)	0.01	0.8 (0.6-1.0)	0.02	0.8 (0.6-1.0)	0.03
€160,001-240,000	0.8 (0.7-1.1)	0.17	0.8 (0.7-1.1)	0.14	0.8 (0.7-1.1)	0.13	0.9 (0.7-1.1)	0.21	0.8 (0.7-1.1)	0.15
€240,001-320,000	0.7 (0.5-0.8)	p<0.001	0.7 (0.5-0.8)	p<0.001	0.7 (0.5-0.8)	p<0.001	0.7 (0.5-0.8)	p<0.001	0.7 (0.5-0.8)	p<0.001
€320,001-400,000	0.7 (0.5-1.0)	0.03	0.7 (0.5-1.0)	0.03	0.7 (0.5-0.9)	0.02	0.7 (0.5-1.0)	0.03	0.7 (0.5-0.9)	0.02
€400,001-480,001	0.9 (0.6-1.6)	0.80	1.0 (0.6-1.6)	0.86	0.9 (0.5-1.6)	0.74	1.0 (0.6-1.6)	0.86	0.9 (0.5-1.5)	0.72
€480,001-560,000	0.6 (0.4-0.9)	p<0.01	0.6 (0.4-0.9)	p<0.01	0.6 (0.4-0.8)	p<0.01	0.6 (0.4-0.9)	p<0.01	0.6 (0.4-0.9)	p<0.01
≥€560,000	0.7 (0.5-0.9)	0.02	0.7 (0.5-0.9)	0.02	0.6 (0.4-0.9)	0.01	0.7 (0.5-0.9)	0.02	0.6 (0.4-0.9)	0.01
R-sqr(dfres)	458.414 (15)		459.853 (15)		449.343 (15)		488.915 (15)		561.271 (15)	
N	7570		7570		7570		7570		7570	
AIC	5099.3		5097.8		5108.3		5068.8		4996.4	
BIC	5210.2		5208.7		5219.3		5179.7		5107.3	

DISABILITY

	Vision impairment		Hearing impairment		Chronic respiratory		Arthritis		Osteoporosis	
	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value
Condition 11-15	3.9 (2.7-5.6)	p<0.001	3.4 (2.5-4.8)	p<0.001	1.9 (1.6-2.3)	p<0.001	3.2 (2.8-3.7)	p<0.001	1.9 (1.5-2.3)	p<0.001
Male (Ref)	*1*		*1*		*1*		*1*		*1*	
Female	1.1 (1.0-1.3)	0.06	1.2 (1.0-1.4)	0.02	1.1 (1.0-1.3)	0.09	1.0 (0.8-1.1)	0.74	1.0 (0.9-1.2)	0.64
50-59 years (Ref)	*1*		*1*		*1*		*1*	.	*1*	
60-69 years	1.2 (1.0-1.4)	0.09	1.2 (1.0-1.4)	0.09	1.2 (1.0-1.4)	0.09	1.0 (0.8-1.2)	0.89	1.1 (0.9-1.4)	0.24
70-79 years	1.5 (1.2-1.9)	p<0.001	1.5 (1.2-1.9)	p<0.001	1.6 (1.3-2.0)	p<0.001	1.2 (1.0-1.5)	0.10	1.5 (1.2-1.8)	p<0.01
80+ years	3.1 (2.4-4.0)	p<0.001	3.1 (2.4-3.9)	p<0.001	3.2 (2.5-4.1)	p<0.001	2.4 (1.9-3.1)	p<0.001	3.0 (2.3-3.8)	p<0.001
3rd Level + (Ref)	*1*		*1*		*1*		*1*		*1*	
Secondary	0.9 (0.8-1.1)	0.53	0.9 (0.8-1.1)	0.47	0.9 (0.8-1.2)	0.59	1.0 (0.8-1.2)	0.76	0.9 (0.8-1.2)	0.60
Primary/none	1.3 (1.1-1.6)	0.01	1.3 (1.1-1.6)	0.01	1.4 (1.1-1.7)	p<0.01	1.4 (1.1-1.7)	p<0.01	1.4 (1.1-1.7)	p<0.01
No GMS (Ref)	*1*		*1*		*1*		*1*		*1*	
Full GMS	2.1 (1.8-2.6)	p<0.001	2.2 (1.8-2.6)	p<0.001	2.1 (1.7-2.6)	p<0.001	2.1 (1.7-2.5)	p<0.001	2.2 (1.8-2.7)	p<0.001
≤€80,000 (Ref)	*1*		*1*		*1*		*1*		*1*	
€80,001-160,000	0.8 (0.6-1.0)	0.03	0.8 (0.6-1.0)	0.02	0.8 (0.6-1.0)	0.02	0.8 (0.6-0.9)	0.01	0.8 (0.6-0.9)	0.01
€160,001-240,000	0.8 (0.7-1.1)	0.17	0.8 (0.6-1.1)	0.12	0.8 (0.7-1.1)	0.15	0.8 (0.7-1.1)	0.16	0.8 (0.7-1.1)	0.16
€240,001-320,000	0.7 (0.5-0.8)	p<0.001	0.7 (0.5-0.8)	p<0.001	0.7 (0.5-0.8)	p<0.001	0.7 (0.5-0.8)	p<0.001	0.7 (0.5-0.8)	p<0.001
€320,001-400,000	0.7 (0.5-1.0)	0.04	0.7 (0.5-0.9)	0.02	0.7 (0.5-1.0)	0.04	0.7 (0.5-1.0)	0.04	0.7 (0.5-1.0)	0.02
€400,001-480,001	1.0 (0.6-1.6)	0.89	0.9 (0.5-1.6)	0.79	0.9 (0.6-1.6)	0.84	1.0 (0.6-1.7)	0.99	1.0 (0.6-1.6)	0.86
€480,001-560,000	0.6 (0.4-0.9)	p<0.01	0.6 (0.4-0.9)	p<0.01	0.6 (0.4-0.8)	p<0.01	0.6 (0.4-0.9)	p<0.01	0.6 (0.4-0.9)	p<0.01
≥€560,000	0.7 (0.5-0.9)	0.02	0.7 (0.5-0.9)	0.02	0.7 (0.5-0.9)	0.02	0.7 (0.5-0.9)	0.02	0.6 (0.4-0.9)	0.01
R-sqr(dfres)	477.283 (15)		477.243 (15)		473.367 (15)		657.231 (15)		462.133 (15)	
N	7570		7570		7570		7570		7570	
AIC	5080.4		5080.4		5084.3		4900.5		5095.6	
BIC	5191.3		5191.4		5195.2		5011.4		5206.5	

DISABILITY

	Cancer		Parkinson's disease		Stomach ulcer		Varicose ulcer		Liver disease	
	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value
Condition 16-20	1.3 (1.0-1.7)	0.04	3.8 (1.9-7.5)	p<0.001	2.0 (1.6-2.6)	p<0.001	2.1 (1.6-2.9)	p<0.001	3.5 (1.8-6.7)	p<0.001
Male (Ref)	*1*		*1*		*1*		*1*		*1*	
Female	1.2 (1.0-1.3)	0.05	1.2 (1.0-1.3)	0.04	1.2 (1.0-1.4)	0.02	1.1 (1.0-1.3)	0.09	1.2 (1.0-1.4)	0.04
50-59 years (Ref)	*1*	.	*1*		*1*		*1*		*1*	
60-69 years	1.2 (1.0-1.4)	0.13	1.2 (1.0-1.4)	0.12	1.2 (1.0-1.5)	0.08	1.2 (1.0-1.4)	0.12	1.2 (1.0-1.4)	0.10
70-79 years	1.5 (1.2-1.9)	p<0.001	1.5 (1.2-1.9)	p<0.001	1.6 (1.3-2.0)	p<0.001	1.5 (1.2-1.9)	p<0.001	1.5 (1.2-1.9)	p<0.001
80+ years	3.1 (2.4-3.9)	p<0.001	3.0 (2.4-3.9)	p<0.001	3.2 (2.5-4.1)	p<0.001	3.0 (2.3-3.8)	p<0.001	3.1 (2.4-4.0)	p<0.001
3rd Level + (Ref)	*1*		*1*		*1*		*1*		*1*	
Secondary	0.9 (0.8-1.2)	0.59	0.9 (0.8-1.2)	0.58	0.9 (0.8-1.2)	0.61	0.9 (0.8-1.1)	0.54	0.9 (0.8-1.2)	0.58
Primary/none	1.4 (1.1-1.7)	p<0.01	1.4 (1.1-1.7)	p<0.01	1.4 (1.1-1.7)	p<0.01	1.3 (1.1-1.7)	p<0.01	1.4 (1.1-1.7)	p<0.01
No GMS (Ref)	*1*		*1*		*1*		*1*		*1*	
Full GMS	2.2 (1.8-2.6)	p<0.001	2.2 (1.8-2.7)	p<0.001	2.1 (1.8-2.6)	p<0.001	2.2 (1.8-2.7)	p<0.001	2.2 (1.8-2.6)	p<0.001
≤€80,000 (Ref)	*1*		*1*		*1*		*1*		*1*	
€80,001-160,000	0.8 (0.6-0.9)	0.01	0.8 (0.6-0.9)	0.01	0.8 (0.6-1.0)	0.01	0.8 (0.6-0.9)	0.01	0.8 (0.6-1.0)	0.02
€160,001-240,000	0.8 (0.7-1.1)	0.14	0.8 (0.7-1.1)	0.17	0.8 (0.7-1.1)	0.14	0.8 (0.6-1.1)	0.13	0.8 (0.7-1.1)	0.19
€240,001-320,000	0.7 (0.5-0.8)	p<0.001	0.7 (0.5-0.8)	p<0.001	0.7 (0.5-0.8)	p<0.001	0.7 (0.5-0.8)	p<0.001	0.7 (0.5-0.8)	p<0.001
€320,001-400,000	0.7 (0.5-1.0)	0.03	0.7 (0.5-1.0)	0.03	0.7 (0.5-1.0)	0.03	0.7 (0.5-1.0)	0.03	0.7 (0.5-1.0)	0.03
€400,001-480,001	0.9 (0.6-1.6)	0.84	1.0 (0.6-1.6)	0.90	0.9 (0.6-1.6)	0.83	1.0 (0.6-1.6)	0.87	1.0 (0.6-1.6)	0.87
€480,001-560,000	0.6 (0.4-0.9)	p<0.01	0.6 (0.4-0.9)	p<0.01	0.6 (0.4-0.9)	p<0.01	0.6 (0.4-0.9)	p<0.01	0.6 (0.4-0.9)	p<0.01
≥€560,000	0.6 (0.5-0.9)	0.02	0.7 (0.5-0.9)	0.02	0.7 (0.5-0.9)	0.02	0.6 (0.5-0.9)	0.01	0.7 (0.5-0.9)	0.02
R-sqr(dfres)	434.684 (15)		443.470 (15)		462.164 (15)		451.164 (15)		442.336 (15)	
N	7570		7570		7570		7570		7570	
AIC	5123		5114.2		5095.5		5106.5		5115.4	
BIC	5233.9		5225.1		5206.4		5217.4		5226.3	

DISABILITY

	Memory disorders		Alcohol / substance abuse		Anxiety		Depression		Other mental health conditions	
	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value
Condition 21-25	8.7 (4.7-16.3)	p<0.001	1.9 (1.2-3.0)	p<0.01	2.7 (2.1-3.5)	p<0.001	2.7 (2.1-3.5)	p<0.001	3.2 (2.3-4.5)	p<0.001
Male (Ref)	*1*		*1*		*1*		*1*		*1*	
Female	1.2 (1.0-1.4)	0.03	1.2 (1.0-1.4)	0.02	1.1 (1.0-1.3)	0.13	1.1 (1.0-1.3)	0.08	1.1 (1.0-1.3)	0.07
50-59 years (Ref)	*1*		*1*		*1*		*1*		*1*	
60-69 years	1.2 (1.0-1.4)	0.10	1.2 (1.0-1.4)	0.10	1.2 (1.0-1.5)	0.06	1.2 (1.0-1.5)	0.06	1.2 (1.0-1.5)	0.05
70-79 years	1.5 (1.2-1.9)	p<0.001	1.5 (1.2-1.9)	p<0.001	1.6 (1.3-2.0)	p<0.001	1.7 (1.3-2.1)	p<0.001	1.6 (1.3-2.1)	p<0.001
80+ years	3.1 (2.4-4.0)	p<0.001	3.1 (2.4-4.0)	p<0.001	3.4 (2.6-4.4)	p<0.001	3.4 (2.7-4.4)	p<0.001	3.4 (2.6-4.3)	p<0.001
3rd Level + (Ref)	*1*		*1*		*1*		*1*		*1*	
Secondary	1.0 (0.8-1.2)	0.66	0.9 (0.8-1.2)	0.62	1.0 (0.8-1.2)	0.68	1.0 (0.8-1.2)	0.80	1.0 (0.8-1.2)	0.68
Primary/none	1.4 (1.1-1.7)	p<0.01	1.4 (1.1-1.7)	p<0.01	1.4 (1.1-1.7)	p<0.01	1.4 (1.1-1.7)	p<0.01	1.4 (1.1-1.7)	p<0.01
No GMS (Ref)	*1*		*1*		*1*		*1*		*1*	
Full GMS	2.1 (1.8-2.6)	p<0.001	2.2 (1.8-2.6)	p<0.001	2.1 (1.7-2.6)	p<0.001	2.1 (1.7-2.5)	p<0.001	2.1 (1.7-2.5)	p<0.001
≤€80,000 (Ref)	*1*		*1*		*1*		*1*		*1*	
€80,001-160,000	0.8 (0.6-1.0)	0.02	0.8 (0.6-1.0)	0.02	0.8 (0.6-1.0)	0.02	0.8 (0.6-1.0)	0.03	0.8 (0.6-1.0)	0.03
€160,001-240,000	0.8 (0.7-1.1)	0.18	0.8 (0.7-1.1)	0.17	0.8 (0.6-1.1)	0.13	0.8 (0.7-1.1)	0.18	0.9 (0.7-1.1)	0.20
€240,001-320,000	0.7 (0.5-0.8)	p<0.001	0.7 (0.5-0.8)	p<0.001	0.7 (0.5-0.8)	p<0.001	0.7 (0.5-0.8)	p<0.001	0.7 (0.5-0.8)	p<0.001
€320,001-400,000	0.7 (0.5-1.0)	0.03	0.7 (0.5-1.0)	0.04	0.7 (0.5-1.0)	0.03	0.7 (0.5-1.0)	0.04	0.7 (0.5-1.0)	0.03
€400,001-480,001	1.0 (0.6-1.7)	0.93	1.0 (0.6-1.6)	0.86	1.0 (0.6-1.6)	0.90	1.0 (0.6-1.6)	0.85	1.0 (0.6-1.6)	0.87
€480,001-560,000	0.6 (0.4-0.8)	p<0.01	0.6 (0.4-0.9)	p<0.01	0.6 (0.4-0.9)	p<0.01	0.6 (0.4-0.8)	p<0.01	0.6 (0.4-0.9)	p<0.01
≥€560,000	0.7 (0.5-0.9)	0.02	0.7 (0.5-0.9)	0.02	0.7 (0.5-0.9)	0.02	0.7 (0.5-0.9)	0.02	0.7 (0.5-0.9)	0.02
R-sqr(dfres)	476.666 (15)		437.013 (15)		476.955 (15)		483.314 (15)		467.912 (15)	
N	7570		7570		7570		7570		7570	
AIC	5081		5120.7		5080.7		5074.4		5089.8	
BIC	5191.9		5231.6		5191.6		5185.3		5200.7	

QUALITY OF LIFE

	Angina/heart attack		Heart failure		Stroke/TIA		Heart murmur		Abnormal heart rhythm	
	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value
Condition 1-5	1.8 (1.4-2.2)	p<0.001	1.3 (0.8-2.3)	0.32	1.8 (1.3-2.5)	p<0.001	1.6 (1.3-2.1)	p<0.001	1.7 (1.4-2.1)	p<0.001
Male (Ref)	*1*		*1*		*1*		*1*		*1*	
Female	0.8 (0.8-0.9)	p<0.01	0.8 (0.7-0.9)	p<0.001	0.8 (0.7-0.9)	p<0.001	0.8 (0.7-0.9)	p<0.001	0.8 (0.7-0.9)	p<0.01
50-59 years (Ref)	*1*		*1*		*1*		*1*		*1*	
60-69 years	0.6 (0.5-0.7)	p<0.001	0.6 (0.5-0.7)	p<0.001	0.6 (0.5-0.7)	p<0.001	0.6 (0.5-0.7)	p<0.001	0.6 (0.5-0.7)	p<0.001
70-79 years	0.5 (0.4-0.5)	p<0.001	0.5 (0.4-0.6)	p<0.001	0.5 (0.4-0.6)	p<0.001	0.5 (0.4-0.6)	p<0.001	0.5 (0.4-0.6)	p<0.001
80+ years	0.7 (0.6-1.0)	0.03	0.8 (0.6-1.0)	0.08	0.8 (0.6-1.0)	0.04	0.8 (0.6-1.0)	0.06	0.8 (0.6-1.0)	0.03
3rd Level + (Ref)	*1*		*1*		*1*		*1*		*1*	
Secondary	1.1 (1.0-1.3)	0.07	1.1 (1.0-1.3)	0.06	1.1 (1.0-1.3)	0.05	1.1 (1.0-1.3)	0.06	1.1 (1.0-1.3)	0.06
Primary/none	1.2 (1.0-1.4)	0.02	1.2 (1.0-1.4)	0.01	1.2 (1.1-1.4)	0.01	1.2 (1.1-1.5)	0.01	1.2 (1.1-1.5)	p<0.01
No GMS (Ref)	*1*		*1*		*1*		*1*		*1*	
Full GMS	2.0 (1.7-2.3)	p<0.001	2.0 (1.8-2.4)	p<0.001	2.0 (1.8-2.3)	p<0.001	2.0 (1.8-2.3)	p<0.001	2.0 (1.8-2.3)	p<0.001
≤€80,000 (Ref)	*1*		*1*		*1*		*1*		*1*	
€80,001-160,000	1.0 (0.8-1.2)	0.67	1.0 (0.8-1.2)	0.66	1.0 (0.8-1.2)	0.72	1.0 (0.8-1.1)	0.61	1.0 (0.8-1.1)	0.59
€160,001-240,000	0.9 (0.7-1.0)	0.13	0.9 (0.7-1.0)	0.11	0.9 (0.7-1.0)	0.13	0.8 (0.7-1.0)	0.11	0.8 (0.7-1.0)	0.10
€240,001-320,000	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-0.9)	p<0.01
€320,001-400,000	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001
€400,001-480,001	0.6 (0.4-0.9)	0.02	0.6 (0.4-0.9)	0.02	0.6 (0.4-0.9)	0.02	0.6 (0.4-0.9)	0.01	0.6 (0.4-0.9)	0.01
€480,001-560,000	0.6 (0.4-0.7)	p<0.001	0.6 (0.4-0.7)	p<0.001	0.6 (0.4-0.7)	p<0.001	0.6 (0.4-0.7)	p<0.001	0.6 (0.4-0.7)	p<0.001
≥€560,000	0.7 (0.5-0.9)	p<0.01	0.7 (0.5-0.9)	p<0.01	0.7 (0.5-0.9)	p<0.01	0.7 (0.5-0.9)	p<0.01	0.7 (0.5-0.9)	p<0.01
R-sqr(dfres)	326.395 (15)		300.074 (15)		313.625 (15)		313.098 (15)		322.022 (15)	
N	5487		5487		5487		5487		5487	
AIC	7239.9		7266.3		7252.7		7253.2		7244.3	
BIC	7345.7		7372		7358.5		7359		7350.1	

QUALITY OF LIFE

	Diabetes		High blood pressure		High cholesterol		Falls/fracture		Incontinence	
	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value
Condition 6-10	1.3 (1.0-1.6)	0.02	1.3 (1.2-1.5)	p<0.001	1.2 (1.0-1.3)	0.03	1.5 (1.3-1.7)	p<0.001	1.8 (1.5-2.2)	p<0.001
Male (Ref)	*1*		*1*		*1*		*1*		*1*	
Female	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-0.9)	p<0.001	0.8 (0.7-0.9)	p<0.001	0.8 (0.7-0.9)	p<0.001	0.8 (0.7-0.9)	p<0.001
50-59 years (Ref)	*1*		*1*		*1*		*1*		*1*	
60-69 years	0.6 (0.5-0.7)	p<0.001	0.6 (0.5-0.7)	p<0.001	0.6 (0.5-0.7)	p<0.001	0.6 (0.5-0.7)	p<0.001	0.6 (0.5-0.7)	p<0.001
70-79 years	0.5 (0.4-0.6)	p<0.001	0.5 (0.4-0.5)	p<0.001	0.5 (0.4-0.6)	p<0.001	0.5 (0.4-0.6)	p<0.001	0.5 (0.4-0.6)	p<0.001
80+ years	0.8 (0.6-1.0)	0.07	0.7 (0.6-1.0)	0.02	0.8 (0.6-1.0)	0.07	0.8 (0.6-1.0)	0.08	0.8 (0.6-1.0)	0.06
3rd Level + (Ref)	*1*		*1*		*1*		*1*		*1*	
Secondary	1.1 (1.0-1.3)	0.07	1.1 (1.0-1.3)	0.06	1.1 (1.0-1.3)	0.06	1.1 (1.0-1.3)	0.06	1.1 (1.0-1.3)	0.06
Primary/none	1.2 (1.0-1.4)	0.01	1.2 (1.0-1.4)	0.02	1.2 (1.0-1.4)	0.01	1.2 (1.0-1.4)	0.01	1.2 (1.0-1.4)	0.01
No GMS (Ref)	*1*		*1*		*1*		*1*		*1*	
Full GMS	2.0 (1.8-2.3)	p<0.001	2.0 (1.7-2.3)	p<0.001	2.0 (1.8-2.3)	p<0.001	2.0 (1.8-2.4)	p<0.001	2.0 (1.7-2.3)	p<0.001
≤€80,000 (Ref)	*1*		*1*		*1*		*1*		*1*	
€80,001-160,000	1.0 (0.8-1.2)	0.67	1.0 (0.8-1.2)	0.66	1.0 (0.8-1.2)	0.63	1.0 (0.8-1.2)	0.67	1.0 (0.8-1.2)	0.64
€160,001-240,000	0.9 (0.7-1.0)	0.11	0.8 (0.7-1.0)	0.11	0.8 (0.7-1.0)	0.11	0.9 (0.7-1.0)	0.12	0.8 (0.7-1.0)	0.08
€240,001-320,000	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-0.9)	p<0.01
€320,001-400,000	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.7)	p<0.001
€400,001-480,001	0.6 (0.4-0.9)	0.02	0.6 (0.4-0.9)	0.02	0.6 (0.4-0.9)	0.01	0.6 (0.4-0.9)	0.02	0.6 (0.4-0.9)	0.01
€480,001-560,000	0.6 (0.4-0.7)	p<0.001	0.6 (0.4-0.7)	p<0.001	0.6 (0.4-0.7)	p<0.001	0.6 (0.4-0.8)	p<0.001	0.6 (0.4-0.7)	p<0.001
≥€560,000	0.7 (0.5-0.9)	p<0.01	0.7 (0.5-0.9)	p<0.01	0.7 (0.5-0.9)	p<0.01	0.7 (0.5-0.9)	p<0.01	0.7 (0.5-0.9)	p<0.01
R-sqr(dfres)	304.372 (15)		318.590 (15)		303.828 (15)		326.435 (15)		336.941 (15)	
N	5487		5487		5487		5487		5487	
AIC	7262		7247.7		7262.5		7239.9		7229.4	
BIC	7367.7		7353.5		7368.3		7345.7		7335.2	

QUALITY OF LIFE

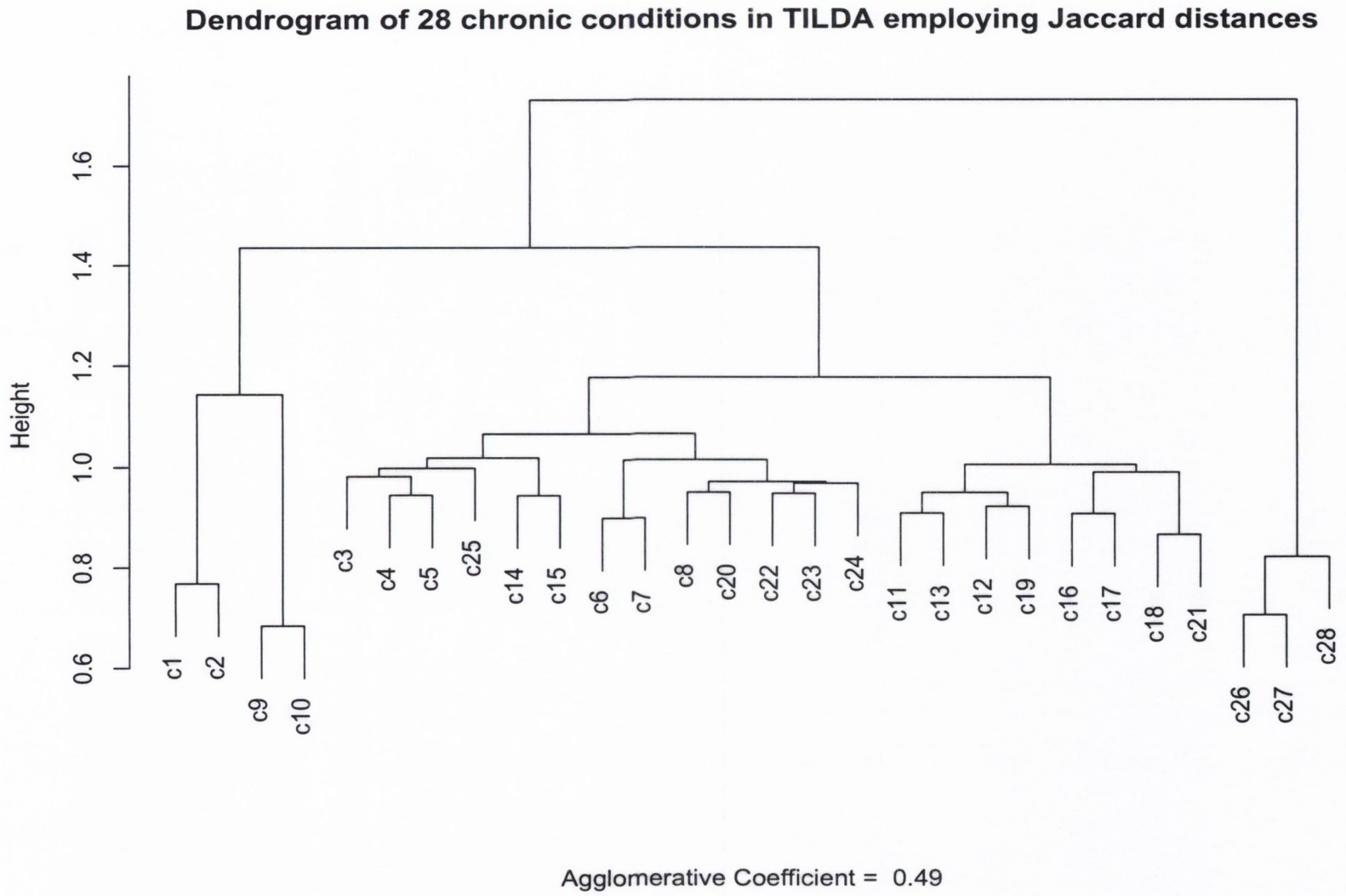
	Vision impairment		Hearing impairment		Chronic respiratory		Arthritis		Osteoporosis	
	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value
Condition 11-15	2.5 (1.5-4.2)	p<0.001	1.7 (1.2-2.6)	p<0.01	1.3 (1.1-1.6)	p<0.01	1.7 (1.5-1.9)	p<0.001	1.2 (1.0-1.5)	0.06
Male (Ref)	*1*		*1*		*1*		*1*		*1*	
Female	0.8 (0.7-0.9)	p<0.001	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-0.9)	p<0.001	0.8 (0.7-0.9)	p<0.001	0.8 (0.7-0.9)	p<0.001
50-59 years (Ref)	*1*		*1*		*1*		*1*		*1*	
60-69 years	0.6 (0.5-0.7)	p<0.001	0.6 (0.5-0.7)	p<0.001	0.6 (0.5-0.7)	p<0.001	0.6 (0.5-0.6)	p<0.001	0.6 (0.5-0.7)	p<0.001
70-79 years	0.5 (0.4-0.6)	p<0.001	0.5 (0.4-0.6)	p<0.001	0.5 (0.4-0.6)	p<0.001	0.4 (0.4-0.5)	p<0.001	0.5 (0.4-0.6)	p<0.001
80+ years	0.8 (0.6-1.0)	0.06	0.8 (0.6-1.0)	0.08	0.8 (0.6-1.0)	0.09	0.7 (0.5-0.9)	0.01	0.8 (0.6-1.0)	0.06
3rd Level + (Ref)	*1*		*1*		*1*		*1*		*1*	
Secondary	1.1 (1.0-1.3)	0.07	1.1 (1.0-1.3)	0.07	1.1 (1.0-1.3)	0.05	1.1 (1.0-1.3)	0.05	1.1 (1.0-1.3)	0.06
Primary/none	1.2 (1.0-1.4)	0.02	1.2 (1.0-1.4)	0.02	1.2 (1.0-1.4)	0.01	1.2 (1.0-1.4)	0.01	1.2 (1.0-1.4)	0.01
No GMS (Ref)	*1*		*1*		*1*		*1*		*1*	
Full GMS	2.0 (1.8-2.3)	p<0.001	2.0 (1.8-2.4)	p<0.001	2.0 (1.8-2.3)	p<0.001	2.0 (1.7-2.3)	p<0.001	2.0 (1.8-2.4)	p<0.0010
≤€80,000 (Ref)	*1*		*1*		*1*		*1*		*1*	
€80,001-160,000	1.0 (0.8-1.2)	0.71	1.0 (0.8-1.2)	0.64	1.0 (0.8-1.2)	0.65	1.0 (0.8-1.2)	0.67	1.0 (0.8-1.2)	0.64
€160,001-240,000	0.9 (0.7-1.0)	0.11	0.8 (0.7-1.0)	0.10	0.8 (0.7-1.0)	0.10	0.9 (0.7-1.0)	0.13	0.8 (0.7-1.0)	0.11
€240,001-320,000	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-0.9)	p<0.01
€320,001-400,000	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001
€400,001-480,001	0.6 (0.4-0.9)	0.02	0.6 (0.4-0.9)	0.02	0.6 (0.4-0.9)	0.02	0.6 (0.4-0.9)	0.02	0.6 (0.4-0.9)	0.02
€480,001-560,000	0.6 (0.4-0.7)	p<0.001	0.6 (0.4-0.7)	p<0.001	0.6 (0.4-0.7)	p<0.001	0.6 (0.4-0.8)	p<0.001	0.6 (0.4-0.7)	p<0.001
≥€560,000	0.7 (0.5-0.9)	p<0.01	0.7 (0.5-0.9)	p<0.01	0.7 (0.5-0.9)	p<0.01	0.7 (0.5-0.9)	p<0.01	0.7 (0.5-0.9)	p<0.01
R-sqr(dfres)	313.241 (15)		306.962 (15)		310.217 (15)		362.120 (15)		302.571 (15)	
N	5487		5487		5487		5487		5487	
AIC	7253.1		7259.4		7256.1		7204.2		7263.8	
BIC	7358.9		7365.1		7361.9		7310		7369.5	

QUALITY OF LIFE

	Cancer		Parkinson's disease		Stomach ulcer		Varicose ulcer		Liver disease	
	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value
Condition 16-20	1.1 (0.9-1.4)	0.26	3.4 (1.4-8.3)	p<0.01	1.6 (1.3-2.0)	p<0.001	1.2 (0.9-1.7)	0.29	1.8 (0.8-3.9)	0.14
Male (Ref)	*1*		*1*		*1*		*1*		*1*	
Female	0.8 (0.7-0.9)	p<0.001	0.8 (0.7-0.9)	p<0.001	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-0.9)	p<0.001	0.8 (0.7-0.9)	p<0.001
50-59 years (Ref)	*1*	.	*1*		*1*		*1*		*1*	
60-69 years	0.6 (0.5-0.7)	p<0.001	0.6 (0.5-0.7)	p<0.001	0.6 (0.5-0.7)	p<0.001	0.6 (0.5-0.7)	p<0.001	0.6 (0.5-0.7)	p<0.001
70-79 years	0.5 (0.4-0.6)	p<0.001	0.5 (0.4-0.6)	p<0.001	0.5 (0.4-0.6)	p<0.001	0.5 (0.4-0.6)	p<0.001	0.5 (0.4-0.6)	p<0.001
80+ years	0.8 (0.6-1.0)	0.08	0.8 (0.6-1.0)	0.06	0.8 (0.6-1.0)	0.10	0.8 (0.6-1.0)	0.07	0.8 (0.6-1.0)	0.08
3rd Level + (Ref)	*1*		*1*		*1*		*1*		*1*	
Secondary	1.1 (1.0-1.3)	0.06	1.1 (1.0-1.3)	0.06	0.1 (1.0-1.3)	0.05	1.1 (1.0-1.3)	0.06	1.1 (1.0-1.3)	0.06
Primary/none	1.2 (1.0-1.4)	0.01	1.2 (1.0-1.4)	0.01	1.2 (1.0-1.4)	0.02	1.2 (1.0-1.4)	0.01	1.2 (1.0-1.4)	0.01
No GMS (Ref)	*1*		*1*		*1*		*1*		*1*	
Full GMS	2.0 (1.8-2.4)	p<0.001	2.1 (1.8-2.4)	p<0.001	2.0 (1.8-2.3)	p<0.001	2.0 (1.8-2.4)	p<0.001	2.0 (1.8-2.4)	p<0.001
≤€80,000 (Ref)	*1*		*1*		*1*		*1*		*1*	
€80,001-160,000	1.0 (0.8-1.2)	0.64	0.9 (0.8-1.1)	0.59	0.9 (0.8-1.1)	0.59	1.0 (0.8-1.2)	0.65	1.0 (0.8-1.2)	0.68
€160,001-240,000	0.8 (0.7-1.0)	0.11	0.9 (0.7-1.0)	0.12	0.8 (0.7-1.0)	0.09	0.8 (0.7-1.0)	0.11	0.9 (0.7-1.0)	0.12
€240,001-320,000	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-0.9)	0.006	0.8 (0.7-0.9)	p<0.01
€320,001-400,000	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001
€400,001-480,001	0.6 (0.4-0.9)	0.02	0.6 (0.4-0.9)	0.02	0.6 (0.4-0.9)	0.02	0.6 (0.4-0.9)	0.02	0.6 (0.4-0.9)	0.02
€480,001-560,000	0.6 (0.4-0.7)	p<0.001	0.6 (0.4-0.8)	p<0.001	0.6 (0.4-0.7)	p<0.001	0.6 (0.4-0.7)	p<0.001	0.6 (0.4-0.7)	p<0.001
≥€560,000	0.7 (0.5-0.9)	p<0.01	0.7 (0.5-0.9)	p<0.01	0.7 (0.5-0.9)	p<0.01	0.7 (0.5-0.9)	p<0.01	0.7 (0.5-0.9)	p<0.01
R-sqr(dfres)	300.350 (15)		307.742 (15)		318.256 (15)		300.180 (15)		301.265 (15)	
N	5487		5487		5487		5487		5487	
AIC	7266		7258.6		7248.1		7266.2		7265.1	
BIC	7371.7		7364.4		7353.8		7371.9		7370.8	

QUALITY OF LIFE

	Memory disorders		Alcohol / substance abuse		Anxiety		Depression		Other mental health conditions	
	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value	Odds Ratio (95% C.I.)	P-value
Condition 21-25	2.2 (0.9-5.2)	0.07	2.5 (1.5-4.1)	p<0.001	3.3 (2.5-4.4)	p<0.001	2.9 (2.2-3.8)	p<0.001	3.8 (2.5-5.8)	p<0.001
Male (Ref)	*1*		*1*		*1*		*1*		*1*	
Female	0.8 (0.7-0.9)	p<0.001	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-0.9)	p<0.001	0.8 (0.7-0.9)	p<0.001	0.8 (0.7-0.9)	p<0.001
50-59 years (Ref)	*1*		*1*		*1*		*1*		*1*	
60-69 years	0.6 (0.5-0.7)	p<0.001	0.6 (0.5-0.7)	p<0.001	0.6 (0.5-0.7)	p<0.001	0.6 (0.5-0.7)	p<0.001	0.6 (0.5-0.7)	p<0.001
70-79 years	0.5 (0.4-0.6)	p<0.001	0.5 (0.4-0.6)	p<0.001	0.5 (0.4-0.6)	p<0.001	0.5 (0.4-0.6)	p<0.001	0.5 (0.4-0.6)	p<0.001
80+ years	0.8 (0.6-1.0)	0.07	0.8 (0.6-1.0)	0.10	0.8 (0.6-1.1)	0.16	0.8 (0.6-1.1)	0.17	0.8 (0.6-1.1)	0.15
3rd Level + (Ref)	*1*		*1*		*1*		*1*		*1*	
Secondary	1.1 (1.0-1.3)	0.06	1.1 (1.0-1.3)	0.05	1.1 (1.0-1.3)	0.04	1.2 (1.0-1.3)	0.02	1.1 (1.0-1.3)	0.05
Primary/none	1.2 (1.0-1.4)	0.01	1.2 (1.1-1.5)	0.01	1.2 (1.1-1.5)	p<0.01	1.3 (1.1-1.5)	p<0.01	1.2 (1.1-1.4)	0.01
No GMS (Ref)	*1*		*1*		*1*		*1*		*1*	
Full GMS	2.0 (1.8-2.4)	p<0.001	2.0 (1.8-2.3)	p<0.001	2.0 (1.7-2.3)	p<0.001	2.0 (1.7-2.3)	p<0.001	2.0 (1.7-2.3)	p<0.001
≤€80,000 (Ref)	*1*		*1*		*1*		*1*		*1*	
€80,001-160,000	1.0 (0.8-1.2)	0.67	1.0 (0.8-1.2)	0.74	1.0 (0.8-1.2)	0.79	1.0 (0.8-1.2)	0.73	1.0 (0.8-1.2)	0.90
€160,001-240,000	0.8 (0.7-1.0)	0.11	0.9 (0.7-1.0)	0.13	0.8 (0.7-1.0)	0.09	0.8 (0.7-1.0)	0.11	0.9 (0.7-1.0)	0.13
€240,001-320,000	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-0.9)	0.01	0.8 (0.7-0.9)	p<0.01	0.8 (0.7-1.0)	0.01	0.8 (0.7-1.0)	0.01
€320,001-400,000	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.5-0.8)	p<0.001
€400,001-480,001	0.6 (0.4-0.9)	0.02	0.6 (0.4-0.9)	0.02	0.6 (0.4-0.9)	0.02	0.6 (0.4-0.9)	0.01	0.6 (0.4-0.9)	0.02
€480,001-560,000	0.6 (0.4-0.7)	p<0.001	0.6 (0.5-0.8)	p<0.001	0.6 (0.4-0.8)	p<0.001	0.6 (0.4-0.7)	p<0.001	0.6 (0.5-0.8)	p<0.001
≥€560,000	0.7 (0.5-0.9)	p<0.01	0.7 (0.6-0.9)	p<0.01	0.7 (0.5-0.9)	p<0.01	0.7 (0.5-0.9)	p<0.01	0.7 (0.5-0.9)	p<0.01
R-sqr(dfres)	302.656 (15)		313.593 (15)		373.463 (15)		366.757 (15)		341.983 (15)	
N	5487		5487		5487		5487		5487	
AIC	7263.7		7252.7		7192.9		7199.6		7224.4	
BIC	7369.4		7358.5		7298.6		7305.3		7330.1	


Dendrogram of 28 chronic conditions in TILDA employing Jaccard distances
Height
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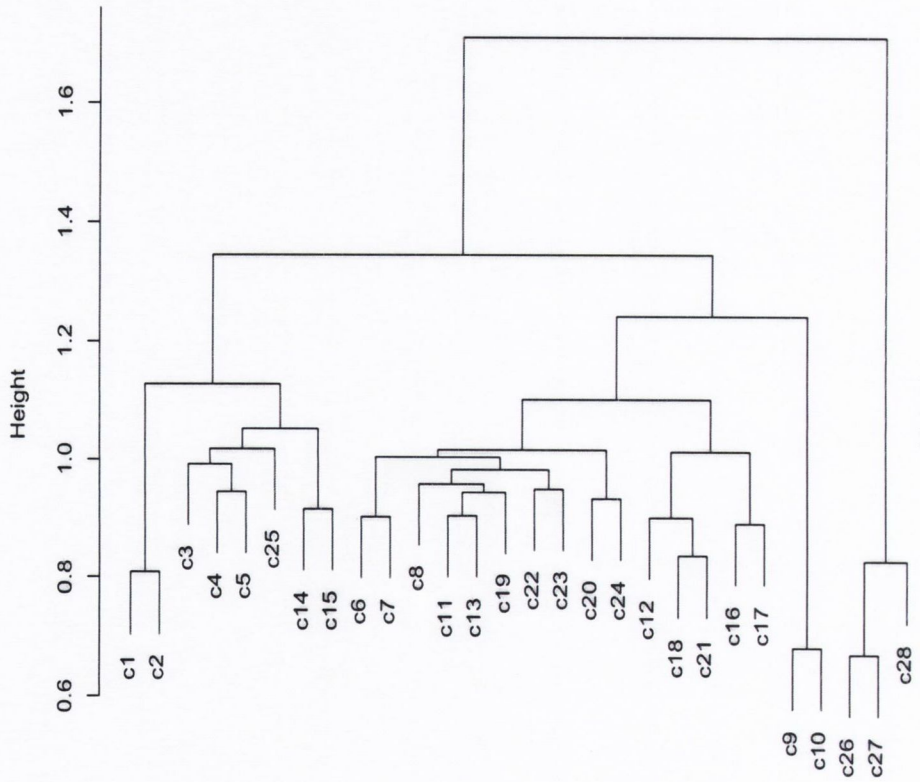
1.0
1.2
1.4
1.6
c1
c2
c9
c10
c3
c4
c5
c25
c14
c15
c6
c7
c8
c20
c22
c23
c24
c11
c13
c12
c19
c16
c17
c18
c21
c26
c27
c28
Agglomerative Coefficient = 0.49

Appendix 3.5

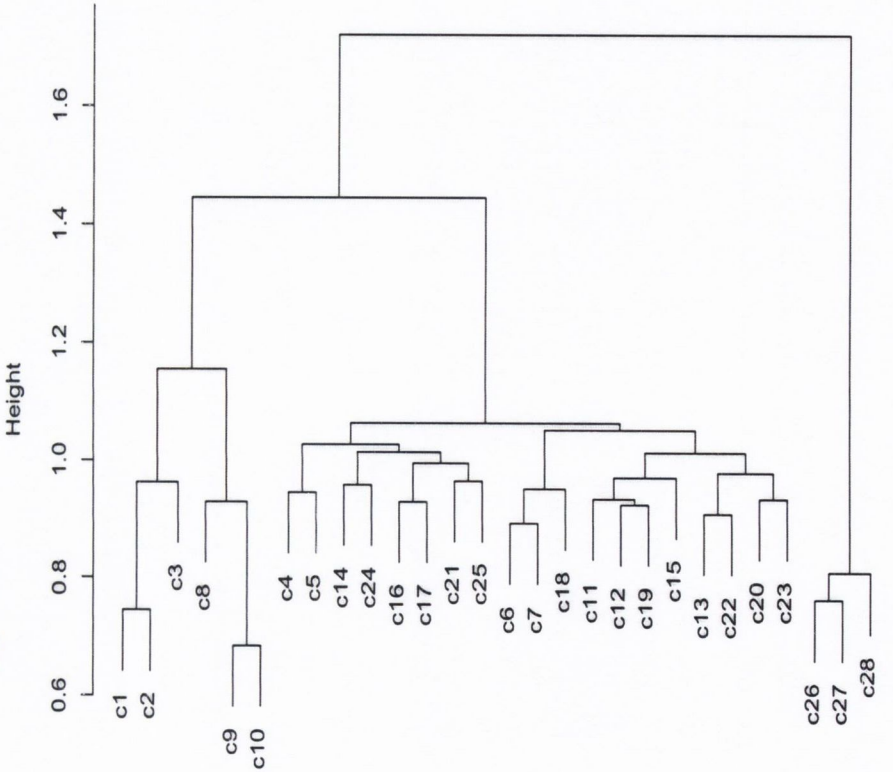
Dendrogram of 28 chronic conditions for women employing Jaccard distances



Agglomerative Coefficient = 0.49

Appendix 3.6

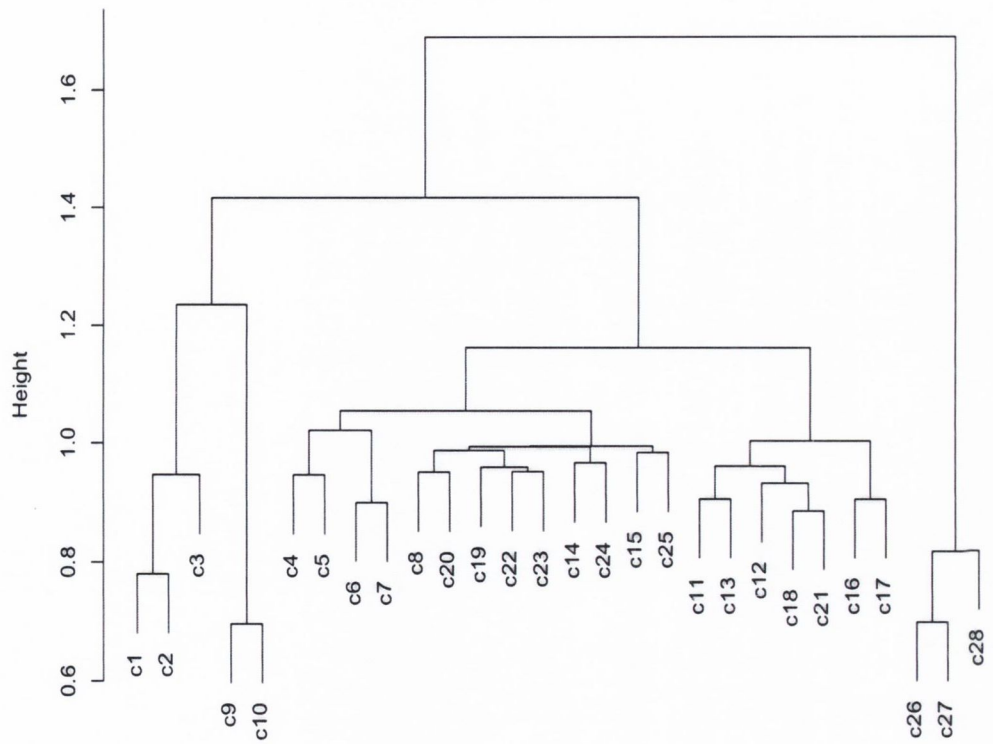
Dendrogram of 28 chronic conditions for men employing Jaccard distances



Agglomerative Coefficient = 0.48

Appendix 3.7

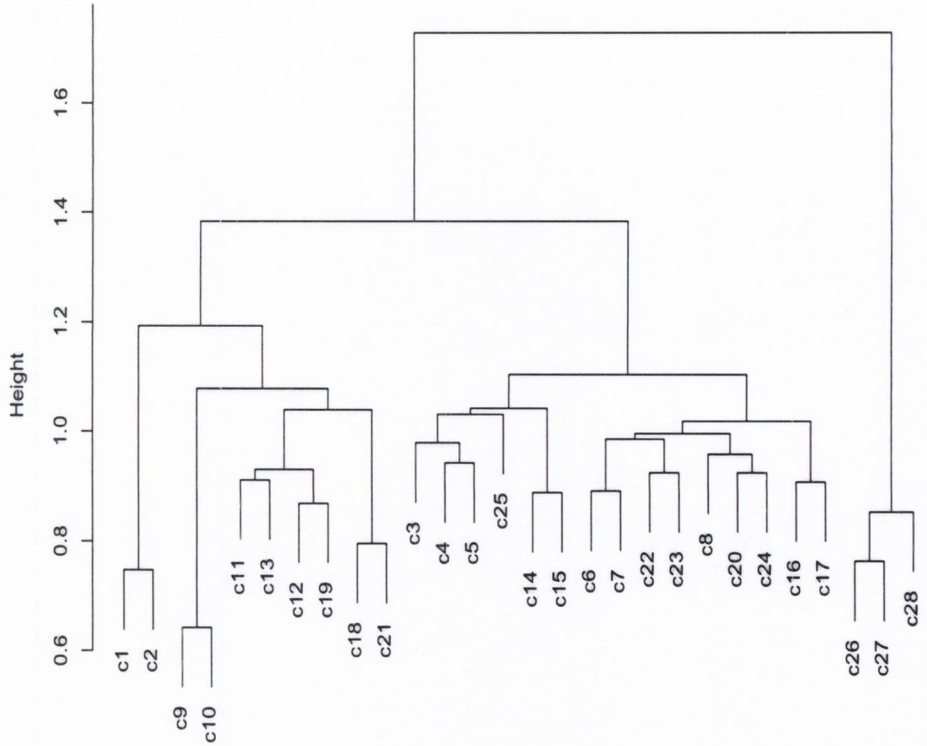
Dendrogram of 28 chronic conditions for aged < 75 years, employing Jaccard distances



Agglomerative Coefficient = 0.48

Appendix 3.8

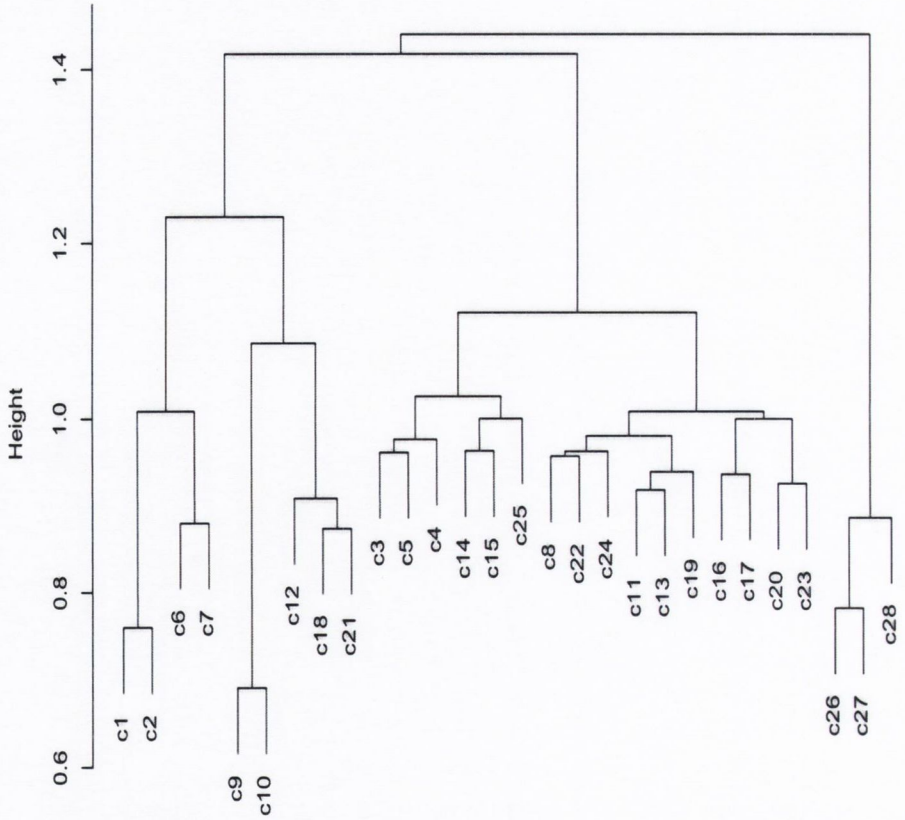
Dendrogram of 28 chronic conditions for aged ≥ 75 years, employing Jaccard distances



Agglomerative Coefficient = 0.5

Appendix 3.9

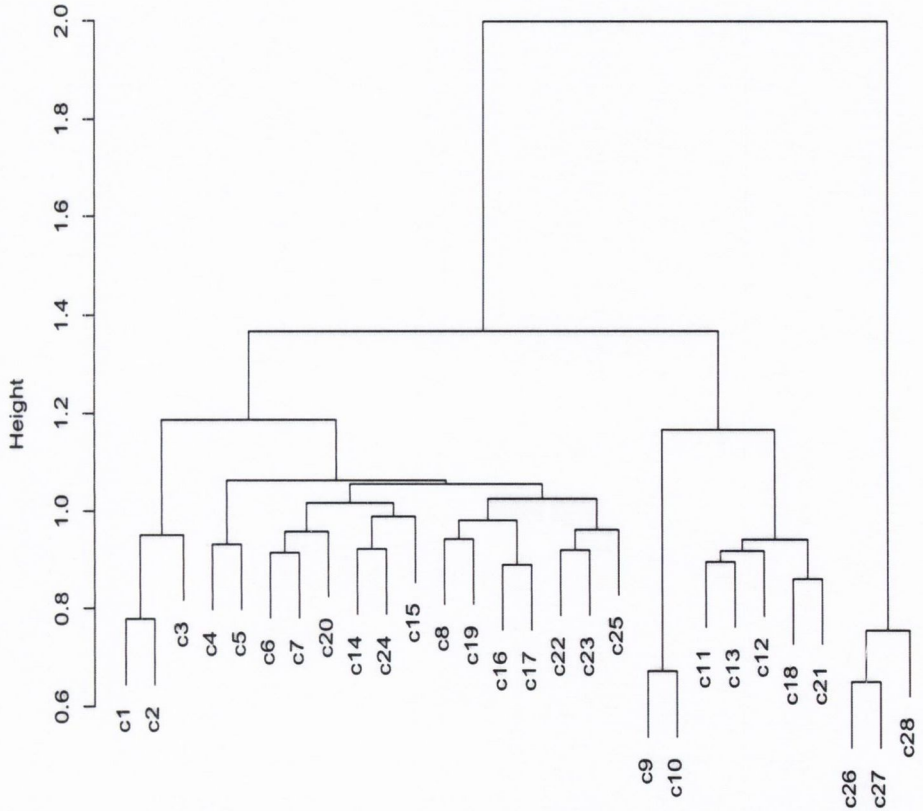
Dendrogram of 28 chronic conditions for most affluent, employing Jaccard distances



Agglomerative Coefficient = 0.38

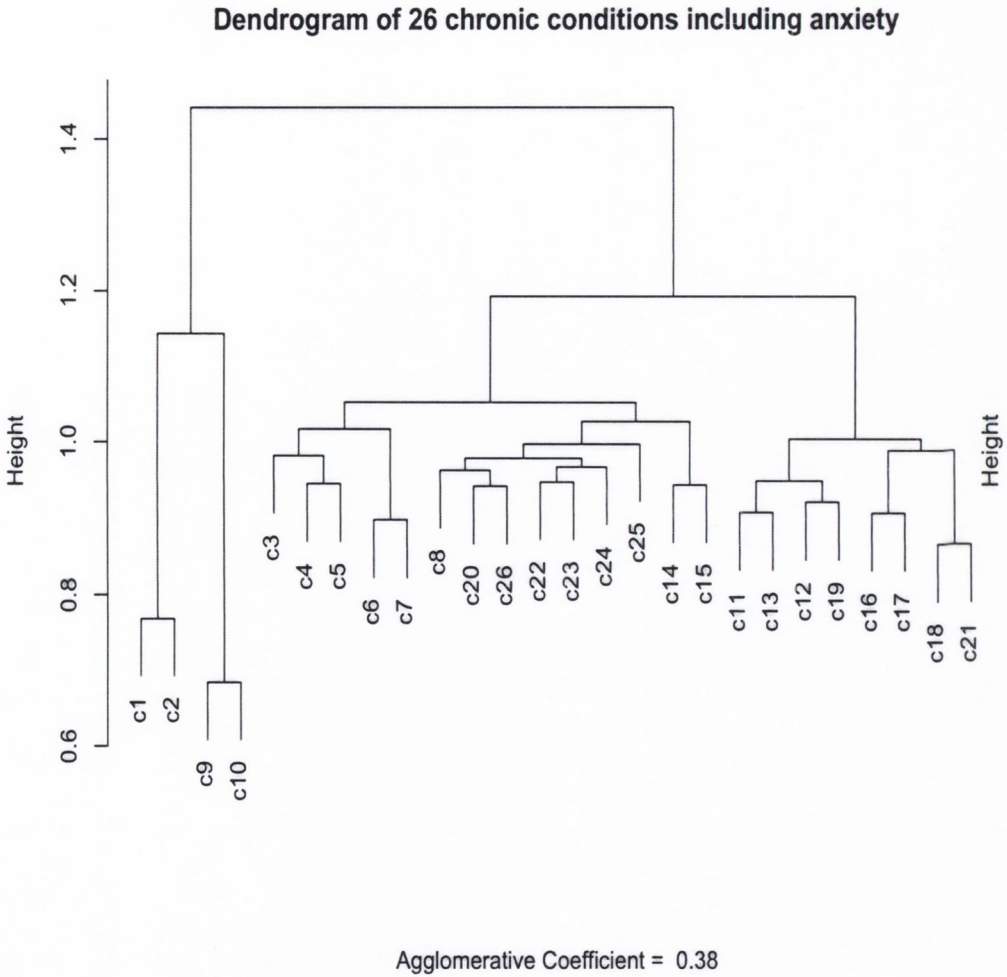
Appendix 3.10

Dendrogram of 28 chronic conditions for most deprived, employing Jaccard distances

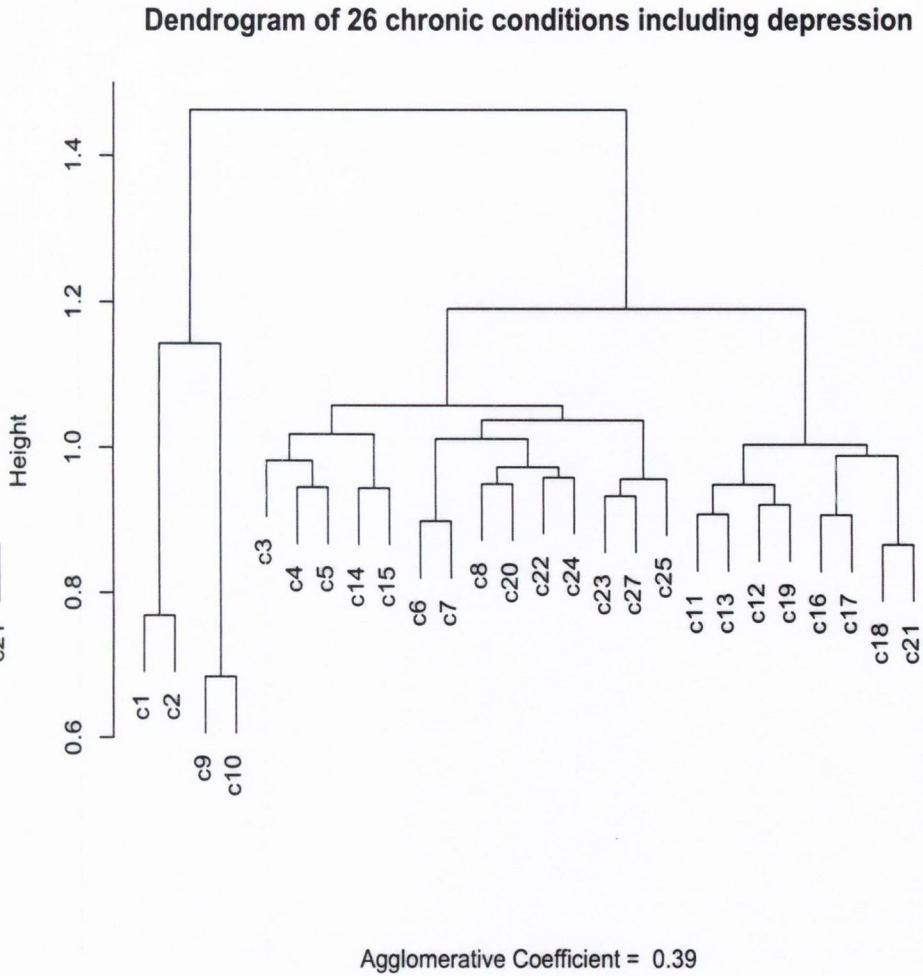


Agglomerative Coefficient = 0.57

Appendix 3.11

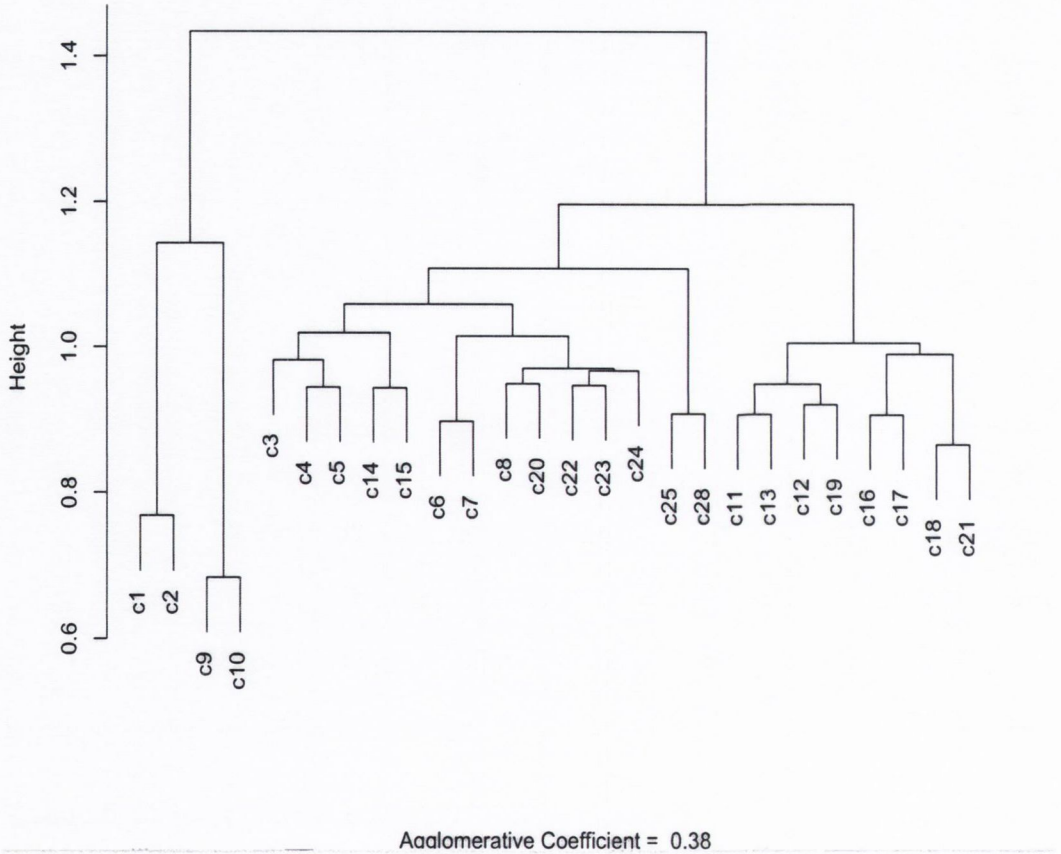


Appendix 3.12



Appendix 3.13

Dendrogram of 26 chronic conditions including other mental health conditions



Agglomerative Coefficient = 0.38

Appendix 4.1 Bivariate logistic and negative binomial regression analyses of Multimorbidity Levels as dependent variable and all independent variables.

	Bivariate logistic		Bivariate zero-truncated	
	Odds Ratio (95% C.I.)	P-value	Incident Rate Ratio (95% C.I.)	P-value
Demographic Factors				
Sex				
Male (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Female	1.4 (1.2-1.5)	<0.001	1.2 (1.1-1.2)	<0.001
Age in 5 years				
50-54 (ref)	1 (1.0-1.0)	.	1 (1.0-1.0)	.
55-59	1.4 (1.2-1.7)	p<0.001	1.3 (1.2-1.4)	p<0.001
60-64	2.1 (1.8-2.4)	p<0.001	1.5 (1.4-1.6)	p<0.001
65-69	3.2 (2.6-3.9)	p<0.001	1.8 (1.7-1.9)	p<0.001
70-74	3.7 (3.0-4.6)	p<0.001	1.9 (1.8-2.1)	p<0.001
75-79	5.0 (3.8-6.5)	p<0.001	2.2 (2.0-2.4)	p<0.001
80-84	4.6 (3.3-6.5)	p<0.001	2.1 (2.0-2.3)	p<0.001
85+	4.4 (2.9-6.7)	p<0.001	2.1 (1.9-2.4)	p<0.001
Nationality				
Irish (ref)	1 (1.0-1.0)	.	1 (1.0-1.0)	.
Northern Irish	0.9 (0.7-1.1)	0.25	1 (0.9-1.1)	0.80
British	1.1 (0.8-1.4)	0.57	1 (0.9-1.1)	0.51
Other	0.6 (0.4-1.0)	0.04	0.8 (0.6-0.9)	p<0.01
Household location			0.062	
Urban (ref)	1 (1.0-1.0)	.	1 (1.0-1.0)	.
Rural	1.3 (1.1-1.4)	p<0.001	1.1 (1.1-1.1)	p<0.001
Economic factors				
Educational Status	124.559		84.710	
Third level + (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Secondary level	1.0 (0.9-1.2)	0.58	1.0 (1.0-1.1)	0.19
Primary or none	1.7 (1.5-2.0)	p<0.001	1.3 (1.3-1.4)	p<0.001
Employment status	109.738		77.300	
Employed /self-employed	1 (1.0-1.0)	.	1 (1.0-1.0)	.
Retired	3.1 (2.7-3.5)	p<0.001	1.8 (1.8-1.9)	p<0.001
Home-maker	2.0 (1.7-2.4)	p<0.001	1.7 (1.6-1.8)	p<0.001
Unemployed or in education/training	1.1 (0.9-1.4)	0.31	1.2 (1.1-1.3)	p<0.001
Permanently sick or disabled	8.8 (5.5-14.0)	p<0.001	2.7 (2.5-2.9)	p<0.001
Unclassed	2.4 (1.4-4.1)	p<0.001	1.7 (1.5-2.0)	p<0.001
Deprivation Decile				
1	1 (1.0-1.0)	.	1 (1.0-1.0)	.
2	0.9 (0.7-1.1)	0.27	1 (0.9-1.1)	0.92
3	1.1 (0.8-1.4)	0.59	1 (0.9-1.1)	0.97
4	0.9 (0.7-1.1)	0.28	0.9 (0.9-1.0)	0.24
5	1.1 (0.9-1.3)	0.57	1 (0.9-1.1)	0.51
6	0.9 (0.7-1.1)	0.39	1 (0.9-1.1)	0.63
7	1.1 (0.9-1.4)	0.37	1 (1.0-1.1)	0.30
8	1.2 (0.9-1.4)	0.22	1 (0.9-1.1)	0.60
9	1.1 (0.9-1.3)	0.41	1.1 (1.0-1.2)	0.00
10	1.3 (1.1-1.6)	p<0.01	1.2 (1.1-1.3)	p<0.001
Lifestyle factors				
Smoking status				
Never (ref)	1 (1.0-1.0)	.	1 (1.0-1.0)	.
Past	1.3 (1.1-1.4)	p<0.001	1.2 (1.1-1.2)	p<0.001
Light	1.4 (1.0-1.9)	0.06	1.1 (1.0-1.3)	0.02
Moderate	1.1 (0.9-1.4)	0.41	1.1 (1.0-1.1)	0.22
Heavy	0.9 (0.7-1.1)	0.32	1.1 (1.0-1.2)	0.00

Alcohol status				
None or rare (ref)	1 (1.0-1.0)	.	1 (1.0-1.0)	.
1-2 days p/w	1.3 (1.1-1.5)	p<0.001	1.2 (1.2-1.3)	p<0.001
3-4 days p/w	1.1 (0.9-1.3)	0.61	1.1 (1.0-1.2)	0.08
Almost every day	1.5 (1.2-1.9)	p<0.001	1.2 (1.1-1.3)	p<0.001
Unclassed	1.1 (0.9-1.3)	0.29	1.2 (1.1-1.3)	p<0.001
Exercise status				
High (ref)	1 (1.0-1.0)	.	1 (1.0-1.0)	.
Moderate	1.4 (1.2-1.6)	p<0.001	1.2 (1.2-1.3)	p<0.001
Low	2.1 (1.8-2.4)	p<0.001	1.5 (1.5-1.6)	p<0.001
Unclassed	0.8 (0.5-1.3)	0.32	1 (0.8-1.2)	0.87
Weight				
Normal (and underweight)	1 (1.0-1.0)	.	1 (1.0-1.0)	.
Overweight	1.1 (1.0-1.3)	0.13	1.0 (1.0-1.1)	0.16
Obese	1.8 (1.5-2.1)	p<0.001	1.4 (1.3-1.40	p<0.001
Unclassed	1.1 (0.9-1.3)	0.29	1.1 (1.0-1.2)	p<0.01
Trouble sleeping				
Rarely/never (ref)	1 (1.0-1.0)	.	1 (1.0-1.0)	.
Sometimes	1.7 (1.5-2.0)	p<0.001	1.3 (1.2-1.3)	p<0.001
Most of the time	2.6 (2.1-3.3)	p<0.001	1.6 (1.5-1.7)	p<0.001
Childhood factors				
Wealth in childhood				
Well off	1 (1.0-1.0)	.	1 (1.0-1.0)	.
Average	0.9 (0.8-1.1)	0.40	1 (0.9-1.0)	0.16
Poor	1.3 (1.0-1.6)	0.02	1.1 (1.0-1.2)	p<0.01
Health in childhood				
Favoirable	1 (1.0-1.0)	.	1 (1.0-1.0)	.
Unfavourable	3.2 (2.3-4.4)	p<0.001	1.5 (1.4-1.6)	p<0.001
Social/ Psychosocial Factors				
Marital Status				
Married	1 (1.0-1.0)	.	1 (1.0-1.0)	.
Widowed	0.9 (0.8-1.1)	0.496	1 (1.0-1.1)	0.165
Separated/divorced	1.3 (1.0-1.6)	0.027	1.2 (1.1-1.3)	p<0.001
Never married	2.4 (2.0-2.9)	p<0.001	1.4 (1.4-1.5)	p<0.001
Social connectedness				
Most integrated (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
moderately integrated	1.0 (0.9-1.2)	0.60	1.1 (1.0-1.0)	<0.01
Moderately isolated	1.0 (0.9-1.2)	0.82	1.1 (1.1-1.2)	<0.001
Most isolated	1.5 (1.1-1.9)	<0.01	1.4 (1.3-1.5)	<0.01
Unclassed	1.0 (0.8-1.1)	<0.59	1.1 (1.1-1.2)	<0.001
Worry				
Not a life worrier	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Life worrier	2.1 (1.6-2.7)	p<0.001	1.5 (1.4-1.6)	p<0.001
Unclassed	1.0 (0.9-1.0)	0.74	1.1 (1.1-1.2)	p<0.001
Access to Healthcare				
Healthcare coverage				
No additional coverage (ref)	1 (1.0-1.0)	.	1 (1.0-1.0)	.
GMS only	2.9 (2.4-3.4)	p<0.001	1.9 (1.7-2.0)	p<0.001
Insurance only	1.3 (1.1-1.5)	p<0.01	1.2 (1.1-1.2)	p<0.001
GMS * insurance	3.9 (3.1-4.8)	p<0.001	1.9 (1.8-2.1)	p<0.001
Distance to GP (in meters)				
Furthest 10% (ref)	1 (1.0-1.0)	.	1 (1.0-1.0)	.
Rest of 4th quintile	0.9 (0.7-1.1)	0.42	0.9 (0.9-1.0)	0.12
3rd quintile	1.1 (0.9-1.3)	0.41	1 (0.9-1.0)	0.24
2nd quintile	1.3 (1.1-1.6)	p<0.01	1.1 (1.0-1.2)	p<0.01
rest of 1st quintile	1.4 (1.1-1.7)	p<0.01	1.1 (1.0-1.2)	p<0.01
Closest 10%	1.2 (0.9-1.5)	0.16	1.1 (1.0-1.2)	0.02

* All variables significant for all independent variables for both logistic and negative binomial regression analysis at the α 0.05 level.

Appendix 4.2

Bivariate multinomial logistic regression analyses of Multimorbidity Type as dependent variable and ≤1 conditions specified as the base category and physical-physical compared to physical-mental, all independent variables significant @ 0.10 level included.

	Bivariate compared to ≤1 condition for Phyiscal-physical mm		Bivariate compared to ≤1 condition for Phyiscal-mental mm		Bivariate compared to phyiscal-physical mm for physical-mental	
	Relative Risk Ratio (95% C.I.)	P-value	Relative Risk Ratio (95% C.I.)	P-value	Relative Risk Ratio (95% C.I.)	P-value
Demographic Factors						
Sex						
Male (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.		
Female	1.3 (1.2-1.4)	<0.001	1.5 (1.2-1.7)	<0.001		
Age in 5 years						
50-54 (ref)	1 (1.0-1.0)	.	1 (1.0-1.0)	.	1.0 (1.0-1.0)	.
55-59	1.8 (1.5-2.1)	p<0.001	1.1 (0.9-1.4)	0.42	0.6 (0.5-0.8)	p<0.01
60-64	2.7 (2.3-3.2)	p<0.001	1.5 (1.1-1.9)	p<0.01	0.6 (0.4-0.7)	p<0.001
65-69	4.2 (3.6-5.0)	p<0.001	1.8 (1.3-2.3)	p<0.001	0.4 (0.3-0.6)	p<0.001
70-74	5.0 (4.2-6.0)	p<0.001	2.1 (1.5-2.8)	p<0.001	0.4 (0.3-0.6)	p<0.001
75-79	7.2 (5.9-8.8)	p<0.001	1.7 (1.2-2.6)	p<0.01	0.2 (0.2-0.4)	p<0.001
80-84	6.4 (5.0-8.2)	p<0.001	1.1 (0.7-2.0)	0.64	0.2 (0.1-0.3)	p<0.001
85+	5.8 (4.3-7.9)	p<0.001	0.9 (0.4-1.9)	0.90	0.2 (0.1-0.3)	p<0.001
Nationality						
Irish (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Northern Irish	0.9 (0.7-1.1)	0.36	1.4 (1.0-2.1)	0.05	1.6 (1.0-2.3)	0.01
British	1.0 (0.8-1.3)	0.91	1.3 (0.8-1.9)	0.27	1.3 (0.8-1.9)	0.25
Other	0.6 (0.4-0.9)	0.01	0.3 (0.1-1.0)	0.05	0.5 (0.2-1.7)	0.27
Household location			0.062			
Urban (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Rural	1.2 (1.1-1.3)	p<0.001	1.5 (1.2-1.8)	p<0.001	1.2 (1.0-1.4)	0.05
Economic factors						
Educational Status						
Third level + (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Secondary level	1.1 (1.0-1.2)	0.15	0.9 (0.7-1.1)	0.21	0.8 (0.7-1.0)	0.05
Primary or none	1.8 (1.6-2.1)	p<0.001	1.3 (1.1-1.7)	p<0.01	0.7 (0.6-0.9)	0.00
Employment status						
Employed /self-employed	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Retired	3.4 (3.0-3.8)	p<0.001	2.7 (2.1-3.3)	p<0.001	0.8 (0.6-1.0)	0.04
Home-maker	2.7 (2.3-3.1)	p<0.001	2.6 (2.0-3.5)	p<0.001	1.0 (0.7-1.3)	0.89
Unemployed or in education/training	1.1 (0.9-1.4)	0.37	2.4 (1.7-3.4)	p<0.001	2.2 (1.5-3.1)	p<0.000
Permanently sick or disabled	5.3 (4.0-6.9)	p<0.01	15.1 (10.7-21.4)	p<0.001	2.9 (2.1-3.9)	p<0.000
Unclassed	2.0 (1.3-3.1)	p<0.001	5.5 (3.1-9.7)	p<0.001	2.7 (1.5-4.9)	p<0.000
Deprivation Decile						
1	1 (1.0-1.0)	.	1 (1.0-1.0)	.	1.0 (1.0-1.0)	.
2	0.8 (0.7-1.0)	0.12	1.3 (0.9-2.1)	0.13	1.6 (1.1-2.4)	0.02
3	1.0 (0.8-1.3)	0.84	0.8 (0.5-1.2)	0.25	0.7 (0.5-1.2)	0.21
4	0.9 (0.7-1.1)	0.36	0.8 (0.5-1.2)	0.24	0.8 (0.5-1.3)	0.46
5	1.0 (0.9-1.2)	0.98	1 .0(0.7-1.5)	0.81	1.0 (0.7-1.5)	0.82
6	0.9 (0.7-1.1)	0.26	1.2 (0.8-1.7)	0.42	1.3 (0.9-2.0)	0.17
7	1.0 (0.8-1.3)	0.77	1.3 (0.9-1.9)	0.16	1.3 (0.9-1.8)	0.22
8	1.0 (0.8-1.2)	0.94	1.1 (0.8-1.6)	0.56	1.1 (0.8-1.6)	0.53
9	1.1 (0.9-1.2)	0.54	1.3 (0.9-1.8)	0.13	1.2 (0.9-1.7)	0.23
10	1.2 (1.1-1.4)	0.03	1.6 (1.2-2.2)	p<0.01	1.3 (1.0-1.8)	0.08
Lifestyle factors						
Smoking status						
Never (ref)	1 (1.0-1.0)	.	1 (1.0-1.0)	.	1.0 (1.0-1.0)	.

Past	1.3 (1.1-1.4)	p<0.001	1.4 (1.2-1.8)	p<0.001	1.1 (0.9-1.4)	0.17
Light	1.2 (0.9-1.6)	0.12	1.9 (1.2-2.9)	p<0.01	1.5 (1.0-2.4)	0.06
Moderate	0.9 (0.8-1.1)	0.50	1.5 (1.0-2.1)	0.03	1.6 (1.1-2.3)	0.01
Heavy	0.9 (0.7-1.0)	0.13	2.5 (1.9-3.3)	p<0.001	2.9 (2.2-3.9)	p<0.001
Alcohol status						
None or rare (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
1-2 days p/w	1.5 (1.3-1.6)	p<0.001	2.1 (1.7-2.7)	p<0.001	1.5 (1.1-1.9)	0.00
3-4 days p/w	1.0 (0.9-1.2)	0.69	1.4 (1.0-2.0)	0.06	1.4 (1.0-1.9)	0.09
Almost every day	1.4 (1.2-1.7)	p<0.001	2.3 (1.7-3.3)	p<0.001	1.7 (1.2-2.4)	0.00
Unclassed	1.2 (1.0-1.4)	0.02	1.9 (1.4-2.5)	p<0.001	1.6 (1.2-2.1)	0.00
Exercise status						
High (ref)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.		
Moderate	1.5 (1.3-1.7)	p<0.001	1.5 (1.2-1.9)	p<0.001		
Low	2.3 (2.0-2.5)	p<0.001	2.2 (1.7-2.7)	p<0.001		
Unclassed	0.8 (0.5-1.2)	0.32	0.9 (0.4-2.4)	0.90		
Weight						
Normal (and underweight)	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Overweight	1.2 (1.0-1.3)	0.05	0.9 (0.7-1.2)	0.62	0.8 (0.6-1.1)	0.13
Obese	1.8 (1.6-2.1)	p<0.001	1.7 (1.3-2.3)	p<0.001	1.0 (0.7-1.2)	0.71
Unclassed	1.3 (1.1-1.4)	p<0.01	1.3 (1.1-1.4)	0.79	0.8 (0.6-1.0)	0.06
Trouble sleeping						
Rarely/never (ref)	1 (1.0-1.0)	.	1 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Sometimes	1.7 (1.5-2.0)	p<0.001	1.3 (1.2-1.3)	p<0.001	1.5 (1.2-1.8)	p<0.001
Most of the time	2.6 (2.1-3.3)	p<0.001	1.6 (1.5-1.7)	p<0.001	2.2 (1.8-2.8)	p<0.001
Childhood factors						
Wealth in childhood						
Well off	1 (1.0-1.0)	.	1 (1.0-1.0)	.		
Average	1.0 (0.9-1.2)	0.93	1.0 (0.7-1.3)	0.84		
Poor	1.1 (0.9-1.3)	0.17	1.5 (1.1-2.0)	0.02		
Health in childhood						
Favorable	1 (1.0-1.0)	.	1 (1.0-1.0)	.		
Unfavourable	2.2 (1.8-2.7)	p<0.001	3.8 (2.8-5.0)	p<0.001	1.7 (1.3-2.3)	p<0.001
Social/ Psychosocial Factors						
Marital Status						
Married	1.0 (1.0-1.0)	.	1 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Widowed	1.0 (0.9-1.2)	0.94	1.6 (1.2-2.1)	p<0.01	1.6 (1.2-2.1)	p<0.000
Separated/divorced	0.9 (0.8-1.1)	0.44	3.0 (2.3-2.6)	p<0.001	3.3 (2.5-4.3)	p<0.000
Never married	2.3 (2.0-2.6)	p<0.001	2.0 (1.6-2.6)	p<0.001	0.9 (0.7-1.1)	0.318
Worry						
Not a life worrier	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.	1.0 (1.0-1.0)	.
Life worrier	1.6 (1.3-1.9)	p<0.001	6.0 (4.7-7.8)	p<0.001	3.8 (3.0-4.8)	p<0.001
Unclassed	1.1 (1.0-1.2)	0.25	1.4 (1.1-1.7)	p<0.01	1.3 (1.0-1.6)	0.03
Access to Healthcare						
Healthcare coverage						
No additional coverage (ref)	1 (1.0-1.0)	.	1 (1.0-1.0)	.		
GMS only	3.3 (2.8-3.9)	p<0.001	3.7 (2.6-5.2)	p<0.001		
Insurance only	1.3 (1.1-1.5)	p<0.01	1.5 (1.0-2.0)	0.03		
GMS * insurance	4.1 (3.4-4.9)	p<0.001	4.0 (2.8-5.8)	p<0.001		

Empty cells indicate non significant variables @ bivariate level.

Appendix 5. 1

Mean number of healthcare utilisation visits by chronic condition ranked in order from highest to lowest use for GP visits, outpatient visits and hospital length of stay.

General Practitioner		Outpatient		Hospital length of stay	
	Mean ± SD		Mean ± SD		Mean ± SD
Vision	8.3 ± 14.3	Cirrhosis	3.6 ± 9.6	Memory disorder	6.8 ± 24.6
Memory disorder	8.2 ± 10.5	Cancer	3.0 ± 9.5	Stroke/TIA	4.5 ± 14.0
Parkinson's	7.9 ± 13.5	Stroke/TIA	2.1 ± 6.1	Parkinson's	4.5 ± 16.2
Stroke/TIA	7.8 ± 7.7	Heart failure	2.1 ± 4.8	Vision	3.5 ± 15.5
Other mental health condition	7.1 ± 8.1	Heart Murmur	2.0 ± 7.2	Heart failure	3.0 ± 8.2
Heart failure	6.7 ± 8.6	Diabetes	1.7 ± 5.9	Hearing	3.0 ± 15.4
Heart rhythm	6.6 ± 8.6	Heart Rhythm	1.5 ± 5.2	Cancer	2.6 ± 16.2
Cirrhosis	6.1 ± 5.5	High Blood pressure	1.4 ± 5.2	Osteoporosis	2.6 ± 10.7
Hearing	6.1 ± 7.1	Stomach ulcer	1.4 ± 4.8	Other mental health condition	2.4 ± 12.8
Alcohol or substance	6.0 ± 6.9	Vision	1.4 ± 3.7	Angina or heart attack	2.2 ± 8.7
Depression	6.0 ± 6.4	Parkinson's	1.4 ± 2.8	Heart rhythm	2.2 ± 9.9
Stomach	5.9 ± 9.0	Alcohol or substance	1.3 ± 5.9	Anxiety	2.0 ± 15.6
Diabetes	5.9 ± 6.3	Other mental health condition	1.3 ± 5.4	Incontinence	1.9 ± 10.9
Respiratory	5.9 ± 7.5	Incontinence	1.3 ± 5.2	Depression	1.8 ± 14.4
Anxiety	5.9 ± 6.4	Angina or heart attack	1.3 ± 4.8	Cirrhosis	1.6 ± 6.3
Cancer	5.8 ± 6.0	Respiratory	1.2 ±6.1	Varicose	1.5 ± 9.1
Arthritis	5.6 ± 6.2	Hearing	1.2 ± 4.9	Heart murmur	1.3 ± 7.3
Incontinence	5.6 ± 6.1	Falls/Fractures	1.2 ±4.3	Diabetes	1.3 ± 8.2
Heart murmur	5.4 ± 5.5	Anxiety	1.2 ± 4.3	Alcohol or substance	1.1 ± 7.0
Varicose	5.3 ± 7.5	Depression	1.1 ± 4.0	Falls or fracture	1.1 ± 7.6
Osteoporosis	5.3 ± 6.2	Arthritis	1.0 ± 3.6	Respiratory	1.1 ± 6.7
High blood pressure	5.3 ± 5.4	Osteoporosis	1.1 ± 3.4	Arthritis	0.9 ± 6.8
Falls or fracture	4.9 ± 6.1	Varicose ulcer	1.1 ± 3.1	High blood pressure	0.8 ± 7.6
High cholesterol	4.9 ± 5.8	High Cholesterol	1.0 ± 4.6	Stomach	0.8 ± 5.0
Angina or heart attack	4.0 ± 5.4	Memory disorder	0.9 ± 2.1	High cholesterol	0.6 ± 6.3

Appendix 5.2

Quality of care indicators by chronic condition ranked in order from highest to lowest use for Emergency Department visits and polypharmacy.

Frequent Emergency Department visits		Polypharmacy > 5 medications	
	Weighted % (95% CI's)		Weighted % (95% CI's)
Heart failure	10.5 (5.4-19.5)	Heart failure	76.4 (65.9-84.5)
Memory disorder	6.4 (2.1-17.7)	Angina or heart attack	66.1 (62.2-67.8)
Stroke/TIA	5.3 (3.3-8.4)	Diabetes	62.6 (58.5-66.6)
Hearing	5.0 (2.5-9.7)	Stroke/TIA	60.0 (53.8-65.9)
Anxiety	4.7 (2.8-7.6)	Parkinson's	59.1 (42.8-73.5)
Respiratory	4.4 (3.2-6.0)	Memory disorder	51.4 (36.9-65.7)
Heart rhythm	4.4 (3.0-6.6)	Heart rhythm	49.7 (45.3-54.1)
Angina or heart attack	4.2 (2.8-6.3)	Vision	47.2 (38.8-55.9)
Depression	4.2 (2.6-6.8)	High cholesterol	41.6 (39.3-43.9)
Vision	4.0 (1.8-8.8)	High blood pressure	40.4 (38.4-42.5)
Varicose	3.7 (1.8-7.4)	Osteoporosis	39.1 (35.4-43.0)
Parkinson's	3.5 (0.8-13.6)	Heart murmur	38.5 (33.4-43.8)
Falls or fracture	3.4 (2.6-4.6)	Other mental health condition	38.3 (31.4-45.7)
Stomach	3.4 (2.2-5.4)	Incontinence	37.6 (33.9-41.5)
Incontinence	3.3 (2.2-4.9)	Respiratory	37.4 (34.2-40.7)
Osteoporosis	3.1 (2.0-4.8)	Cirrhosis	37.1(23.9-52.6)
Other mental health condition	3.0 (1.8-8.1)	Hearing	36.3 (29.5-43.6)
Alcohol or substance	2.9 (1.0-8.0)	Anxiety	36.2 (31.3-41.4)
Arthritis	2.7 (2.1-3.6)	Arthritis	35.8 (33.7-38.0)
Cancer	2.7 (1.6-4.6)	Depression	35.8 (31.2-40.7)
High blood pressure	2.3 (1.8-3.0)	Varicose	35.1(29.3-41.5)
High cholesterol	2.3 (1.7-3.1)	Cancer	31.8 (27.7-36.3)
Diabetes	2.2 (1.3-3.8)	Stomach	28.9 (25.1-33.0)
Heart murmur	1.7 (1.4-2.0)	Falls or fracture	28.8 (26.3-31.4)
Cirrhosis	0	Alcohol or substance	27.9 (20.7-36.3)

Appendix 5.3

Quality of care indicators by chronic condition ranked in order from highest to lowest use for Emergency Department visits and polypharmacy.

Public Health Nurse visit		Formal Care Assistance	
	Weighted % (95% CI's)		Weighted % (95% CI's)
Parkinson's	46.8 (31.3-63.0)	Parkinson's	34.0 (19.9-51.7)
Memory disorder	26.4 (15.2-41.6)	Vision	15.0 (10.0-22.1)
Vision	24.3 (17.6-32.6)	Stroke/TIA	13.8 (9.6-19.6)
Hearing	17.8 (12.7-24.5)	Memory disorder	12.7 (5.6-26.2)
Varicose	17.3 (12.9-22.8)	Varicose	11.7 (8.0-16.9)
Angina or heart attack	16.5 (13.6-19.8)	Incontinence	10.4 (8.1-13.1)
Incontinence	16.4 (13.6-19.8)	Angina or heart attack	10.2 (7.8-13.1)
Heart rhythm	15.7 (12.7-19.2)	Hearing	10.1 (6.4-15.6)
Heart failure	15.5 (9.1-25.0)	Heart rhythm	9.3 (7.0-12.4)
Stroke/TIA	15.2 (11.4-20.1)	Osteoporosis	9.0 (6.8-11.9)
Cancer	13.7 (10.8-17.4)	Cirrhosis	7.8 (2.7-20.9)
Heart murmur	13.4 (10.2-17.4)	Arthritis	7.6 (6.4-9.1)
Cirrhosis	12.7 (5.5-26.5)	Diabetes	6.9 (4.9-9.6)
Diabetes	12.0 (9.5-15.0)	Heart murmur	6.8 (4.5-10.2)
Osteoporosis	11.8 (9.4-14.6)	Respiratory	6.3 (4.7-8.2)
Arthritis	11.3 (9.9-12.8)	Cancer	6.1 (4.0-9.2)
Other mental health condition	10.7 (6.9-16.3)	High blood pressure	5.9 (4.9-7.1)
Stomach	10.5 (8.1-13.6)	Stomach	5.7 (3.6-8.8)
High blood pressure	10.2 (8.9-11.6)	Depression	5.5 (3.6-8.3)
Depression	10.2 (7.4-13.7)	Other mental health condition	5.4 (2.9-9.7)
Alcohol or substance	9.6 (5.4-16.5)	Falls or fracture	5.0 (3.8-6.4)
Falls or fracture	9.3 (7.8-11.1)	High cholesterol	4.9 (3.9-6.1)
Respiratory	8.9 (7.1-11.1)	Anxiety	4.9 (3.0-7.8)
High cholesterol	7.9 (6.7-9.2)	Alcohol or substance	4.0 (1.8-9.0)
Anxiety	7.3 (5.0-10.7)	Heart failure	3.6 (1.2-10.7)

Appendix 5.4

	Bivariate models for GP visits	
GP visits	**Crude OR (95% CI)**	**P-value**
Need Factors		
Primary independent variables of interest		
Multimorbidity		
0 (ref)	1.0 (1.0-1.0)	.
1	2.3 (2.0-2.7)	<0.001
2	5.2 (4.2-6.3)	<0.001
3	12.5 (8.9-17.7)	<0.001
4	15.7 (9.7-25.3)	<0.001
5	17.1 (8.7-33.3)	<0.001
6	27.1 (12.0-61.2)	<0.001
Multimorbidity type		
< 1 condition (ref)	1.0 (1.0-1.0)	.
Physical multimorbidity	5.6 (4.7-6.6)	<0.001
Physical + mental multimorbidity	6.1 (4.1-9.1)	<0.001
Disability		
No ADL (ref)	1.0 (1.0-1.0)	.
ADL	4.4 (3.1-6.3)	<0.000
Frailty		
Not frail (ref)	1.0 (1.0-1.0)	.
Prefrail	2.2 (1.8-2.7)	<0.001
Frail	9.3 (3.0-29.32)	<0.001
Unclassed	1.2 (1.0-1.4)	0.011
Self-rated health		
Not negative self-rated health (ref)	1.0 (1.0-1.0)	.
Negative self-rated health	4.4 (3.5-5.7)	<0.001
Predisposing Factors		
Sex		
Male (ref)	1.0 (1.0-1.0)	.
Female	1.3 (1.2-1.5)	<0.001
Age		
50-59 (ref)	1.0 (1.0-1.0)	.
60-69	1.9 (1.6-2.2)	<0.001
70-79	4.4 (3.5-5.5)	<0.001
80+	5.7 (3.8-8.5)	<0.001
Nationality		
Irish (ref)	1.0 (1.0-1.0)	.
Northern Irish	0.7 (0.5-0.9)	<0.01
British	0.8 (0.6-1.2)	0.30
Other	0.5 (0.3-0.8)	<0.01
Enabling Factors		
Living arrangement		
With other persons (ref)	1.0 (1.0-1.0)	.
With spouse	1.8 (1.5-2.0)	<0.001

Living alone	2.0 (1.6-2.4)	<0.001
Healthcare coverage		
No additional coverage (includes GP card only) (ref)	1.0 (1.0-1.0)	.
GMS only	4.8 (3.8-5.9)	<0.001
Insurance only	1.6 (1.3-1.9)	<0.001
Dual cover	7.2 (5.3-9.7)	<0.001
Employment status		
Employed or in educaiton/training (ref)	1.0 (1.0-1.0)	.
Retired	0.5 (0.4-0.6)	<0.001
Home-maker	1.1 (0.9-1.4)	0.27
Unemployed	0.6 (0.4-0.7)	<0.001
Permanently sick or disabled	4.0 (2.3-7.2)	<0.001
Unclassed	2.2 (0.9-5.0)	0.07
Health behaviours		
Exercise status		
High (ref)	1.0 (1.0-1.0)	.
Moderate	1.6 (1.4-1.9)	<0.001
Low	2.2 (1.8-2.6)	<0.001
Unclassed	0.7 (0.4-1.2)	0.15
Trouble sleeping		
Rarely/never (ref)	1.0 (1.0-1.0)	.
Sometimes	1.6 (1.4-1.9)	<0.001
Most of the time	2.1 (1.6-2.7)	<0.001

Appendix 5.5

	Bivariate models for OP visits	
OP visits	**Crude OR (95% CI)**	**P-value**
Need Factors		
Primary independent variables of interest		
Multimorbidity		
0 (ref)	*1.0 (1.0-1.0)*	.
1	2.0 (1.6-2.5)	<0.001
2	3.2 (2.6-4.0)	<0.001
3	3.5 (2.8-4.4)	<0.001
4	4.2 (3.2-5.3)	<0.001
5	5.7 (4.3-7.5)	<0.001
6	6.5 (5.0-8.7)	<0.001
Multimorbidity type		
< 1 condition (ref)	*1.0 (1.0-1.0)*	.
Physical multimorbidity	2.6 (2.3-2.9)	<0.001
Physical + mental multimorbidity	2.9 (2.3-3.5)	<0.001
Other Need Factors		
Disability		
No ADL (ref)	*1.0 (1.0-1.0)*	.
ADL	1.8 (1.4-2.3)	<0.001
Frailty		
Not frail (ref)	*1.0 (1.0-1.0)*	.
Prefrail	1.5 (1.3-1.7)	<0.001
Frail	2.2 (1.6-3.1)	<0.001
Unclassed	0.9 (0.8-1.0)	0.06
Self-rated Health		
Not negative self-rated health (ref)	*1.0 (1.0-1.0)*	.
Negative self-rated health	2.5 (2.2-2.8)	<0.001
Predisposing Factors		
Sex		
Male (ref)	*1.0 (1.0-1.0)*	.
Female	1.0 (0.9-1.1)	0.68
Age		
50-59 (ref)	*1.0 (1.0-1.0)*	.
60-69	1.3 (1.1-1.4)	<0.001
70-79	1.2 (1.1-1.4)	<0.01
80+	0.7 (0.5-0.9)	<0.001
Nationality		
Irish (ref)	*1.0 (1.0-1.0)*	.
Northern Irish	1.1 (0.8-1.4)	0.67
British	1.1 (0.8-1.5)	0.49
Other	0.5 (0.3-1.0)	0.04
Enabling Factors		
Living arrangement		
With other persons (ref)	*1.0 (1.0-1.0)*	.
With spouse	1.2 (1.1-1.4)	<0.01
Living alone	1.1 (0.9-1.3)	0.33
Healthcare coverage		

No additional coverage (includes GP card only)	*1.0 (1.0-1.0)*	.
GMS only	0.8 (0.7-1.0)	0.01
Insurance only	0.8 (0.6-0.9)	<0.01
GMS * insurance (ref)	0.6 (0.5-0.7)	<0.001
Educational Status		
Third level +	*1.0 (1.0-1.0)*	.
Secondary level	0.8 (0.7-0.9)	<0.01
Primary or none	0.8 (0.7-0.9)	<0.01
Employment status	(ref)	
Employed or in educaiton/training (ref)	*1.0 (1.0-1.0)*	.
Retired	0.9 (0.7-1.1)	0.14
Home-maker	0.9 (0.7-1.0)	0.10
Unemployed	1.0 (0.7-1.3)	0.80
Permanently sick or disabled	2.0 (1.6-2.5)	<0.001
Unclassed	1.3 (0.8-2.1)	0.27
Health behaviours		
Smoking status		
Never (ref)	*1.0 (1.0-1.0)*	.
Past	1.3 (1.2-1.5)	<0.001
Light	1.3 (1.0-1.8)	0.08
Moderate	0.8 (0.6-1.1)	0.23
Heavy	0.9 (0.7-1.2)	0.57
Alcohol status		
None or rare (ref)	*1.0 (1.0-1.0)*	.
1-2 days p/w	0.9 (0.8-1.1)	0.43
3-4 days p/w	1.2 (1.0-1.5)	0.03
Almost every day	1.2 (1.0-1.5)	0.08
Unclassed	0.9 (0.8-1.1)	0.21

Appendix 5.6

	Bivariate logistic models for number of nights in hospital (at least one night spent in hospital)	
Number of nights in hospital	**Crude OR (95% CI)**	**P-value**
Need Factors		
Primary independent variables of interest		
Multimorbidity		
0 (ref)	*1.0 (1.0-1.0)*	.
1	1.7 (1.3-2.3)	<0.001
2	2.9 (2.3-3.8)	<0.001
3	3.7 (2.8-4.8)	<0.001
4	4.6 (3.5-6.2)	<0.001
5	7.0 (5.1-9.6)	<0.001
6 +	8.0 (5.8-10.7)	<0.001
Multimorbidity type		
< 1 condition (ref)	*1.0 (1.0-1.0)*	.
Physical multimorbidity	3.0 (2.6-3.5)	<0.001
Physical + mental multimorbidity	2.6 (2.1-3.4)	<0.001
Other Need Factors		
Disability		
No ADL	*1.0 (1.0-1.0)*	.
ADL	1.9 (1.5-2.5)	<0.001
Frailty		
Not frail (ref)	*1.0 (1.0-1.0)*	.
Prefrail	2.2 (1.9-2.6)	<0.001
Frail	6.6 (4.7-9.2)	<0.001
Unclassed	1.6 (1.4-1.9)	<0.001
Predisposing Factors		
Self-rated Health		
Not negative self-rated health (ref)	*1.0 (1.0-1.0)*	.
Negative self-rated health	3.3 (2.9-3.8)	<0.001
Sex		
Male (ref)	*1.0 (1.0-1.0)*	.
Female	1.0 (0.9-1.1)	0.69
Age		
50-59 (ref)	*1.0 (1.0-1.0)*	.
60-69	1.3 (1.1-1.5)	<0.01
70-79	1.8 (1.5-2.1)	<0.001
80+	1.6 (1.3-2.1)	<0.001
Enabling Factors		
Healthcare coverage		
No additional coverage (ref)	*1.0 (1.0-1.0)*	.
GMS only	2.7 (2.1-3.6)	<0.001
Insurance only	1.6 (1.2-2.2)	<0.01
Dual cover	3.0 (2.2-4.0)	<0.001
Educational Status		
Third level + (ref)	*1.0 (1.0-1.0)*	.
Secondary level	1.0 (0.9-1.2)	0.68
Primary or none	1.2 (1.0-1.5)	0.02

Employment status		
Employed or in educaiton/training (ref)	*1.0 (1.0-1.0)*	.
Retired	0.8 (0.7-1.1)	0.14
Home-maker	1.0 (0.8-1.2)	0.87
Unemployed	0.8 (0.6-1.2)	0.32
Permanently sick or disabled	2.5 (2.0-3.3)	<0.001
Unclassed	1.8 (1.1-2.9)	0.02
Health behaviours		
Smoking status		
Never (ref)	*1.0 (1.0-1.0)*	.
Past	1.2 (1.0-1.3)	0.04
Light	1.3 (1.0-1.9)	0.09
Moderate	1.0 (0.8-1.4)	0.79
Heavy	1.1 (0.9-1.4)	0.41
Exercise status		
High (ref)	*1.0 (1.0-1.0)*	.
Moderate	1.3 (1.1-1.6)	<0.001
Low	2.1 (1.8-2.5)	<0.001
Unclassed	0.4 (0.1-1.3)	0.11

Appendix 5.7

Emergency Department visits	Bivariate logistic models for Emergency Department visits (at least one night spent in hospital)	
	Crude OR (95% CI)	P-value
Need Factors		
Primary independent variables of interest		
Multimorbidity		
0 (ref)	*1.0 (1.0-1.0)*	.
1	1.4 (0.7-3.0)	0.34
2	1.0 (0.4-2.3)	1.00
3	3.5 (1.7-7.1)	<0.01
4	5.1 (2.5-10.5)	<0.001
5	5.1 (2.2-11.7)	<0.001
6	15.0 (7.6-29.8)	<0.001
Multimorbidity type		
< 1 condition (ref)		
Physical multimorbidity		
Physical + mental multimorbidity		
Other Need Factors		
Disability		
No ADL (ref)	1.0 (1.0-1.0)	.
ADL	2.0 (1.1-3.7)	0.02
Frailty		
Not frail (ref)	*1.0 (1.0-1.0)*	.
Prefrail	3.2 (2.0-5.2)	<0.001
Frail	11.6 (6.1-22.3)	<0.001
Unclassed	2.5 (1.6-3.9)	<0.001
Self-rated Health		
No NegSRH (ref)	*1.0 (1.0-1.0)*	.
NegSRH	4.8 (3.4-6.8)	<0.001
Predisposing Factors		
Sex		
Male (ref)	*1.0 (1.0-1.0)*	.
Female	1.0 (0.7-1.4)	0.84
Age		
80+ (ref)	*1.0 (1.0-1.0)*	.
70-79	*1.1 (0.9-1.5)*	0.91
60-69	1.0 (0.7-1.2)	0.85
50-59	0.9 (0.7-12)	0.18
Enabling Factors		
Medical card coverage		
No GMS medical card (ref)	*1.0 (1.0-1.0)*	.
GMS medical card		
Employment status		
Employed or in educaiton/training (ref)	*1.0 (1.0-1.0)*	.
Retired	0.7 (0.3-1.3)	0.26
Home-maker	0.8 (0.4-1.4)	0.39
Unemployed	0.3 (0.1-1.4)	0.13
Permanently sick or disabled	5.8 (3.8-9.0)	<0.001
Unclassed	0.6 (0.1-4.6)	0.65

Appendix 5.8

Polypharmacy	Bivariate logistic models for polypharmacy	
	Crude OR (95% CI)	P-value
Need factors		
Primary independent variables of interest		
Multimorbidity		
0 (ref)	*1.0 (1.0-1.0)*	.
1	4.5 (2.9-6.9)	<0.001
2	12.3 (8.2-18.5)	<0.001
3	31.4 (20.9-47.1)	<0.001
4	69.4 (45.8-105.1)	<0.001
5	94.2 (60.8-146.1)	<0.001
6	208.4 (132.7-327.2)	<0.001
Multimorbidity type		
< 1 condition (ref)		
Physical multimorbidity		
Physical + mental multimorbidity		
Other Need Factors		
Self-rated Health (R2)	**937.166**	
No NegSRH (ref)	*1.0 (1.0-1.0)*	.
NegSRH	6.2 (5.5-7.0)	<0.001
Disability (R2)	**114.637**	
No ADL (ref)	1.0 (1.0-1.0)	.
ADL	3.3 (2.7-4.1)	<0.001
Frailty (R2)	**437.720**	
Not frail (ref)	*1.0 (1.0-1.0)*	.
Prefrail	3.3 (2.8-3.8)	<0.001
Frail	12.9 (9.2-18.2)	<0.001
Unclassed	1.9 (1.7-2.2)	<0.001
Predisposing Factors		
Sex		
Female (ref)	*1.0 (1.0-1.0)*	.
Male	1.1 (1.0-1.2)	0.19
Age (R2)	**600.301**	
50-59 (ref)	*1.0 (1.0-1.0)*	.
60-69	2.3 (2.0-2.7)	<0.001
70-79	5.0 (4.3-5.8)	<0.001
80+	6.5 (5.4-8.0)	<0.001
Enabling Factors		
Living arrangement	**177.036**	
With other persons (ref)	*1.0 (1.0-1.0)*	.
With spouse	1.9 (1.7-2.2)	<0.001
Living alone	2.5 (2.2-2.9)	<0.001
Medical card coverage	**596.780**	
No GMS medical card (ref)	*1.0 (1.0-1.0)*	.
GMS medical card	4.3 (3.8-4.9)	<0.001
Employment status	**289.114**	
Employed or in educaiton/training (ref)	*1.0 (1.0-1.0)*	.
Retired	0.3 (0.3-0.4)	<0.001
Home-maker	1.1 (1.0-1.3)	0.084
Unemployed	0.5 (0.3-0.6)	<0.001
Permanently sick or disabled	3.7 (3.0-4.6)	<0.001
Unclassed	1.2 (0.8-1.9)	0.412

Health behaviours		
Smoking status	**48.290**	
Never (ref)	*1.0 (1.0-1.0)*	.
Past	1.5 (1.3-1.7)	<0.001
Light	1.1 (0.8-1.5)	0.522
Moderate	1.1 (0.9-1.4)	0.501
Heavy	1.0 (0.9-1.3)	0.672
Alcohol status	**93.514**	
None or rare (ref)	*1.0 (1.0-1.0)*	.
1-2 days p/w	0.6 (0.5-0.6)	<0.001
3-4 days p/w	0.5 (0.4-0.6)	<0.001
Almost every day	0.8 (0.7-1.0)	0.066
Unclassed	0.8 (0.7-0.9)	<0.001
Exercise status	**247.298**	
High (ref)	*1.0 (1.0-1.0)*	.
Moderate	1.8 (1.5-2.0)	<0.001
Low	3.0 (2.6-3.4)	<0.001
Unclassed	1.2 (0.6-2.3)	0.574

Appendix 5.9

Public Health Nurse	Bivariate logistic models (at least one night spent in hospital)	
	Crude OR (95% CI)	**P-value**
Need Factors		
Primary independent variables of interest		
Multimorbidity		
0 (ref)	*1.0 (1.0-1.0)*	.
1	2.5 (1.5-4.2)	<0.001
2	4.8 (3.0-7.9)	<0.001
3	6.3 (3.8-10.3)	<0.001
4	10.0 (6.0-16.5)	<0.001
5	15.8 (9.4-26.6)	<0.001
6	28.2 (17.2-46.3)	<0.001
Multimorbidity type		
< 1 condition (ref)		
Physical multimorbidity	4.7 (3.7-6.0)	<0.001
Physical + mental multimorbidity	5.0 (3.5-7.1)	<0.001
Other Need Factors		
Self-rated Health		
Not negative self-rated health (ref)	*1.0 (1.0-1.0)*	.
Negative self-rated health	4.2 (3.5-5.1)	<0.001
Disability		
No ADL (ref)	1.0 (1.0-1.0)	.
ADL	2.0 (1.5-2.9)	<0.001
Frailty		
Not frail (ref)	*1.0 (1.0-1.0)*	.
Prefrail	4.8 (3.7-6.4)	<0.001
Frail	26.1 (17.7-38.7)	<0.001
Unclassed	4.2 (3.2-5.5)	<0.001
Predisposing Factors		
Sex		
Male (ref)	*1.0 (1.0-1.0)*	.
Female	1.3 (1.1-1.6)	<0.01
Age		
50-59 (ref)	*1.0 (1.0-1.0)*	.
60-69	1.7 (1.2-2.4)	<0.001
70-79	5.8 (4.3-7.7)	<0.001
80+	14.3 (10.6-19.4)	<0.001
Enabling Factors		
Living arrangement		
With other persons (ref)	*1.0 (1.0-1.0)*	.
With spouse	1.2 (0.9-0.5)	0.13
Living alone	3.2 (2.5-4.0)	<0.001

Healthcare coverage		
Dual cover (ref)	*1.0 (1.0-1.0)*	.
Insurance only	0.1 (0.1-0.1)	<0.001
GMS only	1.4 (1.1-1.7)	<0.01
No additional coverage (includes GP card only)	0.1 (0.0-0.2)	<0.001
Employment status		
Employed or in educaiton/training (ref)	*1.0 (1.0-1.0)*	.
Retired	0.3 (0.2-0.5)	<0.001
Home-maker	1.2 (1.0-1.6)	0.08
Unemployed	0.2 (0.1-0.5)	<0.001
Permanently sick or disabled	2.9 (2.2-4.0)	<0.001
Unclassed	1.3 (0.6-2.7)	0.46
Distance to Community/General hospital or GP		
Furthest 10% (ref)	1.0 (1.0-1.0)	.
Rest of 4th quintile	1.1 (0.7-1.7)	0.65
3rd quintile	1.1 (0.8-1.6)	0.61
2nd quintile	1.0 (0.7-1.5)	0.97
rest of 1st quintile	1.2 (0.8-1.8)	0.40
Closest 10%	1.7 (1.1-2.6)	0.02
Health behaviours		
Exercise status		
High (ref)	*1.0 (1.0-1.0)*	.
Moderate	1.8 (1.3-2.4)	<0.001
Low	5.0 (3.8-6.6)	<0.001
Unclassed	1.6 (0.5-5.1)	0.46

Appendix 5.10

Formal Care Assistance	Bivariate analyses for Formal Care Assistance	
	Odds Ratio (95% C.I.)	**P-value**
Need Factors		
Primary independent variables of interest		
Multimorbidity		
0 (ref)	*1.0 (1.0-1.0)*	.
1	1.5 (0.8-2.7)	0.23
2	3.1 (1.7-5.4)	<0.001
3	4.7 (2.6-8.2)	<0.001
4	7.9 (4.5-14.0)	<0.001
5	8.6 (4.6-16.0)	<0.001
6	17.8 (10.1-31.4)	<0.001
Multimorbidity type		
< 1 condition (ref)	1.0 (1.0-1.0)	.
Physical multimorbidity	5.02 (3.5-7.1)	<0.001
Physical + mental multimorbidity	4.9 (3.0-7.9)	<0.001
Other Need Factors		
Self-rated Health		
Not negative self-rated health (ref)	*1.0 (1.0-1.0)*	.
Negative self-rated health	4.6 (3.6-5.8)	<0.001
Disability		
No ADL (ref)	1.0 (1.0-1.0)	.
ADL	1.6 (1.0-2.6)	0.04
Frailty		
Not frail (ref)	*1.0 (1.0-1.0)*	.
Prefrail	10.1 (6.4-15.8)	<0.001
Frail	47.1 (27.3-81.1)	<0.001
Unclassed	7.7 (5.0-12.1)	<0.001
Predisposing Factors		
Sex		
Male (ref)	*1.0 (1.0-1.0)*	.
Female	1.7 (1.3-2.2)	<0.001
Age		
50-59 (ref)	*1.0 (1.0-1.0)*	.
60-69	2.6 (1.4-4.8)	<0.01
70-79	12.9 (7.6-21.9)	<0.001
80+	50.4 (29.7-85.5)	<0.001
Enabling Factors		
Living arrangement		
With other persons (ref)	*1.0 (1.0-1.0)*	.
With spouse	1.5 (1.0-2.2)	0.04
Living alone	7.3 (5.2-10.4)	<0.001
Healthcare coverage		
Dual cover (ref)	*1.0 (1.0-1.0)*	.
Insurance only	0.1 (0.0-0.1)	<0.001

GMS only	1.1 (0.9-1.5)	0.38
No additional coverage (includes GP card only)	0.0 (0.0-0.1)	<0.001
Employment status		
Employed or in educaiton/training (ref)	*1.0 (1.0-1.0)*	.
Retired	0.1 (0.0-0.3)	<0.001
Home-maker	1.0 (0.7-1.4)	0.86
Unemployed	0.1 (0.0-0.6)	<0.01
Permanently sick or disabled	2.3 (1.5-3.4)	<0.001
Unclassed	1.9 (0.9-4.2)	0.10
Health behaviours		
Exercise status		
High (ref)	*1.0 (1.0-1.0)*	.
Moderate	2.0 (1.2-3.2)	<0.01
Low	9.3 (6.1-14.3)	<0.001
Unclassed	2.9 (0.7-12.5)	0.15

Appendix 5.11 Letters to confirm ethical approval for thesis study.

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Trinity Centre,
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Friday, 02 May 2008

Study Title
The Irish longitudinal study on ageing

Dear Applicant

Further to a meeting of the Faculty of Health Sciences Research Ethics Committee 2007 - 2008, I am pleased to inform you that the above project has been approved without further audit.

Yours sincerely

Dr. Orla Sheils
Chairperson
Faculty of Health Sciences Ethics Committee

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8th April 2010

Re: The chronic-ills of ageing – the causes and consequences of multimorbidity in Irelands ageing population,
Application 08/2010/19

Dear Olga,

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,

C. S. Normand

Prof Charles Normand
Chair of the HPM/CGH REC

Professor Charles Normand
Edward Kennedy Professor of Health Policy and Management

PhD Thesis Abstract

Title: The Chronic-ills of multimorbidity: a cross-sectional examination of the prevalence, patterns and factors associated with multimorbidity in the Irish population aged 50 years and over and its corresponding impact on health and social care utilisation.

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Background: Multimorbidity predicts many adverse health outcomes and presents substantial challenges for population health and future healthcare policy and planning. Three empirical studies were conducted in this thesis to gain a greater understanding of the prevalence, patterns and factors associated with multimorbidity at a population level in Ireland, as well as the corresponding impact of multimorbidity on health and social care utilisation. Conceptual issues of multimorbidity definition and measurement were considered to contextualise multimorbidity within population health and inform a framework for evaluating multimorbidity in community-dwelling populations.

Methods: Cross-sectional data were obtained from the first wave Irish Longitudinal Study of Ageing (TILDA) (n = 8,612). Population prevalence of multimorbidity was estimated based on 25 self-reported conditions and investigated according to sample characteristics generalisable to the community-dwelling population aged 50 years and over in Ireland. Non-random patterns of multimorbidity were investigated by cluster analyses. A two-part modelling process examined the factors associated with multimorbidity distinct from morbidity and factors associated with multimorbidity with a mental health component were examined in a multinomial regression model. The Anderson Phase-3 Model of Health Service Utilisation was employed as an analytical framework to examine the impact of multimorbidity on health and social care utilisation controlling for other need, predisposing, enabling and behavioural factors.

Results: A substantial burden of multimorbidity was observed ranging from two to 13 concurrent conditions. 53.8% of the Irish population aged 50 years and over had threshold multimorbidity (≥ 2 conditions), 7.5% had physical-mental health multimorbidity and 3.3% had mental health multimorbidity. Nine associative patterns of multimorbidity were identified. Prevalence was significantly higher in women, those living alone, unemployed and permanently sick and disabled persons. A social gradient in prevalence was found for all types of multimorbidity and was more pronounced for multimorbidity with a mental health component. Prevalence of co-occurring mental health conditions increased substantially with increasing levels of multimorbidity. Findings indicate an under-recognised burden of multimorbidity in mid-life and highlight the need to adopt a lifecourse approach to multimorbidity prevention. Further longitudinal research is required to gain a more comprehensive understanding of the pathways of multimorbidity risk factors. Findings highlight the role of multimorbidity as a significant driver of healthcare in Ireland, across all care services examined, even after controlling for age effects and other gerontological constructs such as disability and frailty. It was significantly associated with both propensity to use healthcare services and recurrent health service use. Multimorbid individuals were also at a significantly higher risk of polypharmacy after controlling for a range of factors highlighting potential issues with quality of care. Co-occurring mental health conditions were significantly associated with higher use of social care services, and polypharmacy. Multimorbidity was a better predictor of healthcare use than age; however it is likely that the absolute numbers of people with multimorbidity will increase with population ageing, placing a significant burden on health and social care services.

Conclusion: Population based studies of multimorbidity are particularly useful to quantify the burden of multimorbidity, qualify relationships between conditions and examine the overall effects of co-occurring conditions at a population level. As population health and healthcare systems evolve to address demographic changes, existing vertical approaches to chronic disease prevention and management will need to reorient to tackle the substantial challenge posed by multimorbidity now and in the future.