Inequalities in Mortality Amenable to Healthcare Intervention in Scotland

Megan Amy Yates

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MRC/CSO Social and Public Health Sciences Unit

Institute of Health and Wellbeing
College of Medical, Veterinary and Life Sciences
University of Glasgow

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Abstract

Mortality amenable to health care intervention are premature deaths which, theoretically, should not occur in the presence of timely and effective health care. As Scotland has a universal health care system, where health care is freely provided at the point of access to all residents, there should be no socioeconomic inequalities in rates of amenable mortality (AM). However, gradients in rates of AM have been found in many countries, using various measures of socioeconomic position. The routine monitoring of rates of AM, and subgroups of amenable conditions, will contribute towards an indicator of health care performance.

Records of all deaths occurring between 1980 and 2013, records of hospitalisations for amenable conditions, and mid-year population estimates were used to calculate rates of age standardised mortality and incident hospitalisations respectively. Absolute and relative inequalities in both rates for the total population were estimated using an area based measure of material deprivation, the Carstairs index. Individual level measurements of socioeconomic position, such as educational attainment, were used to measure inequalities in rates of deaths for a sample of the population, allowing for some comparison with European countries. Rates of AM in Scotland and England were compared in two natural experiments in the final two chapters, aiming to explore the direct and indirect effects of policy changes on health care systems abilities to effectively prevent amenable deaths.

Rates of AM in Scotland have been found to be decreasing for both men and women. Mortality rates within two of the three subgroups of amenable conditions have also declined, with the third having too few deaths to comment on trends. The rates of incident hospitalisations of amenable conditions between 1996 and 2013 have remained relatively stable, suggesting that rates of AM may be reflecting improvements in the detection, treatment, and management of amenable conditions. Absolute and relative inequalities in mortality rates were largest when estimated using educational attainment, whilst occupational measures produced the smallest inequalities. The rate of decline in rates of AM slowed in Scotland, relative to England, following devolution, however the attempts to adequately control for differing levels of deprivation were unsuccessful. The final chapter saw step increase in rates of AM in England, compared to Scotland, following the publication of a White Paper for the Health and Social Care Act - however, this failed to reach statistical significance.

This thesis concludes that the continued study of amenable mortality in Scotland is worthwhile, given that mortality rates continued to decline against stable rates of incident hospitalisations, and relative inequalities in mortality rates were found to be increasing, despite decreasing absolute inequalities. The monitoring of inequalities in rates of AM provides the potential for weaknesses in the provision and delivery of care to be identified and corrected.

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Author's Declaration

I declare that, except where explicit reference is made to the contribution of others, that this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

Megan A. Yates

Abbreviations

AMIEHS	Avoidable Mortality in the European Union: Towards better Indicators for the Effectiveness of Health Systems
ASMR	Age standardised mortality rate
C&C	Cholelithiasis and cholecystitis
CEE	Central and Eastern Europe
COPD	Chronic Obstructive Pulmonary Disease
CVD	Cardiovascular Disease
E&W	England & Wales
EC	European Community
EDI	Early detection and intervention
ESP	European Standard Population
GDP	Gross Domestic Product
GP	General Practitioner
HIV/AIDS	Human immunodeficiency virus/Acquired immune deficiency syndrome
HR	Hazard Ratio
HSCA	Health and Social Care Act (2012)
ISCE	International Standard Classification of Education
IHD	Ischaemic Heart Disease
ITMC	Improved treatment and medical care
MRR	Median Rate Ratio
NHI	National Health Insurance
NHS	National Health Service
NHSCR	National Health Service Central Register
NS-SEC	National Statistical Socioeconomic Classification
ONS	Office for National Statistics
PAM	Primary Avoidable Mortality
PP	Primary prevention
RCT	Randomised Control Trial
(RG)SC	(Registrar-General's) Social Class
RII	Relative Index of Inequality
RR	Relative Risk
SAM	Secondary Avoidable Mortality
SEP	Socioeconomic position
SII	Slope Index of Inequality
(S)LS	(Scottish) Longitudinal Study
SMR	Standardised Mortality Ratio
TAM	Tertiary Avoidable Mortality

TB	Tuberculosis
YLL	Years of Life Lost
95%CI	95% Confidence Interval

Chapter 1

Introduction

The United Kingdom's National Health Service (NHS) was established in 1948, following the National Health Service Act 1946 (European Observatory on Health Care Systems 1999), with the aim of providing a health service which was free at the point of access and could enable the "divorce the care of health from questions of personal means or other factors irrelevant to it" (Ministry of Health 1944, p. 47). The NHS in Scotland was organised and managed in a similar manner to the rest of the United Kingdom until devolution in 2000. Since then, there have been greater divergences in health care policies (Steel & Cylus 2012), with the structure of the NHS in Scotland remaining relatively stable since 2004.

Whilst the universal health care system has contributed towards some progress in reducing inequalities in health, a gap in health status continues to persist (Steel & Cylus 2012). In Scotland, inequalities in all cause mortality rates between the most and least deprived areas have increased since 1981, owing to greater declines in the less deprived areas (Leyland et al. 2007*a*). The Scottish Government's Ministerial Task Force on Health Inequalities recommended the monitoring of inequalities in premature all-cause mortality as an indicator of the country's progress in reducing health inequalities (Scottish Government 2008).

Mortality amenable to health care intervention is an extension to this indicator, measuring unnecessary premature deaths (Rutstein et al. 1976). It was initially outlined as a measure of the quality of medical care delivered, as deaths resulting from the selected conditions could be avoided, given timely and effective health care (Nolte & McKee 2004). Since then, changes in rates of amenable mortality have been explored over time, and within and between countries. However, very few studies have concluded that their results are reflective of improvements in the delivery or effectiveness of health care (Plug et al. 2012), and advise caution in any interpretations (McCallum et al. 2013).

Given that amenable deaths are characterised as being resultant of diseases with effective cures or treatments, it could be expected that there be little-to-no socioeconomic gradient in the rates of amenable mortality, especially within universal health care settings, which should improve health outcomes through equal access (Commission on Social Determinants of Health 2008). Therefore, it has been proposed that rates of amenable mortality could be used as indicators of the equity of such a health care system (Lumme et al. 2012).

1.1 Aims and Objectives

This thesis aims to explore the use of deaths amenable to health care intervention as indicators of the equity of a health care system, and as a comparator between health care systems. In order to facilitate this aim, the following objectives were identified:

1. Analyse the trends in rates of amenable mortality, by individual cause and groups of causes.
2. Explore the socioeconomic gradient in rates of amenable mortality, using area level deprivation, and the extent to which this gradient has changed over time.
3. Examine the trends and socioeconomic gradients in the incidence of selected amenable conditions in the Scottish population.
4. Investigate socioeconomic patterning of amenable mortality by individual characteristics such as education and occupational social class.
5. Investigate the effects of policy changes to health system organisation and management on rates of amenable mortality, through comparisons between Scotland and England.

Through these objectives, this thesis will contribute towards a growing literature on the inequalities in amenable mortality, adding to the evidence base by exploring inequalities by diagnosis group and at the individual and area level. This thesis further explores the use of amenable mortality to compare countries and their healthcare systems, using natural experiments and vast amounts of administrative data.

1.2 Thesis structure

A review of the amenable mortality literature is detailed in chapter 2, focusing on the concept's evolution and applications across the world.

The main methods and data sources employed throughout the thesis are detailed in chapter 3, although subsequent analysis chapters include further methods specific to their focus. The methods used have previously been applied in other contexts to investigate trends and gradients in rates of all-cause and amenable mortality.

Chapters 4 to 8 report the analyses performed in this thesis. Each chapter is introduced with the overarching objective it aims to meet, along with chapter specific methods. The chapters conclude with a discussion of the findings; identifying relations to previous research, and reflections on their implications. Chapters 4 to 6 use only Scottish data in the analyses, providing insights into inequalities in rates of incidence and mortality at area level, and the individual level for the latter.

Chapter 4 explores trends and inequalities in rates of amenable mortality in Scotland, between 1980 and 2013. Three subgroups of amenable conditions are used to further explore the changes over time, along with an investigation into selected individual conditions of interest.

A limitation of previous explorations of amenable mortality is the lack of consideration of the disease incidence within the general population. Decreasing rates may be reflecting changing patterns in disease incidence, rather than improvements in the delivery and effectiveness of health care. Chapter 5 explores this possibility, making use of linked hospital discharge records for the whole population.

Studies of socioeconomic inequality at the population level in Scotland are limited to using area level measures of deprivation, whereas many countries in Europe benefit from the use of individual level linked records. The possibility of ecological fallacy in the findings of chapter 4 are explored in chapter 6, making use of the Scottish Longitudinal Study. The chapter is introduced with a further exploration of the literature focusing on the potential individual level measures of socioeconomic position. Relative and absolute inequalities in rates of amenable, non-amenable and all-cause mortality in the study are presented.

The final two empirical results chapters extend the setting to England, detailing two separate comparison analyses of amenable mortality in Scotland and England. The inclusion of these chapters provides an illustration of the uses of amenable mortality as a method for comparing health care systems between countries. Natural experiment study designs are used in Chapters 7 and 8 to investigate the effects of population-wide interventions (i.e. the political devolution of Scotland, and the introduction of the Health and Social Care Act in England) on health system performance, using rates of amenable mortality. Chapter 7 includes a discussion of the difficulty in cross country comparisons of mortality rates.

Finally, the contribution of this work is positioned in the context of the current research findings in chapter 9. Future directions for research is proposed, along with a critique of the strengths and limitations of this thesis.

1.3 Terminology

Throughout this thesis, references to several key terms will be made. In order to aid understanding, the general definition used in this thesis for each term is given in Table 1.1. Where a term is referred to in the definition of another, the term is emphasised in bold.

Table 1.1: Glossary of common terms

Glossary	
Amenable mortality	Deaths which are avoidable through both timely interactions with the healthcare system, and treatment resultant from the delivery of effective services, at the individual level.
Avoidable mortality	Avoidable mortality comprises both **preventable** and **amenable** deaths. The distinction between terms is given in greater detail in subsection 2.3.2
Preventable mortality	Deaths which may be avoided through changes to public health policies delivered at the population level, requiring the involvement of other sectors, such as changes to driving speed limits to prevent road traffic related deaths.
Healthcare	This thesis narrows the definition of healthcare to services and interventions delivered at the individual level by healthcare professionals in order to promote, maintain, or improve health. It includes medical and surgical interventions, as well as screening and immunisation programmes.
Medical care	Medical care is seen to comprise disease treatment and subsequent care. In this thesis, **healthcare** is seen to encompass medical care, in that both preventative interventions and treatments are available to individuals. The original research into avoidable mortality used a wider definition of medical care: 'the services of all medical and allied health personnel, institutions and laboratories, the resources of governmental, voluntary, and social agencies' (Rutstein et al. 1976, p. 582)

Glossary	
Incidence rate	The rate of new diagnoses of a condition in a defined population within a specified time period.
Incident hospitalisation rates	As above, the rate of new diagnoses of a condition within a population, however, limited by only using data from hospitalisation records. These rates are therefore expected to be lower than the true population incidence rate.
Inequalities in health	A variation in indicators of health (e.g. rates of morbidity or mortality) which are associated with measures of socio-demographic variables, such as ethnicity, income or occupation.
Inequities in health	Inequities in health refer to unfair, avoidable **health inequalities**. They require a judgement of the fairness of the causes of the variations, and are therefore difficult to measure.
Primary prevention	Deaths which could have been avoided through immunisations. These immunisations are distributed at the individual level, and require contact with the healthcare system in order to receive them.
Early detection & intervention	Deaths from conditions which are able to be identified early through screening or testing, *and* have an effective intervention (medical or surgical) which can avert deaths in the majority of cases.
Improved treatment & medical care	Comprises both chronic conditions which require long-term medication and monitoring, and conditions which can be healed through specialist medical care, such as surgery.

Chapter 2

Literature Review

The literature contained in this chapter aims to support the research aims and objectives identified in section 1.1, by evaluating the past and current research into amenable mortality across the world.

The literature review will include a critique of the previous and current uses of the amenable mortality concept over time and space. Any research pertaining to Scotland will be of particular interest, along with research exploring socioeconomic gradients within the rates of amenable mortality.

Potential data sources, analysis methods, socioeconomic indicators and lists of conditions considered to be amenable to health care intervention will be collated for use in this and further research, as well as any limitations which have previously been acknowledged.

2.1 Search Strategy

The original literature search was performed between October and December of 2014, making use of Scopus and PubMed. These sources were identified as being appropriate through discussion with an Information Scientist. Two main search terms were used: 'amenable mortality', 'avoidable mortality', in order to identify literature on amenable or avoidable mortality, given these are the most common keywords used to describe this subject area. Additional search terms were enhanced through the use of the Boolean logic "AND" and "OR" term, and truncation: 'socioeconomic', Scot*, employ*, educat*, income, and depriv*. 'Death' was also included in place of 'mortality'. The screening process for the 1,269 returned hits is described in Figure 2.1.

‘Preventable mortality’ was not included in the search strategy as it is outside the scope of this thesis. The distinction between ‘treatable’ and ‘preventable’ deaths has existed since its initial conceptualisation (Rutstein et al. 1976), and the majority of literature published since then has continued this distinction. This exclusion was previously used in a published review on avoidable mortality (Nolte & McKee 2004).

Automatic alerts were set up on Web of Science based on the two main search terms, in order to identify newly published literature on amenable mortality. Between September 2014 and May 2017, 55 additional reports, books and articles were included from these alerts, or were identified from the reference lists of the initial literature.

This literature review was not designed to be systematic, however, every effort was made to obtain articles where possible. One third of the total literature gathered after initial screening was rejected for inclusion into the review (see Figure 2.1). Reasons include: not being available in English (51.8%), not relevant (39.8%) or not available for download/on-line reading (8.4%). The articles which were not available for download/on-line reading at the initial search were regularly checked for accessibility throughout the write up of this research. Articles were obtained through interlibrary loans where possible.

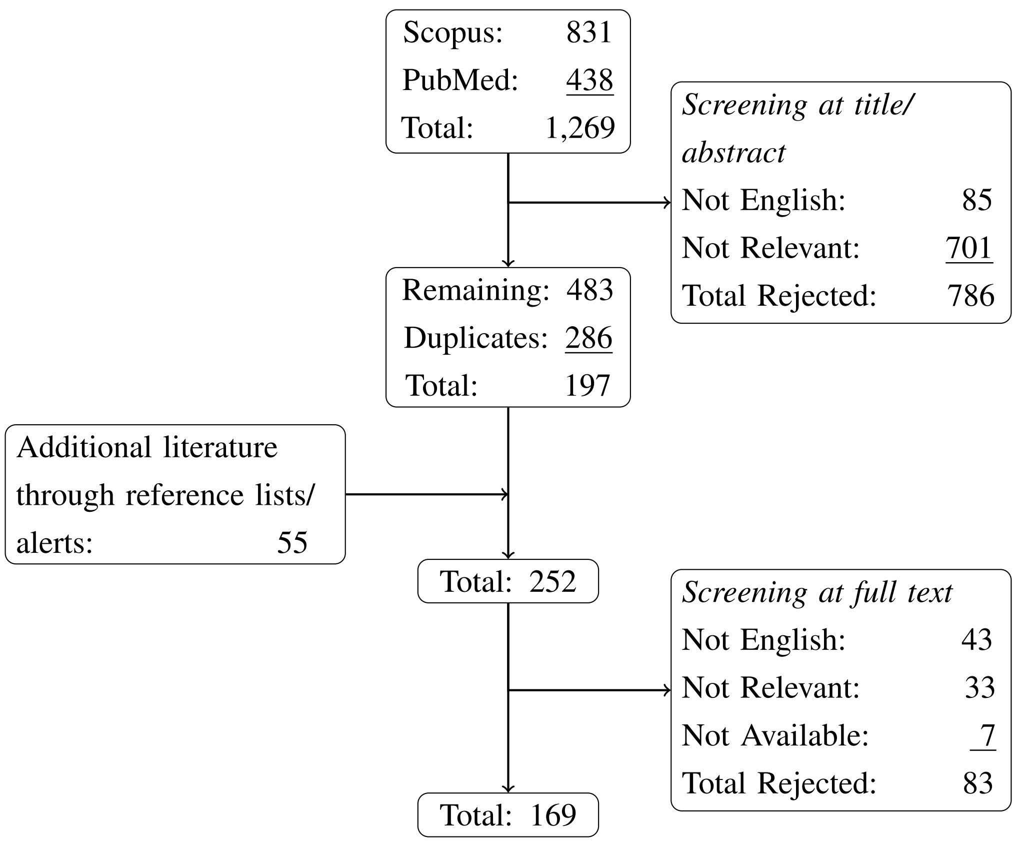

Figure 2.1: PRISMA diagram

2.2 Overview of studies

Whilst the concept of avoidable deaths was first introduced by Rutstein et al. (1976) in North America, the majority of empirical studies (n=130) have been carried out across Europe (n=75), with a smaller number of studies based in Australia (n=12) and the Americas (n=17). Over the last 20 years, 12 studies have been conducted in Asia. No studies look at African countries specifically, however, Moroccan migrants were included in a Dutch study (Stirbu et al. 2006). International comparisons make up the final 14 studies. Of the 130 empirical studies on avoidable mortality, 68 (52.3%) focus specifically on amenable causes of death.

On the whole, studies conducted sex-specific analyses. Analyses were restricted to men only in three studies (Marshall et al. 1993, Wood et al. 1999, Song & Byeon 2000), and no sex-specific analyses were conducted in another (Plug et al. 2012).

Two main overall upper age limits have been used. Early studies make use of an upper age limit of 65 years and in 2001, this was increased to 75 years by Tobias & Jackson, to reflect a greater life expectancy. A number of amenable conditions have narrower age limits applied, however, these tend to differ across studies, with little overall consensus. The measure of socioeconomic position (SEP) also impacts the age range utilized by the study.

The use of SEP as a means of investigating gradients in rates of amenable mortality within a population was first used in 1988 by Mackenbach, Looman, Kunst, Habbema & van der Maas (1988*b*), however, only 47 (34%) studies have explored gradients of avoidable or amenable mortality using either individual SEP or area level proxy measures.

2.3 The concept of 'amenable mortality': History and evolution

An article published in 1966 told of a change in the United States' government priorities from acquiring new knowledge, to the improved dissemination of current knowledge for several major causes of disease, such as cancers, strokes and heart disease (Burgess Jr et al. 1966). The "prevention of untimely death" [p. 794] was identified as an area in which shortfalls in the operation and effectiveness of medical care could be distinguished.

Eight years after this, in 1974, the 'Blueprint for medical care' was published, an outline plan designing an integrated health care system for the United States. Included in this was a discussion of how the quality of the medical care delivered could be measured through indices of “unnecessary disease, and unnecessary disability, and unnecessary untimely death” (Rutstein 1974, p.162). The proposed negative index of health care was an extension of the already used measures of maternal and infant mortality rates to reflect the quality of obstetric and infant care (Rutstein 1974). The occurrence of an untimely death would act as an indication of the potential to improve the quality of care.

Examples of causes of untimely deaths were given in the Blueprint and a full list of treatable and preventable conditions was later proposed (Rutstein et al. 1976), and revised (Rutstein et al. 1980). It was created after consultation with specialists, and included several conditions which had already been eradicated in the United States, such as cholera, allowing for the concept to be applied internationally. The conditions, or Sentinel Health Events, were divided into three groups: (1) those where a single death or occurrence of the disease qualified for an investigation into the causes and care delivered, (2) those for which the rate of death should not exceed a “minimum [undefined] rate” (Rutstein et al. 1976, p. 588), and (3) conditions which did not have sufficiently described treatments, or imprecise outcomes, and therefore could not not be measured accurately. These conditions still warranted “special study” [p. 588]. Additionally, conditions were categorised as to whether they were considered to be preventable, treatable or both. Those which were deemed to be preventable were typically resultant of occupational and environmental exposures, or lifestyle choices, such as smoking, and could be prevented by reducing or removing such contact. Treatable conditions were those where therapies or interventions delivered by the health care system could effectively cure the condition, or at the very least, prolong life.

The first practical application was performed in England and Wales for the years 1974 - 1978 by Charlton et al. (1983), using 14 causes of death to compare area health authorities. Of the conditions used, 11 were contained in Rutstein et al.’s first grouping of diseases considered to be amenable to health care intervention where a single death warranted an investigation. The chosen conditions were limited to those for which there were at least 200 deaths. Those which were mainly avoidable through policy preventions were excluded, leaving those which were regarded as treatable through medical intervention. It was in this paper that the deaths were first described as ‘amenable to medical intervention’ [p. 691].

Over 160 studies have followed Charlton et al. (1983), exploring mortality rates within and between countries, over time, and across SEP gradients. A selection of these will be outlined in section 2.4.

Rutstein et al. (1983) further developed the concept to be applied to specific diseases, disabilities and deaths resultant of occupational factors, such as pneumoconiosis in coal miners. These would be used as a surveillance tool for occupational health and safety, as well as aiding doctors in diagnosing occupational related conditions. There is less research resultant from this extension to the Sentinel Health Events concept, however it does continue to appear in modern research (Garcia & Checkoway 2003, Koh & Aw 2003, Schulte et al. 2013). Occupational factors are not a focus of this research, as such, this aspect of amenable mortality will not be addressed any further in this thesis. The focus of this thesis are those conditions which relate to health system performance/quality of medical care.

2.3.1 Definition of amenable mortality

Mortality amenable to medical intervention was designed to provide warning signals of Sentinel Health Events for future investigation, either from a single case of disease or death, or through a deviation in mortality rates away from an acceptable level. These would then provide an indication of the quality of medical care delivered (Rutstein et al. 1976).

Where rates of amenable mortality have been calculated, their success as an indicator of health care quality is mixed. Carr-Hill (1985) was the first to critically appraise the concept, as the treatable causes of death used by Charlton et al. (1983) to evaluate health care services could also have been partly influenced by preventative measures, such as lifestyle changes or health policies. Therefore, the deaths could not be solely attributable to a lack of health care intervention. This limitation of the concept has been acknowledged in many publications since then, concluding that the majority, and not all, of deaths are expected to be prevented through interaction with the health care system (Nolte et al. 2004, Newey et al. 2004).

A limitation featuring in almost every publication included in this literature review is the lack of measurement or consideration for the incidence of these so called amenable conditions in the general population (Charlton et al. 1983). Declining rates of amenable mortality may be reflecting a fall in the number of cases of the disease within the population, and not as a result of an increased quality of care delivered. Two studies have investigated this possibility, each finding that whilst rates of incidence do account for some of the variation in mortality rates, there remain other influencing factors for which the health care system could be responsible (Bauer & Charlton 1986, Treurniet et al. 2004). Limitations of these analyses include that the true incidence rates of disease within the population could not be known - each relied on the proxy measures of hospital discharge data and disease registries, which will underestimate the incidence of amenable conditions which will not typically require hospitalisation, such as diabetes and asthma, both of which are typically managed in primary care.

Variations in amenable mortality may also be due to artefact, such as differences in case severity, disease incidence or changes to diagnostic coding practice (Barry 1992, Page et al.

2006). However, these issues are not specific to amenable mortality studies, they will be common amongst any cross country and/or time trend studies of overall mortality (Nolte & McKee 2004). The majority of authors acknowledge this possibility, and this limitation should be taken into account when interpreting results.

Mortality rates may, perhaps to a lesser extent, be influenced by patients' own health care seeking behaviours and compliance with medications or treatments (Holland 1988). Whilst the healthcare system has the ability to provide preventative, curative or life extending measures for these amenable conditions, it is reliant on the patient making the initial contact with relevant services, and maintaining a relationship in the case of ongoing conditions.

The Avoidable Mortality in the European Union: Towards better Indicators for the Effectiveness of Health Systems (AMIEHS) study aimed to create a new list of conditions which should be considered amenable based on those which had had an identifiable intervention introduced, and which coincided with a decrease in mortality rates (Plug et al. 2011, Mackenbach et al. 2013). A Delphi procedure, a structured questionnaire used to reach consensus among a panel of experts (Black et al. 1999), highlighted the differences in opinions of which conditions the 23 experts considered to be indicators of health care improvements (Mackenbach et al. 2013). The authors concluded that the lack of association between introduction of specific health care innovations and a decline in mortality rates, and the lack of expert consensus, meant that rates of amenable mortality were not suitable for monitoring health care performance across countries. However, a decline in amenable mortality rates may not be due to a single innovation, rather a wide range of improvements across the health care system, all of which act together to prevent death, such as improvements in the safety of anaesthetics (Mackenbach et al. 2013). These still reflect an improvement in the quality of care delivered, but were not recognised through this analysis. The study had difficulty in identifying the introduction date for many innovations, which may have introduced bias into the results.

Strong, positive correlations between amenable mortality, and all cause or premature mortality have also been found (Lavergne & McGrail 2013). Two lists of conditions were used: Nolte & McKee (2004) and Tobias & Yeh (2009), both of which comprise treatable conditions only, however there were some differences. Tobias & Yeh included bladder and thyroid cancers, as well as rheumatic fever, whilst Nolte & McKee included maternal deaths, surgical and medical misadventures and influenza. Correlations, and overall numbers of amenable deaths, using the list from Nolte & McKee were lower than the ones calculated using the list from Tobias & Yeh, despite Nolte & McKee being the larger list. The authors argue that given these high correlations (all between 0.73 and 0.94), amenable mortality fails to offer any additional information on the effectiveness of a health care system. Allin & Grignon

(2014) later dispute these conclusions. They claim the strong correlations indicate that there is no systematic differences in the measurement of amenable mortality from total or premature mortality. The fact that there is not perfect correlation (i.e. 1) further indicates that there is additional information being captured by the amenable mortality measure, which is not reflected in total or premature mortality rates. Therefore, the authors conclude that amenable mortality is a reliable and sensitive measure of health care system effectiveness.

The additional strengths of the indicator include the ease of measurement of amenable deaths, given that data on deaths are routinely collected, and are usually complete and of a high quality (Burgess Jr et al. 1966). There is also no ambiguity as to whether the event has occurred: death is the "hardest of hard endpoints" (Page et al. 2006, p. 1). A scoping review found that amenable mortality was a suitable method for exploring disparities in the health of migrants across Europe (Makarova et al. 2015), and it has been found to be a useful tool for health resource planning (Poikolainen & Eskola 1986*a*).

2.3.2 Distinction between avoidable and amenable mortality

The division between *avoidable* and *amenable* deaths is not always clear in the literature, and many studies use the terms interchangeably (for example Kossarova et al. (2009), Makarova et al. (2015)).

Avoidable mortality is typically defined as any premature death which could have been avoided; either through preventable measures, such as through policy, or by treating the cause medically, such as through prescribing medication or surgeries. Amenable mortality is defined as only the latter (Korda & Butler 2006). This stems from what the 'health care system' is considered to be: only personal health services, or inclusive of the health, social and environmental promotional or protective activities undertaken by other governmental departments, often through policy implementations (New Zealand Ministry of Health 2010). Rutstein et al. (1976) originally proposed that medical care should be considered in its broadest sense; as comprising medical knowledge, research output, and governmental agencies, through which policies could be introduced. However, many studies now limit their investigations to those deaths only avoidable through immunisations, screening programmes, medicines and surgeries organised by the health care system.

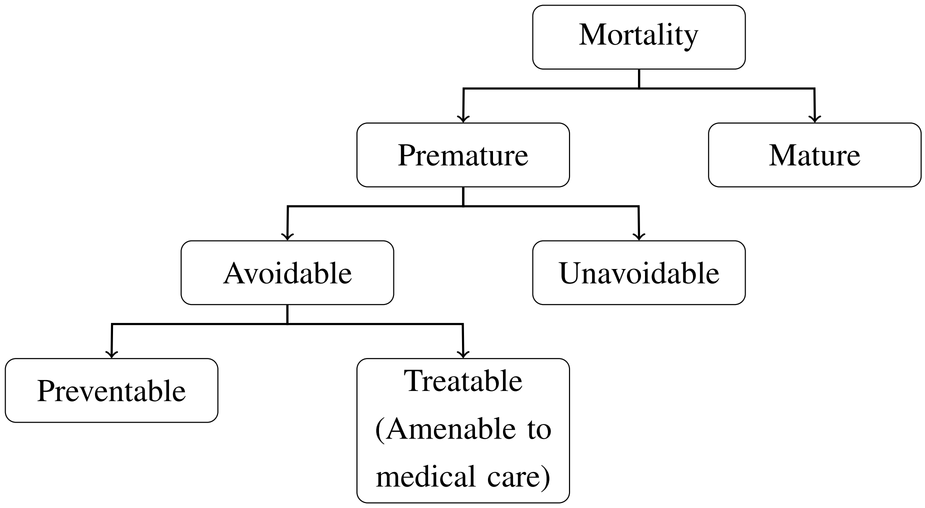

Figure 2.2: Flowchart of amenable mortality (Adapted from Tobias (2009))

Figure 2.2 outlines this distinction, but suggests that the categories of being preventable or treatable were mutually exclusive. However, there are many conditions for which the resultant death could be considered to be both, leading towards what Kamarudeen (2010) describes as an 'imprecise' indicator. Rutstein et al. (1976) made this observation in the original list, regarding many causes of death both preventable and treatable. In the research conducted since then, the majority of authors regard these deaths as preventable in the first instance (Tobias & Yeh 2007), however there were cases where deaths have been categorised as both (e.g. Kinge et al. (2015)).

It also is important to also note that whilst a treatable condition may be regarded as amenable to health care, not all of the resultant deaths werw expected to be averted (Newey et al. 2004). There are a number of external factors which could affect the successful avoidance of death, such as a patient's delayed or lack of seeking medical attention (Holland 1988), or the presence of multiple co-morbidities which may complicate or limit the treatments available (Desai et al. 2011).

Whilst many studies do clearly state their definitions of the health care system, it is often left for the reader to inspect the conditions included in the data selection processes, and therefore decide if the outcome of interest is avoidable or amenable mortality. In the more recent literature, a clearer separation between the terms has been used, with avoidable mortality including both treatable and preventable deaths, and limiting amenable mortality to consist of only those which can be treated (Castelli & Nizalova 2011).

2.3.3 Further categorisations

As well as investigating rates of amenable mortality as a whole, the comparison of rates of causes of death which are detected and treated in similar manners are also of interest, allowing for focussed analyses and selective uses of the indicators (Carr et al. 1989).

The separate analysis of conditions amenable to primary prevention or medical treatment, and those avoidable through public health or policy interventions was first made by Holland (1988, 1991). This was refined by Simonato et al. (1998), further categorising avoidable deaths as: (1) those avoidable through primary prevention; (2) those amenable through early detection and intervention; and (3) those amenable through improved treatments and medical care. Primary prevention, under this definition, encompassed conditions which are generally brought about by lifestyle choices, and those which can be minimised through legal and societal policies. Conditions amenable through early detection and intervention included conditions which, if detected in a timely manner, such as through screening programmes, could be effectively treated. Conditions which were amenable through improved treatment and medical care were taken to be infectious diseases, as well as conditions requiring medical or surgical intervention. Table 2.1 contains examples of conditions within each category.

Table 2.1: Subcategories of causes of avoidable deaths: Simonato et al.

Group	Example conditions
Primary prevention	Malignant neoplasm of the liver
	Injury and poisonings
Early detection and treatment	Malignant neoplasms of the skin, female breast, uterus
Improved treatment and medical care	Infectious and parasitic diseases
	Leukaemia
	Appendicitis
	Maternal mortality

A similar classification was used in New Zealand, however, proportions of responsibility were assigned to each category, rather than assigning full responsibility for the death to a single health care area (Tobias & Jackson 2001). The proportions of responsibility of primary, secondary and tertiary care for four example conditions are displayed in Table 2.2. The only other studies found to make use of this set of classification rules were performed in Australia (Hayen et al. 2002, Ward et al. 2006, Piers et al. 2007).

Table 2.2: Examples of proportions of responsibility in primary, secondary and tertiary care: Tobias & Jackson

Condition	PAM	SAM	TAM
Tuberculosis	0.6	0.35	0.05
Breast cancer	0.15	0.35	0.5
Stroke	0.3	0.5	0.2
Epilepsy	0.0	0.9	0.1

P/S/T AM: Primary/Secondary/Tertiary Avoidable Mortality

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These classifications, and in particular, group 1, comprise both preventable and treatable, and therefore avoidable, causes of death. In 2012, Lumme et al. updated the definitions to only include amenable conditions. Conditions amenable to primary prevention now comprise infectious diseases which could be avoided through immunisations or through improved hygiene measures. Conditions amenable through improved treatment and medical care were limited to conditions which, without treatment, could be fatal. Conditions amenable through early detection and intervention remained as defined by Simonato et al. (1998). These conditions were grouped according to the type and level of intervention required, as described in Table 2.3.

Table 2.3: Groups of amenable conditions: Lumme et al.

Place	Timing	Example conditions
Primary health care	Primary Prevention	Diptheria & Tetanus Rubella
	Early detection and treatment	Tuberculosis Malignant neoplasms of the breast, skin, bladder
	Improved treatment and medical care	Diabetes mellitus Epilepsy
Specialised health care	Improved treatment and medical care	Septicaemia Influenza Leukaemia Maternal death

Reprinted from Social Science & Medicine, 75(5), Lumme et al., Socioeconomic equity in amenable mortality in Finland 1992-2008, pp 905-913, Copyright (2012), with permission from Elsevier

Whilst useful for analysing related sections of a health care system, these approaches have been criticised as being too reliant on expert opinion, especially in the case of Tobias & Jackson (2001), whereby proportions of attribution were highly dependent on the assessment of the selected experts (Page et al. 2006).

The Office for National Statistics (ONS) regularly produces reports on rates of avoidable mortality occurring in England and Wales. Rates were reported by disease group (e.g. neoplasms, respiratory diseases, injuries etc.), rather than by subgroups of conditions as outlined by Lumme et al. (2012). Following a public consultation in 2015 on the definition of avoidable mortality used to produce these reports (Olatunde et al. 2016), ONS continued this approach, rather than adopting the recommended grouping of Lumme et al. Their reasoning included disagreeing with the assumption that the total responsibility for a death could be attributed to a single area of the health care system, where in reality, other areas may, to a lesser extent, be able to contribute towards its avoidance.

2.3.4 Choice of amenable conditions

The conditions typically regarded as amenable to medical care intervention were derived from the original list of 79 avoidable causes of death created by Rutstein et al. (1976). These conditions were selected because they were easily recognisable to a medical practitioner, deaths due to them were theoretically preventable or treatable, and a single occurrence should result in an inquiry (Rutstein et al. 1983). At the time of its creation, Rutstein et al. noted that revisions to the list would be required, in order to reflect improvements in medical knowledge and practice. The lists were also updated to reflect changes from version 8 to 9, and later to 10, of the International Classification of Diseases (ICD).

Whilst the majority of lists used do largely overlap, there is no overall consensus as to which conditions should be deemed amenable to medical intervention. This has resulted in a limited number of studies which were truly comparable across borders, or over time. The effects of using different cause lists has been investigated five times over the years, by Albert et al. (1996), French & Jones (2006), Wheller et al. (2007), Gay et al. (2011) and Lavergne & McGrail (2013).

Both Albert et al. and French & Jones compare lists created by Charlton et al. (1983) and Holland (1988), in studies of mortality in Valencia, Spain, and England, Wales and Scotland respectively. Both Wheller et al. (2007) and Lavergne & McGrail (2013) use the definition by Nolte & McKee (2004), comparing to Page et al. (2006) and Tobias & Yeh (2009) respectively. Gay et al. (2011) compares a later list of Nolte & McKee (2008), with a slightly modified version of Tobias & Yeh (2009). The comparisons between Nolte & McKee and Tobias & Yeh were the only to contrast two traditionally amenable lists, whilst the others compare an amenable list with a wider list of avoidable causes, although the list of avoidable conditions by Page et al. (2006) can be broken down into amenable and preventable causes. Therefore the study by Wheller et al. (2007) contains some results for comparisons of amenable conditions only. Between 1993 and 2005, rates of amenable mortality decreased fairly similarly for men and women. Using the causes from Nolte & McKee, male rates decreased by 43%, and female rates by 38%, whereas using the amenable subgroup causes from Page et al. resulted in a 46% and 41% decline for men and women.

Gay et al. (2011) is the only study to compare cross country differences when comparing two versions of amenable condition lists. 31 OECD countries were analysed between 1997 and 2007. Rates of amenable mortality were lower when using the list by Nolte & McKee, rather than by Tobias & Yeh, for all but four countries (exceptions: Estonia, the Slovak Republic, Korea and Japan). All countries experienced a decline over the analysis period, but the rate of decline was country and list dependent.

Previously, the ONS required that at least 100 deaths had occurred annually before a condition could be included into the definition of avoidable mortality (Office for National Statistics 2012*a*). This was used to minimise the possibility that reported trends were affected by chance. Following a public consultation in 2015 (Olatunde et al. 2016), this requirement was removed. The definition now recognises the importance of monitoring trends in diseases which currently result in small numbers of deaths (e.g. measles and rubella), but the success of treatments and interventions can quickly be affected by changes in public perception.

The Avoidable Mortality in the European Union: Towards better Indicators for the Effectiveness of Health Systems (AMIEHS) project concluded in 2011. This project aimed, amongst others, to develop a new list of conditions which could be considered to be amenable (Plug et al. 2011). This was because previous selections were based on expert opinions (e.g. Tobias & Jackson (2001), rather than published evidence. Identified causes of death were required to have at least 100 deaths in 2000 and evidence of effective interventions introduced since 1970 which had resulted in at least a 30% decline in mortality rates. Evidence from Randomised Control Trials (RCTs) was preferred, but in some cases, observational studies and natural experiments were accepted, due to the limited external validities of some RCTs (e.g. excluding the very young, the very old, or those with co-morbidities (Plug et al. 2011)). A Delphi procedure was then performed on the 14 causes of death which met these requirements, and 12 additional causes which the authors felt should be included on the list. After two rounds, only three conditions reached consensus as appropriate indicators: cerebrovascular disease, and malignant neoplasms of the colon and rectum, and of the breast.

Contentious conditions

The designation of ischaemic heart disease (IHD), cerebrovascular disease and diabetes mellitus as conditions which are amenable to health care intervention has been contentious.

The original list of causes of untimely, unnecessary deaths, outlined by Rutstein et al. (1976) regarded all three as indices of limited use. IHD was introduced as being "partly amenable" by Poikolainen & Eskola (1986*b*, pp. 220-1), due to new medical knowledge which enabled at least some of the resultant deaths to be avoided. In this first study, the rate of decline of IHD mortality was found to be similar to that of non-amenable conditions. Later studies by Poikolainen & Eskola did not include IHD as part of the analyses, even under the 'partly amenable' categorisation (Poikolainen & Eskola 1988).

Boys et al. (1991) analysed IHD deaths separately, owing to the lack of comparable data over the analysis period, the large proportion of deaths IHD was responsible for, and that deaths from IHD were being avoided through both health behaviour changes and medical improvements. The paper therefore included two separate analyses; including and excluding IHD from the 'non-amenable' category. The difference in relative percentage change from 1970-74 to 1985-87 between the 'non-amenable' groups including and excluding IHD were largely similar for Hungary, Federal Republic of Germany and England and Wales, whilst there were larger differences between Czechoslovakia, Poland, German Democratic Republic, Canada and the US, with the larger percentage change typically occurring in the group including IHD deaths.

IHD was included as a 'partly avoidable' cause of death in the second volume of the second edition of the European Community Atlas of 'Avoidable Death' (Holland 1993), given both timely medical care and preventative interventions, for ages 35 to 64 years. Also included in this list were breast cancers, peptic ulcers and other conditions which are currently considered to be amenable to health care intervention.

Carstairs (1993) questioned the inclusion of IHD into the 'partly avoidable' categorisation in the Atlas, as high levels of incidence were occurring in people with low risk factors for the disease, and therefore the potential for avoiding deaths in these cases was reduced. Carstairs did, however, acknowledge that the importance of having cross-country comparable data for this condition, as provided by the Atlas.

Tobias & Jackson (2001) proportioned each cause of avoidable death into the level of intervention required: Primary (PAM), Secondary (SAM) and Tertiary avoidable mortality (TAM). PAM were defined as being avoidable through individual behaviour modifications and health policy, whilst SAM and TAM causes were avoided through a health care system.

Half of the ‘avoidability’ of IHD was assigned to PAM, and the remaining 50% was shared between SAM and TAM, acknowledging the medications and surgeries that could be performed to avert death. These proportions were decided upon by the authors, after consulting with literature and an expert panel.

In 2003, IHD was included as a ‘cause amenable to medical care’ (Andreev et al. 2003, p. 439). Age standardised mortality rates for IHD only were found to be increasing between 1965 and 1995 in Russia, Estonia, Latvia and Lithuania, whilst rates were steadily decreasing in the UK.

Cerebrovascular disease was combined with hypertensive disease in Charlton et al.’s follow up study in 1986, in order to minimise errors in certification known in ICD version 8. Charlton et al.’s initial study used age limits of 5 to 64 years for hypertension, however the minimum age limit for the combined group of strokes and hypertension was raised to 35, as strokes occurring prior to this age were not considered to be avoidable.

Mackenbach (1988) and Mackenbach, Looman, Kunst, Habbema & van der Maas (1988*a*) included both diabetes and cerebrovascular disease as amenable conditions, citing increased survival, as well as improved hypertension detection and treatment. Both conditions have since frequently been considered to be wholly amenable, until Page et al. (2006) regarded only 50% of each condition to be amenable to health care intervention.

The concept of using a percentage of the deaths is favoured by some, as excluding all deaths could result in an underestimation of the role medical care plays in improved survival (Page et al. 2006). However this percentage has been debated, with Nolte & McKee (2004) including reports of the true percentage of IHD deaths avoidable through health care (including primary prevention, reduction of risk factors, and treatments) lying between 25% (Hunink et al. 1997) and 46% (Bots & Grobbee 1996, Capewell et al. 2000). The percentage of IHD deaths attributable to medical care in Scotland between 1975 and 1994 was reported to be 40% (Capewell et al. 1999). Only 4 further studies have used half of the diabetes and cerebrovascular disease related deaths (Schwarz 2007, Tobias & Yeh 2007, 2009, Park et al. 2015), whilst the remainder continue to use all deaths.

The separation of IHD from the remaining amenable conditions is another common choice (Nolte et al. 2004). The separation removes the question of what percentage of deaths to include (Tunstall-Pedoe et al. 2000), and also allows the patterns in mortality rates of the other amenable conditions to be inspected, without the risk of gradients reflecting only IHD, due to the large number of deaths involved (Nolte et al. 2004).

The AMIEHS project included IHD as a possible amenable condition, in that it met the selection criteria of having at least 100 deaths in 2000, identifiable health care interventions introduced since 1970, and mortality rates had declined by at least 30% (Plug et al. 2011). Whilst it met the required median score for being considered an appropriate indicator of health system performance, it did not achieve consensus during the Delphi procedure (Hoffmann et al. 2013).

Of the 130 empirical studies of avoidable and amenable mortality included in this review, 56 have excluded IHD as a cause of death, 27 include it, and a further 26 include 50% of the deaths. IHD was analysed as a separate category in the remaining 21 studies.

2.3.5 Age limits

The age ranges in which a death could be considered to be untimely and avoidable were not defined for the vast majority of conditions in the original list by Rutstein et al. (1976). Six conditions were assigned upper age limits, ranging between 50 and 65 years, whilst the remainder had no such limits imposed. No discussion was given as to how the decision was made to incorporate these age limits.

The first empirical application of the concept in 1983, incorporated an overall age interval from 5 to 64 years, to "increase the proportion" of avoidable deaths (Charlton et al. 1983, p. 692). Upper limits ranging between 34 and 49 years were used for pneumonia and bronchitis, asthma, chronic rheumatic heart disease, acute respiratory disease and Hodgkin's disease. Maternal deaths were limited to those occurring between the ages of 10 and 44 years. No justification was given as to why these selected conditions had differing limits applied, however, they were said to improve the validity of using the concept as a health care indicator (Barry 1992). The upper age limit of 64 years continued to be used for the majority of studies conducted in the early years of analyses, along with narrower limits for selected diseases.

The currently accepted upper age limit of 74 years was first used by Mackenbach, Looman, Kunst, Habbema & van der Maas (1988*b*). This higher limit was used as rates of amenable mortality were being compared to rates of other and total mortality, and was used to exclude deaths in the very old, where the cause of death diagnosis may be more questionable. Studies of amenable mortality published after this did not adopt the increased limit until 2001, when Tobias & Jackson (2001) proposed it in order to reflect the greater life expectancy experienced by developed countries, as well as improvements in coding of cause of deaths at these older ages, despite a high prevalence of co-morbidities (Page et al. 2006). Other studies have justified the limit citing that "medical care [... is] more likely to be most effective in prolonging life at younger ages" (Elo et al. 2014, p. 105), as many RCTs typically exclude the very old from participating (New Zealand Ministry of Health 2010).

A small number of studies conducted since 2001 (Logminiene et al. 2004, Treurniet et al. 2004, Bozgunchievz & Ito 2007, Macinko & Elo 2009) retained the original lower age limit of 64 years, allowing for their findings to be comparable to previous publications. Recently Sundmacher (2013) used an upper limit of 70 years, in line with research on premature mortality from the Robert Koch Institute in Germany (Gaber & Wildner 2011). No other studies have been found which use this limit.

The AMIEHS study, and a report by New Zealand Ministry of Health (2010) have criticised the upper age limit of 75 years, describing it as ‘ageist’, and stating that it did not reflect the inequality in life expectancy between men and women (Plug et al. 2011). Following the publication of these reports, no analyses have introduced sex-specific age limits, in fact, later papers by members of the AMIEHS working group did not include sex-specific analyses (Plug et al. 2012).

When exploring socioeconomic gradients in rates of amenable mortality, age limits have been further modified. The changes, generally increasing the lower age limit, depend upon the choice of SEP measure used in the analyses. Where educational attainment or income have been used, the lower limit is typically increased to age 25, reflecting the time in life by which the majority of the population would have reached their highest attainment level, and begin to earn their own income (Lumme et al. 2012, McCallum et al. 2013, Reques et al. 2014).

2.4 Applications

At its conception, the concept of using Sentinel Health Events to monitor medical care had two possible applications: the single event indicators, for which each occurrence could justify a medical audit into the care path, and the rate-event indicators, where deviations from an ‘acceptable level’ (Carr et al. 1989, p. 706) were required to trigger an investigation.

To my knowledge, only one paper has been published which investigated each death from the selected amenable conditions, as outlined by the single event indicator (Walsworth-Bell & Allen 1988). Case files for eight causes of death occurring during 1981-83 in Bolton, England were investigated by a steering group, due to being identified as the second worst performing Area Health Authority in the analyses by Charlton et al. (1983). Each death record was checked against the case file to ensure that the recorded cause of death accurately depicted the patients’ condition. A ‘model of good care’ was then defined for each cause of death, and the processes required were checked against the case files. This enabled a decision to be made as to whether there were medical factors missing in the course of care which could have prevented the death, and the accuracy of death certification to be checked.

Of the 49 identified deaths, 46 cases were investigated by the steering group. Inadequate care was identified in 24 (52%) cases, of which 19 had clear diagnoses with no complicating co-morbidities which could influence the care given. One death was deemed to be mis-coded on the death certificate. Deaths due to neoplasms of the cervix uteri and hypertension were identified as being the most plausible indicators of inadequate health care, whilst the deaths due to bronchitis and pneumonia, cholelithiasis, appendicitis, abdominal hernias, asthma and tuberculosis were considered to either have received the required level of care, or had co-morbidities which could have influenced care.

It is not surprising that this is the only such investigation found. The level of investigation undertaken by Walsworth-Bell & Allen is impractical in every day practice, given the large numbers of amenable deaths occurring within an area, and the amount of time and level of expertise required to consider each case.

The two approaches defined by Rutstein et al. were attempted using hospital discharge and death records in New York state (Carr et al. 1989), investigating preventable and treatable unnecessary diseases and deaths. Over 17,000 deaths which occurred during 1983 were identified as being avoidable by either definition. The single event indicator deaths comprise approximately 54% of these, but this does include deaths which were considered to be preventable, as well as those amenable to medical intervention, such as lung cancer. No individual investigations were carried out for each of these deaths, as again, the impracticality of the index is evident. The lack of defined acceptable minimum mortality rate for the second application meant that little interpretation could be made.

Since Charlton et al. (1983), various modelling strategies have been employed when analysing rates of amenable mortality over the years, which depart from the original applications. The timing and location of each study impacts the analysis decisions made, such as which conditions would considered as being amenable (Kamarudeen 2010), as well as the type and level of data that were available for analysis.

Castelli & Nizalova (2011) note that since updating the literature review first performed by Nolte & McKee (2004), the methodologies and lists of causes used have become more homogeneous. Most studies compare one or more geographical locations over time.

As explained in Section 2.3.2, many authors use ‘avoidable’ and ‘amenable’ mortality interchangeably. Tables 2.4 to 2.8 summarise the empirical studies investigating conditions mainly considered to be amenable to health care. However, a selection of key publications on 'avoidable' mortality have been included in the text. These will be explicitly identified, and, as found in Section 2.3.4, will have higher mortality rates than would be expected for amenable conditions only. Results are presented by continent, and then country (countries) of analysis, in order to provide an overview of the geographic and time trends within similar areas. International comparison studies across continents are presented separately.

2.4.1 Europe

As noted in the chapter overview (section 2.2), the majority of empirical studies have been performed in Europe. Table 2.4 summarises the 38 studies which were found in the literature search, and were specifically interested in amenable, and not avoidable mortality.

The first article summarised in the table is based on work to which Carstairs contributed - the 'European Community Atlas of Avoidable Death', edited by Holland (1988). The EC Atlas presented indirectly standardised mortality ratios (SMR) at the small area level for 17 disease groups considered to be avoidable through prevention and treatment within 10 countries. The Atlas aimed to only illustrate patterns for the individual disease groups within and between countries, rather than interpret any findings. Scotland was included in the atlas, and was the focus of Carstairs' paper, including data on 11 amenable conditions. The EC Atlas found that whilst for many diseases Scotland as a whole was close to the EC average, several Scottish Health Board specific SMRs were the largest, or amongst the largest, in Europe (for tuberculosis, childhood respiratory diseases, abdominal hernias, maternal deaths, asthma and hypertensive disease or strokes). Carstairs extended the work presented in the Atlas by including a time comparison with mortality data for 1979 - 1984, and found large declines in the annual average rates per million population for all 11 amenable conditions presented - including a decline of 94 per million for Cholecystitis.

A further three EC Atlases have since been published (Holland 1991, 1993, 1997), each including further years for comparison. The second volume of the second edition focused on eight 'partly avoidable' conditions, seven of which are now considered to be fully amenable in current literature, as well as IHD (Holland 1993). Data presented in the second editions (Holland 1991, 1993) were once again used to explore the Scottish data in more detail (Carstairs 1993). Scotland, along with England and Wales, was found to have the largest SMR for breast cancers (SMR=137) in 1980 - 84, but the smallest for Leukaemia (SMR=78), and Cholelithiasis and Cholecystitis (SMR=5). Whilst Scotland as a whole performed fairly well in relation to the rest of the European Community, the Health Boards within Scotland experienced large variations in SMRs, including Lanarkshire having the largest SMR for

IHD in Europe (SMR=307). Many of the Health Boards' large SMRs corresponded to a small number of rare deaths, such as 5 deaths from hernias (SMR=224) in Forth Valley, or 6 deaths (SMR=326) in Dumfries and Galloway for testicular cancer.

Area level variations in SMRs continued to be of interest in England and Wales, and across the UK in later years (Desai et al. 2011). Mortality rates from amenable conditions were found to be the highest in Scotland, compared to England and Wales, and Northern Ireland, despite each nation experiencing considerable declines over the years. An increased rate of decline in England and Wales coincided with increased health care expenditure per capita from 1999 onwards, compared to Scotland.

The contributions of amenable and avoidable mortality towards life expectancy, or (Potential) Years of Life Lost was a common method of measuring the impact healthcare services had on the population. Nolte et al. (2004) examined amenable mortality in Lithuania, Hungary and Romania, compared to West Germany. Consistently positive gains in temporary (between birth and age 75) life expectancy were experienced in West Germany between 1980 and 1997 for both men and women, whilst there were consistent losses for Romanian men. The remaining countries were less consistent; small gains in life expectancy between 1980 and 1988 in Lithuania and Hungary were followed by larger losses in 1992 for men, whereas women retained some of the life expectancy gained in the first period. If all amenable deaths had been successfully treated in Spain between 1975 and 1986, Alfonso Sanchez et al. (1993) estimated that life expectancy for men would increase by 1.76 years per person born, and 0.6 years for women.

The earliest periods of analysis begin in the 1950s in the Netherlands (Mackenbach, Kunst, Looman, Habbema & van der Maas 1988, Mackenbach, Looman, Kunst, Habbema & van der Maas 1988*a*). Rates of amenable mortality were found to be more strongly correlated with educational attainment, than measures of health care supply. The Netherlands, along with Sweden, Finland, and England and Wales have had the most country specific studies performed investigating either avoidable or amenable mortality. Neither Sweden nor the Netherlands have had individual country results published on data since 2000 (Hjern et al. 2004, Stirbu et al. 2006), however, they have been included in several cross country comparisons (Stirbu et al. 2010, Heijink et al. 2013) which include data for later years.

Table 2.4: Empirical studies of amenable mortality in Europe

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Carstairs (1989)	10 EC countries with focus on Scotland	1974-1978	• Time & cross sectional • Conditions: 11 • Age group: 1 to 64 • Basis: Holland (1988)	none	annual average death rates per million population	Scotland's Health Boards were in the highest bands for TB, respiratory diseases in children, abdominal hernias, maternal causes, asthma & hypertensive disease or strokes
Holland (1993)	12 EC countries	1980-1984	• Cross sectional • Conditions: 8 (inc IHD) considered to be partly amenable • Age group: 0 to 64	none	Disease specific SMRs at the country & small area level	Scotland has second highest SMR for IHD in EC (SMR=255), after Ireland. Large between country variation for other conditions
Carstairs (1993)	EU & Scotland	1974-1978 vs 1980-84	• Time • Conditions: 22 (inc IHD) • Age group: 0 to 64 • Basis: Holland (1991, 1993)	none	SMR	Lanarkshire had the highest SMR for IHD in Europe (SMR = 307). Asthma was the only cause to increase between the two time periods, although declines experienced by the other conditions were smaller than found in other countries

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Mackenbach (1991)	11 EC countries	1980-1984 with some variations	• Cross sectional • Conditions: 12 • Age group: 5 to 64 • Basis: Holland (1988)	none	Association between SMRs & GDP	SMRs of TB, chronic rheumatic heart disease, children's respiratory disease, hypertensive & cerebrovascular diseases, & perinatal mortality are moderately to strongly correlated with GDP spending. This relationship is seen across the countries analysed. In Portugal, 8 of the 12 conditions have SMRs larger than EU average, whilst the Netherlands has 1 of the 12 (C&C)
Stirbu et al. (2010)	15 European countries	longitudinal data approx. 1990-2000, Cross sectional data approx. 1998 - 2003	• Cross sectional • Conditions: 15 • Age group: Longitudinal: 30-64, Cross-sectional: 35-69 yrs • Basis: Rutstein et al. (1976)	Educational attainment: 4 levels, lowest being no or primary level education	RII to estimate extent of inequalities across education levels	Inequalities in total avoidable mortality are present in all countries analysed. Smallest inequalities seen in South Europe, & largest seen in CEE & Baltic countries

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Plug et al. (2012)	14 European countries	1991-2003 widest range	• Cross sectional • Conditions: 15 (inc IHD) • Age group: Longitudinal data: 30 to 74 Cross sectional data: 35 to 79 years • Basis: Rutstein et al. (1976), Stirbu et al. (2010)	Educational attainment: 2 levels: lower (up to lower secondary education) & upper (upper secondary & above)	ASMR	Relative risk of all cause, non amenable & amenable mortality highest in CEE, followed by the Baltic Region. Lowest RR in Southern Europe. Correlations between inequalities in four groups of amenable causes & visits to any doctor are significant, however, so are correlations for inequalities in non-amenable deaths
Hoffmann et al. (2014)	15 European cities including London, Helsinki & Stockholm	Various, but generally 1995-2009	• Cross sectional • Conditions: 14 (inc HIV) • Age group: none described	Area level deprivation index: % unemployed, % manual workers, % of popn under 25 with primary education or lower, % of popn with university degree & % of foreigners from low income countries	Spatial patterns of AM rate ratios	Deprived neighbourhoods are associated with higher levels of 'avoidable' death. Rate ratios differ between cities & genders. Eastern & Southern Europe have higher levels of 'avoidable' mortality. Associations between SEP and rates of AM are weaker in Southern Europe and stronger in Northern Europe

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Charlton et al. (1983)	England & Wales	1974-1978	• Cross sectional • Conditions: 14 • Age group: 5 to 64 • Basis: Rutstein et al. (1976)	none	SMR by area, adjusting for socioeconomic factors (% households without cars, % of unskilled workers, % rented households, % birthweights under 2500g (1980))	Significant area level variation for most diseases. There was some correlation between SMRs & social indicators, with the % of non-car ownership households & the % of unskilled workers having similar disease specific correlations. The percentage of variation explained by all three social indicators varied by between 8% for maternal deaths to 63.7% for TB
Bauer & Charlton (1986)	England & Wales	1974-1978	• Cross sectional • Conditions: 13 • Age group: not specified • Basis: Charlton et al. (1983)	none	Correlation of SMRs with morbidity indicators (hospital discharge, disease registries) & social factors (% households without cars, % of unskilled workers, % rented households)	Larger percentages of variation in SMRs were explained by social factors rather than by the morbidity measures, however, the most variation explained by both is 55.6% (TB)
Charlton et al. (1986)	England & Wales	1974-78 vs 1979-83	• Time • Conditions: 8 • Age group: 5 to 64 • Basis: Charlton et al. (1983)	none	SMRs at the area level & age-specific mortality rates	Significant area level variation remained for most areas, & all disease groups (except for appendicitis & maternal deaths), above what would have been expected by chance

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Walsworth-Bell & Allen (1988)	Bolton, England	1981-1983	• Cross sectional • Conditions: 8 • Age group: 0 to 64 • Basis: Charlton et al. (1983)	none	Study of case notes, evaluating whether inadequate care was given	Of the 46 deaths which met the criteria, 24 received inappropriate clinical care (n=11) or health service care (n=13). Complicating co-morbidities were found for 5 cases. Shortcomings in treatment were most often found for cervical cancers & hypertension
Mackenbach et al. (1989)	England & Wales, Netherlands	• EW: 1931, 61, 81 • NL: 1952, 62, 72, 82	• Time • Conditions: 25 • Age group: EW: 15 to 64, NL: 0 to 74 • Basis: Rutstein et al. (1976)	• Occupational social class: England & Wales • Area level index of deprivation: Netherlands	Deprivation specific SMRs	There were large relative & absolute declines in AM in E&W across all occupational classes in 1931-61. Relative declines were greatest in the highest occupational category for all conditions except for neonatal mortality. There was a less clear gradient in absolute reductions. Declines for 1961-81 were smaller. These results were only found for 4 of the 25 causes of death in the Netherlands

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Grant et al. (2006)	Scotland	1981-2004	• Time & cross sectional • Conditions: 34 (inc 50% IHD) • Age group: 0 to 74 • Basis: Nolte & McKee (2003, 2004)	Area level deprivation index: SIMD	ASMR	Country & Health Board rates of AM have been decreasing over time (with some fluctuation in Orkney). The percentage decline in most Health Boards was faster in 1996-04 than in 1986-95. ASMR are strongly correlated with deprivation in 2000-04, & whilst rates across deprivation levels decreased, the ratio between most & least deprived remained stable
Desai et al. (2011)	UK	1990-99 vs 2000-09	• Time • Conditions: 33 (inc 50% IHD) • Age group: 0 to 74 • Basis: Nolte & McKee (2008)	none	ASMR	Mortality rates were highest in Scotland over both time periods, followed by Northern Ireland & E&W. Scotland & N. Ireland had a higher rate of decline than E&W in the first period, however, E&W exceeded that of Scottish men & women, & Irish women in the second period, coinciding with increased NHS spending

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Barr et al. (2014)	England	2001-2011	• Time & cross sectional • Conditions: 35 (inc IHD) • Age group: 0 to 74 • Basis: Nolte & McKee (2004)	Area level deprivation index: Index of Multiple Deprivation	Association between NHS resource allocation & rates of amenable mortality	Areas which had the greatest absolute increases in NHS funding experienced the greatest absolute declines in AM. In the most deprived areas, each additional £10M in funding was associated with a 4.0 & 1.8 per 100,000 reduction in AM for men & women respectively. Associations were not significant in the more affluent areas. Relative inequalities remained fairly constant
Poikolainen & Eskola (1986*b*)	Finland	1969-1981	• Time • Conditions: 22 • Age group: 0 to 64 • Basis: Rutstein et al. (1976)	none	ASMR & trend tests	Rates of AM fell faster than non-AM for both men & women. The ratio of male to female deaths was also lower for AM than non-AM

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Poikolainen & Eskola (1995)	Helsinki, Finland	1980-1986	• Cross sectional • Conditions: 23 (inc IHD) • Age group: 0 to 64 • Basis: Rutstein et al. (1976)	• Occupational social class: 6 social groups • Marital status • District of residence	Case-control	After adjusting for confounders, significant differences in the relative risk of AM death remained between the social groups, & were larger than the crude risk ratios. No significant risk ratios remained after adjustment for confounders across marital status, & for most districts of residence
Lumme et al. (2012)	Finland	1992-2008	• Time • Conditions: 41 • Age group: 25 to 74 • Basis: Nolte & McKee (2008), Page et al. (2006)	Income: disposable family net income	ASMR, Concentration Index & Slope Index of Inequity	No change in aboslute inequity for men over time, but slight increase for women. Increasing trend in relative inequities. Inequity increased more in secondary than in primary health care
McCallum et al. (2013)	Finland	1992-2003	• Time • Conditions: 35 (IHD separately) • Age group: 25 to 74 • Basis: Nolte & McKee (2004, 2008)	Income: family net income	ASMR	Rates fell for both men & women. Larger rates of decrease in AM than in all cause. SEP gradient increased over the 12 years

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Manderbacka, Peltonen & Martikainen (2014)	Finland	2000-2007	• Cross sectional • Conditions: 30 • Age group: 25 to 74 at baseline (1999) • Basis: Nolte & McKee (2004)	• Income: consumption income • Living arrangements: married, cohabiting, living alone, lone parent & other	Hazard ratios adjusting for age, region of residence, education, occupational social class & economic activity	Significant HR were found across income groups, with an inverse relationship for both sexes. HR were attenuated by adjusting for economic activity & living arrangements. Those living alone, those cohabiting & lone parents were found to have higher HR than married people. Differences were largely independent of any co-variates
Manderbacka, Arffman, Sund & Karvonen (2014)	Finland	1992-2008	• Time • Conditions: 40 • Age group: 25 to 59 • Basis: Nolte & McKee (2004)	• Income: family net income, • Social deprivation: living alone vs others, • Regional deprivation: urban/rural, • Employment: working, short & long term unemployed	ASMR & Poisson regression models. Models were stratified by living arrangement (living alone vs 2+ person household)	All SEP measures were associated with AM. Rapid decline in highest income group, no decline in lowest income group (or long-term unemployed group). Regional deprivation not associated with AM

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Bernat Gil & Rathwell (1989)	Spain	1960-1984	• Time • Conditions: 13 • Age group: 5 to 64 • Basis: Rutstein et al. (1976)	none	ASMR	Amenable mortality declined faster than non-amenable (67% vs 21%). Cervical cancer was the only condition to see an increase over time
Alfonso Sanchez et al. (1993)	Spain	1975-1986	• Time • Conditions: 14 • Age group: 5 to 64 • Basis: Holland (1988)	none	Life Expectancy Free of Avoidable Mortality	In 1986, if deaths had been avoided, there would be a gain of 1.09 years per person born (1.76 for men, 0.6 for women)
Bautista et al. (2005)	Spain	1998-2000	• Cross sectional • Conditions: 18 • Age group: 5 to 64 • Basis: Holland (1988, 1991)	• Marital status • Birth place • Regional language • Employment status • Property ownership • Vehicle ownership • Family income • Education level • Social class	Case-control for in-hospital deaths	88 cases & 300 controls. Education was the only SEP measure to be significantly associated with amenable mortality

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Nolasco et al. (2014)	3 Spanish Cities: Alicante, Castellon & Valencia	1996-1999, 2000-2003, 2004-2007	• Time • Conditions: 34 (inc 50% IHD) • Age group: 0 to 74 • Basis: Nolte & McKee (2008, 2011)	Area level deprivation index: • % Unemployed • % low level of education • % low level of education amongst young people (16-29) • % Manual workers • % of Temporary workers	RR of death were estimated between SEP levels using sex specific Poisson regression models, adjusted for age & study period	AM represented approx. 12% of total mortality in the first period, & approx. 10% in the third. Compared to the first period, all three cities had significantly lower RR for both sexes, except for men in Alicante. RR for the deprivation indices were mixed, with more significant risks in Alicante, than in Castellon

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Mackenbach, Kunst, Looman, Habbema & van der Maas (1988)	Netherlands	1950-54, 1960-64, 1970-74 & 1980-84	• Time • Conditions: 15 • Age group: 0 to 74 • Basis: Rutstein et al. (1976)	none	Percentage of variation explained by medical care supply variables (No. GPs per 10,000, No. hospital beds per 1,000, % of regional hospital beds in university hospitals, % of regional hospital beds in small hospitals)	Significant negative correlations between cause specific AM and: GP density (Rheumatic heart disease) & % of beds in university hospitals (3 surgical conditions & congenital heart disease). Positive correlations for % of beds in small hospitals (hypertensive disease & 3 surgical conditions). % of variation explained by medical care supply variables increased over the 4 time periods for TB, 3 surgical conditions & cerebrovascular disease, once SEP variables were adjusted for
Mackenbach, Looman, Kunst, Habbema & van der Maas (1988*b*)	Netherlands	1969 - 1984	• Time • Conditions: 13 • Age group: 0 to 74 • Basis: Charlton et al. (1983)	• Education: % of population with more than first level education, • Income: % average income per inhabitant, • Unemployment: % of working population temporarily without work	Poisson regression to estimate regional mortality levels & trends	Hospital bed density, number of GPs & unemployment were not associated with AM. AM rates were negatively correlated with education & income

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Mackenbach, Looman, Kunst, Habbema & van der Maas (1988*a*)	Netherlands	1950-1968, 1969-1984	• Time • Conditions: 35 • Age group: none described • Basis: Rutstein et al. (1976)	none	Poisson regression to compare trends before & after the introduction of an intervention (cause specific)	Evidence of spontaneous declines in cause specific mortality rates, rather than ones coinciding with the introduction of an intervention
Treurniet et al. (1999)	Netherlands	1984-1994	• Cross sectional • Conditions: 16 • Age group: 0 to 74 & 5 to 64 • Basis: Rutstein et al. (1976)	none	Incidence, estimated using Poisson regression	Regional differences in amenable mortality were only partly explained by regional differences in disease incidence (except for cervical cancer)
Quercioli et al. (2013)	Italy	1993-2003	• Cross sectional • Conditions: 35 (inc 50% IHD) • Age group: 0 to 74 • Basis: Nolte & McKee (2004)	none	Associations between additional public & private healthcare funding, & rates of AM	Each additional 100 €of spending for public health care was associated with a decrease of 1.47%. No statistically significant associations were found for private health care

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Fantini et al. (2012)	Italy	2006-2008	• Cross sectional • Conditions: 33 (inc 50% IHD) • Age group: 0 to 74 • Basis: Nolte & McKee (2003, 2004, 2008)	none	Regional variability in health care services using AM & correlations with public health spending per capita, GDP & no. diagnostic & lab tests per 1,000	Significant regional variation in ASMR were found ranging between 54.1 to 76.3 per 100,000. Male rates in the Southern regions exceeded the national average, whilst Northern & Central regions were lower. No clear geographical separation for women. Negative correlations between ASMR & GDP, & number of diagnostic tests were statistically significant, whilst compared to public health spending was not significant
Schwarz (2007)	Austria	1991-1992	• Cross sectional • Conditions: 28 (inc 50% IHD) • Age group: 30 to 74 • Basis: Blakely et al. (2005)	Educational attainment: 3 levels, with the lowest being compulsory education	RII & SII - linear regression	RII for men approx. 0.6, & for women approx. 0.4. The SII for men was 136 per 100,000, & for women was 82 per 100,000. AM contributed a greater % towards the differentials among women, than it did for men

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Nolte et al. (2004)	Lithuania, Hungary, Romania & West Germany	1980-1997	• Time & cross sectional • Conditions: 28 • Age group: 0 to 74 • Basis: Nolte et al. (2002)	none	Life expectancy by age & cause of death	AM causes (except in infancy) consistently contributed negatively to life expectancy in Romania
Nagy et al. (2012)	Hungary	2004-2008	• Cross sectional • Conditions: 34 (inc IHD) • Age group: 0 to 74 • Basis: Nolte & McKee (2004)	Area level deprivation index: • Income • level of education • rate of unemployment • rate of one-parent families • rate of large families • density of housing • car ownership	Disease mapping using ASMRs	The 2 least deprived quintiles had ASMRs significantly below the average ASMR for Hungary, whilst the middle to most deprived quintiles were significantly larger. The ASMRs in the poorest quintiles were 70% & 63% higher than the least deprived quintiles for men & women respectively
Kossarova et al. (2013)	Czech Republic & Slovakia	1971-1989, 1990-2008	• Time • Conditions: 17 (inc IHD) • Age group: 5 to 64 • Basis: Holland (1997)	none	ASMR	ASMR decreased faster for avoidable causes than non-avoidable for both countries. A divergence in ASMR for the two countries is evident in 1989 (fall of regime) & 1993 (separation), where Slovakia falls behind the progress of the Czech Republic

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Gavurová & Vagašová (2015)	Slovakia	2002-2012/13	• Time • Conditions: 26 (inc 50% IHD) • Age group: 0 to 74 • Basis: Nolte & McKee (2008)	none	ASMR	Male & female ASMR decreased by 34% & 32.4% between 2002 & 2013 respectively. The contribution of tumours towards total amenable mortality increased for both men (8.85% to 12.64%) & women (26.56% to 37.84%)
Hem et al. (2007)	Norway	1994 - 1999	• Cross sectional • Conditions: 34 (IHD separately) • Age group: 25 to 49, 50 to 74 • Basis: Nolte & McKee (2004)	Educational attainment: 4 categories, by years	Hazard ratios	HR increased with decreasing educational attainment (relative to Higher education). The hazards experienced between the two age groups were of similar magnitude, & men had larger hazards than women
Goldberger & Haklai (2012)	Israel	1998-2000, 2007-09	• Time and cross sectional • Conditions: 33 (inc 50% IHD) • Age group: 0 to 74 • Basis: Nolte & McKee (2004)	none	ASMR	Male mortality rates fell by 31% and females fell by 28%

2.4.2 Americas

Of the 17 American based avoidable mortality studies, 8 were limited to amenable conditions only, and are summarised in Table 2.5. Occupational social class is a commonly used measure of SEP in Canada, whereas demographic differences between ethnicities were of interest in the United States, for both amenable and avoidable studies.

Both Wood et al. (1999) and Mustard et al. (2010) used a 5 level measure of occupation, on a sample of Canadian deaths. Mustard et al. (2010) used a 15% sample of both male and female deaths occurring between 1991 and 2001, finding that professional and unskilled women (extremes of the skill level categories), as well as women with no occupation, had significantly different standardised rate ratios from the reference group of all occupations. Whilst for men, the only occupational skill level which did not significantly differ from the reference group was that of Skilled/Technical/Supervisory occupations. There were similar gradients in amenable and all other causes of death, for both men and women in the sample.

In an earlier study of a 20% sample of men only, Wood et al. (1999) found 8 of the 9 amenable conditions had rate ratios above 1, however, only one disease rate ratio (pneumonia and bronchitis - 45.4% of the deaths within the sample), and the overall amenable rate ratio were significantly higher than 1. No analyses were performed for non-amenable conditions.

Scores based on income, education, and a combination of the two were also explored in the sample (Wood et al. 1999). Larger relative risks for each disease were found for the education score, whereas the income and combined scores were not consistently different from the occupational social class. The rate ratio for all amenable conditions overall was similar, and significant for the education and income scores alone, however the combined score estimated a larger relative risk (approximately 1.9 vs 2.1).

Ethnic variations in rates of amenable and avoidable mortality have been explored across North America. Simple differences between Black and White populations were explored by Elo & Drevenstedt (2006), Macinko & Elo (2009) and Elo et al. (2014), where as Kunitz et al. (2014) and Park et al. (2015) used Indigenous state to classify population groups of interest. Kunitz et al. (2014) explored differences between American Indian/Alaskan Native and the non-native population in the United States of America, finding greater mortality rates, and larger variations for the Indigenous populations than the non-natives.

Only one study of amenable mortality has thus far been conducted in a South American country - Brazil (Hone et al. 2017). Rates and trends of amenable mortality were used to explore whether the expansion of a community based primary health care programme reduced amenable deaths, and how the effectiveness of the programme varied by levels of governance (as measured using a composite measure of 18 binary indicators). A 6.8% decline in rates of amenable mortality was associated with the expansion of the programme to a municipality, whereas there was no significant association with non-amenable mortality. Further significant declines in rates of amenable mortality were found in municipalities with the highest level of governance, and it was estimated that there could be up to 6,400 fewer deaths per year, should the programme be expanded to all municipalities. This study demonstrated the importance of increased primary care availability within a community for reducing rates of amenable mortality.

Table 2.5: Empirical studies of amenable mortality in North and South America

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Pampalon (1993)	Quebec, Canada	1969-1973 vs 1982-1990	• Time and cross sectional • Conditions: 13 • Age group: 5 to 64 • Basis: Holland (1988)	none	SMR	Significant regional variations for 3 conditions. SMR for chronic rheumatic heart disease for the first period is 12.2 times that of the second period, whereas asthma has an SMR 0.7 times the second period - the only condition which has an increasing SMR
Wood et al. (1999)	British Columbia, Canada	1981-1991	• Cross sectional • Conditions: 12 • Age group: 15 to 64 • Basis: Charlton et al. (1983)	• Occupational social class: RGSC - 5 levels, • Education: Blishen education index (BEI), • Income: Blishen Income index (BII), • Overall Blishen index (BI)	ASMR and relative risk	Relative risk for all AM was 1.9 (1.3 - 2.6) - same for RGSC and BEI. BII had a relative risk of 1.8 (1.4 - 2.2). The overall BI had a relative risk of 2.1 (1.7 - 2.5)

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Mustard et al. (2010)	Canada	1991-2001	• Cross sectional • Conditions: 29 (inc 50% IHD) • Age group: 30 to 69 at 1991, 0-74 list wise • Basis: Charlton et al. (1983), Carr-Hill et al. (1987), Holland (1988), Pampalon (1993), Tobias & Jackson (2001), Manuel & Mao (2002), James et al. (2006), Nolte & McKee (2008), Mackenbach et al. (2008)	Occupational social class: 5 levels & No occupation	ASMR and Standardised rate ratios (SRR)	SRR for the highest and lowest categories (professional and unskilled) were significantly different from the ‘all occupations’ reference category for women. For men, only the third category (skilled/ technical/ supervisory) was not significantly different from the reference. Whilst amenable mortality rates were lower than that of the all other causes, the SRR were fairly similar across the two mortality groups
Hisnanick & Coddington (1995)	USA	1972-1987	• Time • Conditions: 8 • Age group: 5 to 75 • Basis: Rutstein et al. (1976)	none	ASMR	57% decline in ASMR between 1972-79 and 1980-87. The relative decline was fairly similar for men and women

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Schoenbaum et al. (2011)	USA	2004-2005	• Cross sectional • Conditions: 33 (inc 50% IHD) • Age group: 0 to 74 • Basis: Nolte & McKee (2003)	none	tests of association between access and system performance indicators	ASMR ranged between 63.9 per 100,000 (Minnesota) and 158.3 per 100,000 (District of Columbia). A 10% increase in the percentage of uninsured people is significantly associated with a 2.4% increase in state AM. An 10% increase in the percentage of the population that is black is associated with a 1.4% increase in state level AM
Kunitz et al. (2014)	USA	1990-1998 vs 1999-2009	• Time • Conditions: 33 (inc 50% IHD) • Age group: 0 to 74 • Basis: Nolte & McKee (2011)	Ethnicity: American Indians and Alaska Natives (AI/AN)	ASMR	ASMR were higher for AI/AN populations than the white populations overall for both periods. The percentages of all cause mortality that are amenable are similar across the two ethnic groups. The rate ratio increased from 1.32 in the first period to 1.49 in the second period (AI/AN: white)

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Manuel & Mao (2002)	USA and Canada	1980-1996	• Time • Conditions: 11 (inc IHD) • Age group: 5 to 64 • Basis: Holland (1997)	none	SMR	9 of the 11 conditions in Canada had SMRs below 100 (European Standard), whilst the US only had 5 of the 11. Three of the disease groups in the USA had SMRs not significantly different from the European standard
Hone et al. (2017)	Brazil	2000-12	• Time • Conditions: 45 • Age group: 0 to 74 • Basis: Nolte & McKee (2008), Alfradique et al. (2009)	ESF (Family health strategy) coverage	ASMR, and Poisson regression to study the effect of changes in ESF coverage and rates of mortality	ASMR declined by 1.7% per year. Expansion of ESF coverage was associated with a 6.8% decline in AM, but not with non-AM. Greater reductions in AM were found in municipalities with the highest health governance scores

2.4.3 Australasia

Avoidable mortality is currently used as a key performance indicator of progress in the Australian National Health Agreement (Australian Government 2017), and there were a number of reports published on amenable and avoidable mortality in Australia and New Zealand. Table 2.6 describes the six studies performed focused on amenable conditions.

An atlas of avoidable mortality for both Australia and New Zealand was published in 2006, improving on the work conducted by Holland for the European Community Atlas by presenting mortality rates by age, sex, ethnic group and area level deprivation (Page et al. 2006). Sections on both amenable and avoidable mortality were presented in the atlas, recognising the 'complicated interpretation' of using avoidable mortality as a measure of health care effectiveness (Page et al. 2006, p. 1). Age standardised mortality rates and Years of Life Lost (YLL) were used to estimate differences by sex, major condition groups and social factors. Cancers made up 40.2% of all Australian amenable deaths, and accounted for 517,000 YLL, with the largest contributors of the group being colorectal and female breast cancers. Deaths due to tuberculosis made up the smallest percentage of deaths and YLL (0.2% and 2,000 respectively). In New Zealand, the group of Cardiovascular diseases (CVD - including 50% of deaths due to IHD and cerebrovascular disease) were the largest proportion of amenable deaths (40%), however, YLL from Cancers remained larger than from CVD (122,742 vs 115,931). Thyroid disorders contributed the smallest proportion to amenable deaths (0.1%).

The major causes of death within each age group were similar between Australia and New Zealand, except diabetes is included as a major contributor towards overall amenable mortality in an younger age group in New Zealand, than it is in Australia, replacing skin cancer in the 45 - 64 year group.

The New Zealand Ministry of Health (2010) later published a large report, exploring the concept of amenable mortality, discussing methodology issues and describing trends in amenable mortality in New Zealand. Rates of male amenable mortality form 49% of total mortality - much higher than in many other countries. This larger proportion is due to the inclusion of deaths from IHD, HIV/AIDS and injuries, such as suicides and transport accidents, as amenable conditions. Age-specific ratios of amenable to non-amenable deaths highlight the impact of the inclusion of these additional causes of death, especially injuries, in men - the 15 to 24 year age group has a ratio of 2.37. For women, the largest ratio (1.5) occurs in young adulthood (ages 25-44 years), where deaths from female cancers were more common. After age 44 years, a larger proportion of male and female deaths were non-amenable.

The age group contributing most towards this large proportion is 15-24 years, where age-specific amenable mortality rates for men were over double that of non-amenable mortality rates. The proportion for women is smaller (43%), and the largest contribution towards the overall deaths comes from ages 25 - 44 years.

Ethnicity is also considered in the report; focusing on Maori, Pacific and Asian ethnic groups. The ratios of Maori and Pacific people to Europeans/others (mutually inclusive, i.e. Maori vs non-Maori) were larger for amenable conditions than non-amenable conditions, for both men and women. These relative inequalities indicate the importance of health care to ethnic inequalities in mortality. The pattern is reversed for Asian people, where the ratios were below 1, and ratios for amenable deaths were smaller than for non-amenable deaths. The report suggests this is indicative of the 'healthy migrant effect', as New Zealand requires migrants to be of good health in order to immigrate (Rasanathan et al. 2006).

Table 2.6: Empirical studies of amenable mortality in Australasia

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Marshall & Keating (1989)	Auckland, Australia	1977-1985	• cross sectional • Conditions: 15 • Age group: 0 to 64 • Basis: Rutstein et al. (1976)	none	SMR	Pattern between sexes is similar. SMRs range between <0.5 to >2 (ref = 1)
Malcolm & Salmond (1993)	New Zealand	1968-1987	• Time • Conditions: 15 • Age group: 0 to 64 • Basis: Charlton et al. (1983)	Ethnicity: Maori to non-Maori	ASMR. The 'excess' decline in mortality is estimated by comparing the 1987 regression estimate with an expected rate.	AM ASMR declined significantly more for Maori men and women, than non-Maori men and women. The estimated % decline due to improvements in medical care is estimated to be greater for non-Maori men and women, than for Maori men and women
Marshall et al. (1993)	New Zealand	1975-77, 1985-87	• Time • Conditions: 12 • Age group: 15 to 64 • Basis: Charlton et al. (1983)	Occupational social class: Elley-Irving scale	ASMR and trend tests	Strong social class gradients were found during both periods, with lower SEP groups experiencing higher mortality rates. The strength of the gradient declined from 34% to 28% between the two periods

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Tobias & Yeh (2007)	New Zealand	2000-02	• Time and cross sectional • Conditions: 27 (inc 50% IHD) • Age group: 0 to 74 • Basis: Page et al. (2006)	Area level deprivation index: NZDep2001	ASMR, contribution to health care calculated as: [AMR1 - AMRref] / [TMR1 - TMRref] for group of interest and reference groups of AM and total mortality rates respectively	Amenable causes counted for 25.6% (22.6-27.6%) of the mortality disparity experienced by deprived males, and 30.4% (25.9-33.8%) for females. Whilst AM causes made a bigger contribution to mortality disparity for females, the difference is not statistically significant
Tobias & Yeh (2009)	New Zealand	1981-2004	• Time and cross sectional • Conditions: 28 (inc IHD) • Age group: 1 to 74 • Basis: Page et al. (2006)	• Income: equivalised household income, • Ethnicity: Maori (M), Pacific (P), Asian (A) and European/Other (E/O)	Standardised rate difference and SII	AM contributed towards 19.6% of the health inequality between M:E/O in the first period, rising to 23.6% in the second for men, and 24.6 to 26% for women. For the P:E/O health gap, there was a negative gap for men of 10.8% (i.e. inequalities were higher for E/O), increasing to +26.2%. The health inequality for women increased from 0% to 33.8%. The A:E/O health gap was the only to decrease, from 65% to 18% for men, and 48% to 43% for women. Men SII: 94 to 65 per 100,000, women: 44 to 43 per 100,000

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
New Zealand Ministry of Health (2010)	New Zealand	1996-2006	• Time and cross sectional • Conditions: 35 (inc IHD, HIV/AIDS and injuries) • Age group: 0 to 74 • Basis: Nolte & McKee (2003), Page et al. (2006), Plug et al. (2011)	• Ethnicity: Maori, Pacific, Asian • Area level deprivation index: NZDep version as appropriate	ASMR	In 2006 Maori rates were 3 times the non-Maoris, Pacific people's rates were twice that of non-Pacific people, and Asian rates were approximately half of non-Asians. Absolute inequalities were constant for all three, and only relative inequalities increased for Maori mortality. People living in the most deprived quintile had AM rates 1.9 (men) and 1.7 (women) times that of the least deprived quintile. No significant trends in absolute nor relative inequalities

2.4.4 Asia

Four of the 12 avoidable mortality studies conducted in Asia have focused on conditions amenable to medical care. Avoidable mortality studies on this continent were fairly recent, the first being published in 2001 (Niti & Ng), however the periods of analysis include data of comparable time frames to the earliest European studies (see Table 2.7).

Chau et al. (2011) and Gusmano et al. (2015) both study Chinese city rates of amenable mortality, comparing Hong Kong and Shanghai respectively to London, Paris and Manhattan/New York. Cities were chosen as the unit of analysis as they were regarded as having advanced health care services, but also large inequalities within their populations (Gusmano et al. 2015). Chau et al. found that Hong Kong had the second lowest amenable mortality rates, following Paris. London was found to have the highest rates, however, the proportion of total mortality regarded as amenable was highest in Hong Kong. Gusmano et al. found similar patterns over a longer time period, however, New York City's amenable mortality rates exceeded that of London's. The cross city analyses allowed for some insight as to how differently organised health systems contributed towards improving rates of amenable mortality (Chau et al. 2011). The lack of screening programmes for colorectal and breast cancers in Hong Kong at the time of analysis, as well as the need for payment for cervical cancer screening, meant that the three cancers combined had a greater proportion of the overall amenable mortality, whereas IHD ranked first in the western cities.

The introduction of a National Health Insurance (NHI) scheme in Taiwan in 1995 provided the opportunity for a natural experiment, comparing amenable and non-amenable mortality rates before and after the NHI, within specific age groups (Lee et al. 2010). Using joinpoint regression, three discontinuities were found; at 1993, 1996, a year after the introduction of NHI, and 2003. After the introduction of NHI there was an increased rate of decline, particularly amongst those aged under 20, and to a lesser extent, the over 65s. Those of working age were least affected by the introduction, as they typically already had social insurance. A much smaller effect was found for total and non-amenable mortality. Rates of amenable mortality were also used to evaluate the introduction of a similar scheme in China in 2009 (Feng et al. 2016), using multilevel modelling. Reductions in rates of both amenable and non-amenable mortality were found.

Two studies have also been performed in Iran, making use of two different provinces. Rates of treatable mortality were found to have increased in urban and rural areas between 2004 and 2011 (Omranikhoo et al. 2013), however the increase was not significant. Amiresmaili et al. (2013) found rates of avoidable mortality had decreased for men and women during 2004 - 2008, but had risen back to the original levels by 2010.

Table 2.7: Empirical studies of amenable mortality in Asia

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Lee et al. (2010)	Taiwan	1981 - 2005	• Time • Conditions: 34 (IHD separately) • Age group: 0 to 74 • Basis: Nolte & McKee (2003, 2004)	none	ASMR by three age groups - under 20, 20-64 and 65+. Join point regression to identify changes in trends	Significant decline prior to NHI (1981-1992), briefly insignificant (1993-95), and then significant following NHI introduction (1996-99). Effect of introduction was strongest in the under 20s, not significant for working age or 65+, but the older group had a higher rate of decline than the working age population
Chau et al. (2011)	Hong Kong, compared to Paris, London and Manhattan	1999-2003 vs 2004-06	• Time • Conditions: 23 (inc 50% IHD) • Age group: 1 to 74 • Basis: Weisz et al. (2008)	none	ASMR	A larger percentage of female deaths were classified as being amenable, than male deaths. The proportions of AM across age groups was U shaped, with the largest proportion of deaths occurring in the oldest age group (65-74 years). Cross-city analyses revealed that Hong Kong had the highest percentage of AM within total mortality, and Paris experienced the lowest percentage

Author	Country/ Region	Period of Analysis	Study Characteristics	Measure of SEP	Main Outcome / Methods	Results
Gusmano et al. (2015)	Shanghai, compared to New York City (NYC), Inner London and Paris	2000-2010	• Time • Conditions: 23 (inc 50% IHD) • Age group: 1 to 74 • Basis: Nolte & McKee (2008)	none	ASMR	ASMR decreased from 0.72 to 0.5 per 1,000 in Shanghai, with CVD contributing the most number of deaths. ASMR decreased by 42% in London, 30% in Shanghai and NYC, and 25% in Paris
Feng et al. (2016)	China	2006-2012	• Time • Conditions: 34 (inc IHD) • Age group: 0 to 74 • Basis: Nolte & McKee (2003)	mean years of education within 161 disease surveillance points (areas)	Multilevel negative binomial regression (level 1: age, sex and year, level 2: area)	Introduction of universal health insurance was associated with reductions in rates of AM, but also rates of non-AM and selected tracer conditions. Median rate ratios for geographical variation were estimated to be 1.49 and 1.28 for AM, and non-AM respectively

2.4.5 Africa

No studies were found to include either single country analyses of avoidable or amenable mortality in Africa, nor have any been included in cross country or international analyses.

Pubmed and Scopus were further searched for studies by including 'Africa' as a search term with the previously used 'amenable mortality' and 'avoidable mortality' in March of 2017. The 261 and 177 results returned by each mainly focused on specific amenable conditions, such as infectious diseases, and perinatal and maternal deaths, and not the concept of amenable conditions as a whole.

The only study found to have some relevance at title and abstract screening was by Stirbu et al. (2006), including Moroccan migrants in a comparison of 26 causes of avoidable mortality between native Dutch and four of the largest migrant groups in The Netherlands between 1995 and 2000. The study analysed both amenable and preventable causes of death, including liver cancer, suicides and HIV/AIDS. Male Moroccan migrants had significantly lower relative risks of avoidable death compared to the native Dutch population, after adjusting for age, gender, marital status, urbanisation level and area income. The relative risk for women was not statistically significant, but suggestive of a lower risk in Moroccan migrants, as for men. Moroccan men and women had significantly higher relative risks of deaths due to diabetes and infectious diseases, compared to the native Dutch population.

2.4.6 International studies

Fourteen studies have compared rates of avoidable mortality internationally. European countries were typically compared with Australia, New Zealand, Japan and the USA. Twelve of these were limited to only amenable conditions, and are described in Table 2.8.

No studies investigated socioeconomic gradients in rates of mortality, presumably due to the lack of comparable measurements across borders and a lack of individual measures of SEP in many countries. Hoffmann et al. (2014) created an index of deprivation in a comparison of 15 European cities, using 5 of a possible 13 socioeconomic indicators available from an unnamed dataset (see Table 2.4 for detail). The source, accuracy and comparability of data between cities for the indicators used is not discussed, and therefore the potential for international comparisons using similar data cannot be evaluated.

The first international study investigating amenable mortality was performed by Charlton et al. (1986). The UK's poor performance in amenable mortality is first seen here, with

England and Wales experiencing the lowest levels of decline of the six countries analysed and Japan experiencing the greatest levels of decline. Japan continued to perform well in other international studies (Nolte & McKee 2003, 2008, Gay et al. 2011). As further evidence of the UK's poor performance, amenable mortality rates in Japan and France in 1997/8 were found to be lower than the UK experienced in 2006/7 (Nolte & McKee 2012*b*).

The impact of the choice of conditions thought to be amenable to health care is evident when studies compare two versions of lists. Gay et al. (2011) compares two lists (Nolte & McKee 2008, Tobias & Yeh 2009) in 31 OECD countries. Both lists contain amenable conditions only, but differ on the conditions' ICD codes, age ranges and percentages of conditions to include (e.g. Tobias & Yeh include only 50% of diabetes and cerebrovascular disease deaths). In 2007, the UK was ranked 19th according to amenable mortality rate, according to Nolte & McKee's list, 4 places above the OECD average, whilst using Tobias & Yeh's list, it was ranked 20th, directly above the OECD average. Greece and Korea each climbed 8 ranks using Tobias & Yeh's list, whereas New Zealand fell the furtherest, by 5 ranks. The rate of decline differs between countries, and over time, with the rate slowing for most countries in recent years (Nolte & McKee 2012*b*). The UK performs well in terms of annual percentage decline, with a 5.2% decrease in amenable mortality rates per year, just behind Ireland (5.5% per year), and well above the USA (1.8%) per year (Gay et al. 2011). Using Tobias & Yeh's list, the rate of decline in the UK decreases to 4.6% per year, equal to the decline experienced in Italy, and just below that of Australia (4.9%) and Ireland (5.4%).

The use of amenable mortality in international comparisons is attractive in that it can provide new information that is not directly currently captured by measures such as life expectancy, however, cross country differences may be due to a number of things: differences in diagnosis and coding practices, choice of amenable conditions used, and discrepancies in medical knowledge and technologies available (Gay et al. 2011).

Table 2.8: Empirical studies of amenable mortality in international contexts

Author	Country/ Region	Period of Analysis	Study Characteristics	Main Outcome / Methods	Results
Charlton et al. (1986)	England & Wales, USA, France, Japan, Italy & Sweden	1950-80 (1956-1978)	• Time • Conditions: 10 • Age group: 5 to 64 • Basis: Charlton et al. (1983)	ASMR	Declines in single cause, and all AM were experienced in each country. Japan had the greatest decline of 72%, whilst England and Wales experienced the lowest of 51%. Declines in all other causes were much smaller (between 3 and 19%), except for Japan, which experienced a 43% decline
Poikolainen & Eskola (1988)	25 developed countries	1975-1978	• Cross sectional • Conditions: 16 • Age group: 0 to 64 • Basis: Rutstein et al. (1976)	ASMR and correlations	Rates of AM were moderately correlated with the number of nurses, midwives and hospital beds per 10,000 ($-0.55 < p < -0.4$), and highly correlated with GDP ($p \sim -0.8$). AM was not associated with the number of medical doctors per 10,000 ($p = -0.15, -0.16$) for men and women
Bojan et al. (1991)	Hungary, Czechoslo-vakia, England & Wales, France, Italy, Japan, Portugal & USA	1979-1988	• Time • Conditions: 13 • Age group: 5 to 64 • Basis: Rutstein et al. (1976, 1980, 1983), Mackenbach et al. (1990)	ASMR	Whilst ASMR in all developed countries fell between 1981-88, ASMR in Hungary and Czechoslovakia increased until the middle of the period. The rates of decline after this was faster in rates of AM, than all cause, matching pattern seen in the developed countries

Author	Country/ Region	Period of Analysis	Study Characteristics	Main Outcome / Methods	Results
Boys et al. (1991)	Hungary, Czechoslovakia, Poland, the German Democratic Republic, the Federal Republic of Germany, England & Wales, USA & Canada	1955-1959, 1970-1974 and 1985-1987	• Time • Conditions: 22 (IHD separately) • Age group: 0 to 64 • Basis: Rutstein et al. (1976)	Rate change and % change	Hungary had the largest ASMR in 1985-87 with 103.8 per 100,000, compared to 22.3 per 100,000 in Canada. Rates of IHD increased between periods 1 and 2 for the Eastern European countries, whilst the remaining Western European and North American countries experienced decreases
Kjellstrand et al. (1998)	Australia, Canada, France, Germany, Italy, Japan, New Zealand, Sweden, UK & USA	1980-1990	• Time • Conditions: 6 • Age group: 5 to 64 • Basis: Rutstein et al. (1976)	Financial efficiency estimated using AMR & health expenditure	Australia was the most efficient country, buying 3 times as much 'life/$ ' than the least efficient, USA, which spent the most amount of money

Author	Country/ Region	Period of Analysis	Study Characteristics	Main Outcome / Methods	Results
Nolte & McKee (2003)	19 OECD countries	1998	• Cross sectional • Conditions: 34 (inc 50% IHD) • Age group: 0 to 74 • Basis: Nolte & McKee (2004)	Difference in ranking of ASMR between disability adjusted life expectancy, and AM	When comparing ranking with AM only (excluding 50%IHD) no country retained the same rank - 12 moved more than two places. Japan dropped 12 ranks from 1 to 13, whilst Norway had the largest gains (11 to 2). When 50% of IHD was included, Portugal (rank 18) and Italy (rank 6) retained their ranking, whilst the Nordic countries improved their ranking
Nolte & McKee (2008)	USA, 14 W. European countries, Canada, Australia, New Zealand & Japan	1997-1998 and 2002-2003	• Time and cross sectional • Conditions: 33 (inc 50% IHD) • Age group: 0 to 74 • Basis: Nolte & McKee (2004)	ASMR	Rates of AM fell faster than ‘other’ mortality for all countries, except USA men. Sweden & USA fell the furtherest in AM rankings between the two periods (4 ranks - to bottom for USA). The greatest increases in ranks were experienced by Norway and Finland, which climbed 3 places each. France and Japan remained at 1st and 2nd rank
Weisz et al. (2008)	Paris, London & Manhattan	1988-1990 and 1998-2000	• Time and cross sectional • Conditions: 23 (inc 50% IHD) • Age group: 1 to 75 • Basis: Nolte & McKee (2004)	ASMR and negative binomial regression to assess influence of neighbourhood income level on rate of AM	London had higher rates of AM in 1988-90 and 1998-2000, whilst Paris had the lowest rates of AM. Rates of AM in Manhattan decreased the most (20%), and London the least (13%). A relationship between neighbourhood level income and the percentage of amenable deaths was found for Manhattan only (IRR = 1.66, Paris IRR = 1.06, London IRR = 1.19)

Author	Country/ Region	Period of Analysis	Study Characteristics	Main Outcome / Methods	Results
Nolte & McKee (2011)	16 countries	1997/8 - 2006/7	• Time • Conditions: 33 (inc 50% IHD) • Age group: 0 to 75 • Basis: Nolte & McKee (2004)	ASMR	Declines of between 20.5% (US) and 42.1% (Ireland) were experienced over the study period, with 10 of the 16 countries experiencing declines of at least 30%
Nolte & McKee (2012*a*)	France, Germany, UK & USA	1999-2007	• Time • Conditions: 33 (inc 50% IHD) • Age group: 0 to 74 • Basis: Nolte & McKee (2004)	ASMR and age-specific mortality rates	For people under 65, the USA had the highest mortality rates over the study period, as well as the lowest rate of decline. For people between 65 and 74, the UK had the highest mortality rates at the start of the study period, followed by Germany for men, and the USA for women. By 2007, the USA had the highest rates for both sexes
Nolte & McKee (2012*b*)	16 countries	1997/8 - 2006/7	• Time • Conditions: 33 (inc 50% IHD) • Age group: 0 to 74 • Basis: Nolte & McKee (2004)	ASMR	ASMR decreased in all countries between the two time periods, with Ireland experiencing the greatest declines (42.1%), and USA experiencing the lowest (20.5%). UK has the second highest ASMR in the first (after Ireland), and second (after USA) periods

Author	Country/ Region	Period of Analysis	Study Characteristics	Main Outcome / Methods	Results
Heijink et al. (2013)	Australia, Austria, Denmark, Finland, France, Germany, Japan, Netherlands, New Zealand, Norway, Spain, Sweden, UK & USA	1996-2006	• Time • Conditions: 34 (inc 50% IHD) • Age group: 0 to 74 • Basis: Nolte & McKee (2004)	ASMR	Average decline in ASMR per year was between 2.6% (USA) and 5.3% (Austria). Countries with an above average rise in health care expenditure experienced an above average decline in ASMR (and likewise for below average spending)

2.4.7 Inequalities in rates of amenable mortality

Recently, it has been proposed that amenable mortality may reflect the equitability of a health service (Lumme et al. 2012). This is of particular importance within a universal health care system, where access to immunisations, diagnoses, treatments and surgeries across the population are freely available to all. Socioeconomic gradients in rates of amenable mortality should be minimal if these services are delivered fairly, effectively and to those in most need, given that amenable deaths are theoretically avoidable in the majority of cases. The monitoring of these mortality rates should provide an indication of how equitable a healthcare system is.

Inequalities in amenable mortality rates may be introduced through variations in access, supply, utilisation and quality of the services supplied by the healthcare system, and through disparities in background risk, such as socioeconomic position or disease incidence (Plug et al. 2012).

Variations in access, supply and utilisation

In Scotland, and in many other settings, healthcare is theoretically equally accessible for persons of equal need, via the NHS. Variations in access and utilisation of these healthcare services are difficult to measure, given variations in the need for services across different population groups.

Access to health care has been defined as "the ability to secure a specified range of services, at a specified quality, subject to a specified minimum level of personal inconvenience and cost, whilst in possession of a specified level of information" (Goddard & Smith 2001, p.1151). Therefore, variations in access to healthcare may arise from disparities in the availability and quality of services, financial or otherwise costs, and information within the population. The availability and quality of health services may vary between population groups, given that funding for primary care in Scotland is distributed according to catchment area population size, rather than deprivation level (Mercer et al. 2012), and it has been found that GP consultations in more deprived areas were generally shorter, but have longer scheduled waiting times, and patients in these areas tend to have a greater number of health problems they wish to discuss within an appointment, compared to the least deprived areas (Mercer & Watt 2007). Whilst there should be no direct personal financial costs associated with accessing healthcare in Scotland, there are many indirect and non-financial costs, such as needing time off from work for appointments or travel costs, which are likely to affect those of lower socioeconomic position more than others (Goddard & Smith 2001). Finally, variations in accessing healthcare may be influenced by variations in the information supplied to the population regarding the availability of certain services, due to cultural or language barriers (Goddard & Smith 2001).

Whilst there are indicators which may be used to measure access indirectly, such as scheduled waiting times for appointments, the concept of access as described above is difficult to observe directly for a population (Goddard & Smith 2001).

The relationship between rates of amenable mortality and the physical supply of health care has been repeatedly investigated over the years, using the numbers of general practitioners (GPs), nurses, specialists, beds available, the presence of a university hospital within the region, and length of hospital stay, amongst others, to quantify the amount of care available to the population (Mackenbach, Kunst, Looman, Habbema & van der Maas 1988, Poikolainen & Eskola 1988, Pampalon 1993). The majority of studies find weak or inconsistent relationships, regardless of the measures used; however, the supply or quantity of health care available is not necessarily related to the quality of care provided (Nolte & McKee 2004). Increased health care funding, conversely, has been found to have a positive effect on improving declines in rates of amenable mortality (Lee et al. 2010, Desai et al. 2011, Heijink et al. 2013).

Utilisation of healthcare is similarly difficult to accurately measure in terms of need. Individual contact with the healthcare system can be quantified, however, this does not take into account the length of waiting lists for appointments, nor the reason for the appointment (i.e. whether for medical attention, preventative services, or administrative requirements (e.g. sick notes, health checks)) (Goddard & Smith 2001).

Socioeconomic and demographic variation

The socioeconomic position (SEP) of an individual is defined as their social and economic position in society, in relation to others. Inverse relationships between all cause mortality and many measures of SEP have been documented in many settings (Feinstein 1993), and these inequalities have been said to be "one of the main challenges for public health" (Mackenbach et al. 2008, p. 2469). As many factors can affect the SEP of an individual, there is no one formula or method to measure SEP. Therefore various proxy measures have been used in studies investigating the socioeconomic gradient within rates of amenable mortality.

In countries where individual-level data are routinely collected, and it is possible to accurately link these to death records through the use of personal identifiers, income is a commonly used measure (see Tables 2.4, 2.5 and 2.6) (McCallum et al. 2013, Kinge et al. 2015).

This allows for a level of economic deprivation to be applied to each death, however its accuracy is dependent on the source of the data (i.e. self-reported income may be less reliable than officially collected data for taxation purposes) and does limit the study population to those who are of an economically active age, generally taken to be above 25 years (Lumme et al. 2012).

The United Kingdom has previously favoured occupation as a measure of social class (Graham 2009). However, like income, the measure is only accurate for the actively employed, therefore excluding children, pensioners and those seeking employment. Poikolainen & Eskola (1995) assigned the family's principal supporter's occupation level to any children (age $<$18 years) included in the study of amenable mortality within Helsinki. The same study assigned students and individuals with unknown occupations to the lowest two levels of the subgroups (total levels=6).

European countries tend to measure SEP using educational attainment, as this is typically independent of future health status (see Table 2.4) (Hem et al. 2007, Graham 2009, Stirbu et al. 2010). However, using measures of education, such as number of years spent in education, has limitations. The age at which pupils were allowed to leave school differs between countries, and has varied over time. Therefore, educational policy can influence this measure. The compositional structure of educational attainment has also changed over the years, with many more people achieving higher levels of attainment than what was accessible to older birth cohorts. These changes to the distribution of attainment across a population can affect time trend analyses when not properly accounted for (Mackenbach et al. 2015).

In many countries there is little or no access to regularly updated individual level SEP data, due to privacy restrictions. In these instances, ecological or area-based variables may be used as proxy composite indicators of the affluence or deprivation of the group of individuals based within the geographical area of interest. This requires that the variable is as representative of the group as possible, therefore the data used to create the index typically come from a population Census (Page et al. 2006, Nagy et al. 2012, Barr et al. 2014). Hoffmann et al. (2014) discusses the need for these analyses, stating that the determinants of health and health inequalities were not limited to individual level measures of SEP.

Castelli & Nizalova (2011) conclude that, regardless of the region and time period of interest, inverse relationships between rates of amenable mortality and socioeconomic position continue to exist, with little evidence of a decrease in inequalities.

2.5 Chapter Summary

In an earlier literature review, Kamarudeen (2010) concluded that the lack of agreement on what constituted an amenable condition made the concept imprecise. The current review of the literature has revealed that, whilst small differences remain, the concept has narrowed over time, reflecting changes in how health systems are organised, as well as improvements in medical knowledge and treatments available. There exists a core set of conditions which consistently were identified as being amenable to medical care, and the overall age limits are currently set to under 75 years. Many authors acknowledge its usefulness as a measure of health system outcomes (Gay et al. 2011, Nolte & McKee 2012*b*, Allin & Grignon 2014). However, researchers and users should be mindful that amenable mortality is simply an indicator of problematic areas within a health care system, and is not a definitive measure of its effectiveness (Plug et al. 2011).

2.5.1 Questions arising from the literature review

The literature review revealed that rates of amenable mortality have not been widely investigated in Scotland, compared to many other European countries, such as the Netherlands, Finland, and England and Wales (3 studies compared to a combined total of 23), and that published results were lacking in recent research, as well as investigations into changes in mortality gradients over time. Therefore, the first aim of this thesis will be to describe the changes in rates of amenable mortality in Scotland, over time.

In doing this, socioeconomic gradients in area level measures of deprivation will be analysed, as these are the most commonly used, and easily accessible proxy measures of SEP in the United Kingdom. Gradients in individual level measurements and demographic factors will be explored for a sample of the Scottish population, allowing for comparison with other European countries.

A limitation which is consistently highlighted in the research is the lack of consideration of amenable disease incidence in the population under observation, as discussed in subsection 2.3.1. Using linked medical records from the National Health Service in Scotland, the incidence of amenable conditions in the general population of Scotland can be estimated, and explored much in the same way as mortality rates. This will enable the relationship between rates of incidence and mortality of amenable conditions to be further understood.

Whilst limitations in cross country analyses were identified in the review (see section 2.4.6), comparisons with England will be made, as similar levels of health resources will be available to each, as well as similarities in the level of data available and coding of death practices. This analysis will update current knowledge in the face of a multitude of health system reforms in England. It will also explore the use of amenable mortality as a comparator for health care systems.

The main methods used to explore these research aims are outlined in the next chapter, followed by five analysis chapters.

Chapter 3

General Methods

3.1 Introduction

This chapter will outline the main methods of analysis that have been used throughout this thesis. Each analysis chapter will outline any additional methods which are required to meet the research aims. Repeated references to this chapter will be made.

3.2 Choice of conditions amenable to medical intervention

The original list of diseases which could lead to an 'unnecessary untimely death' was first published by Rutstein et al. in 1976. These conditions were identified through collaborations between the Working Group on Preventable and Manageable Diseases and medical specialists, on the basis that critical increases in mortality rates from these diseases could act as a negative indicator of the quality of care delivered. Over time, this list has been updated and modified to reflect country and time specific advances in medical care (Mackenbach, Looman, Kunst, Habbema & van der Maas 1988*a*).

The literature review revealed that results of amenable mortality studies are highly dependent on the choice of conditions considered to be amenable to health care intervention (see subsection 2.3.4), and that the choice of conditions used was often based on the data available, such as Finnish studies excluding deaths due to surgical or medical misadventure as these were not separately classified in the Finnish Causes of Death Register (Lumme et al. 2012, McCallum et al. 2013). Even with these constraints, the majority of conditions considered to be amenable did overlap across analyses.

The most commonly used list of amenable conditions is that of Nolte & McKee (2004), and its later update in 2008. Given that the last years of analyses presented in this thesis are approximately 9 years after the original publication, it was decided to update the list of conditions considered to be amenable, to one which encompasses a wide range of conditions, including those which are typically excluded due to small counts of death (Office for National Statistics 2012*a*). For this, the two lists of Nolte & McKee (2004, 2008) were combined with lists by Page et al. (2006); Lumme et al. (2012); and McCallum et al. (2013). Of the 51 conditions in the new list (see Table 3.1), 28 (53%) appeared on at least four of the contributory lists. Only 6 (12%) of conditions appeared on just one list - all in Page et al. (2006). The report by Page et al. provided a full rationale for the choice of conditions considered to be amenable to medical care, which was consulted during the process, and used as justification for the inclusion of rubella, bacterial meningitis, malignant neoplasm of the thyroid, other diseases of the gallbladder and billary tract, and diseases of the pancreas. The ICD codes used to identify these conditions are detailed in Appendix A. The amenable conditions contained in these lists are used throughout this thesis.

Table 3.1: Causes amenable to healthcare intervention with age limits

Cause of Death	Age
Primary Prevention	
Intestinal Infections	0-14
Other infections (Diphtheria, Tetanus, Poliomyelitis and Varicella)	0-74
Whooping cough	0-14
Scarlatina	0-74
Meningococcus	0-74
Erysipelas	0-74
Measles	0-14
Rubella	0-74
Malaria	0-74
Streptococcal pharyngitis	0-74
Cellulitis	0-74
Early detection and intervention	
Tuberculosis	0-74
Malignant neoplasm of colon and rectum	0-74
Melanoma of skin	0-74
Malignant neoplasm of skin	0-74

Malignant neoplasm of breast (Women only)	0-74
Malignant neoplasm of cervix uteri	0-74
Malignant neoplasm of unspecified parts of uterus & body of uterus	0-44
Malignant neoplasm of bladder	0-74
Neoplasm of Thyroid	0-74
Benign tumours	0-74
Hypertensive disease	0-74
Cerebrovascular disease	0-74
Bacterial Meningitis	0-74
Improved treatment and medical care	
Septicaemia	0-74
Legionelliosis	0-74
Malignant neoplasm of testis	0-74
Hodgkin's disease	0-74
Leukaemia	0-44
Diseases of the thyroid	0-74
Diabetes mellitus	0-74
Epilepsy	0-74
Rheumatic and other valvular heart disease	0-74
Nephritis and nephrosis	0-74
All respiratory diseases (excl. pneumonia / influenza)	0-14
Influenza	0-74
Pneumonia	0-74
Chronic obstructive pulmonary disease	45-74
Asthma	0-44
Peptic ulcer	0-74
Appendicitis	0-74
Abdominal hernia	0-74
Cholelithiasis and cholecystitis	0-74
Other diseases of the gallbladder	0-74
Other diseases of the billary tract	0-74
Diseases of pancreas	0-74
Obstructive uropathy and prostatic hyperplasia	0-74
Maternal death	0-74
Perinatal deaths (all causes excl. Stillbirths)	0-74
Congenital cardiovascular anomalies	0-74
Misadventure to patients during surgical and medical care	0-74

Conditions which were considered to be amenable to health care intervention, but were responsible for a small number of deaths per year, such as measles or legionellosis were retained in the list, in order to ensure that any changes resulting in increased numbers of death would be identified early. Deaths due to Surgical or Medical Misadventure were included in the list, following its inclusion in both lists by Nolte & McKee (2004, 2008), as well as the original list (Rutstein et al. 1976). The remaining three lists did not include misadventures in their analyses, however McCallum et al. and Lumme et al. both acknowledged its exclusion was necessary due to the Finnish Cause of Death Registry not classifying these deaths separately (Lumme et al. 2012, McCallum et al. 2013).

The amenable conditions will also be studied within the three subgroups, used by Lumme et al. (2012) and McCallum et al. (2013): (1) primary prevention, (2) early detection and intervention, and (3) improved treatment and medical care. The subgroups were defined by the type of intervention required in order to treat or cure a case. These sub-analyses are of interest as they allow for a greater level of evaluation than the overall rates of amenable mortality may provide, such as inequalities in conditions which can specifically be avoided through immunisations, and inequalities in conditions which are typically identified through screening programmes. These groupings were initially introduced by Simonato et al. (1998), as discussed in subsection 2.3.3, as a method of breaking down the overall findings of the research into potentially more enlightening results.

Conditions included within the primary prevention subgroup are conditions which can be prevented through improved hygiene measures or immunisations. Whilst these may be considered to be population level interventions, they are delivered to individual patients within a primary care setting, and so are considered to be amenable to healthcare intervention. The conditions considered amenable to early detection and intervention are diseases which, if identified early, can be cured or managed with treatment. These include cancers with a detectable pre-malignant stage which can be identified through screening, strokes, and hypertensive disease. The final subgroup includes chronic conditions which can be managed within a primary care setting with medications, such as asthma or diabetes, and conditions which require surgical or specialist medical intervention, such as appendicitis, ulcers or maternal conditions. By investigating inequalities in rates of mortality within these three subgroups, inequalities in the access to or provision of specific types of health care can be explored within Scotland, improving the overall indicators ability to identify areas of requiring improvements.

An overall age limit of 0 - 74 years was applied to the majority of the causes of death listed in Table 3.1, in agreement with current research, and the five lists used to create the new list. Selected causes of death had previously been given narrower age limits, such as asthma, which is considered to be amenable before the age of 45 years. The limits used by each of the five main lists were combined, and where they disagreed, the most inclusive range was applied.

3.2.1 Ischaemic heart disease, cerebrovascular disease and diabetes mellitus

As discussed in the literature review (section 2.3.4), Ischaemic heart disease (IHD), cerebrovascular disease and diabetes mellitus have previously been identified as being partially amenable. In earlier research, the deaths due to these conditions have either been included, partially included, or excluded.

For IHD, the option of using 50% of the resultant IHD deaths was not considered in this thesis, as the proportion of total deaths amenable to healthcare intervention is likely to vary over the long time-span used in the analysis. The proportions of deaths avoidable are also likely to vary by socioeconomic groups, and given this thesis' focus on socioeconomic gradients in amenable mortality, the use of a constant percentage of deaths may introduce bias into the results (Blakely et al. 2005).

Given the large share of IHD deaths among all deaths amenable to healthcare intervention, its influence on declining mortality rates in many other countries (Nolte & McKee 2011), and the debate concerning the extent to which such deaths are amenable to healthcare intervention, these were excluded from this analysis, ensuring that trends in the rates of the remaining amenable deaths were not obscured. None of the five lists of amenable conditions combined into Appendix A include all of IHD deaths: two analyse half of the deaths (Page et al. 2006, Nolte & McKee 2008), a further two analyse the deaths separately (Nolte & McKee 2004, McCallum et al. 2013), and the final list excluded all IHD deaths from the analysis (Lumme et al. 2012).

Numbers of deaths, and therefore proportions of amenable mortality, due to cerebrovascular disease and diabetes were smaller than IHD, and they were less frequently identified in the literature as being partially, rather than wholly amenable. Therefore all of these deaths were included in this analysis, in agreement with four of the five lists of amenable conditions this analysis is based upon.

3.3 Data sources

All data used in the analyses described in this thesis are routinely collected for official statistics. The use of these data sources for secondary analysis has many advantages, including their availability at the population level and no costly data collecting exercises are needed.

3.3.1 Outcomes

The main outcome of interest is mortality amenable to health care intervention. For this, records of all deaths occurring to Scottish residents between 1980 and 2013 were used. This database of death records was officially produced by the National Records of Scotland (previously General Register Office for Scotland), and is held by the MRC/CSO Social and Public Health Sciences Unit, University of Glasgow. In Scotland, all deaths are required to be registered within eight days of occurrence, and each death record is automatically quality checked by an electronic system, and the cause of death codes are further checked by staff. The dataset is regarded as the most accurate record of deaths in Scotland (Administrative Data Liaison Service n.d.*a*).

The variables extracted from the death records included year of death, sex, age at death, postcode sector of residence, council or local government district of residence, the final underlying cause of death (as classified using the International Classification of Diseases, ICD), as well as the version of ICD used. Deaths occurring in Scotland were classified using version 9 of the ICD until 1999, and version 10 from 2000 onwards (Administrative Data Liaison Service n.d.*a*). Whilst the ICD codes for each cause of death are harmonised between versions, modifications to the decision making process for underlying cause of death assignments has resulted in some discontinuities in trends.

The amenable deaths were identified using the ICD codes, ICD versions, age restrictions and the list of causes in Appendix A.

3.3.2 Population

Two population size datasets were available for the analyses performed in this thesis. Both are officially produced by the National Records of Scotland.

The first, held by the MRC/CSO Social and Public Health Sciences Unit, University of Glasgow, contains 5-year age sex population estimates at the postcode sector level. These estimates are obtained from Census return forms, therefore the dataset contains population sizes for 1981, 1991, 2001 and 2011 at the small area level. These estimates can be used as the denominator in the calculation of age-standardised mortality rates, however, as Censuses only occur in the UK every 10 years, the estimates at the postcode sector level are not updated on a yearly basis. In order to calculate yearly mortality rates, a constant population size can be used for each area for the 10 years surrounding each Census (e.g. 2001 population size was applied to all years in 1997 to 2006 inclusive).

The second dataset, obtained from the National Records of Scotland, consists of annual mid-year population estimates by 5-year age and sex groups (National Records of Scotland n.d.). These are derived by ageing up populations from the most recent Census, and adjusting for births, deaths and migrations[1]. The mid-year estimates are calculated at the country, NHS Health Board and council level, but not at the postcode sector level, as is available for the Census population estimates. The annual mid-year estimates are used in the calculation of age standardised rates, however as population sizes at the small area level are required for multilevel modelling, the postcode sector population sizes had to be simulated. These were estimated by applying the proportions of each age-sex group observed within each postcode sector at the nearest Census year to the total mid-year population for that year.

An example of this calculation is set out in Table 3.2.

Table 3.2: Example of the calculation of the proportional population sizes: Example case - Men living in AB10 1 (Scotland)

	Aged 0 - 4	Aged 35 - 39
Area 2011 Census population	32	108
Total 2011 Census population	149,224	166,230
∴ proportion	0.000214	0.000649
2010 mid-year estimated population	148,334	168,612
2011 mid-year estimated population	149,746	164,469
2012 mid-year estimated population	150,987	158,147
∴ Estimated population size at 2010	31.81	109.55
∴ Estimated population size at 2011	32.11	106.86
∴ Estimated population size at 2012	32.38	102.75

Note: the 2011 Census was performed on 27^{th} March, therefore three additional months of births, deaths, and migrations are taken into account between the Census population estimate and the mid-year estimate.

[1]For methodology see NRS Mid-Year Population Estimates for Scotland: Methodology Guide at https://www.nrscotland.gov.uk/files//statistics/population-estimates/mid-year-2016/16-mid-year-pe-method-guide.pdf

The population at risk is required for the calculation of age standardised mortality rates and in multilevel modelling. The age standardised mortality rate calculations require overall population sizes by 5 year age and sex groups, whereas the multilevel modelling analyses require these populations at the small area level.

3.3.3 Numerator-denominator bias

When the sources of death records and the population estimates are unlinked, such as in this analysis, the results may be prone to numerator-denominator bias. This occurs when the classifications of the people in each do not align across each source (e.g. the self-reported occupation recorded at the Census may not match the occupation reported on the death certificate). The main classification used in this analysis is an area level deprivation index, rather than an individual measure of socioeconomic position. This method of classification will reduce the risk of numerator-denominator bias, as residential address, which is used to classify persons, will generally be recorded correctly on both the death record, and the Census return form (Tobias & Cheung 2003).

3.4 Age Standardised Rates

The comparison of crude mortality rates over time, or between two different populations may be confounded by differing age structures in the populations (Boyle & Parkin 1991). Age standardised mortality rates adjust for the differing age structures in the populations, therefore comparisons over time and space are more likely to reveal true differences. Previous literature has used both direct and indirect standardisation methods, however direct standardisation is more popular, and will be used in this thesis, as mortality rates from different populations, or different times can be compared to each other (Readhead 2016).

The European Standard Population (ESP) for 2013 (European Commission, 2013) was used to directly standardise the mortality data in all forthcoming analyses. Using a hypothetical standard population allows mortality rates to be compared over time and between groups of conditions (Wheller et al. 2007). The ESP was originally introduced in 1976, but the use of ESP1976 is not recommended for time trend analyses which extend beyond 1994, as in this thesis (Readhead 2016). Table 3.3 details the variables required and calculations undertaken in order to directly age-standardise a mortality rate, along with an example.

The number of deaths (n_i) and population (p_i) depend on the size of area unit being analysed.

Table 3.3: Direct age-specific mortality rates

Age group	Number of deaths	Population	Age-specific rates per 100,000	European Standard population
i	n_i	p_i	$a_i = \frac{n_i}{p_i} \times 100,000$	e_i
0-4	110	149,224	73.714	5,000

In this thesis, mortality rates are calculated for population weighted deciles, and therefore, the population size will be the number of people of age group *i*, living within the decile of interest. Deprivation deciles are designed to contain approximately 10% of the population.

The European standard population details a population structure for the whole age range, divided into 5-year age bands, up to and including "90+ years". As the analyses contained in this thesis are restricted to ages 74 and below, truncated age standardisation is required (Boyle & Parkin 1991). Truncated age standardised amenable mortality rates (TASR) can be calculated using Equation 3.1 for the 15 age groups.

$$TASR = \frac{\sum_{i=1}^{15} a_i e_i}{\sum_{i=1}^{15} e_i} \tag{3.1}$$

These truncated rates are then interpreted as being per 100,000 population.

Confidence intervals for each mortality rate are calculated using the variance of the TASRs, through equations 3.2 and 3.3.

$$Var(TASR) = \frac{\sum_{i=1}^{15} \frac{a_i e_i^2 (100{,}000 - a_i)}{n_i}}{(\sum_{i=1}^{15} e_i)^2} \tag{3.2}$$

$$TASR \pm Z_{\alpha/2} \times \sqrt{Var(TASR)} \tag{3.3}$$

Where $Z_{\alpha/2}$ is the confidence coefficient, here calculated with a significance level of α = 5%.

3.5 Area based measures of deprivation

There are two main methods of measuring material deprivation at the small area level in Scotland: the Carstairs Index, and the Scottish Index of Multiple Deprivation (SIMD). Both have been widely used in analyses of socioeconomic gradients in rates of morbidity and mortality (Leyland et al. 2007*b*). A description of each follows, along with a discussion of their differences.

3.5.1 Carstairs Index

Originally developed in the 1980s, initially using data from the 1991 Census, the Carstairs index has become one of the two most commonly used measures of deprivation in Scotland (McLaren & Bain 1998). Created by combining the four Census variables outlined in Table 3.4, the index reflects the material deprivation of an area, in relation to the rest of Scotland. The indices are calculated at the postcode sector level, a group of postcodes which share the same characters, except for the last two digits, for example (G11 6**). The average population sizes of postcode sectors have remained relatively consistent over the years (1981: 4,895, 1991: 5,096, 2001: 5,012, 2011: 5,233).

Table 3.4: Components of the Carstairs index *(source McLoone (2000))*

Variable	Description
Male unemployment	The proportion of economically active males seeking or waiting to start work
Lack of car ownership	The proportion of all persons in private households which do not own a car.
Overcrowding	The proportion of all persons living in private households with a density of more than one person per room
Low social class*	The proportion of all persons in private households with an economically active head with head of household in social class 4 or 5.

* 1981 and 1991 indices use the Registrar General's social class. The 2001 and 2011 indices make use of the NS-SEC.

As the Carstairs index is calculated using the Census, there have been four versions: 1981, 1991, 2001 and 2011. From 2001 onwards, the Registrar General's Social Class variable was replaced by the National Statistics Socio-economic Classification (NS-SEC). The correlation between the 1991 and 2001 indices (r=0.955) suggests that this change has had little impact on the overall measure (Leyland et al. 2007*b*). The definition of overcrowding variable was also amended between 1981 and 1991, due to the inclusion of kitchens at least 2 meters wide into the room count (McLoone 2000).

3.5.2 Scottish Index of Multiple Deprivation

The Scottish Government use the Scottish Index of Multiple Deprivation (SIMD) to measure and identify small areas (datazones) within Scotland which have relatively high levels of multiple deprivation. Datazones contain a population of between 500 and 1,000 household residents (Office of the Chief Statistician 2004).

The relative deprivation of each datazone is estimated by combining information on seven domains: income, employment, education, housing, health, crime, and geographical access to services (Scottish Government 2006), and the indicators which made up each domain of the 2006 SIMD are described in Table 3.5. Changes to the indicators, domain weighting, and the inclusion of the Crime domain, have been introduced since the initial calculation of SIMD in 2004, therefore the versions of each SIMD may not necessarily be directly comparable (Scottish Government 2006).

Table 3.5: Domains of the Scottish Index of Multiple Deprivation
(source Scottish Government (2006))

Domain	Indicators
Current Income	• No. adults claiming Income Support, Guaranteed Pension Credit or Job Seekers Allowance • No. children dependent on a claimant of Income Support or Job Seekers Allowance
Employment	• Working Age Unemployment Claimants count averaged over 12 months • Working Age Incapacity Benefit and Severe Disablement Allowance claimants • Working Age Compulsory New Deal participants
Education Skills & Training	• School pupil absences • Pupil performance on SQA at stage 4 • Working age people with no qualifications • 17-21 yr olds enrolling into higher education • People aged 16-18 not in full time education
Housing	• Persons in households that are overcrowded • Persons in households without central heating

Health	• Standardised Mortality Ratio • Hospital Episodes related to drug or alcohol use • Comparative Illness Factor • Emergency admissions to hospital • Proportion of population being prescribed drugs for anxiety, depression or psychosis • Proportion of live singleton births of low birth weight
Crime	• Recorded crime rates of violence, domestic housebreaking, vandalism, drugs offences and minor assault
Geographical access to services	• Drive time to GP, petrol station, post office,shopping facilities, and primary & secondary schools • Public transport time to GP, post office, and shopping facilities

Data used to create the domains are provided by the Department for Work and Pensions, Her Majesty's Revenue and Customs (HMRC), National Records of Scotland, Police Scotland, the Census, and the Scottish Qualifications Authority. Each domain contributes a domain score for each datazone, and these are ranked, standardised, transformed and weighted to create the overall SIMD score. The SIMD score is ranked to create the SIMD rank for each datazone. The Employment and Income domains are the highest weighted domains, therefore contributing the most towards the overall ranking, whilst the Housing domain has the smallest weight (Scottish Government 2016*b*).

SIMD was first released for use in 2004, and has since been updated in 2006, 2009, 2012 and 2016. The datazone boundaries have not remained constant over time, owing to movements in the population over time. The 2004, 2006, 2009 and 2012 SIMD versions used the 2001 Datazone boundaries, whereas the 2011 Datazone boundaries were used for the 2016 SIMD (ISD Scotland, n.d.*b*).

3.5.3 Comparison between the Carstairs index and SIMD

Accurate individual level measures of SEP for the Scottish population are not available for population-wide mortality analyses. Therefore, area level measures are necessary to account for differences in the SEP of the population. The advantages and limitations of each of these measures need to be recognised.

The Carstairs index has been calculated for over 30 years, whereas the SIMD was first calculated in 2004. Updates to the SIMD have been far more regular, as the calculation relies on administrative data, rather than the decennial Census data that the Carstairs indices requires. Therefore, the start date, and time span over which analyses are to be performed must be taken into consideration when choosing an index. For analysis of data prior to 1996 (GDP Team 2017), the Carstairs score is preferable.

The underlying data sources of each are important to consider. The Carstairs indices are calculated using the Census, a questionnaire that remains relatively unchanged over time, and are broadly similar across the UK, whereas the individual components of the SIMD can be affected by any policy reforms (Allik et al. 2016). The consistency of the Carstairs indices over time is an advantage for studies with long analysis periods.

The area unit used by the Carstairs indices - the postcode sector - is primarily designed for postal deliveries and is controlled by the Royal Mail. Therefore, whilst its boundaries are recognisable, changes to these have occurred over the years which make health comparisons over time difficult (McLaren & Bain 1998). Data zones for the 2004 - 2012 versions of the SIMD are stable, making comparisons over time simple. However, the change to a new mapping of data zones for the 2016 index (Scottish Government 2016*b*), will introduce similar difficulties of consistency of areas over time for future analyses.

The issue of ecological fallacy, or aggregation bias, whereby associations found at the area level are wrongly assumed to also be true at the individual level, is a further consideration for area level analyses (Gerstman 2013). Not all persons living within a deprived area will be considered to be individually deprived (Fischbacher 2014). Larger areas, containing more people, are less likely to be internally homogeneous, and therefore deprivation indices less accurate. The area unit used by the SIMD, data zones, are designed to contain a smaller number of people within each unit than the postcode sector (mean of approximately 800 vs 5,000), therefore it could be assumed that the SIMD measures are likely to be a more accurate representation of the relative deprivation an area experiences.

The components of each index also require consideration. The Carstairs index has been criticised for its ‘urban view’ of deprivation (Rey et al. 2009). The inclusion of a lack of car ownership component, which aimed to be a proxy of individual income, better reflects the material deprivation of populations within urban areas, where car ownership is a luxury, than rural areas, where car ownership is likely to be considered a necessity, regardless of SEP. The exclusion of women in the ‘low social class’ component of the Carstairs index is a further criticism of its relevance to measuring deprivation in current times, whilst overcrowding has been found to now only affect 3% of the population (Brown et al. 2014). The inclusion of the Standardised Mortality Ratio indicator within the Health domain of the SIMD is problematic for analyses of health and mortality within Scotland, due to the possibility of tautology. Therefore, analyses of mortality data using the SIMD typically make use of only the Income domain of the index (Leyland et al. 2007*b*), as it is highly correlated with the overall index, and is one of the two most heavily weighted domains (28% - tied with Employment) (Scottish Government 2016*b*).

Given all of these considerations, the Carstairs index will be used for these analyses. This thesis aims to explore gradients in amenable mortality in Scotland from 1980 onwards, and whilst the SIMD may be a better measure in terms of limiting ecological fallacy, it cannot be applied to these early deaths. Whilst the use of population quintiles (5 groups, each containing 20% of the population) is generally recommended for routine reporting, a greater level of detail is desired in this thesis, especially when exploring socioeconomic gradients within subgroups of amenable mortality. Therefore, all analyses using the Carstairs index will be calculated using population deciles (10 groups, each containing 10% of the population) (GDP Team 2017). In the published Carstairs index assignments for 1981, 1991 and 2001, decile 1 represented the least deprived, whilst decile 10 contained the most deprived areas. The 2011 published index decile assignments were reversed, with decile 1 now representing the most deprived, and decile 10 representing the least deprived (Brown et al. 2014). This brought the 2011 index in line with the current ordering of the SIMD. The results presented in this thesis using the 2011 index will have their deprivation decile categories re-arranged, matching earlier versions of the Carstairs index.

The four versions of the Carstairs index, calculated from the 1981, 1991, 2001 and 2011 Censuses, will be used in this thesis. Each version will apply to the 10 years surrounding each Census, as described in Table 3.6. These assignments are recommended by the GDP Team (2017).

Table 3.6: Versions of Carstairs indices assigned to years of deaths

Carstairs index version	Year of death
1981	1980 - 1986
1991	1987 - 1996
2001	1997 - 2006
2011	2007 - 2013

3.6 Poisson Regression

Poisson regression was used in all analyses included in this thesis to model the counts of death observed within age groups, deprivations deciles, areas and years. In general, Poisson regression is used to model the number of events which occur within a specified time interval (Faraway 2006). The total number of events does not have an upper bound and within each group may be small, such as the number of amenable deaths occurring within combinations of age group, sex, year and postcode sector or deprivation decile (Rasbash et al. 2012*a*).

When modelling rates of death, an offset is included into the model, which accounts for differences in the population at risk (Faraway 2006), such as differences in age structure over time. Equation 3.4 describes the observed counts of death, d_i distributed as a Poisson rate model, with the mean count of deaths represented as π_i, and p_i is the population at risk in group *i*. $X\beta$ represents the matrix notation of the model, where *X* is the design matrix, and β is the vector of coefficients.

$$\begin{aligned} d_i &\sim Pois(\pi_i) \\ log_e(\pi_i) &= log_e(p_i) + X\beta \\ log_e\left(\frac{\pi_i}{p_i}\right) &= X\beta \end{aligned} \tag{3.4}$$

for d = 0,1,2,... and $\pi_i > 0$. In Poisson regression, the mean is assumed to be equal to the variance (Faraway 2006).

3.7 Measures of inequality

Two methods of measuring inequalities in mortality rates across a socioeconomic gradient are used in this thesis: the relative index of inequality (RII), and the slope index of inequality (SII). These measures have been found to have "optimal measurement properties" when exploring health inequalities (Mustard & Etches 2003, p. 979), and the relative index has previously been recommended as one of three possible metrics in Scotland which were able to give a 'comprehensive picture of inequalities' (Scottish Government 2008, p. 52).

The RII is a regression based approach for measuring the inequalities in rates of mortality for the notionally most deprived, relative to the notionally least deprived. It takes the whole socioeconomic distribution into account, rather than just using the extremes, and is therefore sensitive to changes in the distribution of levels of the SEP within the study population

(Moreno-Betancur et al. 2015). The SII is the equivalent measure of the RII in absolute terms.

RII are calculated by ordering the categories of the socio-demographic group from highest to lowest advantage. This assumes that rates of mortality will increase with decreasing advantage. In order to take the distribution of all categories within the SEP measure into account, rather than the two extremes categories, a 'population fraction' for each category of the SEP measure must be calculated. The population fraction is a weighting variable that utilises the relative position and the size of the SEP group (Schwarz 2007) in order to create a socio-economic rank for each category of the SEP measure. Table 3.7 describes this method for a population divided into three subgroups. The resulting population fraction is a continuous variable, ranging between 0 and 1, with 0 representing the notionally most advantaged, and 1 representing the notionally most disadvantaged.

Table 3.7: Calculating the population fraction and example

Group	Denominator*	Proportion	Cumulative proportion	Population fraction
	a	A = $^{a}/_{a+b+c}$	A	$^{A}/_{2}$
	b	B = $^{b}/_{a+b+c}$	A+B	$^{A+(A+B)}/_{2} = A +^{B} /_{2}$
	c	C = $^{c}/_{a+b+c}$	A+B+C (=1)	$^{(A+B)+(A+B+C)}/_{2} = A + B +^{C} /_{2}$
1	150	0.15	0.15	0.075
2	350	0.35	0.5	0.325
3	500	0.5	1	0.75

$*$ The denominator is either the total population at risk, or the total number of person years, within each group.

When using deprivation deciles, the denominator is 10 approximately equal sized groups of the whole population. The population fraction is therefore 0.05 for the least deprived decile, and 0.95 for the most deprived, when calculated for the whole population, but not necessarily for age and sex groups calculated within a decile.

The population fraction was included in the Poisson regression model in Equation 3.5, modelling the counts of deaths within each category, adjusted for age group, and offset by the person years at risk. Sex specific models were run for each study period.

$$log(d_{ig}) = \alpha + \beta agegroup_i + \gamma populationfraction_g + log(p_{ig}) \tag{3.5}$$

where *d* is the observed number of deaths, *p* is the population denominator (either population size, or person years at risk), *i* represents each age group, and *g* represents the g^{th} category of the SEP measure.

The exponential of γ, the coefficient of the population fraction, is the RII. A large RII indicates greater inequalities in mortality across the socioeconomic gradient. A RII of 1 indicates that there is no inequality in rates of mortality across the gradient, whilst an RII of 2 indicates that the mortality rate in the notionally most deprived group is twice that of the notionally least deprived.

The 95% confidence intervals for the RII were calculated through Monte Carlo simulations, as proposed by Lumme et al. (2015) as the confidence intervals of the regression parameter estimated during the modelling process take sampling error into account, a source of uncertainty which is not relevant when using register-based data sources of the total population. Firstly, it was assumed that the observed population denominator, p_{ig}, were correct for age group *i* and SEP group g. This quantity was held constant for all simulations.

The numbers of deaths within each age and SEP group were then simulated using a Poisson distribution, $\lambda_{ig} \sim Poi(d_{ig})$ where d_{ig} is the observed number of deaths in age group *i* and SEP group g. The Poisson distribution was used as the random process generates whole, non-negative counts, which are used as counts of deaths in the calculation of the RII.

Equation 3.5 was evaluated using the simulated deaths λ_{ig} in place of the observed deaths, d_{ig}. The estimated value of γ was recorded. The values of the population fraction remained constant, as this is calculated using the observed population denominator, p_{ig}.

This process was repeated 10,000 times, resulting in 10,000 simulated γ coefficients for each sex, year group, and SEP measure. The 2.5 and 97.5 percentiles of the distribution were located, and these were exponentiated to form the confidence bands around the RII.

The SII, an absolute measure of the inequalities in mortality rates at either end of the hierarchy, was calculated using Equation 3.6 (Mackenbach et al. 2008, Ezendam et al. 2008).

$$SII_{jk} = 2 \times MR_{jk} \times \frac{RII_{jk} - 1}{RII_{jk} + 1} \tag{3.6}$$

where *j* = 1 (men), 2 (women), *k* represents the study period and MR is the age standardised mortality rate. Confidence intervals for the SII were calculated using the same equation, substituting in the simulated upper and lower limits of the RII where appropriate.

Whilst a statistical significance level of p <0.05 was used for all tests, the size and direction of the inequalities was of more interest. This is due to the size of the sample; small differences were likely to be found to be statistically significant, but may not necessarily be of significance to public health.

3.8 Fractional Polynomials

The effect of a selection of variables on the rates of amenable mortality are of interest, and can be investigated through regression modelling. Three of the collected variables of interest can be thought of as continuous - age, deprivation and year of death. Whilst age and deprivation have been dichotomised into 15 and 10 ordinal groups respectively, in these analyses they have continued to be treated as continuous predictors. This is because mortality rates are likely to increase with increasing age, and the mortality rates for decile *j* are likely to lie between the mortality rates of deciles *j*-1 and *j*+1.

The relationship between a continuous predictor and a response can be difficult to model, especially when it is not linear. Typically, curved relationships are modelled using polynomial regression. However, often the models which best fit the observed data do not meet scientific plausibility. As an alternative, fractional polynomial (FP) models can be used, as proposed by Royston & Altman (1994). Fractional polynomials have been said to produce more realistic functions, compared to linear splines, however their interpretation is more difficult (Tilling et al. 2014).

The procedure for selecting and fitting a fractional polynomial model is described in Royston & Sauerbrei (2008), but essentially involves the repeated selection and statistical testing of up to two powers, **p**, for each continuous variable, x, supplied in the model, with **p** being selected from a predefined set S= { -2, -1, $-^1/_2$, 0, $^1/_2$, 2, 3 }, where the x^0 represents $log_e(x)$. This set is preferred to all real numbers as estimation is faster, and models are more likely to converge (Royston & Sauerbrei 2008). The inclusion of more powers into the set offers minor improvements in model fit, and may allow outliers more influence on model fit (Royston et al. 1999)

The resultant fractional polynomials in the converged model are best presented using a function plot, as reporting of the parameter estimates and polynomial powers alone do not adequately describe the relationship. The function plot models the partial predictor for the continuous variable, *x*, as $\hat{\eta_x} = \hat{\beta}_0 + x^{\mathbf{p}}\hat{\beta}$, where *x* is modelled as an FP with power(s) **p** and parameter estimate β, and $\hat{\beta}_0$ is the intercept.

All fractional polynomials were estimated using Stata (see section 3.10) and the `mfp` procedure[2]. Equation 3.7 describes the Poisson regression model used to estimate the fractional polynomials.

$$\begin{aligned} log(deaths) &= age + decile + year \\ &+ age \times decile + age \times year + decile \times year \\ &+ age \times decile \times year + log(population) \end{aligned} \tag{3.7}$$

Where the age variable represents the 15 age groups, but is centred for each group, i.e. age group 0 to 4 years is represented as age 2 years, age group 5 to 9 years is represented as age 7 years, and age group 70 - 74 years is represented as age 72 years. The $year$ variable is centred so that 1980 is represented as year 0, and 2013 is represented as year 33. The $decile$ variable is coded as normal, with decile 1 denoting the least deprived, and decile 10 denoting the most deprived areas.

3.9 Multilevel modelling

Multilevel modelling allows for the variation found in rates of mortality in the data to be partitioned to each level of the data (Leyland & Goldstein 2001).

In this thesis, the variables selected from the death records allow for hierarchical modelling to be performed, given the multilevel structure of the data. Figure 3.1 describes this structure and the three levels within.

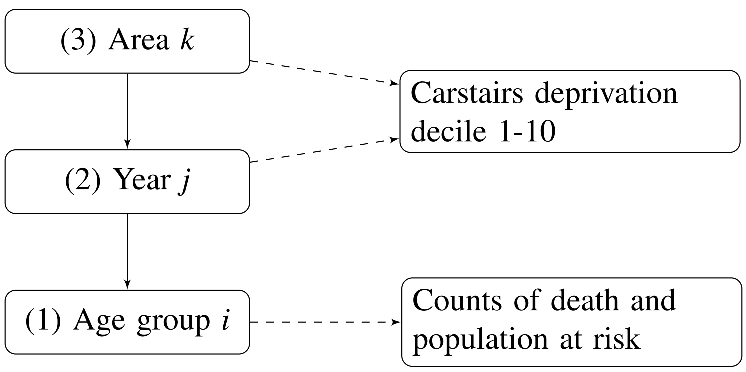


Figure 3.1: Multilevel nature of data

By taking the multilevel structure of the data into account when modelling, the variation in mortality rates at the area and year levels can be estimated, providing valuable information.

[2] https://www.stata.com/manuals13/rmfp.pdf

Equation 3.8 describes the general multilevel equation used in both Chapters 4 and 5. Models are run separately for each sex, owing to the inclusion of sex-specific amenable causes of death, such as cervical cancers and maternal conditions.

The decile variables are indexed by both the area level (*k*) and year level (*j*) indices. This is because although deprivation is calculated at the area level, four versions of the deprivation measure are used in this analysis (one for each Census year), and therefore it is also dependent on the year level.

The transformations produced by the `mpf` procedure were applied to each variable prior to the inputting of the variables into MLwiN, the software used to perform multilevel analyses (Lawson et al. 2003). Equation 3.8 describes the full Poisson regression model possible, where each variable can have up to two fractional polynomial transformations applied in order to best model its relationship (as indicated with the -1 and -2 suffixes to each variable). However, reductions to the model are possible if only one transformation is suggested. The *i, j* and *k* subscripts indicate which level of the model the variable is observed at (see Equation 3.8).

$$\begin{aligned} log(deaths_{ijk}) = \beta_{0jk} constant &+ age1_{ijk} + age2_{ijk} \\ &+ year1_j + year2_j \\ &+ decile1_{jk} + decile2_{jk} \\ &+ (age \times year)1_{ij} + (age \times year)2_{ij} \\ &+ (age \times decile)1_{ijk} + (age \times decile)2_{ijk} \\ &+ (decile \times year)1_{ijk} + (decile \times year)2_{ijk} \\ &+ (age \times decile \times year)1_{ijk} + (age \times decile \times year)2_{ijk} \\ &+ log(popn_{ijk}) \end{aligned} \tag{3.8}$$

Where

$$\beta_{0jk} = \beta_0 + v_{0k} + u_{0jk}$$
$$\begin{bmatrix} v_{0k} \end{bmatrix} \sim N(0, \Omega_v) : \Omega_v = \begin{bmatrix} \sigma^2_{v0} \end{bmatrix}$$
$$\begin{bmatrix} u_{0jk} \end{bmatrix} \sim N(0, \Omega_u) : \Omega_u = \begin{bmatrix} \sigma^2_{u0} \end{bmatrix}$$
$$var(deaths_{ijk} | \pi_{ijk}) = \pi_{ijk}$$

The additional area and year level variation not accounted for within the model are estimated by σ^2_{v0} and σ^2_{u0} respectively. π_{ijk} is the mean of the Poisson distribution, or the mean count of amenable deaths observed in age group *i*, within year *j* and area *k* (Rasbash et al. 2012*a*). The Poisson distribution assumes that the mean is equal to the variance.

The predicted crude mortality rate at the area and year levels, as well for the fixed effects, can be estimated using the model. The predicted mortality rates are of the form: $log_e({}^{deaths_{ijk}}/_{popn_{ijk}})$, which, with some re-arranging, can then be directly standardised as with the observed deaths in section 3.4, to create predicted age standardised mortality rates. The predicted rates for the fixed effects part of the model does not include any of the random effects, whilst the level 3 predicted rates contain the random effect for area, and the level 2 predicted rates contain both the random effects of year and area. These predicted rates can be plotted against year.

The Median Rate Ratio (MRR), defined as the median value of the rate ratio between randomly selected high- and low-risk areas, was calculated for each model (Merlo et al. 2006). This transforms the area level variance estimate, σ^2_{v0}, to the rate ratio scale, which allows it to be directly comparable to the rate ratios calculated for variables within the fixed effects part of the model. In this situation, if we were to repeatedly sample areas within the same deprivation decile, then in half of such comparisons, the rate ratio comparing the area with the higher mortality rate to the area with the lower mortality rate will be at least equal to the MRR (Austin et al. 2018). The MRR is calculated using Equation 3.9.

$$MRR = exp(\sqrt{2\sigma^2} \times \Phi^{-1}(0.75)) \tag{3.9}$$

where σ^2 is the variance at the area level, represented as σ^2_{v0} above, and Φ is the cumulative distribution for the standard Normal distribution, with mean 0 and variance 1 (Larsen & Merlo 2005). This measure is always greater than or equal to 1. A large MRR indicates considerable between area variation, whereas a MRR of 1 indicates no area level variation.

3.10 Software

Four main software packages were used throughout this research process. As the analyses for two of the results chapters were conducted within a Safe Haven environment using their software, different versions have been used over the course of this research process.

- Chapters 4, 7 & 8
  - SAS 9.4
  - R3.0.1 to R3.4.1
  - Stata 13
  - MLwiN 2.34

- Chapter 5: conducted in the Robertson Centre for Biostatistics Safe Haven
  - SAS 9.3
  - R3.0.1
  - Stata 12
  - MLwiN 2.34
- Chapter 6: conducted in the National Records of Scotland Safe Haven
  - SAS 9.4
  - R3.2.0 to R3.3.1

All record/data management, and calculation of age standardised mortality rates and indices of inequality were performed using SAS. The `mfp` procedure in Stata was used to estimate the fractional polynomial transformations used in the multilevel modelling analyses. R was used for the simulation of confidence intervals for the indices of inequality, as well as in preparation of the datasets for multilevel modelling (application of fractional polynomial, labelling areas and sorting). All multilevel results were produced using MLwiN.

3.11 Ethical and Data Access Approval

The death records for Scotland were already held by the MRC/CSO Social and Public Health Sciences Unit, University of Glasgow, obtained from National Records of Scotland (NRS). The English death records were obtained from the Office for National Statistics (ONS, agreement reference 2315/2012, approved researcher reference ONSF70409). These records, used in chapters 4, 7 and 8, are not subject to the Data Protection Act 1998, as they pertain to deceased individuals. Whilst there are no statistical disclosure protocols relating to this data, a duty of care remains not to unintentionally identify individuals. Therefore, in any aggregated tables presented in this thesis any cell counts less than 5 will be suppressed. No names or full addresses were attached to either of the datasets.

An application to the Privacy Advisory Committee (PAC, superseded by the Public Benefit and Privacy Panel for Health and Social Care) was required to obtain the individual level hospital discharge records, cancer registrations, birth and death records analysed in chapter 5. The application process and access to the data was coordinated through the electronic Data Research and Innovation Service (eDRIS). No consent was required from individual participants as the data requested are routinely collected by the Information Services Division (ISD). The general public is informed of the use of their personal data for research purposes through information leaflets available to all users of NHS services in Scotland[3]. All postcode sectors attached to the records were anonymised and no full dates of birth, death or admission were requested, therefore no individuals could be identified. The application for this data underwent National Services Scotland (NSS) proportionate governance review, and was approved on 25 June 2015 (PAC 81/14) for a period of 5 years. Analyses for this chapter were performed in a Safe Haven, and all outputs met with the ISD Statistical Disclosure Control Protocol.

The Scottish Longitudinal Study (SLS) Research Board approved the application for the datasets used in chapter 6 (Project 2015-001). The SLS datasets were accessed through a Safe Haven on stand alone computers, and only aggregated data outputs were approved for release, which met with the SLS Disclosure Control Protocol.

In accordance with data access requirements for both data applications, I undertook the Scottish Health Informatics Programme (SHIP) Information Governance course (awarded 29/12/2014, expired 29/12/2016) and the MRC Research and Data Confidentiality course (awarded 18/12/2016).

[3]http://www.isdscotland.org/About-ISD/Confidentiality/20150910-SafeSecureInfo-web.pdf and http://www.isdscotland.org/About-ISD/Confidentiality/UKACRleafletv115scot.pdf

Chapter 4

Amenable mortality in Scotland

4.1 Introduction

Rates of all-cause mortality in Scotland over time have been regularly analysed, finding that whilst there have been declining trends since 1950, adult (ages 15 - 74 years) all-cause mortality rates have been the highest in Western Europe since 1978 for men, and 1958 for women, with some exceptions between 1965 - 75 (Cannegieter et al. 2003). For younger adults (15 - 44 years), Scotland's mortality rates have ranked highest in Western Europe for men since 2004, and 2002 for women (Whyte & Ajetunmobi 2012). Due to Scotland's poor performance in both external and internal causes of death it has been described as the "sick man of Europe" (McCartney et al. 2012, p. 756).

In terms of amenable mortality; the literature search described in chapter 2 returned relatively few articles focusing on Scotland. Carstairs (1989, 1993) found that the SMRs presented for Scotland as a whole in the European Community Atlases of Avoidable Death (Holland 1988, 1991, 1993, 1997), were significantly different to the European average (SMR=100) for 10 of the 16 individual amenable conditions. All Scottish Health Boards had significantly different SMRs for IHD and cervical cancers compared to the European average in the latest years (1985-89). The Borders was the only Health Board which was not significantly different for Hypertension and Strokes over the same period. When SMRs were calculated relative to the national average (Scotland = 100), 8 of the 12 Health Boards had SMRs for IHD that were significantly different from the national level, followed by Hypertension and Stroke (5 Health Boards), and Breast Cancers (4 Health Boards).

Grant et al. (2006) were the first to produce a Scotland specific report on amenable mortality, calculating mortality rates at the country and Health Board level between 1981 and

2004. Cross country comparisons with western Europe between 1980 - 1998 were made, and gradients in amenable mortality over time from 2001 - 2004 were explored using the Scottish Index of Multiple Deprivation (SIMD). Contrasting to the findings from Carstairs, Grant et al. found that Scotland, as a whole, had the highest age standardised amenable mortality rates compared to selected EU countries, for both men and women. Scotland and Portugal had similar rates of amenable mortality in 1980, however, Portugal had achieved a steeper rate of decline by 1990. Amenable mortality rates in France were approximately half of those experienced by Scotland for both sexes throughout the analysis period. Age-sex standardised amenable mortality rates across the area level deprivation quintiles were found to have decreased, however, the ratios of the most to least deprived remained constant over the 4 years.

Research of amenable mortality in Scotland thereafter has been limited to being included in UK specific analyses (French & Jones 2006, Desai et al. 2011).

4.2 Objectives

This chapter will meet objectives 1 and 2 of this thesis (see section 1.1) by:

1. Describing rates of amenable mortality within Scotland between 1980 and 2013, by sex and deprivation decile.
2. Exploring differences in mortality rates by diagnosis subgroups of conditions, and selected individual conditions over time.
3. Measuring the absolute and relative inequalities in rates of amenable mortality over time.
4. Partitioning the variation in amenable mortality rates to variation at the year and area level
    (a) for overall amenable deaths; and
    (b) within diagnosis groups.

Grant et al. (2006) limited their exploration of deprivation gradients in amenable mortality rates to 4 years, due to the use of SIMD. Therefore this chapter will use an alternative measure of area level deprivation - the Carstairs index - to measure inequalities over 34 years, a considerably longer period of time.

4.3 Methods

4.3.1 Data

All amenable deaths which occurred in Scotland between 1980 and 2013 were extracted as outlined in subsection 3.3.1. The population sizes used for these analyses are the second dataset, outlined in subsection 3.3.2, containing the annual mid-year population estimates.

4.3.2 Assigning deprivation indices

The Carstairs indices of multiple deprivation (versions 1981, 1991, 2001 and 2011), as described in section 3.5, were used to measure relative deprivation at the postcode sector level in Scotland, over the analysis period. The deprivation index was ideally assigned using the postcode sector of residence and the local government district (1980 - 1996) or council (1997 - 2013) codes attached to each death record. There were 2,033 (0.8%) amenable deaths, occurring between 1980 and 2013, where this could not be performed using the data recorded. Table 4.1 details four possible reasons for these.

Table 4.1: Postcode sector, council or LGD re-assignments of deaths

Issue	Explanation
PCS exists, but does not have a deprivation index	PCS population too small to calculate deprivation index. This occurred mainly in Glasgow city centre (in 1981 and 1991) and on the islands.
Reassigning PCS	In 1990, 1991 and 1996, a large number of postcodes were re-assigned, mainly in the Grampian region. PCS registered to deaths occurring in 1990 were updated, and those occurring in 1996 were reverted back to the 1991 PCS.
Partial PCS	A number of PCS spanned two or more councils or LGDs. In many cases, only one appeared in the Carstairs index lookup. PCS on the death records were amended to reflect the part PCS that did appear in the index lookup.
Ninewells Hospital, Dundee	A number of deaths were registered to the hospital's postal address, rather than its physical location. These deaths were mainly associated with infants.

PCS: Postcode Sector LGD: Local Government District

In order to enable the inclusion of all amenable deaths occurring in Scotland into the analysis, alternative methods of attaching a deprivation decile to the 2,033 deaths were explored. A lookup table[1] held by the MRC/CSO Social and Public Health Sciences Unit was consulted in the first instance. This lookup table detailed what a postcode had been known as, or what it was now known as, in order to reassign the postcode sectors. In a number of cases, there was not a unique one-to-one matching between the two versions, but 53.7% (n = 1,091) of records with missing deprivation deciles were able to be assigned to one using this method. A further 1.6% (n = 32) of the records were identified as being registered to an incorrect version of the postal address of Ninewells Hospital in Dundee. These were reassigned to the postcode sector which the hospital was physically located within.

The remaining 44.8% (n = 910) of amenable deaths were assigned to a neighbouring postcode sector through the use of proportional probability allocation. Candidate postcode sectors were identified manually using Google Maps[2] and Doogal[3]. The latter contains both current and decommissioned postcodes, allowing for the most accurate candidates to be identified. Once the candidate postcode sectors had been identified, the probability of being selected was calculated on the basis of their deprivation decile, and the amenable mortality rate for that deprivation decile in the year of death, for that particular sex. The mortality rates for all candidate measures were summed, and a probability of being assigned to each was calculated. For each death, a new postcode sector was then chosen from a sample, with probability proportional to the mortality rate.

4.3.3 Statistical Analyses

Age Standardisation

Age standardised death rates for diagnosis groups, deprivation deciles, and deprivation deciles within the diagnosis groups have been calculated for both sexes using the methods described in section 3.4.

Yearly disease specific mortality rates were calculated for the top 10 individual conditions which contributed the greatest proportions to overall amenable mortality over the whole 34 year analysis period. Age standardised rates by sex and deprivation decile were calculated in each case.

[1] Personal Communication: this table was created by Unit Researchers, and was based on a previous version of the Royal Mail's major address changes information. This version is no longer held on the Royal Mail's website https://www.royalmail.com/sites/default/files/postcode-updates-historical-info.pdf

[2] www.google.co.uk/maps

[3] www.doogal.co.uk/UKPostcodes.php

Indices of inequality

RII and SII, along with 95% confidence intervals for the overall yearly estimates, as well as diagnosis group specific estimates were calculated as described in section 3.7.

Fractional Polynomials

Fractional polynomials were calculated as described in section 3.8 using Poisson regression. Equation 3.7 describes the model containing interactions between age at death, year of death and deprivation decile. All variables were entered into the model with a selection α of 0.05, and four degrees of freedom, allowing for all fractional polynomial combinations to be selected for each covariate (Royston & Sauerbrei 2008).

Multilevel Modelling

Single Response models
The resultant fractional polynomials were used in the multilevel modelling equations outlined in section 3.9.

Multiple Response Models
Multiple response models allow for an additional 'level' within the response data (Rasbash et al. 2012*b*). In the case of single response models, the lowest level of the response was a count of all deaths within an age group. In a multiple response model, the counts of death can be categorised into the type of death, in this case, the diagnosis groups. This will allow for the comparison of area and year level variation across the diagnosis groups within amenable mortality. Figure 4.1 illustrates the additional categorisations, and can be compared to Figure 3.1.

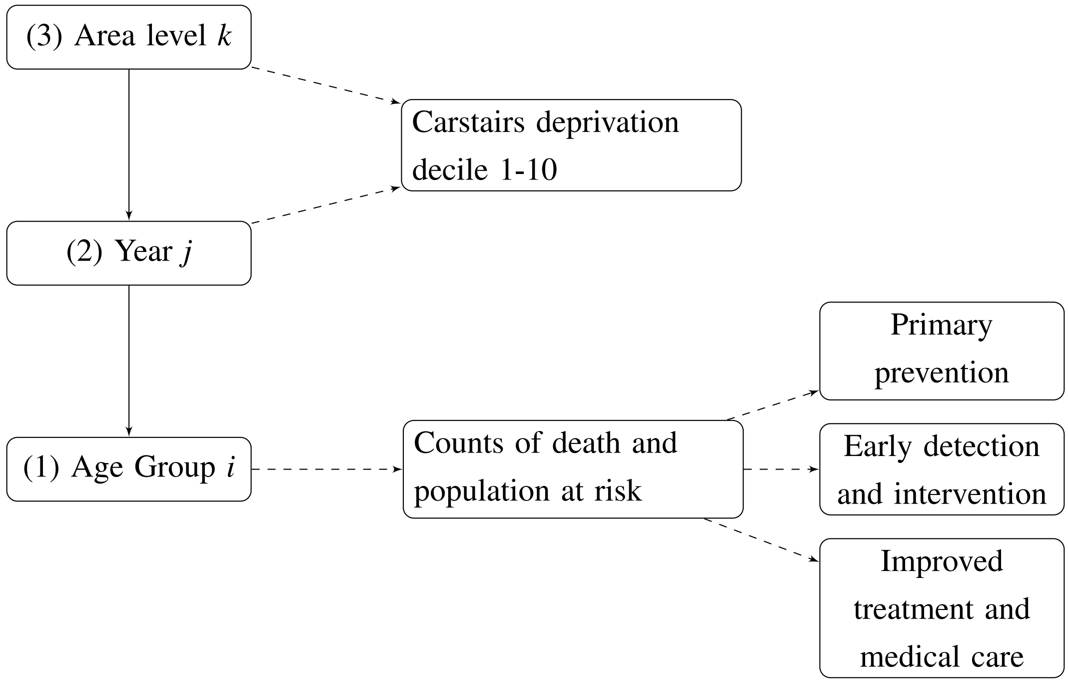


Figure 4.1: Modified multilevel nature of data: multiple response

Equation 4.1 specifies the model with three responses; one for each diagnosis group: (1) primary prevention, (2) early detection and intervention, and (3) improved treatment and medical care. Counts of death within each diagnosis group are Poisson distributed. No fractional polynomial transformations were applied to the variables in these models.

PP: Primary prevention: $resp_{1jk} \sim Poisson(\pi_{1jk})$
EDI: Early detection and intervention: $resp_{2jk} \sim Poisson(\pi_{2jk})$
ITMC: Improved treatment and medical care: $resp_{3jk} \sim Poisson(\pi_{3jk})$

$$
\begin{aligned}
log(\pi_{1jk}) &= \beta_{0k} constant.obsPP_{ijk} + \beta_3 (year - 1980).obsPP_{ijk} \\
&\quad + \beta_6 decile.obsPP_{ijk} + offsetPP_{1kj} \\
\beta_{0k} &= \beta_0 + v_{0k} \\
log(\pi_{2jk}) &= \beta_{1k} constant.obsEDI_{ijk} + \beta_4 (year - 1980).obsEDI_{ijk} \\
&\quad + \beta_7 decile.obsEDI_{ijk} + offsetEDI_{2kj} \\
\beta_{1k} &= \beta_1 + v_{1k} \\
log(\pi_{3jk}) &= \beta_{2k} constant.obsITMC_{ijk} + \beta_5 (year - 1980).obsITMC_{ijk} \\
&\quad + \beta_8 decile.obsITMC_{ijk} + offsetITMC_{3kj} \\
\beta_{2k} &= \beta_2 + v_{2k}
\end{aligned}
\tag{4.1}
$$

$$\begin{bmatrix} v_{0k} \\ v_{1k} \\ v_{2k} \end{bmatrix} \sim N(0, \Omega_v) : \Omega_v = \begin{bmatrix} \sigma^2_{v0} & & \\ \sigma_{v01} & \sigma^2_{v1} & \\ \sigma_{v02} & \sigma_{v12} & \sigma^2_{v2} \end{bmatrix}$$

$$cov \begin{bmatrix} resp_{1jk}|\pi_{1jk} \\ resp_{2jk}|\pi_{2jk} \\ resp_{3jk}|\pi_{3jk} \end{bmatrix} = \begin{bmatrix} \pi_{1jk} & & \\ \rho\sqrt{\pi_{1jk}\pi_{2jk}} & \pi_{2jk} & \\ \rho\sqrt{\pi_{1jk}\pi_{3jk}} & \rho\sqrt{\pi_{2jk}\pi_{3jk}} & \pi_{3jk} \end{bmatrix}$$

Where: ρ and $\rho\sqrt{\pi_{1jk}\pi_{2jk}}$ are the correlation and covariance between diagnosis subgroups 1 and 2 at the year level respectively. The correlation, which measures the strength of the linear relationship at the area level between the same subgroups, is calculated as:

$$\begin{aligned} \rho &= \frac{Cov(x,y)}{\sqrt{Var(x)Var(y}} \\ &= \frac{\sigma_{v01}}{\sqrt{\sigma^2_{v0}\sigma^2_{v1}}} \end{aligned} \tag{4.2}$$

The correlation can range between -1 and +1, with -1 indicating that as one variable increases, the other decreases, and +1 indicates perfect linear increases for both variables. A correlation of 0 denotes no relationship between the two.

In this formulation, the offset is no longer the logarithm of population at risk, but the logarithm of the expected number of deaths for each diagnosis group. By using the expected counts, the age structure of the deaths can be taken into account, without needing an age variable in the model. This reduces the number of observations in the dataset, as a given postcode sector in a given year will have three rows of data associated with it (one for each diagnosis group), rather than the 45 rows (3 diagnosis groups $\times$ 15 age groups) required previously. This method was more efficient in modelling the data, and reduced the computing capacity and time required for the models to converge.

The expected counts of amenable death for diagnosis group *j* were calculated using Equation 4.3, assuming the 2013 age-sex specific rates of amenable death, a_{ij}, calculated as seen in Table 3.3.

$$\begin{gathered} \text{Expected deaths}_j = \sum_{i=1}^{15} \frac{a_{ij} \times p_i}{100,000} \\ \text{where } i = 1, ..., 15 \text{ for age groups 0-4, ..., 70-74 years.} \\ j = 1, 2, 3 \text{ for PP, EDI and ITMC respectively.} \end{gathered} \tag{4.3}$$

4.3.4 Sensitivity Analyses

The population sizes used in the main analyses are annual mid-year estimates. These are estimated by the National Records of Scotland, and are derived by adjusting for births, deaths and migrations, and ageing up the remaining population (National Records of Scotland n.d.).

However, the deprivation indices used to examine socioeconomic inequalities within the rates of amenable mortality are calculated on a 10-year basis, and use the population size of a postcode sector at the Census year as a weight in their calculation. The population sizes of the postcode sectors are also used in the assignment to a decile. As the Carstairs index can only be calculated following a Census, the deprivation decile assignments for a postcode sector remain constant for the 10 years surrounding a Census (i.e. the deprivation decile assigned to a postcode sector from the 2001 Census is applied to all deaths occurring within the postcode sector between 1997 and 2006). It is therefore of interest to examine whether having a constant population, as well as a constant index of deprivation, affects the results.

For this sensitivity analysis, all deaths occurring in 1980 - 1986 will have mortality rates calculated using the 1981 population size as the denominator, and 1981 Carstairs index. The assignments for all years of death, along with a comparison to the main analysis, are described in Table 4.2.

Table 4.2: Versions of population sizes and deprivation indices assigned to years of deaths

Year of	Population size		Carstairs
death	Main analysis*	Sensitivity analysis†	index version
1980 - 1986	1980 - 1986	1981	1981
1987 - 1996	1987 - 1996	1991	1991
1997 - 2006	1997 - 2006	2001	2001
2007 - 2013	2007 - 2013	2011	2011

* Mid-year estimates

† population recorded at census

4.4 Results

4.4.1 Data cleaning and descriptive statistics

The number of all cause and amenable deaths occurring in Scotland over the 34 year period between 1980 and 2013 are displayed in Table 4.3. The numbers of deaths are grouped according to the years surrounding each Census (see subsection 3.5.3). The percentage of amenable deaths occurring within each period of analyses has decreased over time.

Table 4.3: Number (%) of all-cause and amenable deaths: 1980 - 2013

Year	No. Years	Total number of deaths	Amenable + IHD	Amenable only
1980 - 1986	7	441,695	139,896 (31.7)	68,918 (15.6)
1987 - 1996	10	612,059	160,717 (26.3)	80,890 (13.2)
1997 - 2006	10	573,974	112,615 (19.6)	65,338 (11.4)
2007 - 2013	7	379,825	59,038 (15.5)	38,382 (10.1)
Total:	34	2,007,553	472,266 (23.5)	253,528 (12.6)

The percentage of amenable deaths occurring in each year group has decreased over time, from 15.6% to 10.1%. The proportion of amenable deaths within the 'Amenable + IHD' category has increased, from being approximately half in 1980 to 1996, to containing almost two-thirds of the deaths by 2007-2013. In the majority of years, there were slightly more female than male deaths (51.3% female deaths overall). The greatest disparities occurred in 1989 (52.5%), 1992 (53.1%) and 1994 (52.6%).

There were 13 records which were removed from analysis which occurred in the 1980 - 1996 period. These were removed as there was an invalid postcode sector of residence recorded on the death record. Three records were removed in 2007 - 2013 due to having missing sex. These occurred in infants, dying from conditions originating in the perinatal period or congenital malformations. Amendments were made to 2,033 records (0.8%) over the analysis period, either changing the postcode sector or council recorded were made as described in subsection 4.3.2. Table 4.4 details the breakdown of these records.

Table 4.4: Number of deaths with problematic postcode sectors attached by resolution

Year	Removed*	Deaths matched by: Ninewells Hospital	changing postcodes/ councils	probability matching	Total used in analyses
1980-86	2	0	15	37	68,916
1987-96	11	2	1,017	695	80,879
1997-06	0	19	39	177	65,338
2007-13	3	11	20	1	38,379
Total:	16	32	1,091	910	253,512

* Records were removed from analyses if they did not have a valid postcode sector of residence attached (n=13), or if sex was not recorded (n=3).

A breakdown of the percentage of deaths by sex and age group is presented in Figure 4.2. The percentage of amenable deaths occurring before the age of 20 has decreased from 12.1% to 5.8% over the 34 year period, whilst there has been an increase in the number of deaths occurring from age 40. The distribution across age groups is fairly similar across the sexes.

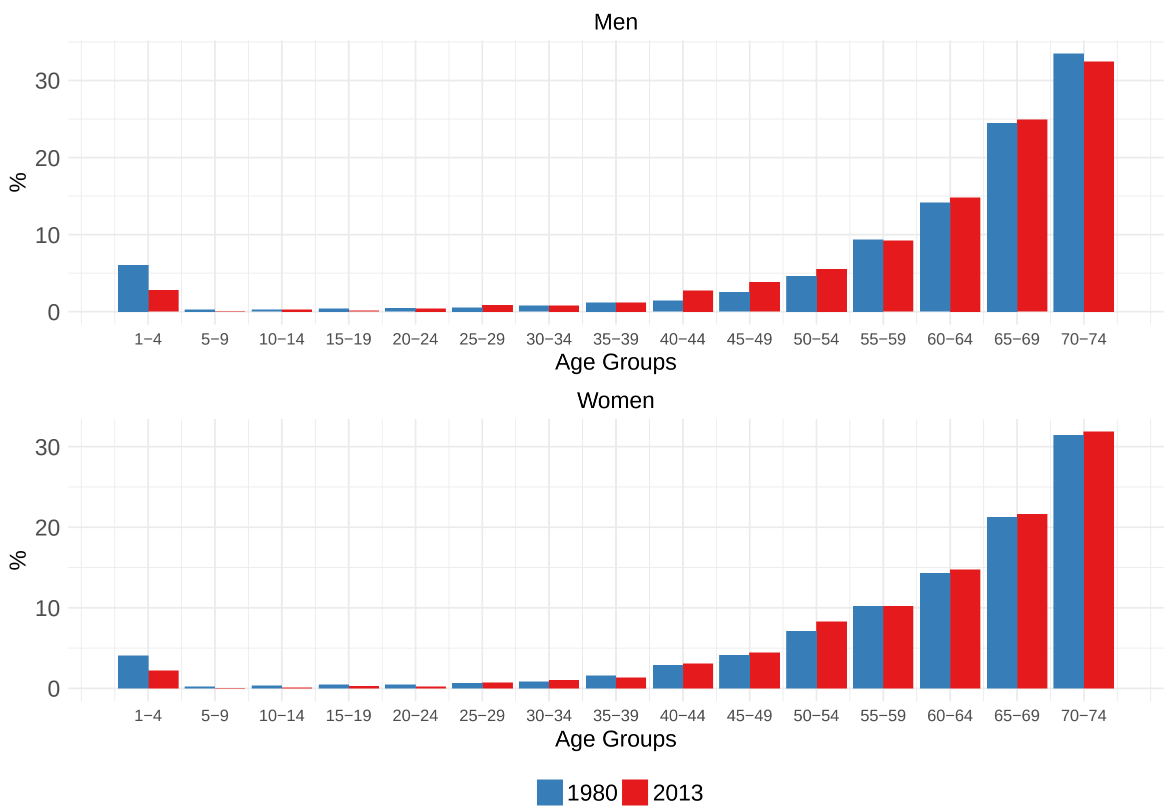


Figure 4.2: Percentage of amenable deaths within each age group: 1980 and 2013

The number and percentage of amenable deaths within each diagnosis group by sex are listed in Table 4.5. The numbers of deaths amenable through primary prevention each year are small, and whilst the percentages are increasing, the pattern across years is highly variable. The male deaths in the remaining two groups are fairly evenly split, whilst in women, there is a greater percentage of female deaths amenable through early detection and intervention, owing to the inclusion of female specific cancers.

Table 4.5: Number (%) of amenable deaths within each diagnosis group by sex

Year	No. Years	Primary Prevention	Early Detection & Intervention	Improved Treatment & Medical Care	Total amenable
Men					
1980 - 1986	7	62 (0.2)	17,228 (51.3)	16,269 (48.5)	33,559
1987 - 1996	10	112 (0.3)	20,268 (52.1)	18,544 (47.6)	38,924
1997 - 2006	10	126 (0.4)	15,889 (49.3)	16,228 (50.3)	32,243
2007 - 2013	7	91 (0.5)	8,886 (47.6)	9,689 (51.9)	18,666
Men total:	34	391 (0.3)	62,271 (50.5)	60,730 (49.2)	123,392
Women					
1980 - 1986	7	71 (0.2)	23,479 (66.4)	11,807 (33.4)	35,357
1987 - 1996	10	101 (0.2)	26,998 (64.3)	14,856 (35.4)	41,955
1997 - 2006	10	118 (0.4)	19,541 (59.0)	13,436 (40.6)	33,095
2007 - 2013	7	97 (0.5)	11,245 (57.0)	8,371 (42.5)	19,713
Women total:	34	387 (0.3)	81,263 (62.5)	48,470 (37.3)	130,120
Overall total:	34	778 (0.3)	143,534 (56.6)	109,200 (43.1)	253,512

4.4.2 Age standardised amenable mortality rates

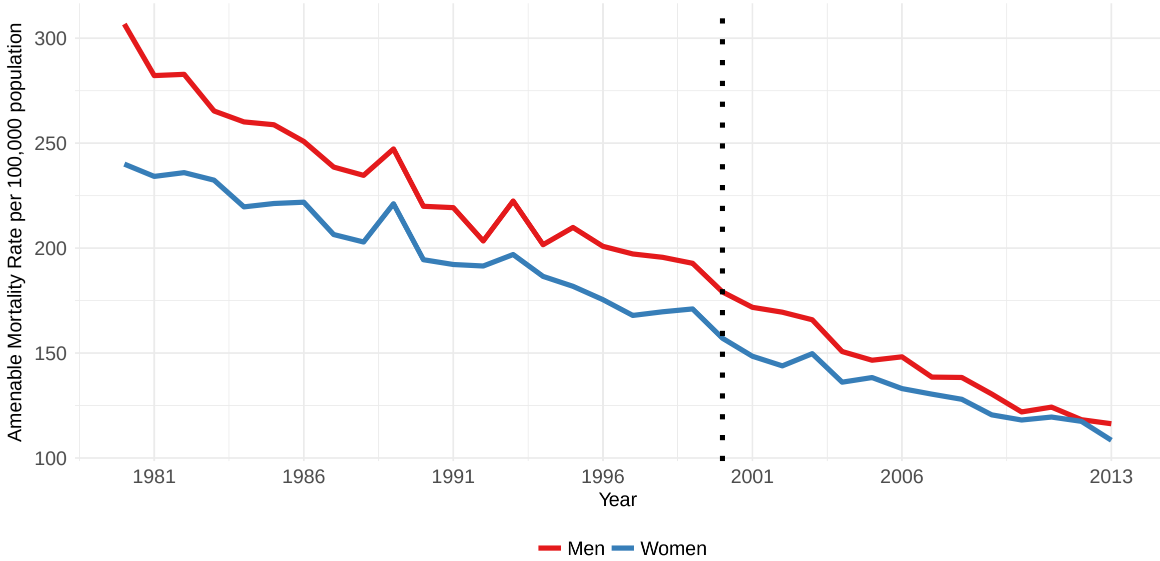


Figure 4.3: Age standardised amenable mortality rates for Scotland by sex, 1980 - 2013. The dashed line indicates the introduction of ICD 10 for coding the cause of death.

Figure 4.3 describes the age standardised amenable mortality rates for men and women in Scotland between 1980 and 2013. Rates of amenable mortality have been consistently decreasing over time, and male rates are higher than female rates over the whole analysis period.

There was an absolute decrease of 190.4 and 131.6 deaths per 100,000 population for men and women respectively between 1980 and 2013. Men experienced a slightly larger relative decrease of 62.1%, whereas rates for women decreased by 54.8% over the same period. The absolute difference between rates for men and women decreased from 66.7 per 100,000 in 1980 to 7.9 per 100,000 in 2013.

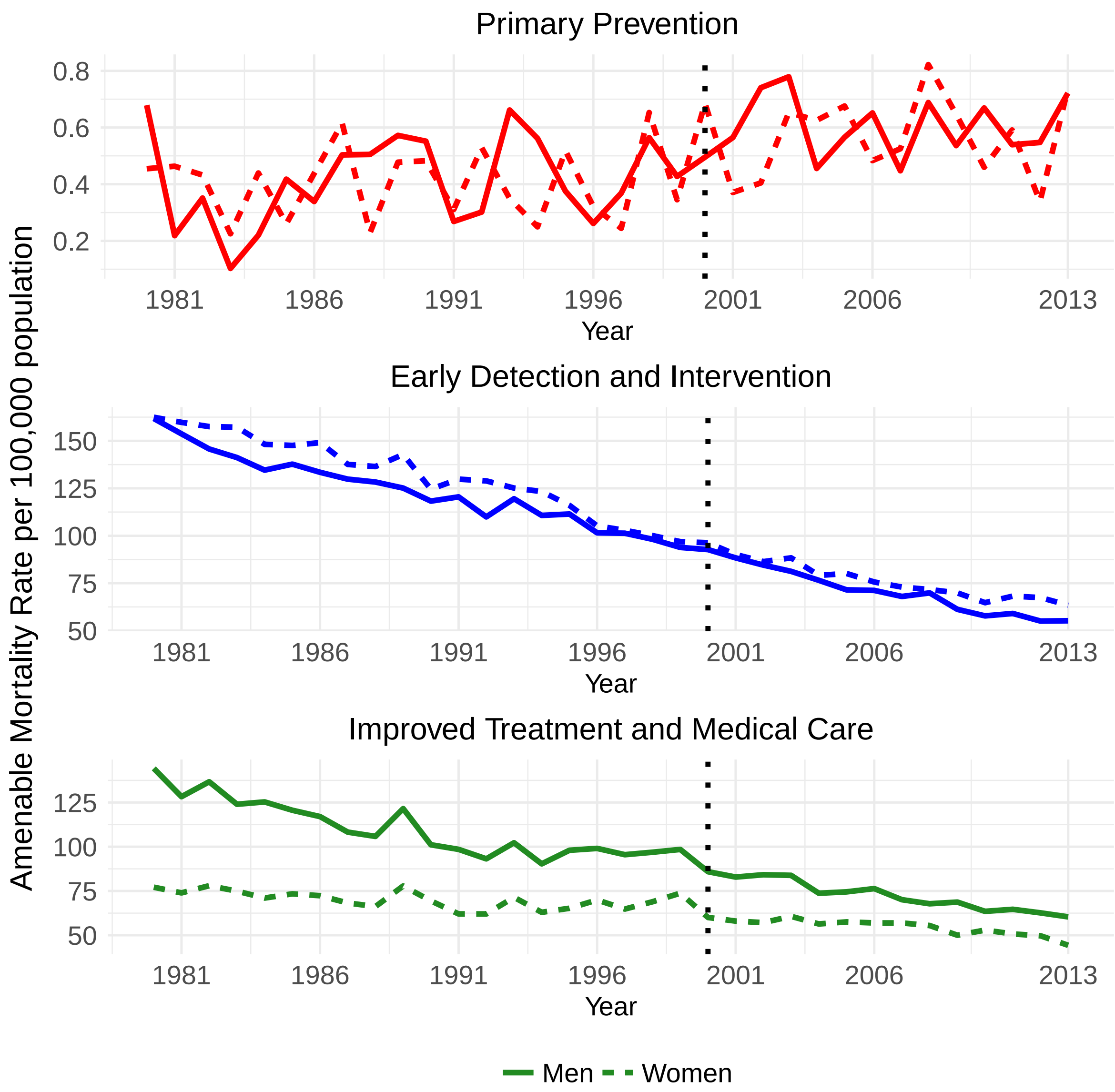


Figure 4.4: Age standardised amenable mortality rates by diagnosis groups and sex, 1980 - 2013. The dashed line indicates the introduction of ICD 10 for coding the cause of death. Note: graphs are on different scales

The numbers of deaths amenable through primary prevention are comparatively small (see Table 4.5), so the mortality rates shown in Figure 4.4 are highly variable[4]. Rates of deaths amenable through early detection and intervention have experienced the largest absolute and relative decreases. Rates for men declined by 106.6 per 100,000 (65.9% decrease), whilst rates for women decreased by 99.0 per 100,000 (61.0%) over the same period. Female rates exceed those of males throughout the study period, with the smallest differences occurring during the late 1990s. The absolute decreases in rates of deaths amenable through improved

[4]Absolute increases of 0.3 and 0.4 per 100,000, and relative increases of 6.3% and 61.8% for men and women respectively

treatment and medical care were more than two times as high for men as for women (83.9 vs 32.8 per 100,000), with relative decreases of 58.1% and 42.5% respectively.

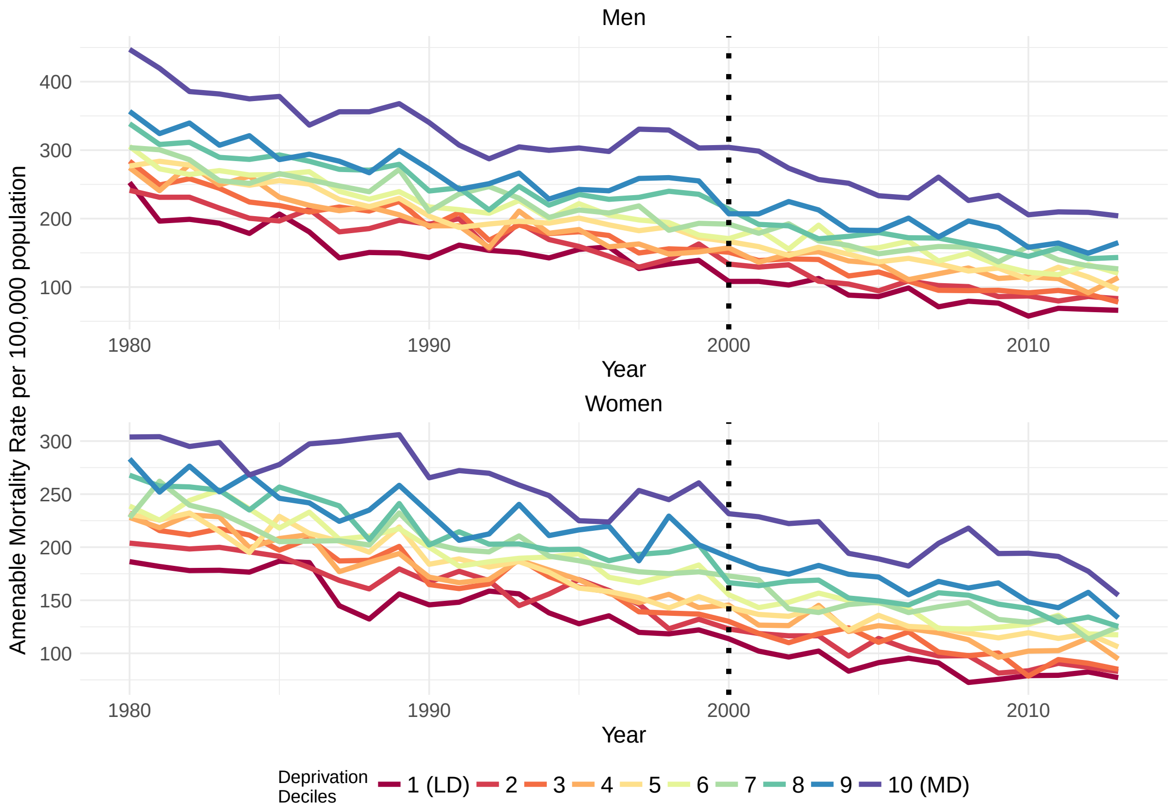


Figure 4.5: Age standardised rates of amenable mortality by sex and deprivation decile, 1980 - 2013. The dashed lines indicates the introduction of ICD 10 for coding the cause of death. Key: Decile 1: least deprived, Decile 10: most deprived. Note: graphs are on different scales

There is a clear socioeconomic gradient in rates of overall amenable mortality for men and women in Scotland between 1980 and 2013, shown in Figure 4.5. Rates of mortality for men in the least deprived (LD) decile decreased by 73.9%, whilst in the most deprived (MD) decile, the decrease was smaller at 54.4%, however men in the most deprived decile did experience larger absolute declines (243.2 vs 186.7 per 100,000). Women living in the least deprived decile experienced an absolute decrease of 109.3 deaths per 100,000 population (relative decrease 58.6%). Over the same period, amenable mortality rates for women living in the most deprived areas decreased by 49.1% (149.0 per 100,000).

Gradients within the mortality rates for some of the diagnosis groups are less strong. As the numbers of deaths amenable through primary prevention are so small, the mortality rates shown in Figure 4.6 indicate very little pattern once broken down by deprivation decile. The more deprived deciles appear to have slightly higher spikes in the mortality rates compared to the lesser deprived deciles, however, there is no clear gradient.

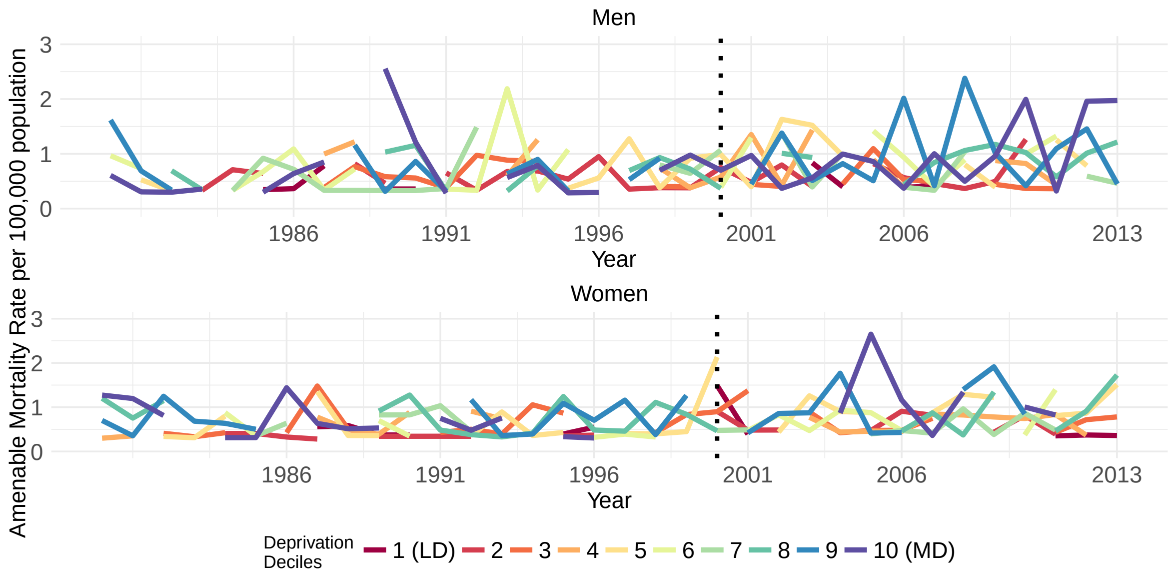


Figure 4.6: Age standardised rates of deaths amenable to primary prevention by sex and deprivation decile, 1980 - 2013. The dashed lines indicates the introduction of ICD 10 for coding the cause of death. Key: Decile 1: least deprived, Decile 10: most deprived.

Within the early detection and intervention subgroup of conditions, there is a greater spread in the deprivation gradient for men, than for women.

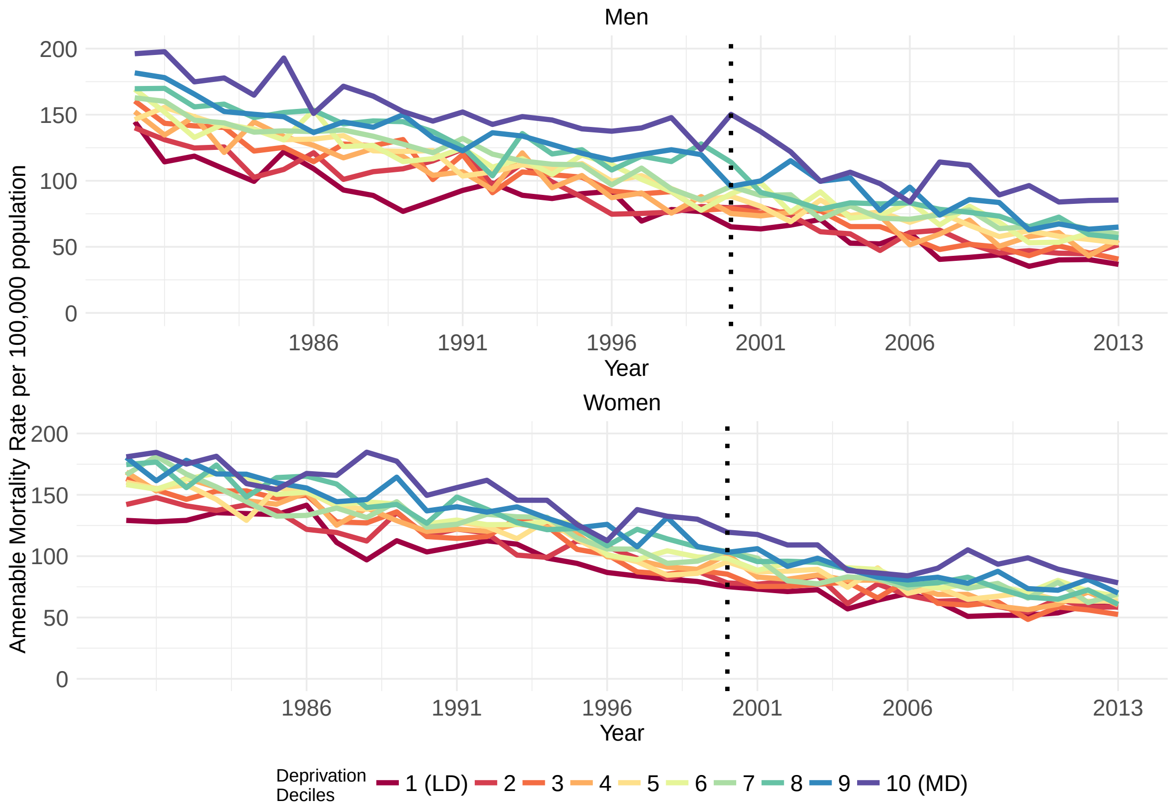


Figure 4.7: Age standardised rates of deaths amenable to early detection and intervention by sex and deprivation decile, 1980 - 2013. The dashed lines indicates the introduction of ICD 10 for coding the cause of death. Key: Decile 1: least deprived, Decile 10: most deprived.

Mortality rates in the most deprived decile (decile 10) decreased by 56% over the 34 year period for both men and women, with male rates decreasing by 110.8 deaths per 100,000, and women decreasing by 102.7 per 100,000. In the least deprived areas (decile 1), the absolute decline for men was fairly similar to that experienced in the most deprived areas (108 per 100,000 population), but a greater relative decline of 74.6%. Mortality rates for women in the least deprived areas had comparable relative declines in mortality rates to women in the most deprived areas (54.8%), however a much lower absolute decline in mortality rates over the analysis period (70.8 deaths per 100,000).

A gradient in mortality rates is clearest within the group of conditions which are amenable through improved treatment and medical care, shown in Figure 4.8.

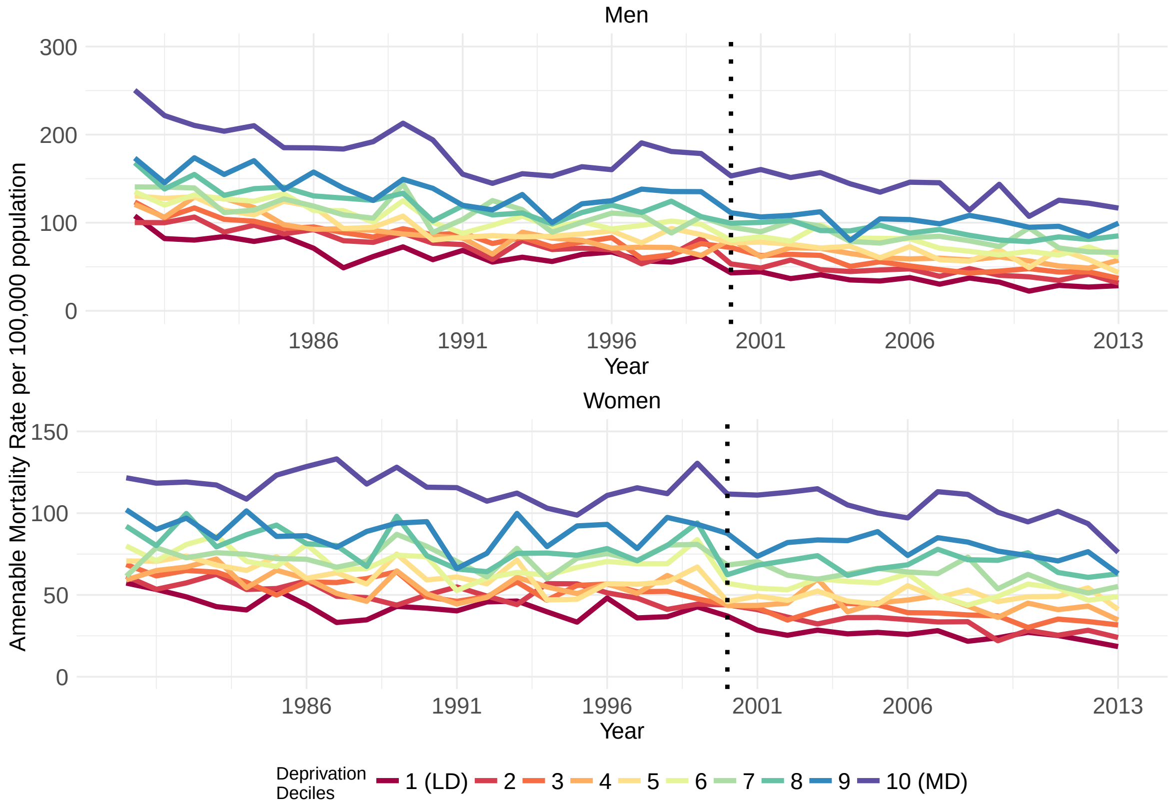


Figure 4.8: Age standardised rates of deaths amenable to improved treatment and medical care by sex and deprivation decile, 1980 - 2013. The dashed lines indicates the introduction of ICD 10 for coding the cause of death.
Key: Decile 1: least deprived, Decile 10: most deprived. Note: graphs are on different scales

Whilst the greatest absolute declines in mortality rates are found within the most deprived areas (133.8 vs. 79.2 and 45.6 vs. 38.8 per 100,000 for men and women respectively), the least deprived areas experienced the greatest relative differences: men of 73.5% vs. 53.4% and women of 67.8% vs. 37.5%.

Cause specific mortality rates

The top 10 conditions which had the highest proportion of deaths within each year group are displayed in Table 4.6, along with the percentage of total cases each contributed. Peptic ulcers ceased to be a top 10 contributor in the last year group, being replaced by septicaemia. Therefore, there are 11 conditions detailed in the table.

Table 4.6: Top 10 conditions (%) within each year group: men & women combined, ages 0 - 74 years. Ordered according to decreasing percentage in the first period.

Condition	1980-86	1987-96	1997-06	2007-13
Cerebrovascular disease $_{\text{EDI}}$	31.98	28.29	22.76	18.13
COPD $_{\text{ITMC}}$	12.96	14.39	17.14	18.85
Pneumonia $_{\text{ITMC}}$	10.11	9.77	8.23	6.46
Malignant neoplasm of colon & rectum $_{\text{EDI}}$	9.58	11.42	12.15	13.30
Malignant neoplasm of breast $_{\text{EDI}}$	8.96	10.13	10.40	10.66
Diabetes mellitus $_{\text{ITMC}}$	3.12	3.19	4.73	5.50
Perinatal conditions $_{\text{ITMC}}$	2.92	2.49	2.31	2.23
Malignant neoplasm of bladder $_{\text{EDI}}$	2.52	2.89	2.78	2.96
Peptic ulcers $_{\text{ITMC}}$	2.26	1.99	1.99	1.52*
Hypertensive disease $_{\text{EDI}}$	2.13	1.80	2.06	2.57
Septicaemia $_{\text{ITMC}}$	0.43*	0.73*	1.75*	2.85

∗ Condition did not appear in the 10 largest percentages for this year set.
EDI: condition is considered amenable through early detection and intervention.
ITMC: condition is considered amenable through improved treatment and medical care.

All conditions listed in Table 4.6 are either amenable to early detection and intervention, or improved treatment and medical care. The largest contributors were cerebrovascular disease, COPD, breast and colorectal cancers. The proportion of deaths due to cerebrovascular disease has almost halved over the analysis period, whilst the proportions of deaths due to COPD and the cancers have increased. Two conditions had no deaths recorded over the 34 year period: scarlatina and rubella, both of which are amenable through primary prevention.

Mortality rates by sex and deprivation decile for four of the conditions (Cerebrovascular disease, COPD, breast cancer and pneumonia) will be presented in the main body of this thesis, whilst the remaining seven conditions, and skin cancers, will be presented in Appendix B.

Cerbrovascular disease, shown in Figure 4.9, is the largest contributor towards overall amenable mortality in Scotland. Mortality rates for men exceed those for women in all years, but both sexes have seen steady decreases over the years, men by 79% and women by 77%. The gap between sexes has reduced over the analysis period.

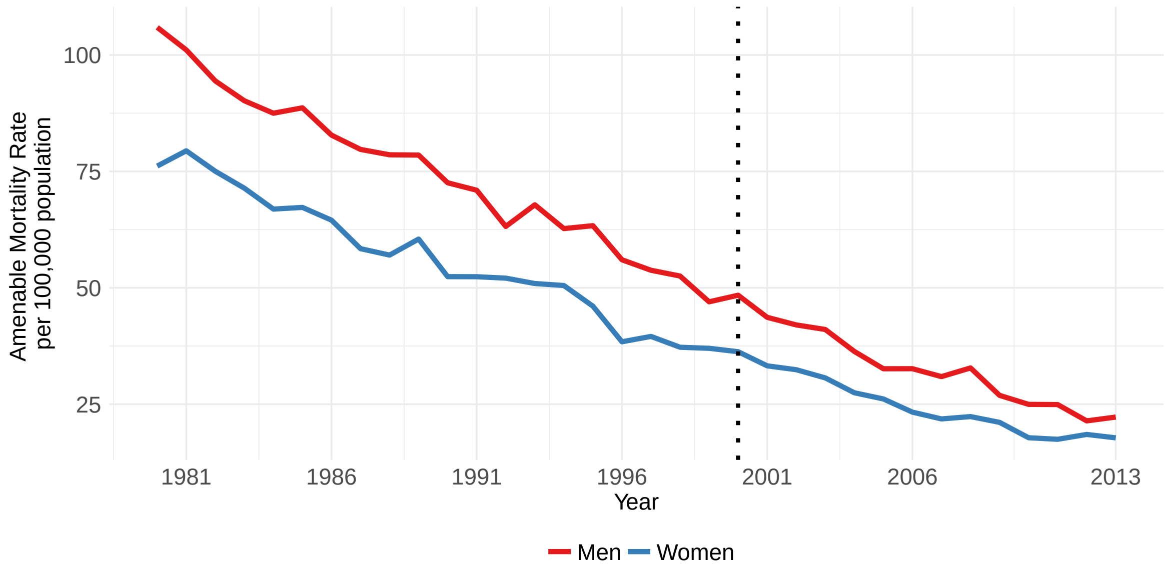


Figure 4.9: Mortality rates of cerebrovascular disease: men & women, 1980 - 2013. The dashed line indicates the introduction of ICD 10 for coding the cause of death.

There is a strong deprivation gradient in the rates of cerebrovasular disease for both sexes, as shown in Figure 4.10, with rates of male deaths in the most deprived decile exceeding those of the least deprived by 43.5 and 30.8 deaths per 100,000 in 1980 and 2013 respectively. The declines over time appear similar for both sexes. In the least deprived decile there were relative declines of 80% for women between 1980 and 2013, and 86% for men, whilst in the most deprived decile female mortality rates declined by 71%, and male rates declined by 67%. The absolute declines in mortality rates were greater in the most deprived decile (men: 86 per 100,000 in the most deprived, and 73 per 100,000 in the least deprived decile).

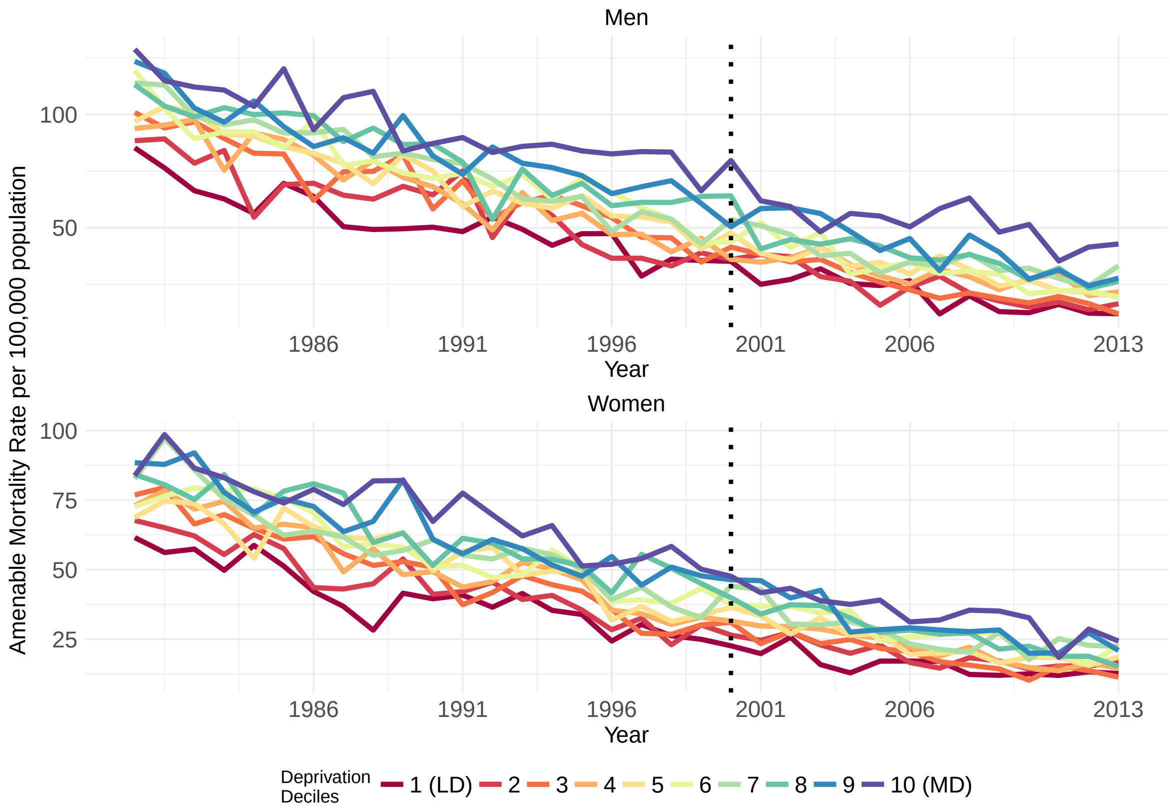


Figure 4.10: Mortality rates of cerebrovascular disease by deprivation decile: men & women, 1980 - 2013. The dashed lines indicates the introduction of ICD 10 for coding the cause of death.

Chronic obstructive pulmonary disease, or COPD, shown in Figure 4.11 is the next largest contributor towards overall counts of amenable deaths. The proportion of deaths it contributes towards, as seen in Table 4.6, has been increasing over the years. The plot shows that whilst male rates have been decreasing over the analysis period, the female mortality rates increased until approximately 2000, and since then have been relatively stable.

Figure 4.12 describes the trends in mortality rates by deprivation. The figure indicates that male mortality rates have declined across the socioeconomic gradient, with relative declines of 67% and 56% in the least and most deprived areas respectively. In contrast, only women living in the least deprived area experienced a decline in mortality rates between 1980 and 2013, of 26%. All other deprivation deciles saw relative increases of between 8% (decile 4) and 86% (decile 7).

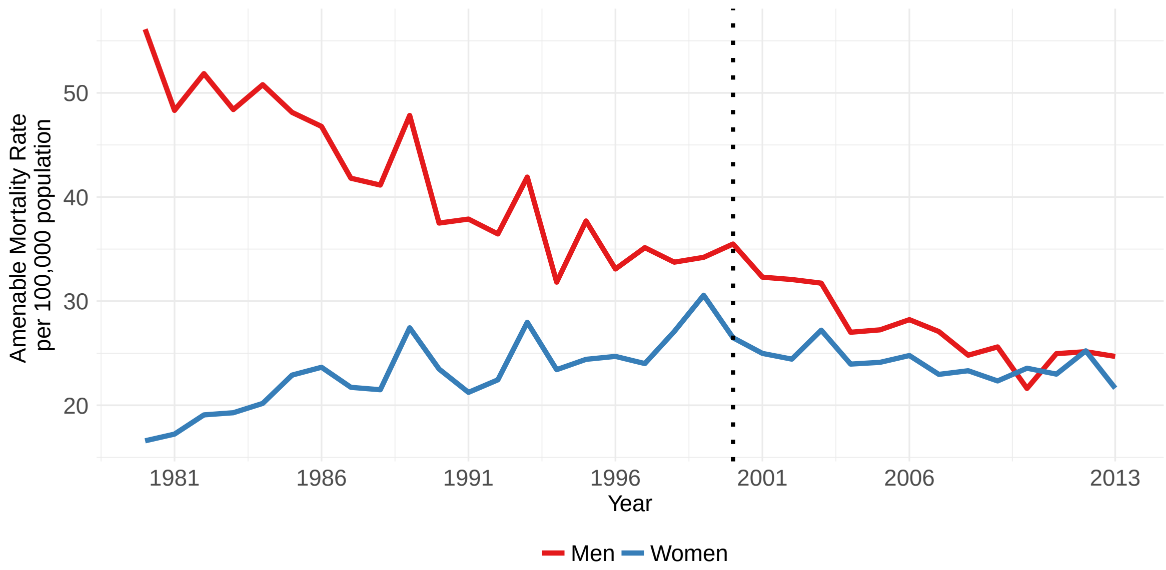


Figure 4.11: Mortality rates of COPD: men & women, 1980 - 2013. The dashed line indicates the introduction of ICD 10 for coding the cause of death.

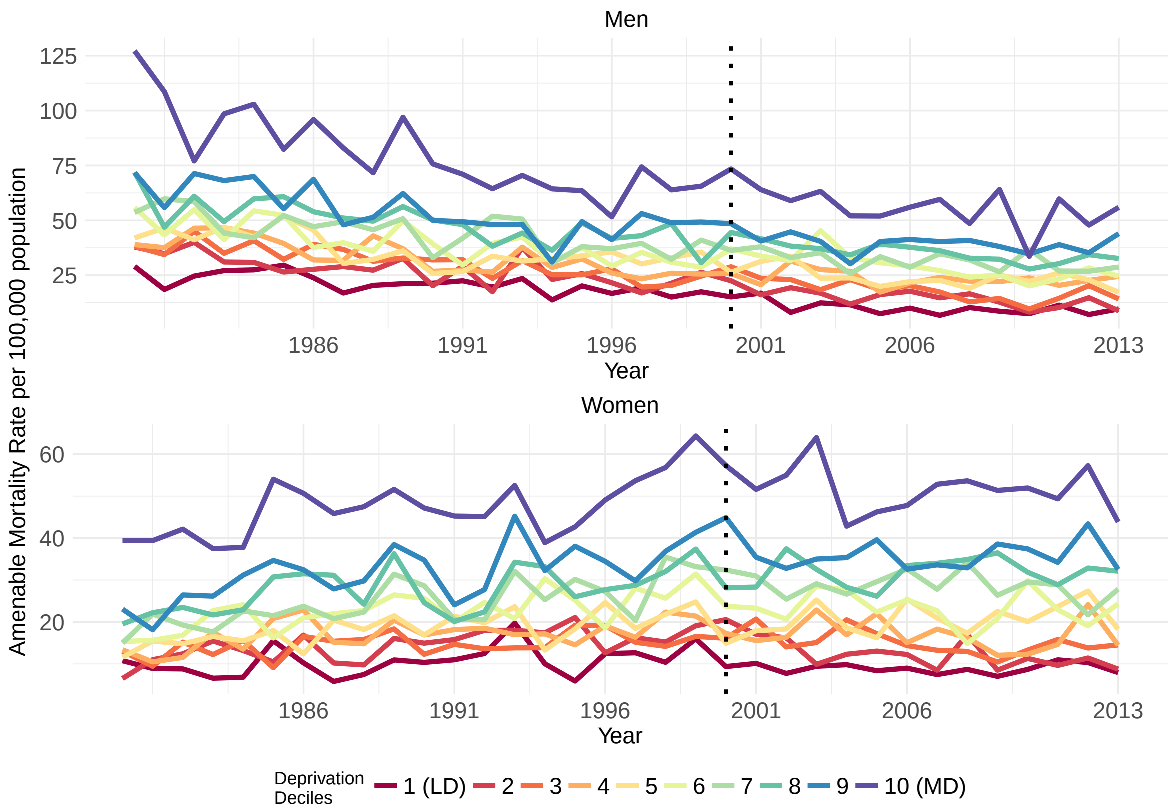


Figure 4.12: Mortality rates of COPD by deprivation decile: men & women, 1980 - 2013. The dashed lines indicates the introduction of ICD 10 for coding the cause of death.
Note: graphs are on different scales

Figure 4.13 describes the mortality rates in malignant neoplasms of the breast, or breast cancer. Whilst successful treatments are available to both sexes post-diagnosis, as screening programmes only target women, breast cancers are considered amenable in women only. Mortality rates have been decreasing, with a stronger decline over recent years.

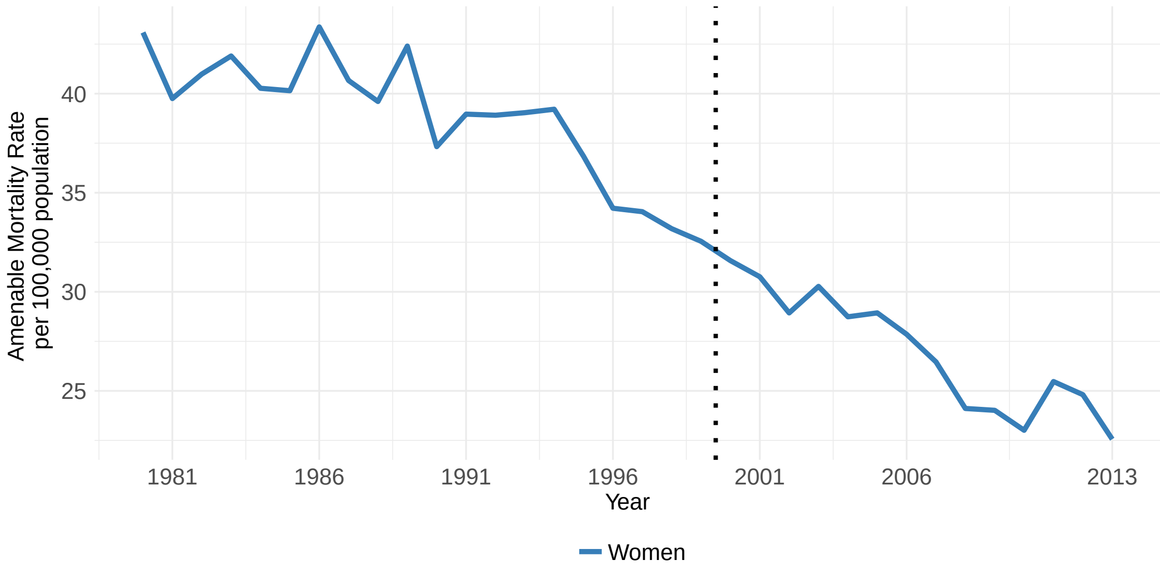


Figure 4.13: Mortality rates of breast cancer: women only, 1980 - 2013. The dashed line indicates the introduction of ICD 10 for coding the cause of death.

Breast cancer mortality rates over the socioeconomic gradient are presented in Figure 4.14. There does not appear to be a strong gradient in the mortality rates, with each deprivation decile experiencing large year on year variation.

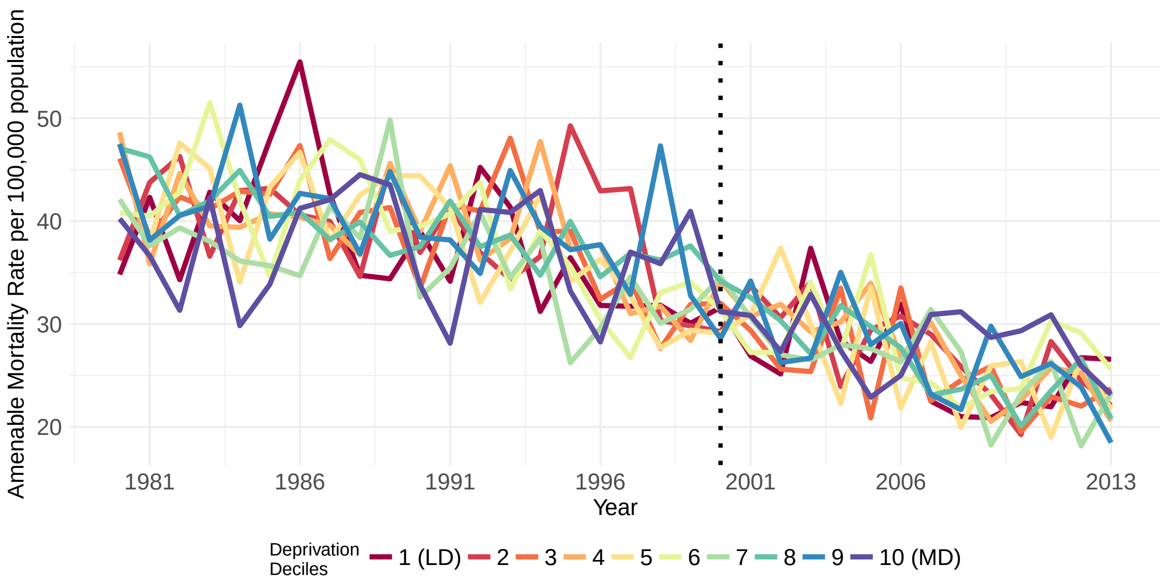


Figure 4.14: Mortality rates of breast cancer by deprivation decile: women only, 1980 - 2013. The dashed line indicates the introduction of ICD 10 for coding the cause of death.

The final individual cause to be discussed in the main body of this thesis is pneumonia, in Figure 4.15. This is the only individual amenable condition inspected that appears to have been affected by the ICD code change for mortality rates. The new version of cause of death coding, along with new coding instructions, was introduced in 2000 in Scotland. Between 1999 and 2000, mortality rates experienced large relative declines of 47% (12 per 100,000) for men, and 51% (8.7 per 100,000) for women. The mortality rates were declining before and after this interval, but not to the same magnitude.

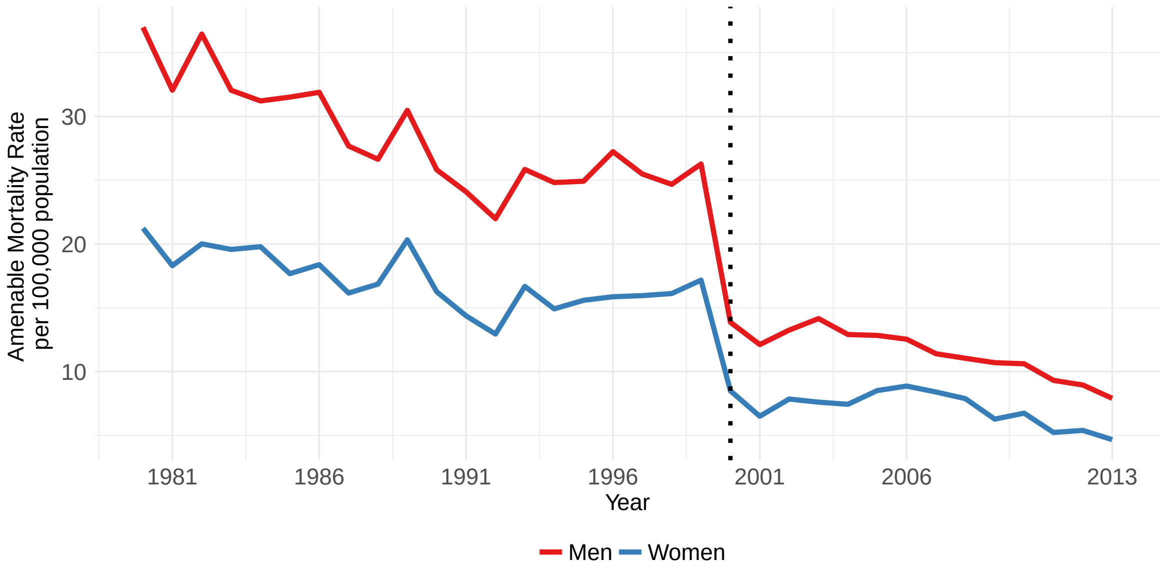


Figure 4.15: Mortality rates of pneumonia: men & women, 1980 - 2013. The dashed line indicates the introduction of ICD 10 for coding the cause of death.

The change in ICD version in 2000 had varying levels of effect across the gradient, shown in Figure 4.16. For men, the most and least deprived deciles experienced similar absolute declines between 1999 and 2000 (approximately 19 deaths per 100,000), with only decile 4 experiencing a small absolute increase of 2.3 deaths per 100,000. For women, the most deprived decile experienced a decrease of 12.2 deaths per 100,000, whilst the least deprived had a decline of 5.2 deaths per 100,000. No deciles saw an absolute increase.

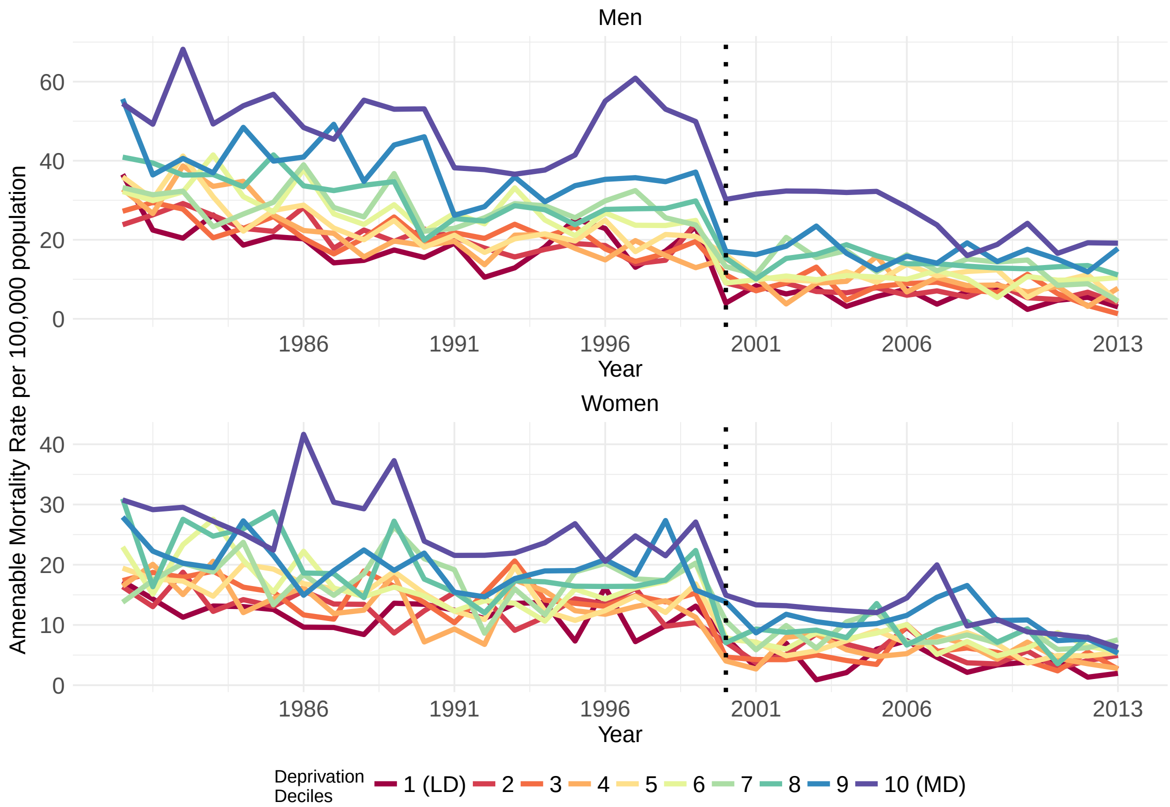


Figure 4.16: Mortality rates of pneumonia by deprivation decile: men & women, 1980 - 2013. The dashed line indicates the introduction of ICD 10 for coding the cause of death. Note: graphs are on different scales

4.4.3 Indices of inequality

Figure 4.17 contains the yearly relative indices of inequality for men and women. Relative inequalities ranged from 1.7 to 3.2 for men, and between 1.5 and 2.7 for women, with the largest inequalities occurring in later years. The 2013 RII are interpreted as there being a 3.1 times higher risk of amenable death for men living in the notionally most deprived areas, compared to those living in the least deprived areas.

Relative inequalities for men are consistently larger than for women, and there is a generally increasing trend over the analysis period, although there is a slight divergence from 2009, where relative inequalities for women decrease, whilst continuing to increase for men.

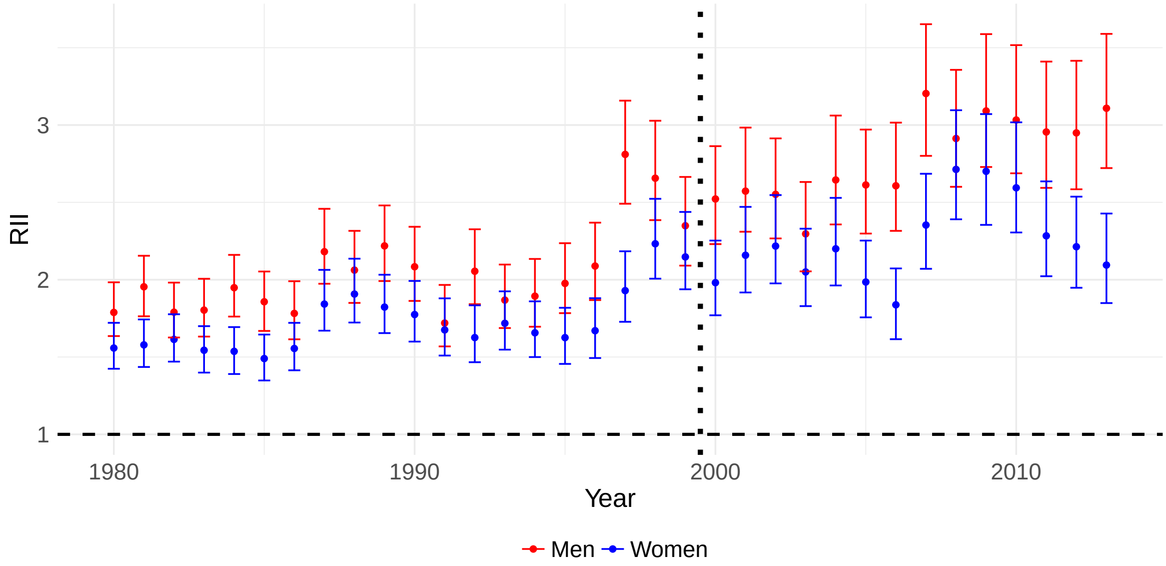


Figure 4.17: Relative indices of inequality: men & women, 1980 - 2013. The dashed line indicates the introduction of ICD 10 for coding the cause of death.

The Slope indices of inequalities presented in Figure 4.18 are absolute measure of inequalities, complementing the relative measures presented in Figure 4.17.

Absolute inequalities in rates of amenable mortality between the notionally most and least deprived areas ranges between 116.1 and 187.4 per 100,000 for men, and 76.7 and 129.4 per 100,000 for women.

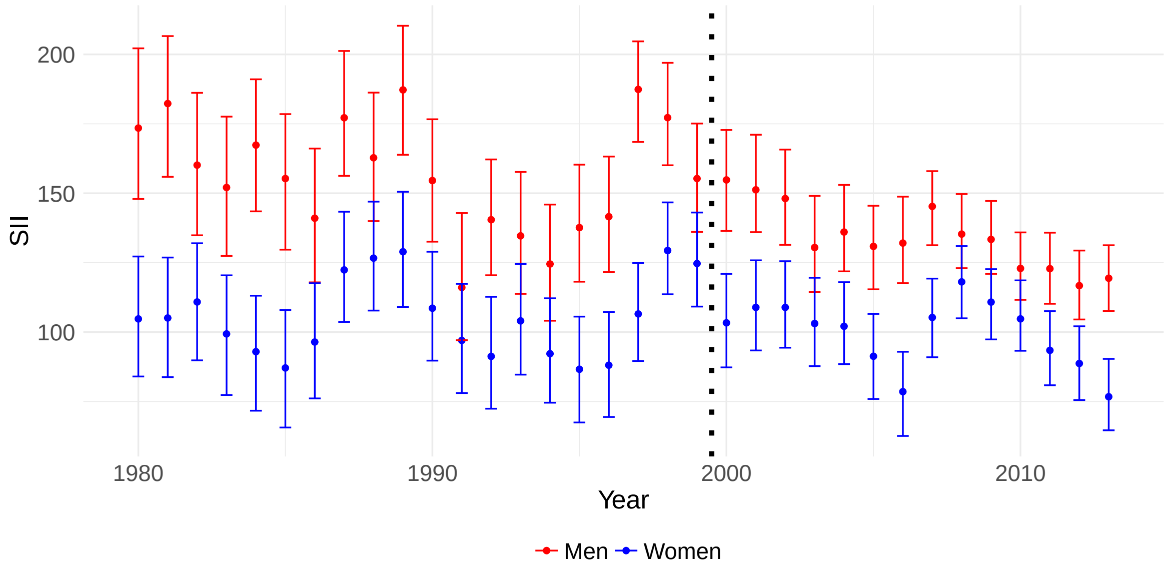


Figure 4.18: Slope indices of inequality: men & women, 1980 - 2013. The dashed line indicates the introduction of ICD 10 for coding the cause of death.

RII by diagnosis group and sex are presented in Figure 4.19.

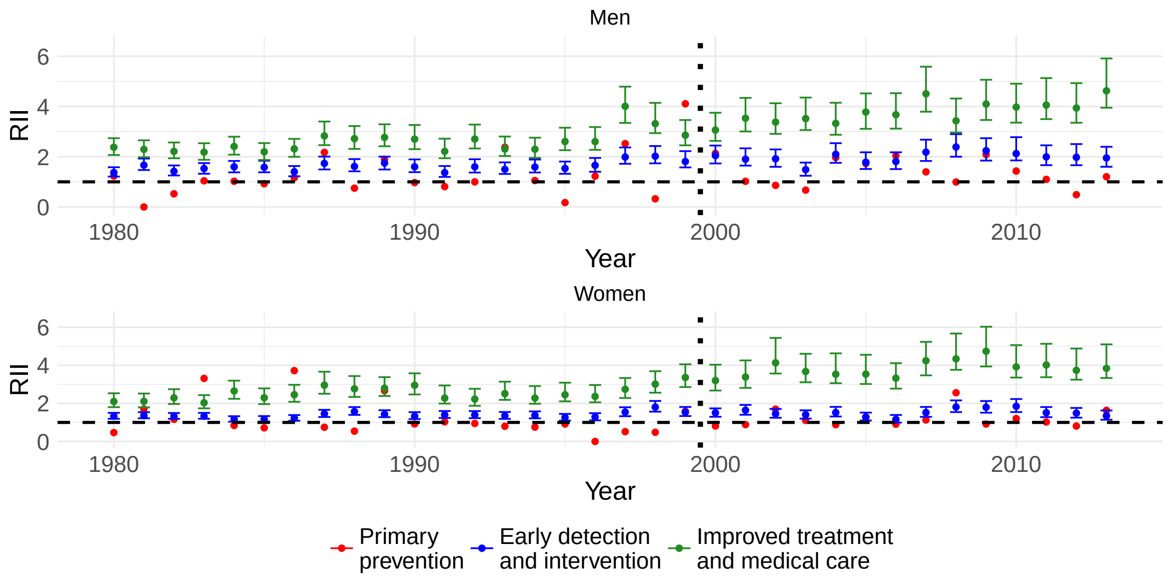


Figure 4.19: Relative indices of inequality by diagnosis group: men & women, 1980 - 2013. The dashed lines indicates the introduction of ICD 10 for coding the cause of death.

The confidence bands for the PP RII are not shown in Figure 4.19, as the Monte Carlo simulation algorithm (see section 3.7) failed to converge due to the small numbers of death amenable to primary prevention occurring within a given year. Therefore point estimates for the RII without confidence intervals are shown for the PP group only.

Relative inequalities are larger in rates of death amenable to ITMC than to EDI for both men and women. ITMC RII are increasing over time, indicating that rates of death are decreasing faster in the least deprived areas, than in the most deprived areas. The confidence intervals are increasing over time, as a result of the decreasing number of deaths occurring in each year.

The relative inequalities in EDI for men are larger than they are for women, despite women having larger age-standardised mortality rates. The RII for women also appear to remain relatively stable over the period, whereas male inequalities can be seen to be increasing.

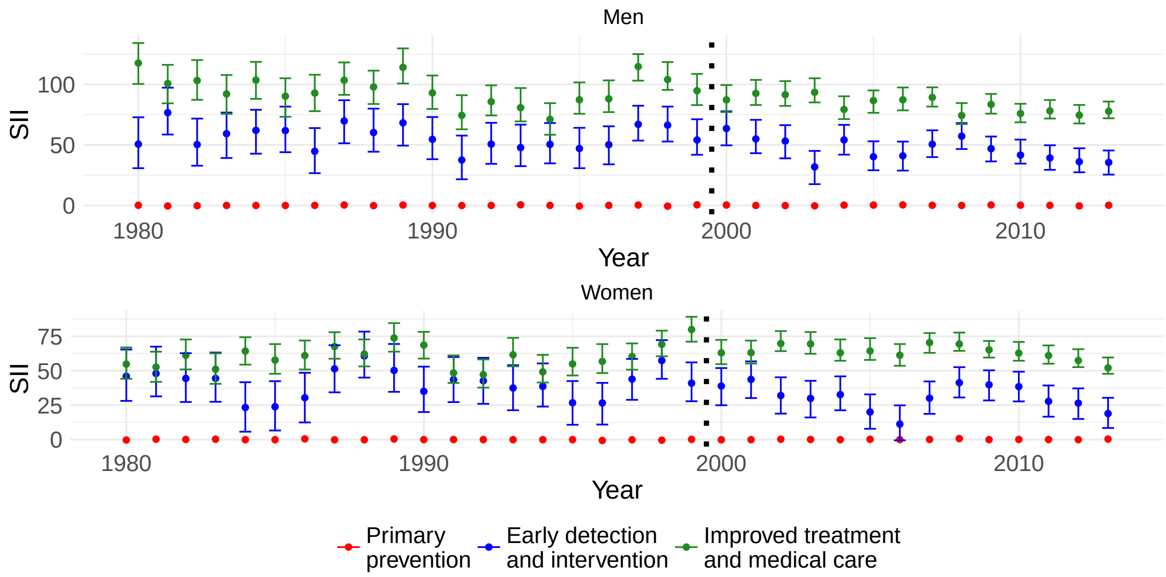


Figure 4.20: Slope indices of inequality by diagnosis group: men & women, 1980 - 2013. The dashed lines indicates the introduction of ICD 10 for coding the cause of death.
Note 1: plots are presented on different scales.

The complementary measure to the relative indices of inequality, the slope indices of inequality, are presented in Figure 4.20. As the simulated confidence intervals for the PP RII failed to converge, and the calculation of the SII confidence bands depends on these, Figure 4.20 only depicts the point estimates for the absolute inequalities in rates of death amenable to primary prevention.

The SII for EDI and ITMC are larger in the beginning of the analysis period, and generally decrease over time, however there is more variation than was seen in the RII. The SII for the ITMC group are narrower than the EDI group, due to the larger number of deaths included in this group.

4.4.4 Fractional polynomials

Fractional polynomials are used to model the non-linear relationships of age, deprivation level and year of death in the data. The estimated transformations, using Equation 3.7, are described in Tables 4.7 and 4.8 for men and women respectively.

Table 4.7: Fractional polynomial (FP) transformations of covariates: men

Covariate	FP	Transformation
Age (1)	-0.5	$(\frac{A}{10})^{-0.5} - 0.520$
Age (2)	1	$\frac{A}{10} - 3.7$
Year_c (1)	0.5	$(\frac{(Y_c)+1}{10})^{0.5} - 1.323$
Year_c (2)	3	$(\frac{(Y_c)+1}{10})^{3} - 5.359$
Decile (1)	-0.5	$D^{-0.5} - 0.426$
Decile (2)	2	$D^{2} - 30.25$
Age $\times$ Year_c (1)	3	$(\frac{A \times Y_c + 1}{1{,}000})^{3} - 0.229$
Age $\times$ Year_c (2)	3	$((\frac{A \times Y_c + 1}{1{,}000})^{3} \times log_e(\frac{A \times Y_c + 1}{1{,}000})) + 0.112$
Age $\times$ Decile (1)	0	$log_e(\frac{A \times D}{100}) - 0.710$
Age $\times$ Decile (2)	3	$(\frac{A \times D}{100})^{3} - 8.427$
Decile $\times$ Year_c (1)	0.5	$(\frac{D \times Y_c + 1}{100})^{0.5} - 0.958$
Decile $\times$ Year_c (2)	1	$\frac{D \times Y_c + 1}{100} - 0.918$
Age $\times$ Decile $\times$ Year_c(1)	0.5	$(\frac{A \times D \times Y_c + 1}{10{,}000})^{0.5} - 0.580$
Age $\times$ Decile $\times$ Year_c (2)	2	$(\frac{A \times D \times Y_c + 1}{10{,}000})^{2} - 0.113$

Y_c = Year_c = Year - 1980 ; 0, 1, ..., 33.

A = Age; 2, 7, 12, ..., 72.

D = Decile; 1, 2, ..., 10.

Table 4.8: Fractional polynomial (FP) transformations of covariates: women

Covariate	FP	Transformation
Age (1)	-2	$(\frac{A}{10})^{-2} - 0.073$
Age (2)	1	$\frac{A}{10} - 3.7$
Year_c (1)	0.5	$(\frac{Y_c+1}{10})^{0.5} - 1.323$
Year_c (2)	1	$\frac{Y_c+1}{10} - 1.750$
Decile (1)	-1	$D^{-1} - 0.182$
Decile (2)	3	$D^3 - 166.375$
Age $\times$ Year_c (1)	1	$\frac{A \times Y_c+1}{1{,}000} - 0.612$
Age $\times$ Year_c (2)	1	$((\frac{A \times Y_c+1}{1{,}000}) \times log_e(\frac{A \times Y_c+1}{1{,}000})) + 0.301$
Age $\times$ Decile	2	$(\frac{A \times D}{100})^2 - 4.141$
Decile $\times$ Year_c	1	$(D \times Y_c) - 90.750$
Age $\times$ Decile $\times$ Year_c	1	$(A \times D \times Y_c) - 3{,}357.750$

Y_c = Year_c = Year - 1980 ; 0, 1, ..., 33.
A = Age; 2, 7, 12, ..., 72.
D = Decile; 1, 2, ..., 10.

As age, year of death and deprivation were not modelled as linear covariates, and they are included in interactions, the interpretation of their covariates is not simple. The effects of the fractional polynomials transformations are best understood by using the models to predict mortality rates for selected situations. Figures 4.21 and 4.22 plot the output of the modelled age-specific mortality rates between age 0 and 74 years, for the most (decile 10) and least (decile 1) deprived decile, and at the beginning (1981) and end (2013) of the analysis period for men and women.

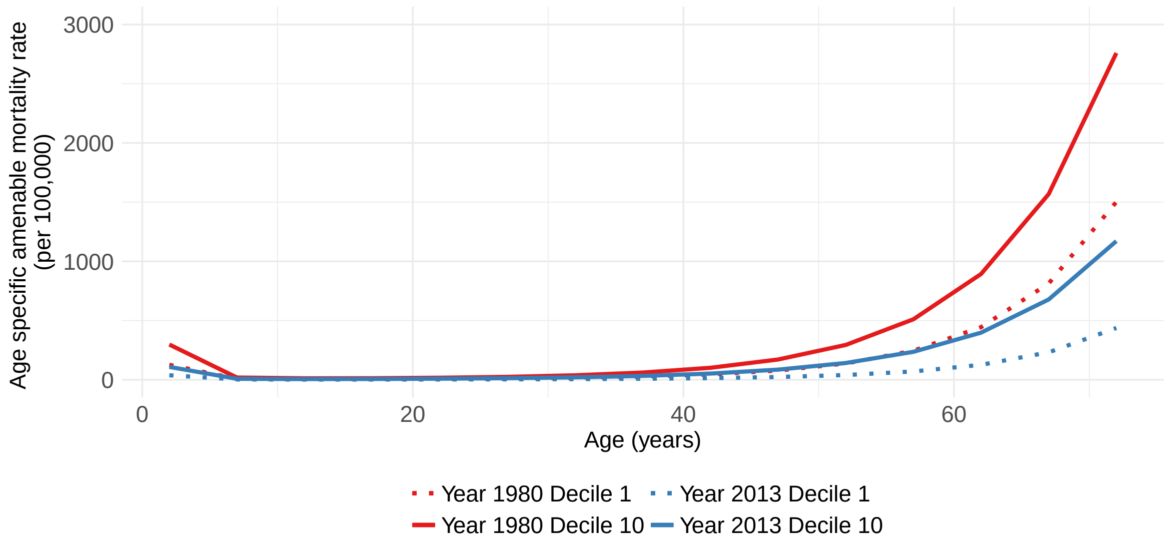


Figure 4.21: Age-specific amenable mortality rates for men at the most and least deprived deciles, 1980 and 2013

Both Figures 4.21 and 4.22 show a higher risk of amenable mortality at the youngest age group (0 - 4 years), compared to the next age group (ages 5 - 9 years). The risk appears to only increase from approximately age 40 onwards. Men in the most deprived decile in 2013 have slightly improved risks of amenable death at the oldest age groups, compared to what the men in the least deprived decile experienced in 1980, whereas for women these risks are approximately equal, suggesting a 34 year lag in improvements for women in Scotland.

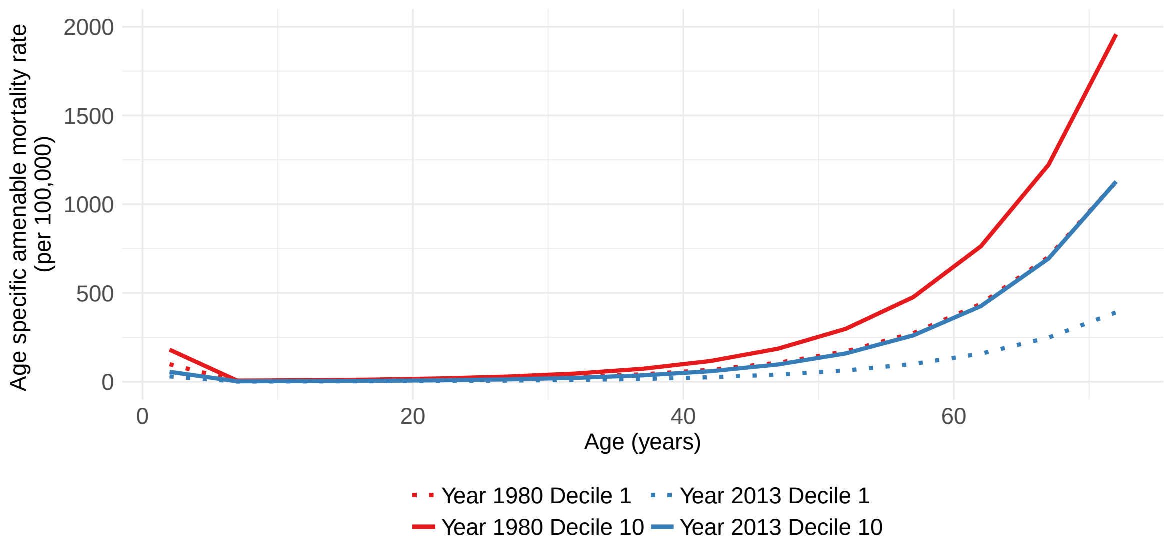


Figure 4.22: Age-specific amenable mortality rates for women at the most and least deprived deciles, 1980 and 2013

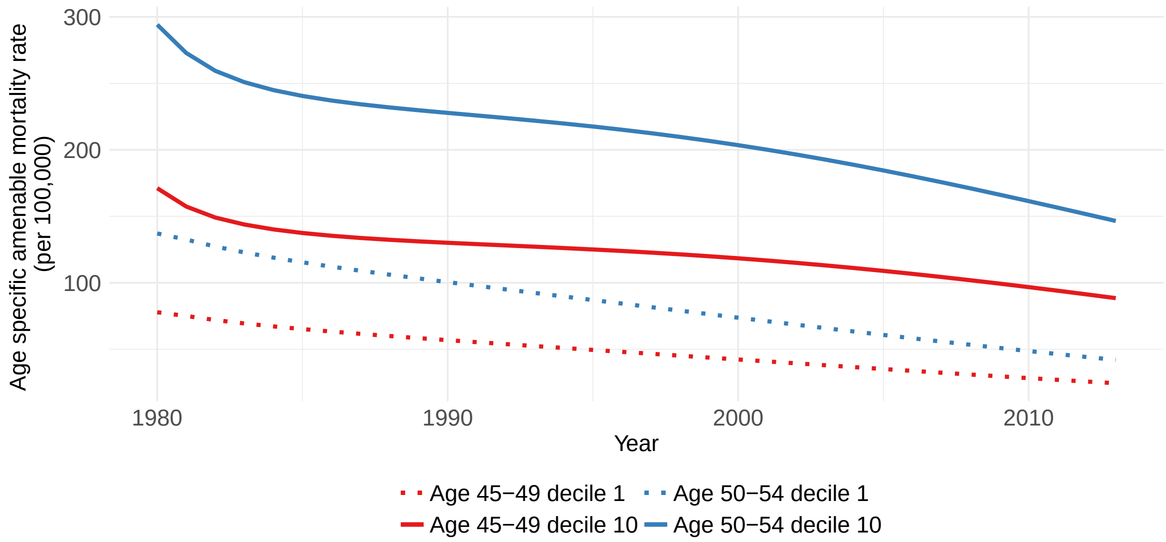


Figure 4.23: Age specific amenable mortality rates for men at the most and least deprived deciles, ages 45 - 54 years

The effect of the single, linear transformation for the decile $\times$ year interaction for women, whilst men have two polynomial transformations, is evident in Figure 4.24, compared to Figure 4.23. The risk of amenable death for men in the most deprived deciles rapidly declines in the first 5 years of the analysis period, whilst the decline over time for women is linear, though there is a steeper gradient for the older age group.

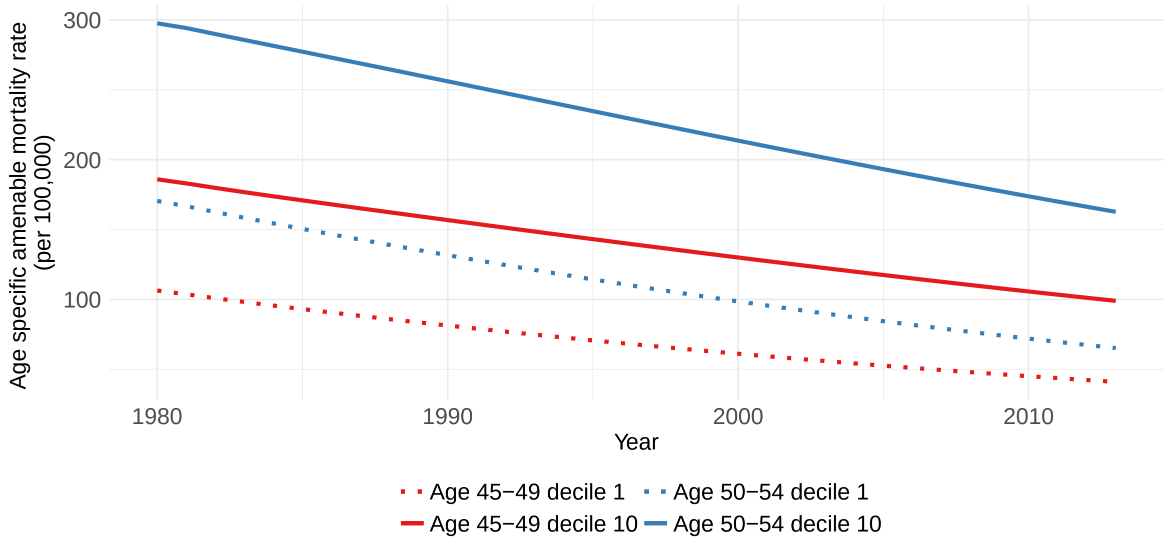


Figure 4.24: Age-specific amenable mortality rates for women at the most and least deprived deciles, ages 45 - 54 years

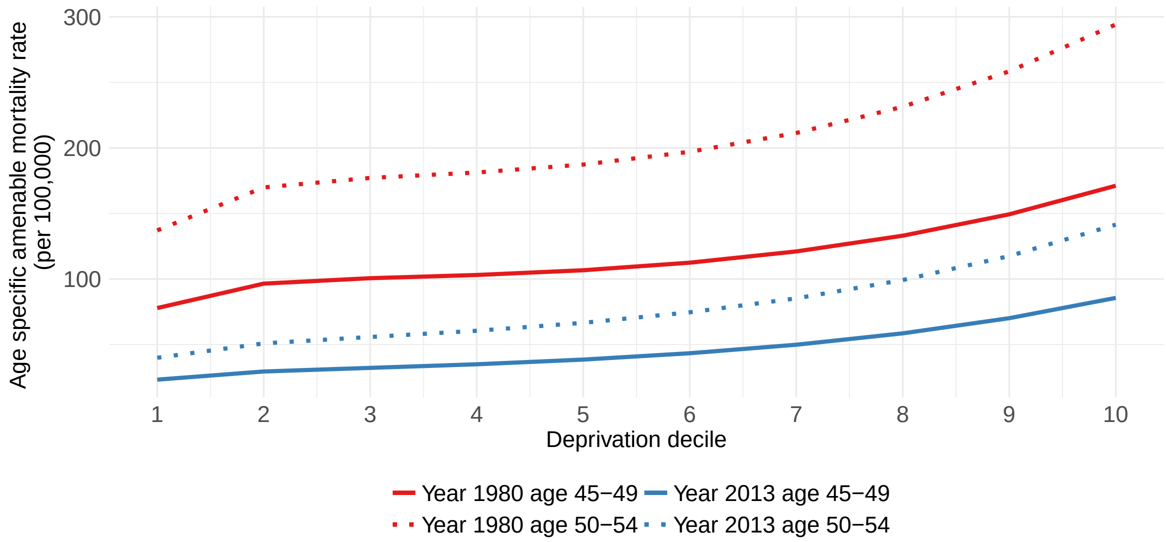


Figure 4.25: Age-specific amenable mortality rates for men, ages 45 - 54 years, 1980 and 2013

Finally, the effects of deprivation on the risk of amenable deaths can be inspected using Figures 4.25 and 4.26. The risk of amenable death has decreased for both men and women over the 34 year period, and for both age groups plotted. There is a sharper change in risk of amenable death between deciles 1 (least deprived) and 2, than between deciles 2 and 3, for both sexes. The change is stronger in 1980, than it is in 2013. The most deprived deciles (10) continues to experience the highest risk of amenable death.

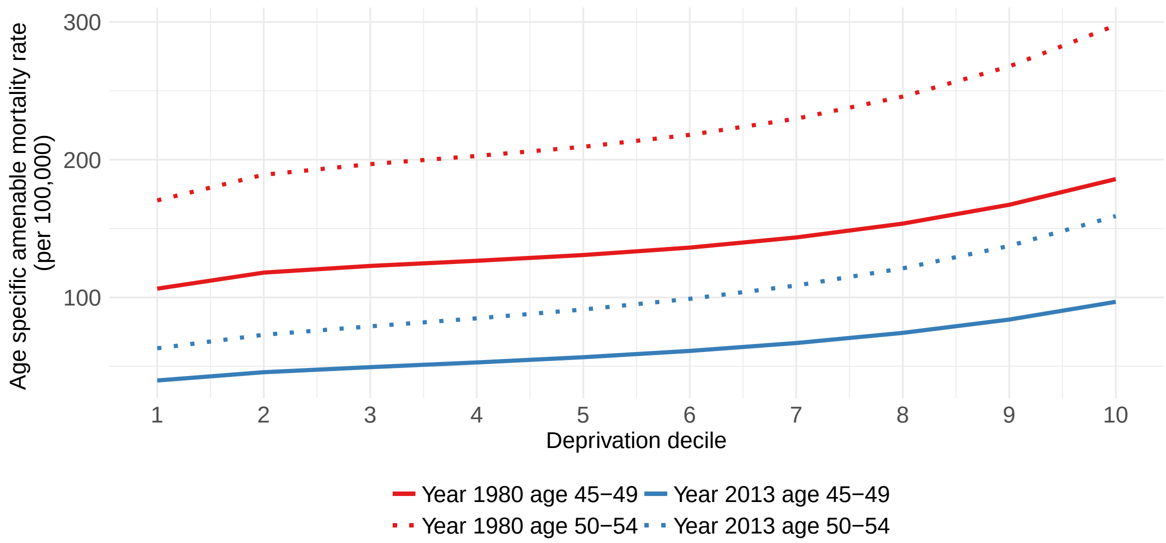


Figure 4.26: Age-specific amenable mortality rates for women, ages 45 - 54 years, 1980 and 2013

4.4.5 Multilevel Modelling

Single Response

Prior to the transformations being applied to the data, minor cleaning and adjustments were made. There were 1,027,920 rows of data, corresponding to 15 age groups, 2 sexes, 2,025 unique combinations of postcode sectors and LGD or council codes, and a varying number of years. As postcode sectors are not constant over time, a postcode sector may contribute between 7 and 34 years to the dataset. Within the dataset, 9,927 rows had zero or missing population sizes, occurring if there was no recorded population of sex and age group within a given area and year. If these rows did not contain a death, they were removed from the dataset, as the offset is not defined for areas with zero population. Rows with at least one death (n=51, deaths = 53) had their population sizes artificially increased to match the numbers of deaths occurring in the area. This inflated the overall population size for the 34 years by 53 people, mainly female (n=36), over the age of 40 (n=43), and were spread across the study period. This should have minimal effect on the results, whilst ensuring all deaths could be included in the analysis.

There were 123,392 male, and 130,120 female amenable deaths, distributed over the analysis period. The fractional polynomials for each sex were applied to the relevant variables, and the resultant multilevel model estimates for men are displayed in Table 4.9 and Table 4.10 for women.

Table 4.9: Incident Rate Ratios and 95% confidence intervals derived from multilevel modelling: men, 1980 - 2013

Men	FP	IRR	95% CI
Intercept		0.0002	
FP age 1	-0.5	9.718	(7.70 - 12.27)
FP age 2	1	4.141	(4.04 - 4.25)
FP year 1	0.5	0.725	(0.65 - 0.81)
FP year 2	3	0.991	(0.99 - 0.99)
FP decile 1	-0.5	0.065	(0.04 - 0.10)
FP decile 2	2	1.011	(1.01 - 1.01)
FP age × year 1	3	0.895	(0.87 - 0.92)
FP age × year 2	3	1.102	(1.08 - 1.13)
FP age × decile 1	0	0.406	(0.34 - 0.48)
FP age × decile 2	3	0.999	(0.99 - 0.99)
FP year × decile 1	0.5	0.338	(0.26 - 0.44)
FP year × decile 2	1	1.550	(1.40 - 1.72)
FP age × decile × year 1	0.5	2.270	(1.98 - 2.61)
FP age × decile × year 2	2	0.919	(0.89 - 0.95)

FP: fractional polynomial

IRR: Incident rate ratio

95% CI: 95% confidence interval

Men	Coef.	s.e.	MRR
σ^2_{v0}	0.027	0.002	1.170
σ^2_{u0}	0.013	0.002	

Where σ^2_{v0} and σ^2_{u0} correspond to the variation at the area and year level respectively.

The interpretation of the IRRs presented in Table 4.9 are difficult, due to the inclusion of the fractional polynomial transformations, and interaction terms.

The MRR for the area level indicates that, within a given deprivation decile, there is a 17% increased risk, in median, between areas with higher and lower rates of amenable mortality for men in Scotland.

Table 4.10: Incident Rate Ratios and 95% confidence intervals derived from multilevel modelling: women, 1980 - 2013

Women	FP	IRR	95%CI
Intercept		0.0003	
FP age 1	-2	1.184	(1.18 - 1.19)
FP age 2	1	2.570	(2.54 - 2.60)
FP year 1	0.5	0.704	(0.58 - 0.85)
FP year 2	1	0.804	(0.74 - 0.87)
FP decile 1	-1	0.832	(0.80 - 0.87)
FP decile 2	3	1.0004	(1.00 - 1.00)
FP age × year 1	1	1.298	(1.15 - 1.46)
FP age × year 2	1	0.812	(0.76 - 0.86)
FP age × decile	2	0.998	(0.99 - 0.99)
FP year × decile	1	1.0002	(0.99 - 1.00)
FP age × decile × year	1	1.00002	(1.00 - 1.00)

FP: fractional polynomial

IRR: Incident rate ratio

95% CI: 95% confidence interval

Women	Coef.	s.e.	MRR
σ^2_{v0}	0.012	0.001	1.110
σ^2_{u0}	0.005	0.002	

Where σ^2_{v0} and σ^2_{u0} correspond to the variation at the area and year level respectively.

The increased risk associated with areas with a higher rate of amenable death, compared to areas with lower risk, within a deprivation decile, is 11% for women; lower than the 17% risk for men.

Plots of predicted age-specific and -standardised mortality rates, calculated at each level of the multilevel model: level 2 (Year), level 3 (Area) and the fixed effects, can be used to interpret the multilevel models described in Tables 4.9 and 4.10.

Firstly, predicted age-specific mortality rates for four years (1980, 1990, 2000 and 2010) are illustrated in Figure 4.27 for men and women. The age-specific mortality rates have decreased over time, with rates in the 1980s being consistently higher at all ages, and 2010 having the lowest mortality rates. The fractional polynomial effects of age, year and their interactions are evident at the older ages, for example the gradient between ages 67 and 72 is shallower in 1990, than it was ten years earlier. Small differences between the sexes are also evident at the older ages.

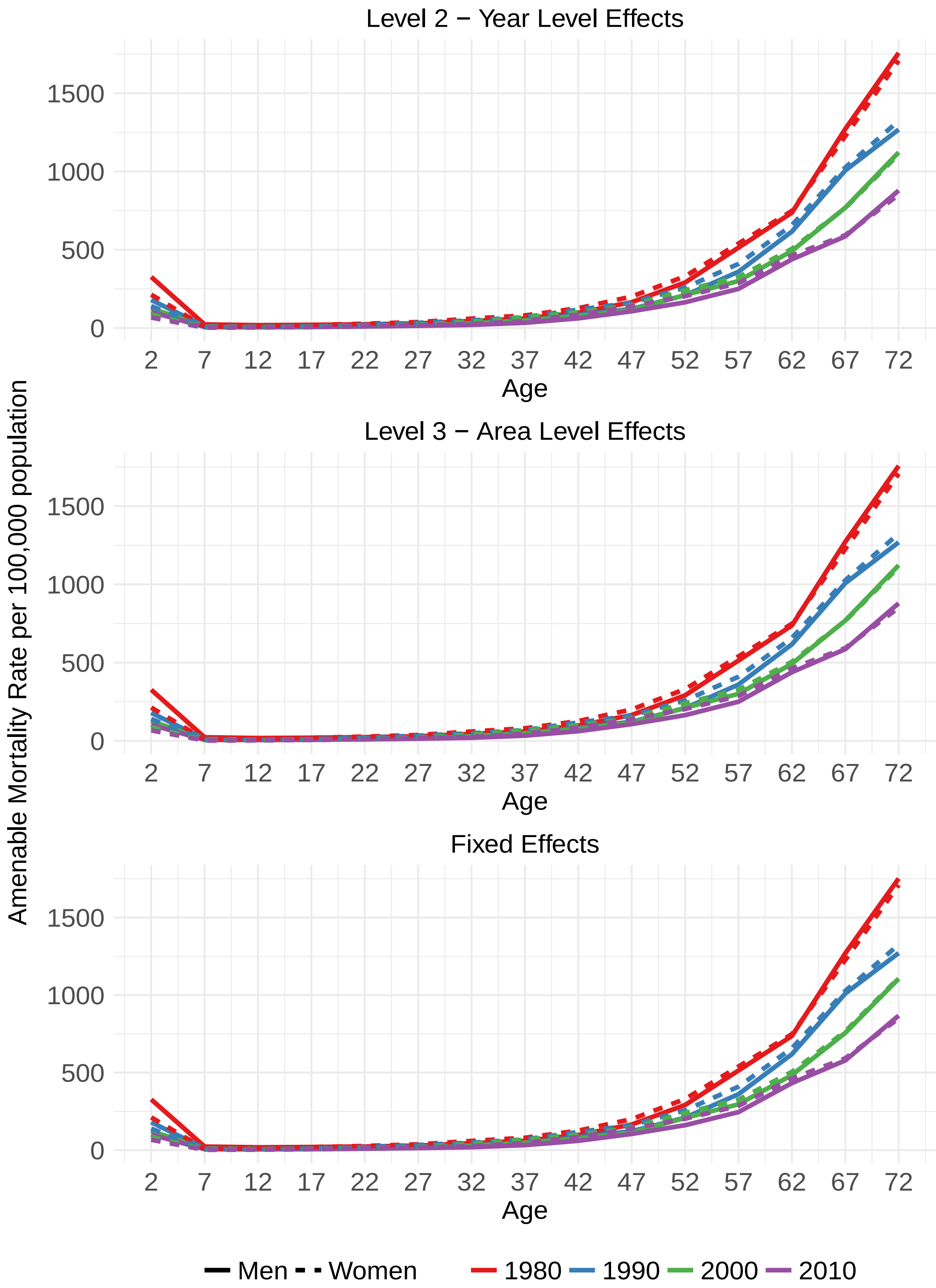


Figure 4.27: Predicted age-specific amenable mortality rates for men (solid) and women(dashed) for selected years at the Year (level 2), Area (level 3) and Fixed effects

The gradients in mortality rates within age groups for a specific year (1980 and 2013) are illustrated in Figures 4.28 and 4.29.

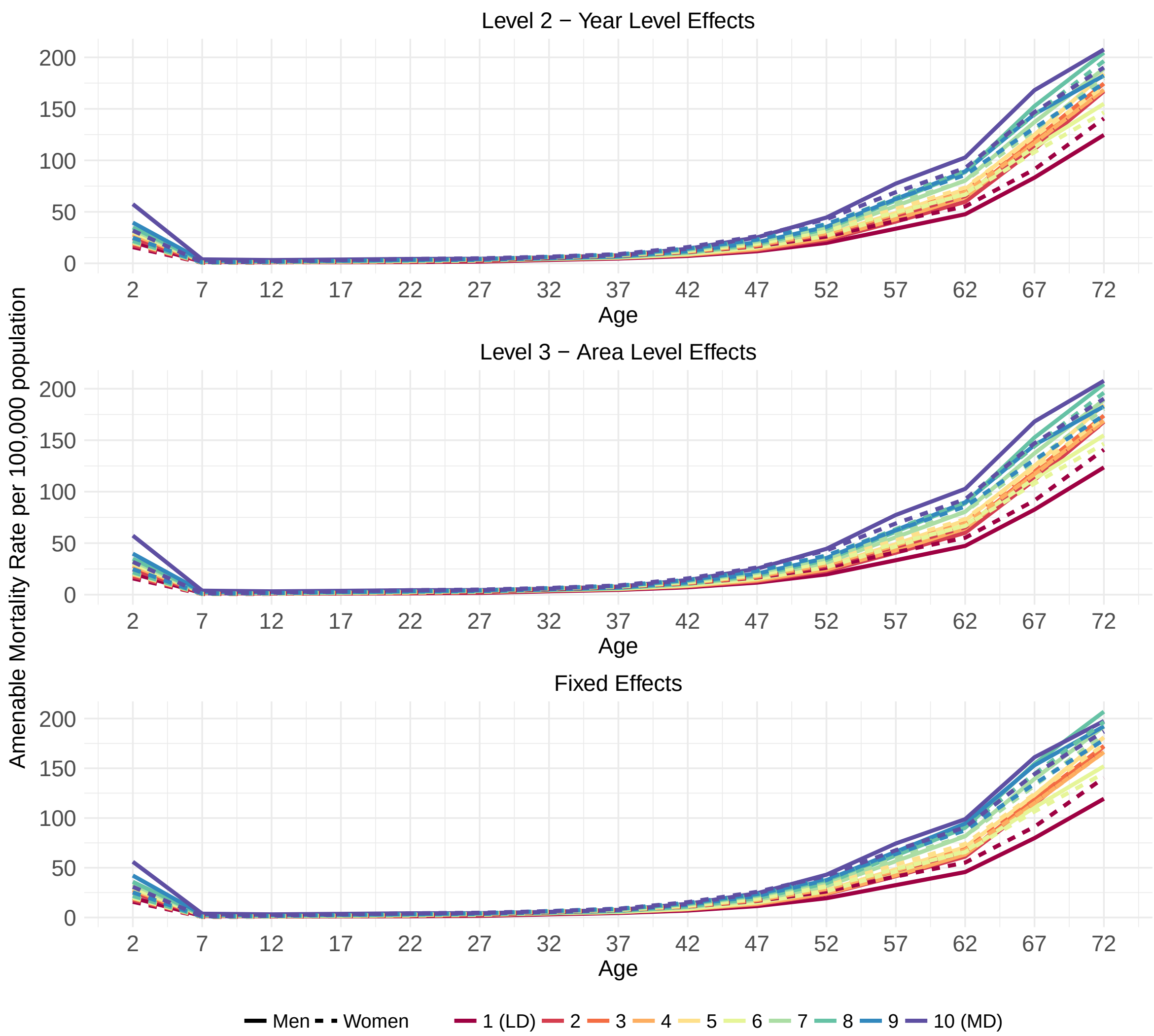


Figure 4.28: Predicted age-specific amenable mortality rates for men (solid) and women (dashed) by deprivation decile in 1980 at the Year (level 2), Area (level 3) and Fixed effects

In 1980, female age-specific mortality rates exceeded those of males in the least deprived decile (decile 1), whereas male mortality rates exceed those of females in the most deprived decile (decile 10). The gap between male and female mortality rates appears to be smaller in the lesser deprived deciles.

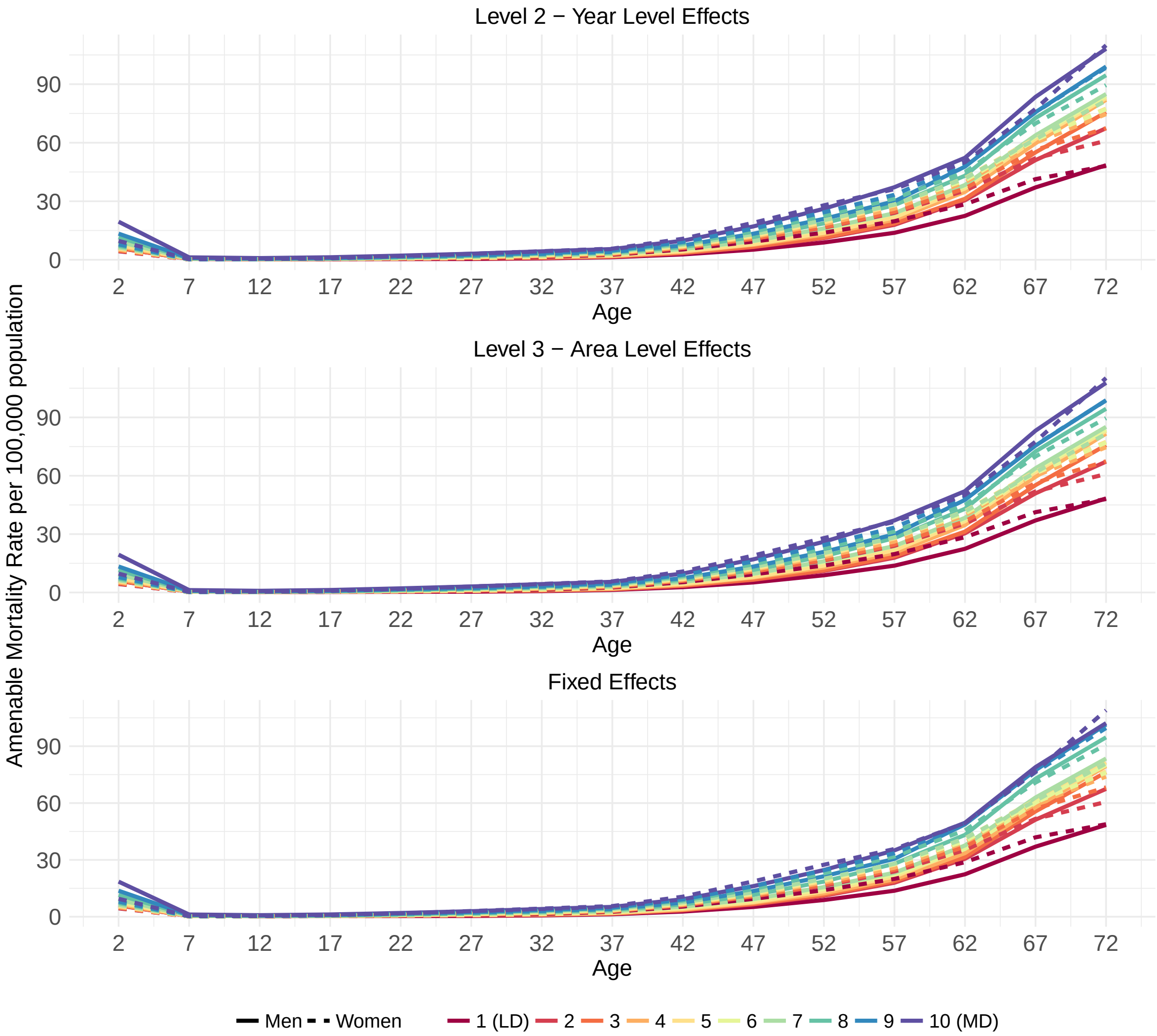


Figure 4.29: Predicted age specific amenable mortality rates for men (solid) and women (dashed) by deprivation decile in 2013 at the Year (level 2), Area (level 3) and Fixed effects

By 2013, the mortality rates have approximately halved for men and women in the the most deprived deciles. Female rates continue to exceed those of males in the least deprived decile, with the greatest difference between the sexes occurring between the ages 50 to 64 years.

Standardising the mortality rates for age then allows for the predicted mortality rates over the years to be plotted.

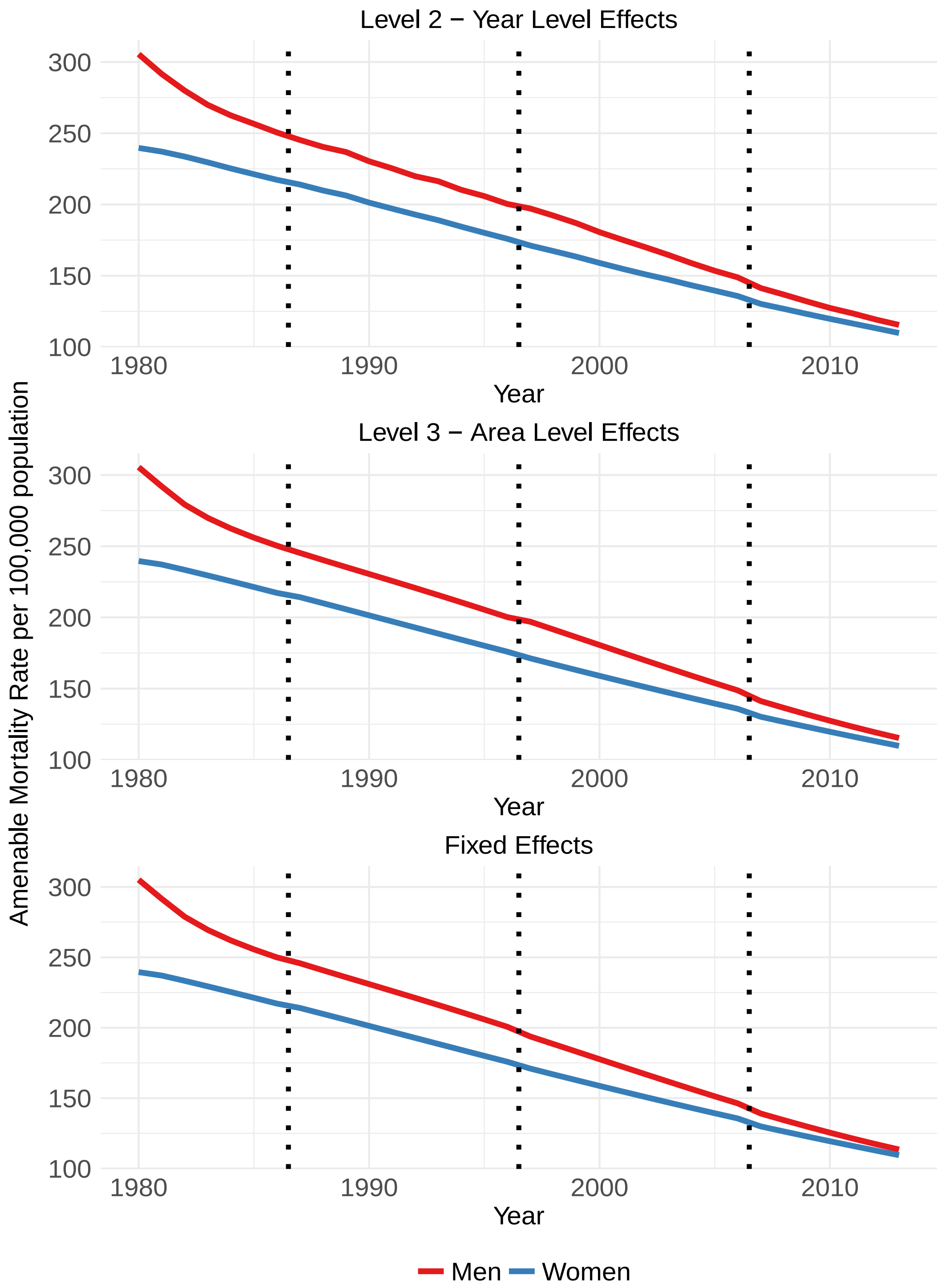


Figure 4.30: Predicted age standardised rates of amenable mortality for the Year (level 2), Area (level 3) and Fixed effects. The dashed lines indicate the points in time where the Carstairs deprivation index version changes (1986/7, 1996/7 and 2006/7).

There is very little difference in the predicted rates estimated for the random and fixed effects in Figure 4.30. The gap in age-standardised mortality rates between men and women has been decreasing over time, and men experienced a greater decrease in the earlier years of analysis compared to women.

Figure 4.31 compares the predicted age-standardised amenable mortality rates in the most and least deprived deciles in Scotland, for men and women, over the analysis period.

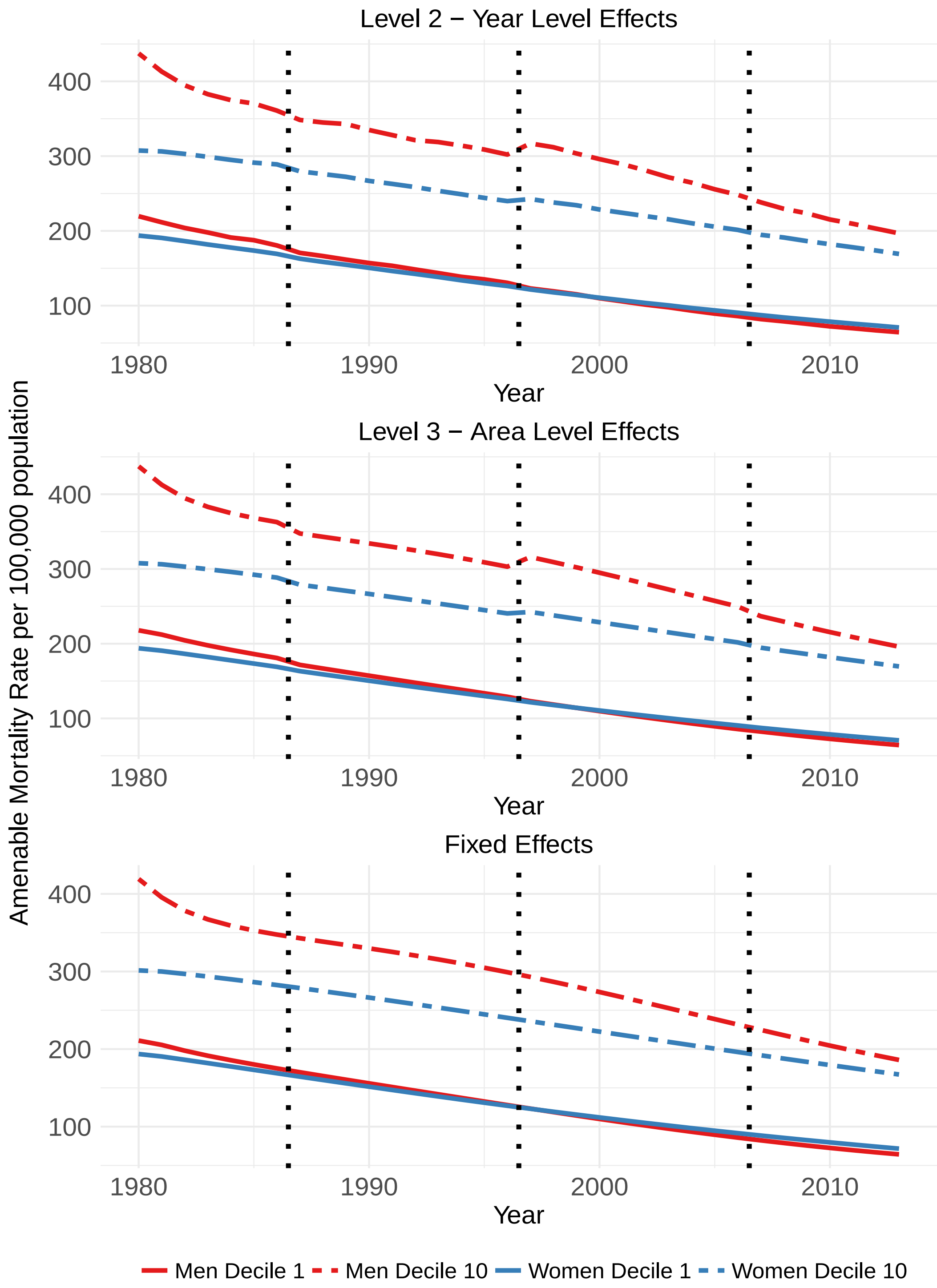


Figure 4.31: Predicted age standardised rates of amenable mortality for the most and least deprived decile for the Year (level 2), Area (level 3) and Fixed effects. The dashed lines indicate the points in time where the Carstairs deprivation index version changes (1986/7, 1996/7 and 2006/7).

Whilst the trends in the least deprived areas appear smoothed, there are noticeable disjoints in the predicted mortality rates at the level 2 (year) and 3 (area) random effects for the most deprived decile (decile 10). These both occur at 1996/7, and can be assumed to be as a result of a change in deprivation decile version (from the version calculated from the 2001 Census to the 2011 Census version). The fixed effects plot does not show any discontinuities. The gap in mortality rates between the most and least deprived areas is larger in men, than in women, with the male gap decreasing faster over time.

Multiple Response Models

Due to errors occurring in the maximum likelihood estimation process the deaths amenable through primary prevention were not included in the multiple response models. These errors produced in the modelling procedure are due to the small, infrequent occurrences of PP deaths over the analysis period (n=778). In order to assess the effects of age and deprivation over the 34 year period in PP deaths, these were fitted using sex-specific single response models. Table 4.11 contains the model output.

Table 4.11: Results of Multilevel modelling of deaths amenable through primary prevention: men & women, 1980 - 2013

Sex	Parameters	IRR	95%CI
Men	Intercept	0.407	
	Decile	1.095	(1.06 to 1.13)
	Year - 1980	1.009	(0.99 to 1.02)
Women	Intercept	0.371	
	Decile	1.081	(1.04 to 1.12)
	Year - 1980	1.010	(1.00 to 1.02)

Sex	Parameters	Coef.	s.e.	MRR
Men	σ^2_{v0}	0.0*	0.0*	1
	σ^2_{u0}	0.0*	0.0*	
Women	σ^2_{v0}	0.0*	0.0*	1
	σ^2_{u0}	0.0*	0.0*	

$*$ to 20 decimal points.

Coef: coefficient

s.e.: standard error

Where σ^2_{v0} and σ^2_{u0} correspond to the variation at the area and year level respectively.

As can be seen, there is no variation at the year nor area level, beyond what would be expected by chance. The MRR suggest that there is no additional risk of death amenable to primary prevention associated with areas with higher rates of mortality amenable to primary prevention, compared with areas with lower rates, within the same deprivation decile.

Deaths amenable to early detection and intervention, and improved treatment and medical care were able to be modelled together in the multiple-response model. This allows for the comparison of area and year level variation in mortality rates across these two diagnosis groups to be estimated.

Table 4.12: Results of Multilevel modelling of deaths amenable through EDI and ITMC: men, 1980 - 2013

Men	IRR	95% CI
Early detection & intervention		
Intercept	2.067	
Decile	1.058	(1.05 - 1.06)
Year - 1980	0.969	(0.96 - 0.97)
Improved treatment & medical care		
Intercept	1.232	
Decile	1.115	(1.11 - 1.12)
Year - 1980	0.975	(0.97 - 0.98)

$$\begin{bmatrix} v_{0k} \\ v_{1k} \end{bmatrix} \sim N(0, \Omega_v) : \Omega_v = \begin{bmatrix} 0.019(0.002) & \\ 0.028(0.002) & 0.055(0.003) \end{bmatrix}$$

$$cov \begin{bmatrix} resp_{1jk}|\pi_{1jk} \\ resp_{2jk}|\pi_{2jk} \end{bmatrix} = \begin{bmatrix} \pi_{1jk} & \\ 0.031(0.006)[\pi_{1jk}\pi_{2jk}]^{0.5} & \pi_{2jk} \end{bmatrix}$$

The results presented in Table 4.12 indicate that the rate ratios effects for deprivation in ITMC deaths are larger than they are for EDI deaths, whilst the effects of year of death are fairly similar. The rate of ITMC deaths increases by 11.5% for each increase in deprivation decile, whereas the rate for EDI deaths increases by 5.8%. For each increase in year, the risk of amenable death decreases by approximately 3%.

The correlations between the Standardised Mortality Ratios of deaths amenable to EDI and to ITMC are 0.031 and 0.89 at the year and area level respectively (see Equation 4.2 for calculation), suggesting that areas with high EDI SMRs are likely to have high ITMC levels, but there is almost no relationship between the two over the years. The MRR at the area level for the EDI and ITMC subgroups respectively are 1.14 and 1.25 respectively, indicating that there is a 25% increased risk of ITMC death in areas with higher mortality rates, and a 14% increased risk associated with EDI deaths, within the same deprivation decile.

Table 4.13: Results of Multilevel modelling of deaths amenable through EDI and ITMC: women, 1980 - 2013

Women	IRR	95%CI
Early detection & intervention		
Intercept	2.228	
Decile	1.037	(1.03 - 1.04)
Year - 1980	0.970	(0.97 - 0.97)
Improved treatment & medical care		
Intercept	0.949	
Decile	1.115	(1.11 - 1.12)
Year - 1980	0.986	(0.98 - 0.99)

$$\begin{bmatrix} v_{0k} \\ v_{1k} \end{bmatrix} \sim N(0, \Omega_v) : \Omega_v = \begin{bmatrix} 0.008(0.001) & \\ 0.011(0.001) & 0.043(0.003) \end{bmatrix}$$

$$cov \begin{bmatrix} resp_{1jk}|\pi_{1jk} \\ resp_{2jk}|\pi_{2jk} \end{bmatrix} = \begin{bmatrix} \pi_{1jk} & \\ 0.064(0.005)[\pi_{1jk}\pi_{2jk}]^{0.5} & \pi_{2jk} \end{bmatrix}$$

The IRR associated with deprivation is approximately the same for men and women in the ITMC group, whereas the increased risk of EDI associated with increasing deprivation for women is lower than for men: 3.7% compared to 5.6%.

There is almost no correlation between SMRs of EDI and ITMC at the year level (ρ=0.064), whereas there are moderate correlations between SMRs at the area level (ρ=0.604). The median relative risk associated with areas with higher risk, compared to areas with lower risk, is increased by 8.7% for EDI deaths, and increased by 22.0% for ITMC for women in Scotland.

4.4.6 Sensitivity analyses

The effects of using a constant population size, measured at the Census over a 10 year period, rather than using the estimated mid-year population size are described in this sensitivity analysis. Figure 4.32 reflects the mortality rates calculated using the constant population and the mid-year population. There are very small differences between the rates calculated with each population. On average, the rates calculated using the constant population exceed those of the mid-year population. The greatest difference occurs for men between 1991 and 1996, where the rates calculated using the constant population exceed those of the rates calculated using the mid-year population by approximately 10 deaths per 100,000.

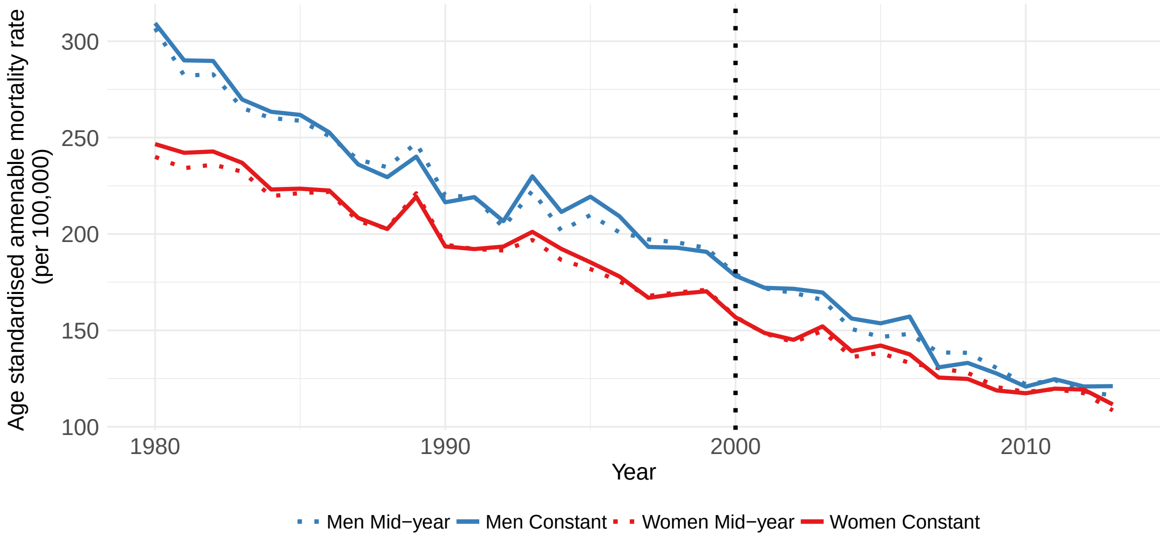


Figure 4.32: Sensitivity analysis: Age standardised mortality rates for Scotland by sex, 1980 - 2013, using a constant population size (solid) or mid-year (dashed) population size. The vertical dashed line indicates the introduction of ICD 10 for coding the cause of death.

The mortality rates using the constant population tend to exceed the mid-year estimates in the years following the Census, indicating that they overestimate the post-Census population of Scotland. In the years before the next Census, the constant population tends to underestimate the population.

Fractional polynomials were estimated using Equation 3.7. Tables 4.14 and 4.15 describe the transformations.

Table 4.14: Sensitivity analysis: Fractional polynomial transformations of covariates: men

Covariate	FP	Transformation
Age (1)	-0.5	$(\frac{A}{10})^{-0.5} - 0.520$
Age (2)	1	$\frac{A}{10} - 3.7$
Year_c (1)	0.5	$(\frac{Y_c+1}{10})^{0.5} - 1.323$
Year_c (2)	2	$(\frac{Y_c+1}{10})^{2} - 3.063$
Decile (1)	-0.5	$D^{-0.5} - 0.426$
Decile (2)	3	$D^{3} - 166.375$
Age × Year_c (1)	1	$\frac{A \times Y_c+1}{1{,}000} - 0.612$
Age × Year_c (2)	1	$((\frac{A \times Y_c+1}{1{,}000}) \times log_e(\frac{A \times Y_c+1}{1{,}000})) + 0.301$
Age × Decile (1)	0	$log_e(\frac{A \times D}{100}) - 0.710$
Age × Decile (2)	0	$log_e(\frac{A \times D}{100})^2 - 0.505$
Decile × Year_c (1)	2	$(\frac{D \times Y_c+1}{100})^2 - 0.842$
Decile × Year_c (2)	3	$(\frac{D \times Y_c+1}{100})^3 - 0.772$
Age × Decile × Year_c(1)	3	$(\frac{A \times D \times Y_c+1}{10{,}000})^3 - 0.038$
Age × Decile × Year_c (2)	3	$(\frac{A \times D \times Y_c+1}{10{,}000})^3 \times log_e(\frac{A \times D \times Y_c+1}{10{,}000})) + 0.041$

Y_c = Year_c = Year - 1980

A = Age

D = Decile

The transformations for the main effects returned in Table 4.14, compared to those using the mid-year estimates in Table 4.7 are the same, except for the second transformations of the year and deprivation decile variable. The second FP for year is now quadratic, rather than cubic, and the second FP for decile is now modelled as a cubic, rather than quadratic function. The use of the constant population affects mortality rates by year and deprivation decile, and so this change is not unexpected. As a result of these changing main-effects, the fractional polynomial transformations for the interactions are also different to those previously estimated for the mid-year populations.

Table 4.15: Sensitivity analysis: Fractional polynomial transformations of covariates: women

Covariate	FP	Transformation
Age (1)	-2	$(\frac{A}{10})^{-2} - 0.073$
Age (2)	1	$\frac{A}{10} - 3.7$
Year$_c$ (1)	1	$(\frac{Y_c+1}{10}) - 1.750$
Year$_c$ (2)	3	$(\frac{Y_c+1}{10})^3 - 5.359$
Decile (1)	-1	$D^{-1} - 0.182$
Decile (2)	3	$D^3 - 166.375$
Age × Year$_c$ (1)	1	$\frac{A \times Y_c+1}{1,000} - 0.612$
Age × Year$_c$ (2)	2	$(\frac{A \times Y_c+1}{1,000})^2 - 0.374$
Age × Decile	2	$(\frac{A \times D}{100})^2 - 4.141$
Decile × Year$_c$	1	$(D \times Y_c) - 90.750$
Age × Decile × Year$_c$	1	$(A \times D \times Y_c) - 3,357.750$

Y_c = Year$_c$ = Year - 1980
A = Age
D = Decile

The fractional polynomial transformations returned for the female data, in Table 4.15 are simpler than the transformations estimated for the male data, in that three of the interaction variables have a single transformation, two of which (Decile × Year$_c$ and Age × Decile × Year$_c$) are restricted to centring only. Compared to the transformations in the main analyses using the mid-year estimated population sizes (Table 4.8), the fractional polynomial transformations applied to the Year main effects, and the second interaction between age and year are different. No such change was made for the year main effects in the male data.

Using a similar process to the main analyses, minor cleaning and adjustments were made prior to the transformations being applied to the data. There were 1,027,920 rows of data, of which 9,924 had zero or missing population sizes. If these rows did not contain a death, they were removed from the dataset, as the offset is not defined for areas with zero population. Rows with at least one death (n=43, deaths = 48) had their population sizes artificially increased to match the numbers of death occurring in the area. This inflated the overall population size by 48 people, mainly in the 10 to 14 year age group, and in the 1980s and 1990s.

There were 123,392 male, and 130,120 female amenable deaths, distributed over 2,025 areas and 34 years. The fractional polynomials for each sex were applied to the relevant data, and the resultant multilevel model estimates for men are displayed in Table 4.16 and Table 4.17 for women.

Table 4.16: Sensitivity analysis: Results of Multilevel modelling: men, 1980 - 2013

Men	FP	IRR	95%CI
Intercept		0.0001	
FP age 1	-0.5	25.229	(20.70 - 30.75)
FP age 2	1	3.597	(3.52 - 3.68)
FP year 1	0.5	0.468	(0.42 - 0.52)
FP year 2	2	0.952	(0.94 - 0.96)
FP decile 1	-0.5	1.380	(1.16 - 1.66)
FP decile 2	3	1.000	(1.00 - 1.00)
FP age $\times$ year 1	1	1.000	(1.00 - 1.00)
FP age $\times$ year 2	1	0.999	(0.99 - 1.00)
FP age $\times$ decile 1	0	0.878	(0.77 - 1.01)
FP age $\times$ decile 2	0	1.013	(1.01 - 1.02)
FP year $\times$ decile 1	2	1.455	(1.33 - 1.60)
FP year $\times$ decile 2	3	0.844	(0.79 - 0.91)
FP age $\times$ decile $\times$ year 1	3	0.858	(0.82 - 0.90)
FP age $\times$ decile $\times$ year 2	3	1.138	(1.08 - 1.19)

FP: fractional polynomial

IRR: Incident rate ratio

95% CI: 95% confidence interval

Men	Coef.	s.e.	MRR
σ^2_{v0}	0.029	0.002	1.176
σ^2_{u0}	0.012	0.002	

Where σ^2_{v0} and σ^2_{u0} correspond to the variation at the area and year level respectively.

The MRR for the area level indicates that there is a 17.6% increased risk associated with areas with a higher risk of amenable mortality, compared to areas with lower risk, within the same deprivation decile. This MRR is only slightly higher than the MRR of 17% previously calculated in Table 4.9 for the mid-year population multilevel model.

Table 4.17: Sensitivity analysis: Results of Multilevel modelling: women, 1980 - 2013

Women	FP	IRR	95% CI
Intercept		0.0003	
FP age 1	-2	1.183	(1.18 to 1.19)
FP age 2	1	2.573	(2.54 to 2.60)
FP year 1	1	0.656	(0.61 to 0.70)
FP year 2	3	1.005	(1.00 to 1.01)
FP decile 1	-1	0.833	(0.80 to 0.87)
FP decile 2	3	1.000	(1.00 to 1.00)
FP age × decile	2	0.998	(0.99 to 0.99)
FP age × year 1	1	1.336	(1.19 to 1.51)
FP age × year 2	2	0.903	(0.88 to 0.93)
FP year × decile	1	1.000	(0.99 to 1.00)
FP age × decile × year	1	1.000	(1.00 to 1.00)

FP: fractional polynomial
IRR: Incident rate ratio
95% CI: 95% confidence interval

Women	Coef.	s.e.	MRR
σ^2_{v0}	0.012	0.001	1.110
σ^2_{u0}	0.005	0.002	

Where σ^2_{v0} and σ^2_{u0} correspond to the variation at the area and year level respectively.

The increased risk associated with areas with higher risk of amenable death, compared to areas with lower risk is 11% for women, within the same deprivation decile. This is lower than the 17.6% risk for men, and is equal to that previously estimated using the mid-year population sizes.

As previously discussed, the coefficients for each of the models are difficult to interpret due to the fractional polynomials and interaction terms. Plots of the fixed effects and the area and year level random effects are useful to interpret the elements of the model.

Figure 4.33 shows that there are very little sex differences in the age-specific mortality rates predicted for the four years.

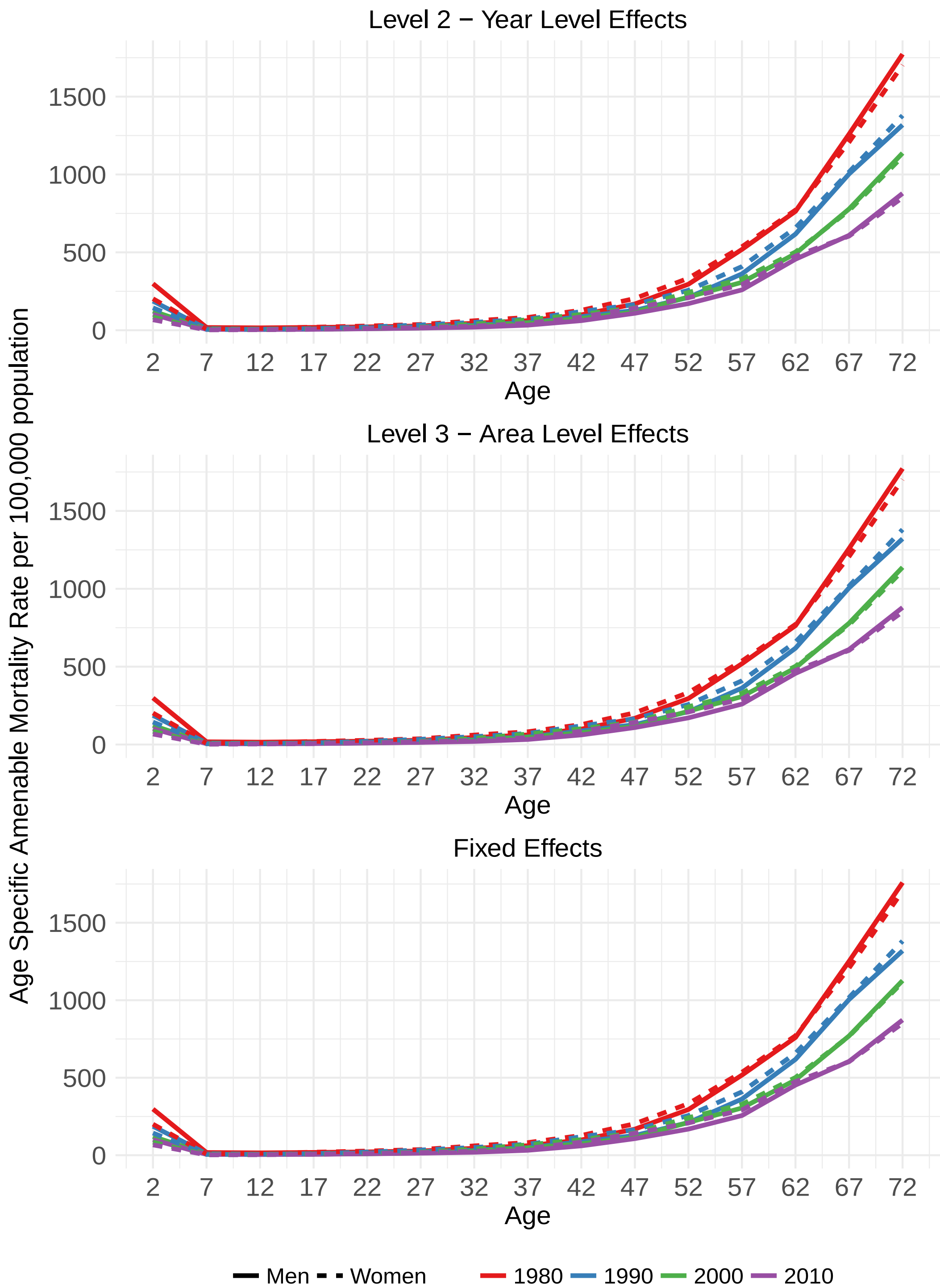


Figure 4.33: Sensitivity analysis: Predicted age-specific amenable mortality rates for selected years at the Year (level 2), Area (level 3) and Fixed effects

Figures 4.34 and 4.35 illustrate the sex-specific mortality rates over the deprivation gradient for two years: 1980 and 2013.

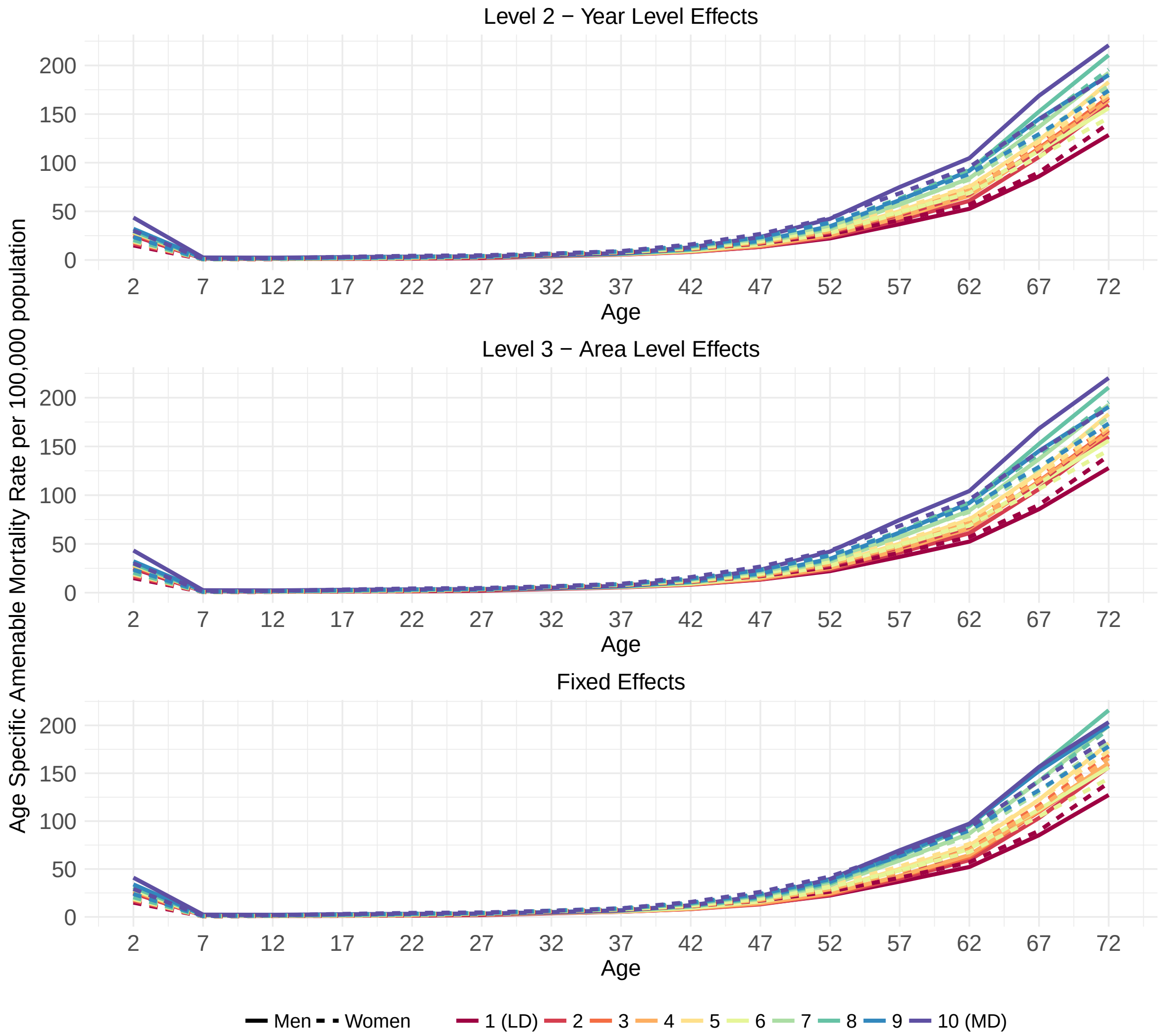


Figure 4.34: Sensitivity analysis: Predicted age-specific amenable mortality rates by deprivation decile in 1980 at the Year (level 2), Area (level 3) and Fixed effects

In 1980, female age-specific mortality rates exceeded those of males in the least deprived decile (decile 1), whereas male mortality rates exceed those of females in the most deprived decile (decile 10). The predicted mortality rate for the oldest age group for men (age 70 - 74 years) in decile 8 exceeds that of the most deprived decile (10) in the fixed effects, but not in either of the random levels.

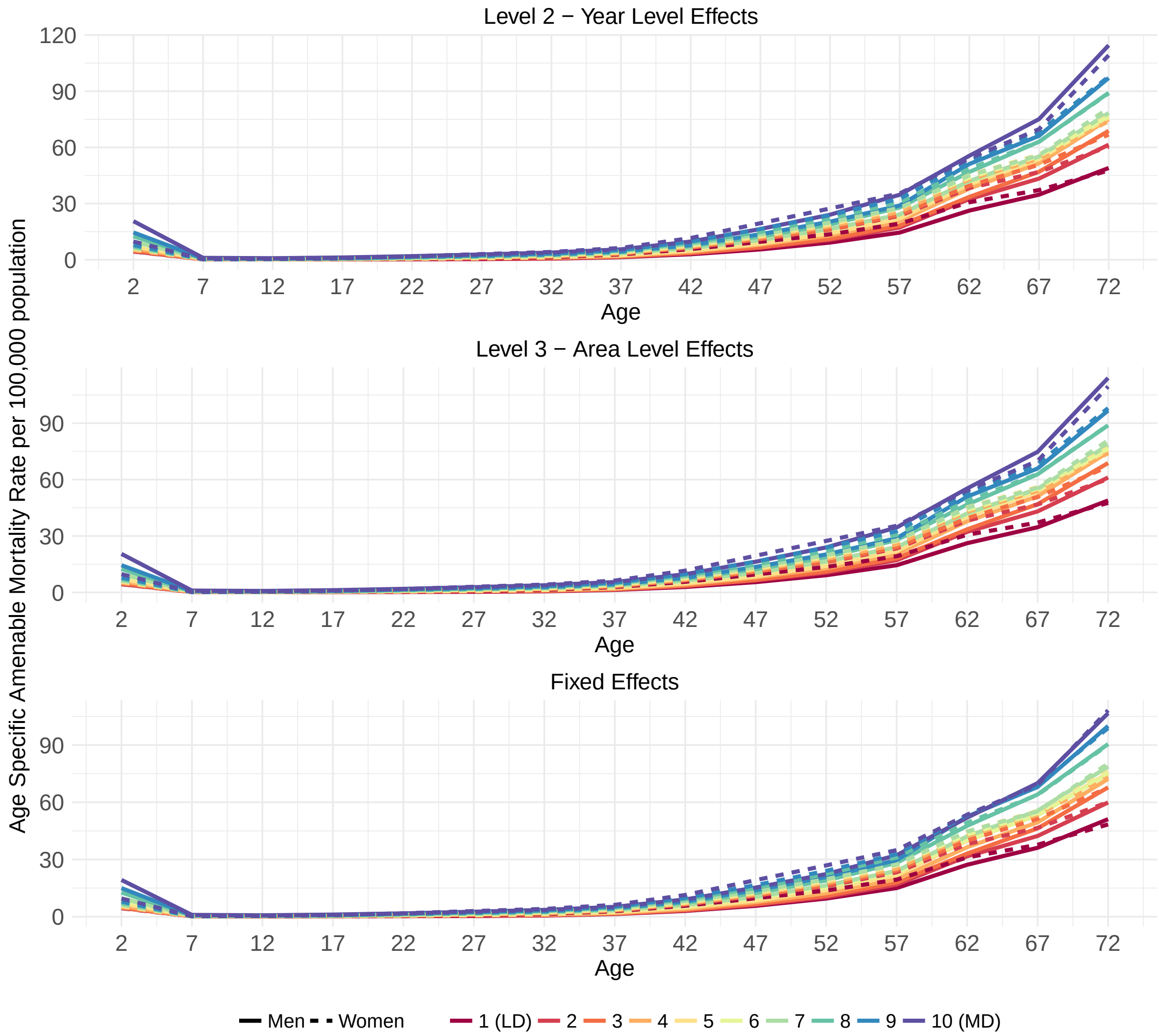


Figure 4.35: Sensitivity analysis: Predicted age-specific amenable mortality rates by deprivation decile in 2013 at the Year (level 2), Area (level 3) and Fixed effects

By 2013, mortality rates have approximately halved. Female rates continue to exceed those of males in the least deprived decile, with the greatest gap occurring at ages 50 to 64 years. Predicted mortality rates for men in decile 8 no longer exceed those estimated for decile 10 at the oldest ages.

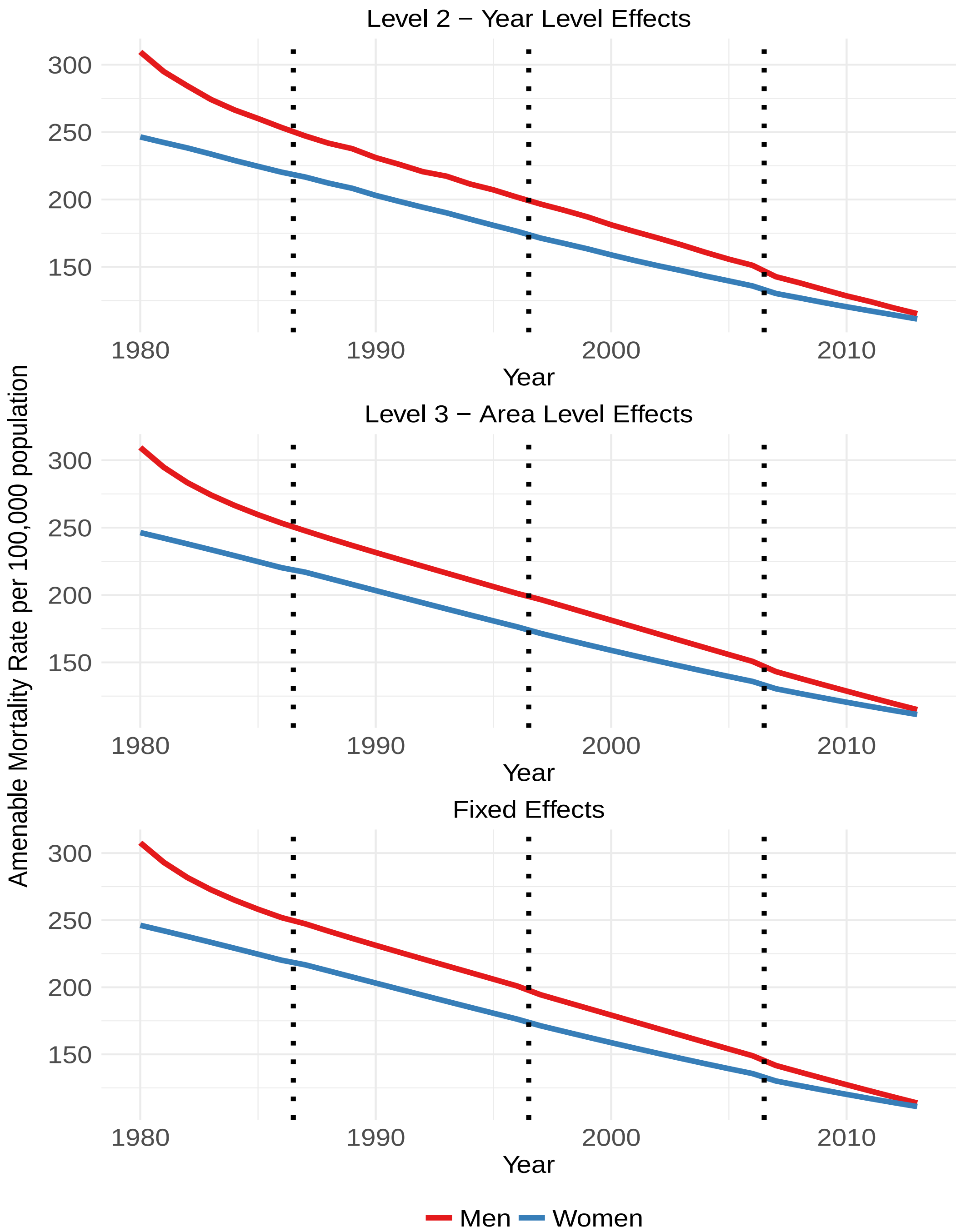


Figure 4.36: Sensitivity analysis: Predicted age standardised rates of amenable mortality for the Year (level 2), Area (level 3) and Fixed effects. The dashed lines indicate the points in time where the Carstairs deprivation index version changes (1986/7, 1996/7 and 2006/7).

The gap in age standardised mortality rates between the sexes over the years, illustrated in Figure 4.36, has been decreasing, similar to what was previously seen in Figure 4.30.

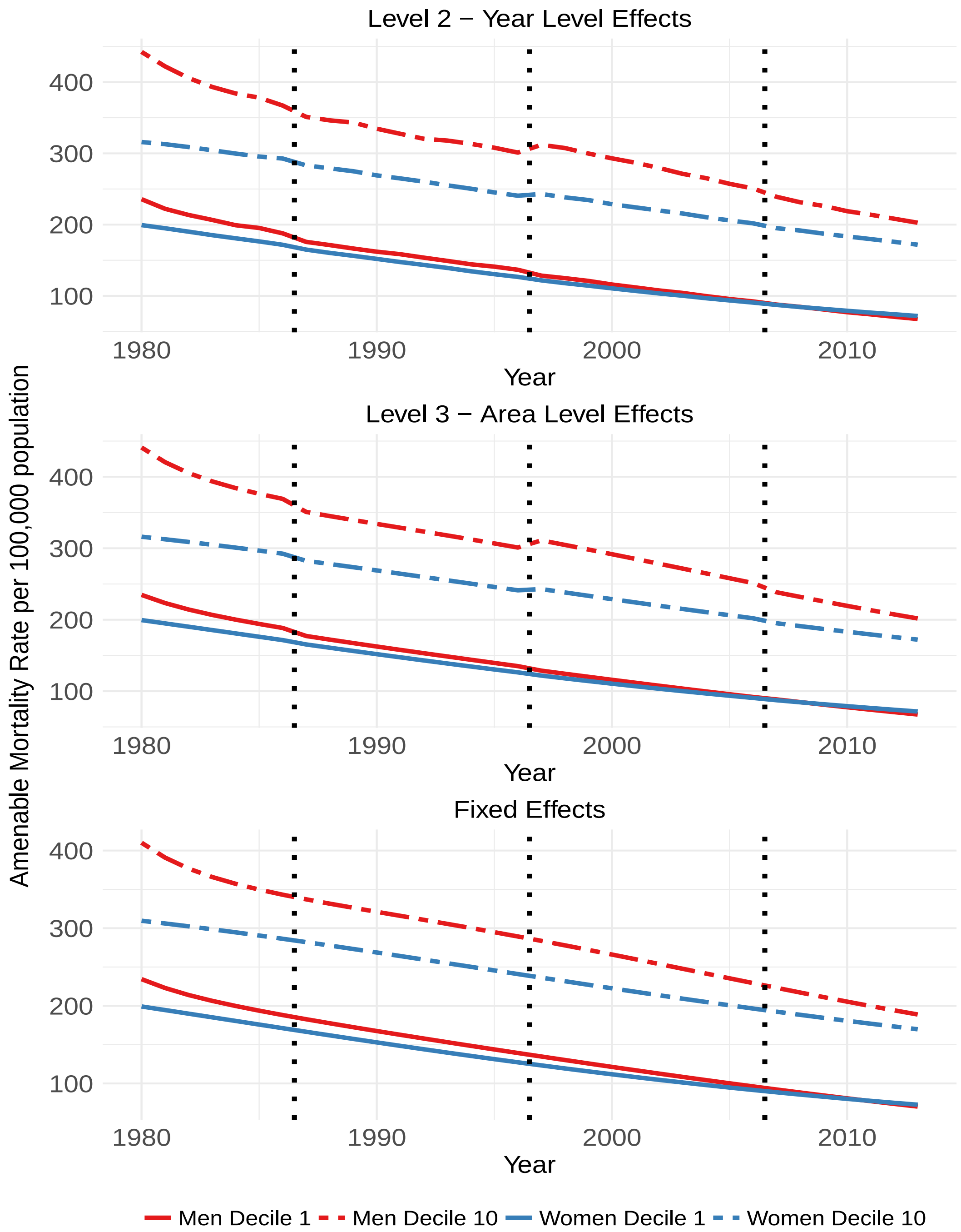


Figure 4.37: Sensitivity analysis: Predicted age standardised rates of amenable mortality for the most and least deprived decile for the Year (level 2), Area (level 3) and Fixed effects. The vertical dashed lines indicate the points in time where the Carstairs deprivation index version changes (1986/7, 1996/7 and 2006/7).

There are clear discontinuities in the predicted mortality rates for both men and women in Figure 4.37, especially visible in the random effects at level 2 and 3, for the most deprived decile (10). These occur in 1996/7, at the point in which both the constant population and deprivation measure change from the version created using the 2001 Census to that created using the 2011 Census.

4.5 Discussion

This chapter aimed to describe the trends and inequalities in rates of amenable mortality in Scotland, over time, and across the socioeconomic gradient.

4.5.1 Principal findings

Rates of amenable mortality have been found to be declining in Scotland between 1980 and 2013, for both men and women, and across the deprivation gradient.

The percentage of total mortality that amenable conditions comprised has decreased over time, from 15% in the first seven years of analysis (1980 - 1986), to 10% in the last seven years (2007-2013). The proportions of amenable deaths occurring at the younger ages (under 30 years) has decreased for both sexes, however there has been a resulting increase in proportions of deaths occurring between ages 30 and 60.

A key finding of this chapter is that it has taken almost 30 years for men and women living in the most deprived areas of Scotland to achieve the rates of amenable mortality the respective sexes in the least deprived areas of Scotland had experienced in the early 1980s (see Figure 4.5), indicating significant time lags in either the improvements of the health of people in the most deprived areas of Scotland, or health system performances in these areas.

Three diagnosis subgroups were used to group the deaths according to the type of intervention delivered by the health care system. The numbers and rates of deaths avoidable through primary prevention were small, and therefore highly variable over the analysis period. There was a fairly even split of male deaths between the two remaining groups: amenable through early detection and intervention, and improved treatment and medical care, whereas there was a larger percentage of female deaths categorised to the former category. This disparity is due to the inclusion of breast cancers as a disease which can be effectively treated if identified early. Age standardised mortality rates within the early detection and intervention group decreased at a faster rate than those amenable to improved treatment and medical care, and there were smaller between-sex differences in the rates of death.

The cause specific investigations within mortality rates revealed encouraging declines in cerebrovascular disease, the current largest contributor towards the overall number of amenable deaths, as well as COPD in men. The Scottish Intercollegiate Guidelines Network (SIGN) released a series of guidelines for the management of strokes in 1997, which have since been updated. The most recent guidelines were released in 2008 (SIGN 2008), and outline a series of recommendations on the management, diagnosis and treatments of strokes. The quality of stroke care delivered in all hospitals is monitored monthly by the Scottish Stroke Care Audit, which was established in 2002 (NHS National Services Scotland 2017). SIGN has published and updated a range of guidelines for many other conditions considered amenable to medical care, including breast (SIGN 2013) and colorectal (SIGN 2015*a*) cancers, asthma (SIGN 2016), epilepsy (SIGN 2015*b*) and diabetes (SIGN 2010). Whilst male mortality rates for COPD decreased, the increases in rates for women are of concern. Possible reasons for this increase have included the delayed rise in the prevalence of smoking in women, or a greater susceptibility towards the risk factors (Laviolette et al. 2007).

The impact of the change in ICD version from 9 to 10, and associated changes in coding guidelines, in 2000 was seen strongly in mortality rates due to pneumonia. The General Registrar for Scotland conducted a bridge coding exercise to investigate the impact of moving from ICD 9 to ICD 10, whereby all deaths, at all ages, which occurred in Scotland in 1999 were coded using both versions (General Register Office for Scotland 2001). The differences between the two results can be used to estimate the effects of coding changes. The ratios between the two were calculated per chapter within the ICD codes, for example, a single ratio is calculated for all neoplasms. Of the 17 chapters investigated in Scotland (out of a possible 19 chapters), 9 chapters fell within $\pm$ 0.05 of the null value of the comparability ratio[5]. The greatest differences between the two versions of codes was found in the Diseases of the Eye and Adnexa chapter (Chapter VII), which contains no amenable conditions (ratio = 1.43). The assignment of pneumonia as the final cause of death was affected by the additional explanatory notes included into Rule 3 of the ICD code selection process. The majority of the deaths which would have been assigned as resultant of pneumonia under ICD 9 were assigned to strokes, neurological diseases and a range of chronic conditions under ICD 10 (General Register Office for Scotland 2001). The whole chapter of respiratory diseases (Chapter X) has a comparability ratio of 0.78 (which includes both influenza and pneumonia), and pneumonia alone has a ratio of 0.54. The change in coding resulted in a 38% reduction in the numbers of deaths coded as due to pneumonia in England and Wales (Brock et al. 2006), smaller than the sex specific reductions found in Scotland through this analysis (47% and 51% for men and women respectively). In Finland, rates of death coded due to pneumonia decreased from 24 per 100,000 in 2003-04 to 9 per 100,000 in 2005-6, after implementing the rule change (Manderbacka et al. 2012). Septicaemia, and Nephritis and Nephrosis were identified as having discontinuities due to the ICD change in a bridge-coding preliminary analysis conducted in the United States (Anderson et al. 2001), however, no such effects are obvious between 1999 and 2000 within rates of death due to Septicaemia (Figure B.8), nor Nephritis and Nephrosis (not shown) in Scotland, potentially due to their

[5]Note: a ratio = 1 does not necessarily imply perfect agreement between the two versions of the ICD, rather, that the gains and losses may have offset each other (General Register Office for Scotland 2001)

relatively small numbers of deaths (less than 100 per sex and year).

Whilst absolute inequalities in rates of amenable mortality have an overall declining trend over time, relative inequalities have been increasing, indicating that mortality rates in the least deprived areas of Scotland have been declining at a faster rate than those living in the most deprived areas. Theoretically, the Scottish health care system is freely available, and there should be no barriers to its equitable use by the population, according to need (McCartney et al. 2013). Therefore, this disparity in the rate of decline is concerning, as it suggests that the health care provided in the least deprived areas may be more effective at preventing these deaths, than in the most deprived areas. Research in primary care has found that there are higher levels of unmet care in more deprived areas, where patients are more likely to have multiple medical needs (Blane et al. 2015), and the ability of any health improvement initiatives designed to reduce inequalities are affected by differential uptake in services across the socioeconomic gradient (Watt 2013). Given that funding for primary care across Scotland is distributed according to population size, rather than the deprivation level of the practices' catchment areas, general practices based in deprived areas are under-staffed and under-resourced to provide the necessary care to patients presenting with more complex health needs (Mercer et al. 2012). Therefore, the higher amenable mortality rates in the most deprived areas may be reflective of the greater strain experienced by primary care services in these areas, rather than a lower efficacy.

Within the diagnosis groups, relative inequalities have seen greater increases within the improved treatment and medical care group, than the early detection and intervention group for both men and women. This group comprises both conditions which can be managed within Primary Care settings, such as diabetes and asthma, as well as those which require specialist surgical interventions. Further investigation into this group would provide valuable insight into the areas with most potential for reducing inequalities, although some of the graphs included in Appendix B point to large inequalities in diabetes, peptic ulcers and septicaemia.

The fractional polynomial transformations provide a method of visually examining changes in age-specific amenable mortality rates over and above basic linear trend analysis that is the case using untransformed continuous age. The age-specific amenable mortality rates for women in the most deprived area in 2013 are approximately equal to those for women in the least deprived area in 1980, whereas male age-specific amenable mortality rates for 2013 in the most deprived deciles continue to lag behind the rates predicted for least deprived deciles in 1980 in the oldest ages.

The multilevel modelling revealed that there was greater unexplained variation at the area level, for men and women, than at the year level, and that there was a 17%, and 11% increased risk of amenable death associated with areas with higher rates of amenable death, compared to areas with lower rates, within the same deprivation decile, for men and women respectively.

Simultaneous multilevel modelling of deaths amenable through early detection and intervention, and improved treatment and medical care was performed. Increased levels of deprivation were associated with higher risks of deaths amenable to ITMC than to EDI. There is a strong, positive correlation between SMRs of ITMC and EDI at the area level for men, but a lower, more moderate correlation within female SMRs. There is almost no correlation at the year level for women, but a weak to moderate correlation within male SMRs. Deaths avoidable through primary prevention were not included in the multiple response modelling due to small numbers of deaths.

4.5.2 Strengths and limitations

The greatest strength of this analysis over previous analyses performed within Scotland, and over many other European countries, is the considerable amount of data available due to the long analysis period. Rates of amenable mortality have been analysed over 34 years.

Subgroups of amenable conditions were also examined, which are not commonly investigated in previous research. These allow for differences within the overall rates of amenable mortality to be measured according to the type of intervention and therefore points to more specific areas of the health system that could require further attention. These analyses have revealed differences in the rates of decline, and differences in inequalities in rates of death. The subgroups provide a more direct indicator of potentially problematic areas within the health care system, than the overall indicator can provide. The selected cause specific investigations found differing trends for men and women in COPD, as well as highlighted the impact of changes to coding guidelines with respect to pneumonia deaths.

The use of multilevel modelling is a further strength. Only three studies have made use of multilevel modelling in the analysis of rates of amenable mortality (Treurniet et al. 2004, French & Jones 2006, Feng et al. 2016), in order to model differences in variation between individuals and regions (Leyland & Groenewegen 2003). The multiple response models analysed in these analyses revealed that the area and year level variations in mortality amenable to primary prevention in Scotland does not exceed what would be considered random variation. There was moderate to strong levels of correlation between SMRs of early detection and intervention and improved treatment and medical care at the area level for women and men respectively, with less strong correlation at the year level for men, and almost none for women.

Whilst the decline in rates of amenable mortality is encouraging, the declines may not be solely due to improvements in the access to, and effectiveness of health care. The literature is more cautious at reporting the decreases in rates of amenable mortality as improvements in health care alone, since declines may be reflecting declines in the incidence rates of amenable conditions within the health care system, an improvement in time to presentation at a health care system, or a decline in case severity. In Scotland, a variety of guidelines for the identification, treatment and management of several major contributors towards overall amenable mortality have been introduced since 1980. The improved mortality rates within the early detection and intervention group have benefited from new cancer screening programmes, increased age ranges of invited participants, and improvements within the treatments available post-diagnosis. The likelihood of each of these explanations cannot be explored through the data used in this chapter.

4.5.3 Relations to other studies

Much like Grant et al. (2006) and Desai et al. (2011), the results presented in this chapter have indicated an encouraging decline in rates of amenable mortality in Scotland over time, with this analysis extending the period of analysis to include more recent data.

Grant et al. also explored area level deprivation gradients within rates of amenable mortality, using the SIMD. These results make use of an alternate measure, the Carstairs score, which, whilst calculated at less regular intervals, is available for use in the earlier years of analysis, allowing for changes in gradients to be explored over a longer period, than possible using SIMD.

As highlighted within the strengths, only three previous studies of amenable mortality have made use of multilevel analyses. French & Jones (2006) explored differences between two lists of avoidable conditions across England and Wales, and Scotland, using electoral wards or postcode sectors at level 2, and districts or local authorities at level 3. As the focus of analysis was on the effects of deprivation, measured at the postcode sector level, rather than geographical location, local authorities were not included as a fourth level within these analyses. Treurniet et al. (2004) used a 2 level model, with random intercepts and slopes to explore deviations in trends of age-standardised avoidable mortality rates over years (level 1) and between 19 countries (level 2) from the overall European trend. Median Rate Ratios have previously been calculated in China, examining the geographical variation in rates of amenable, non-amenable, and individual cause mortality (Feng et al. 2016). The multilevel models used were adjusted for sex, and had counts of death by age group, sex and year at level 1, and an area at level 2. The area level MRR was estimated to be 1.49; substantially larger than the sex-specific MRRs calculated in this analysis (men: 1.17, women: 1.11). The MRR calculated for individual diseases were larger still (IHD: 1.99, oesophageal cancers: 2.76).

The three subcategories of amenable mortality used in this thesis: primary prevention, early detection and intervention, and improved treatment and medical care, were previously used in a study of Finnish amenable mortality (McCallum et al. 2013). The proportions of deaths within each subgroup differ by sex between the two countries. The proportions of Finnish men within each group are similar to the proportions seen in Scottish women, with approximately two-thirds of the deaths occurring in the early detection and treatment subgroup. The proportions of Finnish deaths in the improved treatment and medical care group for women (1992-93: 18.6%, 2002-03: 17%) are approximately half of the proportion of deaths in Scottish women. The Scottish proportions are based on a wider range of causes of death within each category, however the main causes of death included are similar. Rate ratios were calculated in Finland in order to quantify the socioeconomic gradients in the subgroups of death over the analysis period. Rate ratios were not calculated for the Primary Prevention subgroup, owing to the small numbers of deaths. Within the early detection and intervention subgroup, rates in the most deprived income quintile increased from 2 times the least deprived at the start of the analysis period, to 2.66 times. For women, the rate ratios increased from 1.8 to 2.19 times. The rate ratios within the improved treatment and medical care subgroup had larger increases: men increased from 5.47 to 9.43, and women increased from 5.44 to 11.41 between 1992-95 and 2000-03. Whilst not directly equivalent, the relative indices of inequality calculated in Scotland found similar patterns of larger increases within the ITMC subgroup, than in the EDI group.

The literature review described in chapter 2 found very few studies which included results on amenable mortality on Scotland. In August 2017, National Records of Scotland published information on the numbers of deaths which could be considered to have been avoidable in 2014 - 2016 (National Records of Scotland 2017). These analyses made use of the updated ONS definition of avoidable mortality, described in the literature review and in Olatunde et al. (2016), and therefore the deaths are divided into those which are preventable and amenable. The years of data analysed in this thesis precede the years included in the NRS published tables, therefore results cannot be directly be compared. For each year in 2014 - 2016, 14% of the total deaths at any age were identified as being amenable (as well as preventable, but not preventable only). Compared to Table 4.3, this is a slightly larger percentage than may be expected (given that 10% of the deaths occurring in 2013 were regarded as amenable to health care intervention using Appendix A). This is because the ONS definition, and therefore the NRS analyses, consider deaths due to IHD and HIV/AIDS to be both amenable to treatment and preventable, and are therefore included within the results for the ‘amenable’ category. The NRS tables include breakdowns by age group, NHS Health Board, council area, and ICD 10 disease chapters (e.g. Chapter II: Neoplasms and Chapter IX: Circulatory System diseases).

4.5.4 Research implications

Firstly, the three groups of amenable conditions explored within this chapter have not been widely used within the amenable mortality literature. These groupings were used by Lumme et al. (2012) and McCallum et al. (2013) to explore differences by type of intervention. Scottish mortality rates, and inequalities within them, were found to vary between the three subsets. The positive moderate to strong area-level correlations found in the multiple response models (section 4.4.5), between standardised mortality ratios of deaths amenable to early detection and intervention, and improved treatment and medical care (men $\hat{\rho}$ = 0.89, women $\hat{\rho}$ = 0.60) indicate that areas with high levels of deaths in one disease group, are expected to have high levels of the other, after accounting for the area's deprivation. These findings contribute towards making the use of an amenable mortality indicator as a warning system more functional, in that problematic types of intervention can be identified.

4.5.5 Next steps

As discussed in the Literature Review (chapter 2), and in the principal findings and limitations sections of this chapter, a consistently identified limitation of using amenable mortality to measure the effectiveness, quality and equity of a health care system is the possibility that declining mortality rates are reflecting the declining incidence of the condition within the population, rather than improvements in the delivery of health care. In terms of inequalities, the slower rate of decline in the most deprived areas of Scotland, compared to the least deprived areas may be due to differing patterns of disease incidence within the population.

To explore these possibilities in the Scottish population, the next chapter makes use of linked hospital discharge records, cancer registrations, as well as birth and death records as a proxy measure of the incidence rates of conditions amenable to medical care in Scotland.

Chapter 5

Incidence of amenable conditions in Scotland

5.1 Introduction

The literature review discussed a frequently identified limitation of the concept of amenable mortality - that declines in mortality rates may be reflecting declines in the disease incidence in the general population, rather than reflecting the improved success of screening and immunisation programmes, earlier detections and improved treatments of amenable conditions (Whyte & Ajetunmobi 2012).

This possibility has been explored twice over the years. Bauer & Charlton (1986) were the first to investigate the relationship between morbidity and mortality for a selection of amenable conditions in a study of Area Health Authorities (AHA) in England and Wales between 1974 and 1978. This study of the morbidity of amenable conditions was preceded by the first empirical application of the concept of amenable mortality in England and Wales by Charlton et al. (1983). Morbidity of amenable conditions was estimated using data collected from disease registers and a 10% sample of hospital discharge certificates when disease specific registers were not available. Factors affecting the socioeconomic position of the population, such as the proportion of employed people who are unskilled, and the proportion of households without cars within an area, were also collected.

The amenable conditions which produced the highest correlations between mortality and morbidity rates were hypertension, cervical cancer, tuberculosis, chronic rheumatic heart disease and appendicitis. These relationships persisted once social factors were included into a linear model. The remaining variation in mortality rates not explained by the morbidity rates has been suggested as due to variations in: data collection and quality of recording, medical resources, diagnostic practices, clinical severity of disease at presentation, patient compliance, or in delays in seeking health care (Bauer & Charlton 1986).

The second study, performed in the Netherlands between 1984 and 1994, improved on the first by making use of linked health records (Treurniet et al. 1999). The linkage of records allows for individuals with multiple admissions to hospital with the same diagnosis to be identified, and can therefore remove the possibility of overestimating the number of new cases of amenable conditions in a population. Discharge records for an individual were considered to be ‘incident’ if they were the first discharge for that condition that year, or the four years previously. The decision behind this 5 year limit is not described in the paper. Significant area level variations[1] in mortality rates were found for 7 of the 16 causes of death, and mortality and incidence rates were positively associated for all conditions. The study found that the area level variation remained once adjusted for disease incidence and social factors.

Literature published since Treurniet et al. (1999) has recommended the use of hospital discharge data to supplement amenable mortality research (Castelli & Nizalova 2011), as well as the use of cause specific investigations (Whyte & Ajetunmobi 2012) to understand trends. This analysis has not previously been explored in a Scottish context.

5.2 Objectives

This chapter will meet objective 3 of this thesis (see section 1.1) by:

1. Describing incidence rates by sex and deprivation decile in the Scottish population
2. Exploring trends in incidence rates by diagnosis groups of conditions, and selected single conditions
3. Measuring the absolute and relative inequalities in incident rates over time
4. Partitioning the variation in incidence rates to variation at year and area level
5. Comparing the above findings to corresponding mortality findings in chapter 4.

[1] 12 regions with median population sizes ranging between 985,739 in 1984 and 1,050,341 in 1994

5.3 Methods

5.3.1 Data

All hospital discharge records, cancer registrations, and Scottish Birth and Death records with an amenable condition listed as either the main or a subsidiary diagnosis for the period 1981-2013 for the whole Scottish population formed the incidence data. These were obtained from the electronic Data Research and Innovation Service (eDRIS, project code XRB15065. Approved 25/06/2015). Records contained the age, sex, diagnosis ICD codes, Carstairs deprivation score of area of residence, and month and year of registration/ discharge/ death.

As a proportion of these records pertained to live patients, and a number of amenable conditions are relatively rare, the potential for identifying individuals was high. To reduce this possibility the datasets were stored and analysed within a Safe Haven environment. Any geographical identifiers attached to the records, such as postcode sectors, councils and local government districts were anonymised. These were required in order to allow for the multi-level structures in the data to be modelled. All output from the Safe Haven were checked for disclosive results, as described in section 3.11.

Based on previous literature, the analysis was limited to 'first discharge', that is, those patients who did not have a previous hospital admittance with the same diagnosis earlier that year, or within the previous 4 years (Treurniet et al. 1999). If a person had no previous discharge record relating to the final cause of death within the 5 year period, the death record was used as the 'first discharge'. Figure 5.1 explains the identification process for records. Each of Records 1, 2 and 3 relate to the same person, diagnosed with the same amenable condition in each case. The first record (Record 1) relating to this condition in the database is regarded as a 'first discharge'. Record 2 is not regarded as one, as Record 1 occurred within the four years previous to it. There were no records pertaining to the condition between 1998 and 2001, therefore Record 3 in 2002 is regarded as another 'first discharge'.

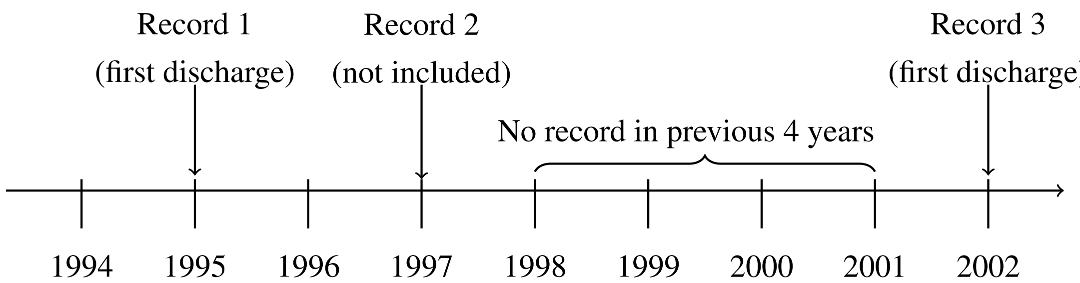


Figure 5.1: Example of the identification of 'first discharges'

The four datasets are described below, including information on when records for each are generated, and any significant changes made over time.

SMR01 - General / Acute Inpatient and Day Case dataset

This dataset contains all occurrences of patients being discharged from a hospital, once admitted and treated by a non-obstetric or non-psychiatric speciality (Administrative Data Liaison Service n.d.*d*). The dataset available for research purposes contains data from 1981 onwards. In April 1996, diagnoses were updated from being coded in ICD version 9 to version 10.

The SMR01 dataset contained 10,794,818 records, pertaining to 3,139,741 unique patient identifiers. Once cleaned, there were 6,411,776 (59.4%) records with an amenable condition listed as the main diagnosis.

SMR06 - Scottish Cancer Registry

The Scottish Cancer Registry contains information on diagnosed malignant neoplasms as well as some benign tumours (Administrative Data Liaison Service n.d.*e*). Cancer diagnosis codes were updated from ICD 9 to ICD 10 at the beginning of January 1997.

The SMR06 dataset contained 347,534 records, pertaining to 321,026 unique patient identifiers. Once cleaned, there were 347,284 (99.9%) records with an amenable cancer listed as the primary cancer.

SMR11 - Neonatal Inpatient Dataset and the Scottish Birth Records

The Neonatal Inpatient dataset has been revised four times over the analysis period, resulting in slightly different data available at each (Administrative Data Liaison Service n.d.*f*,n).

Between 1975 and 1991 each baby born in Scotland was given a universal birth record, on which discharges from specialist baby care units was recorded, if necessary. Babies were admitted to specialist care units if they required medical care other than resuscitation immediately after birth, or had a congenital anomaly. The main diagnosis code listed on all SMR11 birth records supplied during this time classified the infants according to the type of birth (ICD 9 V30 - V39 eg. single/twin, live born/stillborn). Therefore, the secondary diagnosis listed on the records was used to identify those with an amenable condition.

From 1992, a separate discharge record was generated upon discharge from a baby care unit (SMR11EP), along with the universal record all babies had (SMR11UV). In 1996, the universal record system was decommissioned, and only babies discharged from specialist care units were recorded in the neonatal dataset (SMR11). In 2002, the universal record was recommissioned, and all births in Scotland were recorded in the renamed Scottish Birth Record. This was a phased process and therefore SMR11 records continued to be generated until 2003.

The four versions were combined, and checked for duplicate patient IDs. The combined dataset contained 483,858 records. Once cleaned, there were 445,361 (92.0%) records with an amenable condition listed as the main diagnosis (or secondary if born between 1981 and 1991).

Coding changes from ICD 9 to ICD 10 were made at the same time as the SMR01 records (April 1996).

Scottish Death Records

Whilst the Scottish death records were already available for the analysis conducted in chapter 4, these were requested along with the morbidity datasets to allow for linkage, and anonymisation of the geographical identifiers.

Death records were only classed as incident records if there had been no previously linked record pertaining to the cause of death within the year of death, or within the previous 4 years.

The death record dataset contained 339 patient IDs with more than one death record, for deaths occurring at different points in time, for different causes, or with differing years of birth. The probabilistic linkage methods employed to link records was cited as the reason for these by the eDRIS research co-ordinator when questioned. As these pertained to approximately 0.1% of the total records, only the first death record was retained; all subsequent death records were removed from all datasets, and further analyses.

Coding of death records was performed using ICD 9 until the end of 1999, and from 2000 onwards, version 10 has been used.

The Scottish Death Record dataset contained 385,448 records, pertaining to 385,105 unique patient identifiers. Once cleaned, there were 210,212 (54.5%) records with an amenable condition listed as the primary cause of death.

5.3.2 Further data cleaning

There were several Patient IDs which had different sexes attached to them, at different points in time. eDRIS stated that these were due to sex being incorrectly recorded at time of inputting. In these cases, it was decided that the gender with the majority of associated records should be used as the main sex variable. In cases where there was an equal record split between the sexes (n=1,570 SMR01 records) the sex recorded on the most recent record was used, except in the case of sex-specific diagnoses (e.g. cancers of the testis or cervix, or maternal causes). There were 58 SMR11/Scottish Birth Records occurring between 1985 and 2013 with a null code listed as the infant's sex, and no further records associated with their Patient IDs. As no other records were available to extract the correct sex from, these records were removed from further analysis.

Maternal causes of death (ICD10 O01 to O99) were listed as the main cause of death for 1,288 infants (less than 1 year). The codes pertained to failed abortions, modes of delivery and the puerperium (period of time approximately 6 weeks post birth). It was likely that these should have been recorded as secondary 'related' codes, and not the main code. These records were removed from further analysis.

Incident cases were then identified from the remaining records. Any incident record which did not have a deprivation decile attached to it (n=58,790, 1.5%) was excluded from further analysis. In the previous chapter, deaths were assigned to a new deprivation decile if their postcode sector of residence did not have a deprivation decile attached to it (see subsection 4.3.2). As the incidence data contains identifiable information pertaining to alive persons, the postcode sectors, councils and local government districts of residence attached to the records were anonymised by eDRIS prior to transfer to the Safe Haven. This meant that nearby postcode sectors could not be identified for the missing records, and therefore no plausible deprivation deciles could be attached to the records.

5.3.3 Statistical Analyses

Age standardised incidence rates

Age standardised incidence rates were calculated using the methods described in chapter 3, and the mid-year population sizes as the denominator. These population sizes, broken down by 5-year age and sex groups within postcode sectors, were supplied to eDRIS for anonymisation, allowing for population sizes to be matched to the counts of incident cases within the Safe Haven.

Due to the lag time required to identify incident cases (4 years), incidence results will be presented from 1985 onwards, using a look back period of 1981 to 1984 to identify 'first discharges' occurring in 1985.

Yearly age standardised incidence rates were calculated by sex, deprivation decile and diagnosis group. Age-specific incidence rates were also calculated.

Disease specific incidence rates were calculated for 16 selected individual conditions. These were identified through either being amongst the largest counts of cases, having relatively large increases in counts, or through being a condition of interest. Age standardised rates by sex and deprivation decile were calculated in each case.

Incidence of inequality

Absolute and relative inequalities in rates of incidence in the Scottish population were calculated using the SII and RII as described in section 3.7. These will be presented from 1996 onwards, therefore restricting morbidity diagnoses to be coded using version 10 of the International Classification of Diseases (ICD 10). This ensures consistency of recording when selecting and comparing inequalities in rates of amenable conditions.

Fractional Polynomials

Fractional polynomials of the continuous variables of age, deprivation decile and year were calculated as described in section 3.8. The log of the counts of incident cases replaced the log of the count of deaths in Equation 3.7. As with the inequality analyses, the fractional polynomials will be based on data for 1996 onwards.

Multilevel modelling

Multilevel modelling was performed as described in section 3.9, using the fractional polynomial transformations of age, deprivation decile and year.

5.3.4 Sensitivity analyses

The period of time for a discharge to be considered a 'first discharge' was defined to be 5 years[2], in line with Treurniet et al. (1999). Hypertension, asthma and stroke incidence have also individually been measured using a 5 year look-back period (Tu et al. 2008, Gershon et al. 2010, Lewsey et al. 2009).

However, the use of short periods of time to define incidence may falsely elevate rates, as some prevalent cases may erroneously be considered to be incident (Tu et al. 2008). Therefore, the effects of using a longer period of time to define incident cases is of interest.

As only one previous amenable mortality study has used a look back period to identify incident cases (Treurniet et al. 1999), analyses of individual amenable conditions were considered. Within Scotland, in addition to the 5-year period, a 10-year period (Bhopal et al. 2011) has been used to identify incident cases of cerebrovascular disease. Incidence of IHD has been explored in Scotland, using a 7-year period (Davies et al. 2009), whilst a 15-year period was used in Australia (Katzenellenbogen et al. 2010).

It was decided that the 10 and 15 year periods would potentially miss incident cases, therefore this sensitivity analysis will explore the effects of using 7 years to define 'first discharges'.

5.4 Results

5.4.1 Data cleaning and descriptive statistics

Between 1980 and 2013, 7,414,633 hospitalisation, cancer registration, birth and death records were identified as having an amenable condition listed as the main diagnosis, or cause of death. These records were processed, cleaned, and 3,811,304 (51.4%) were identified as being 'first discharges' or incident cases, based on the criteria discussed in subsection 5.3.1. These occurred between 1985 and 2013.

Once the records without sex recorded or without a deprivation decile attached, there were 3,752,483 incident records available for analysis. Table 5.1 describes the breakdown of numbers and percentages of cases by year, and the three diagnosis groups, over the 29 year analysis period.

[2] current year and the four previous years

Table 5.1: Numbers (%) of incident cases by year and diagnosis group, 1985 - 2013

Years	No. Years	PP	EDI	ITMC	Total
1985 - 1986	2	10,328 (5.1)	45,605 (22.3)	148,432 (72.6)	204,365
1987 - 1996	10	60,648 (4.5)	317,940 (23.5)	972,092 (72.0)	1,350,680
1997 - 2006	10	56,957 (4.6)	338,341 (26.8)	868,987 (68.7)	1,264,303
2007 - 2013	7	46,579 (5.0)	232,653 (24.9)	653,903 (70.1)	933,135
Total:	29	174,530 (4.7)	934,539 (24.9)	2,643,414 (70.4)	3,752,483

Compared with breakdown of amenable deaths by the diagnosis groups (see Table 4.5), the greatest proportion of incident conditions are classified as amenable through improved treatment and medical care group (ITMC), rather than early detection and intervention (EDI) which contained the greatest proportions of the deaths (56.6% of overall amenable deaths). The proportion of cases preventable through primary prevention (PP) is also much greater than the proportion of deaths which could have been avoided (0.3%).

In contrast to the deaths, the proportions of incident cases within each group remains fairly stable over the years, whereas we saw a decreasing proportion of EDI deaths, and an increasing proportion of ITMC deaths.

In all years, a greater percentage of the incident cases occurred in women (overall 54.1% cases were female), a greater percentage than seen in the amenable deaths. The breakdown of sexes within PP remains fairly stable over the years, with approximately 56.3% of cases being male. The breakdown in the EDI and ITMC groups have changed over time. There is a larger proportion of female cases in each group, with the proportion slowly declining within the EDI group (61.7% in 2013 to 56.7% in 2013), and therefore, reciprocally rising within the ITMC group (51.4% in 1985 to 53.5% in 2013).

Compared to the breakdown in deaths, the ITMC group had a greater percentage of male deaths, than female deaths, and the PP group had no clear gender pattern, owing to the small number of deaths. Similar patterns in the EDI group are seen in both the incident cases and deaths.

5.4.2 Age standardised incident hospitalisation rates

Figure 5.2 describes the age-standardised incident hospitalisation rates of overall amenable conditions in Scotland, between 1985 and 2013.

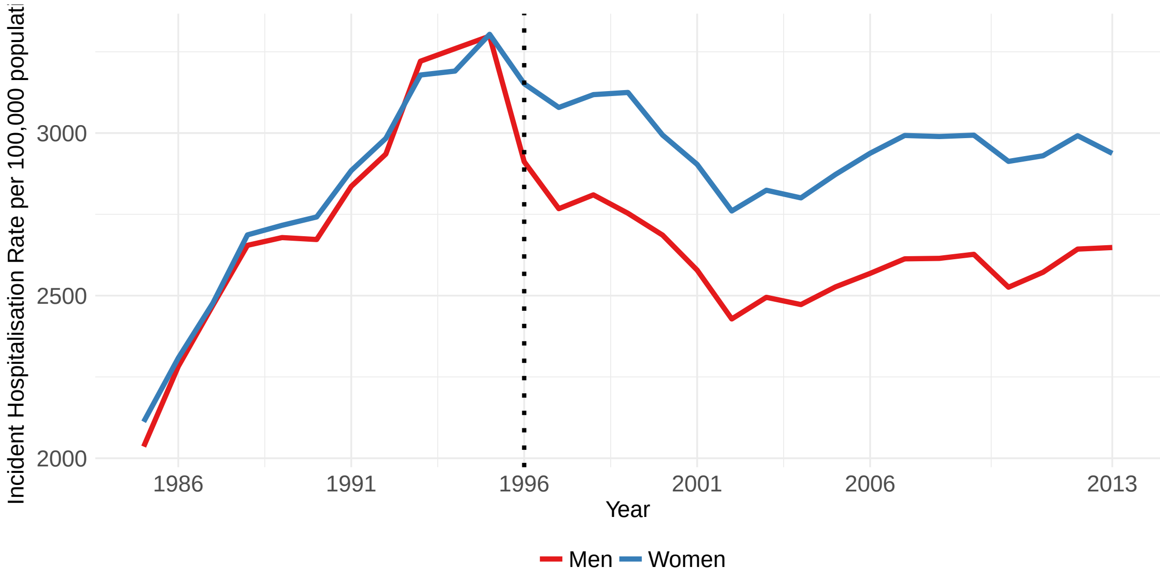


Figure 5.2: Age-standardised incident hospitalisation rates: men & women, 1985 - 2013. The dashed line indicates the introduction of ICD 10 for coding the main reason for hospitalisation

There has been a large increase in rates of incident hospitalisations, occurring in the first 12 years of analysis, until approximately 1996. From there, there is a decrease in trend for both men and women, although rates for women did not experience the same magnitude of decline as men. The ICD version changed from version 9 to version 10, along with updated classification rules, in April of 1996 for the SMR01 and SMR11 records, and SMR06 changed at the end of 1996. This is the most likely explanation for the change in trends occurring at this point, however, it may also be due to increased incidence of the conditions, an improvement in the ability to diagnose amenable conditions, increased hospitalisations, or an improvement in morbidity record generation and storage. Further explanation may be gained through the breakdown of the overall amenable conditions into the three subgroups, as well as the study of selected individual conditions.

Comparing to the age-standardised amenable mortality rates (see Figure 4.3), Figure 5.2 shows that incident hospitalisation rates in women are larger than they are for men, and have been over the whole analysis period. This is due to the inclusion of female-specific amenable conditions, such as breast, cervical and uterine cancers, as well as maternal conditions.

The incident hospitalisation rates by diagnosis groups in Figure 5.3 can be used to investigate whether changes were driven by a particular group of conditions.

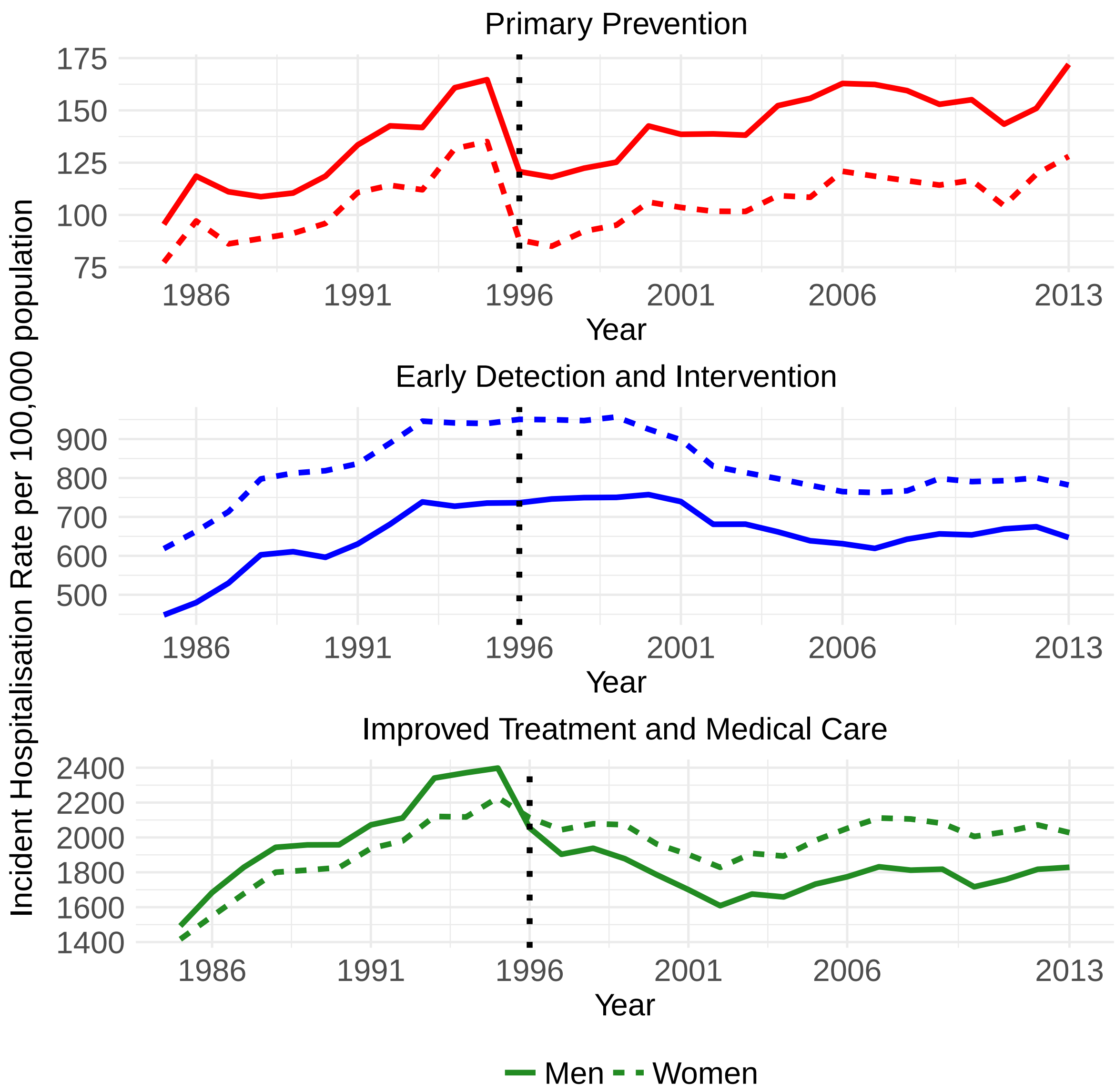


Figure 5.3: Age-standardised incident hospitalisation rates by diagnosis group: men & women, 1985 - 2013. The dashed lines indicates the introduction of ICD 10 for coding the main reason for hospitalisation
Note: graphs are on different scales.

Incident hospitalisation rates of conditions amenable to primary prevention have increased until 1995, followed by a large decline in both sexes at the change in ICD versions. Cases coded using ICD 10 have since continued to rise, with male rates at 2013 exceeding the previous peak in incident hospitalisation rates in 1995. Rates for men are consistently larger than those for women.

The rates of incident conditions in the EDI group increase as with PP group, however, this is not followed by a large, immediate decline in 1996, rather there is a period of stability, followed by a shallow decline over the remainder of the analysis period. Rates are higher for women than they are for men, owing to the female specific cancers included.

The increase in conditions amenable through ITMC is steepest until 1993, largely coinciding with changes to the SMR11 (Neonatal inpatients) records. Deaths from perinatal conditions and congenital cardiovascular anomalies, that the SMR11 records would detail, are considered to be amenable through ITMC. The change from ICD 9 to ICD 10 is more apparent in the male rates, whereas there is almost no change in female rates, except for them now being consistently higher than rates for men. Exploration of selected individual conditions may identify the source of this difference. Mortality rates were larger for men than they were for women over the same period (see Figure 4.4).

Figure 5.4 describes the socioeconomic gradients in incident hospitalisation rates for men and women.

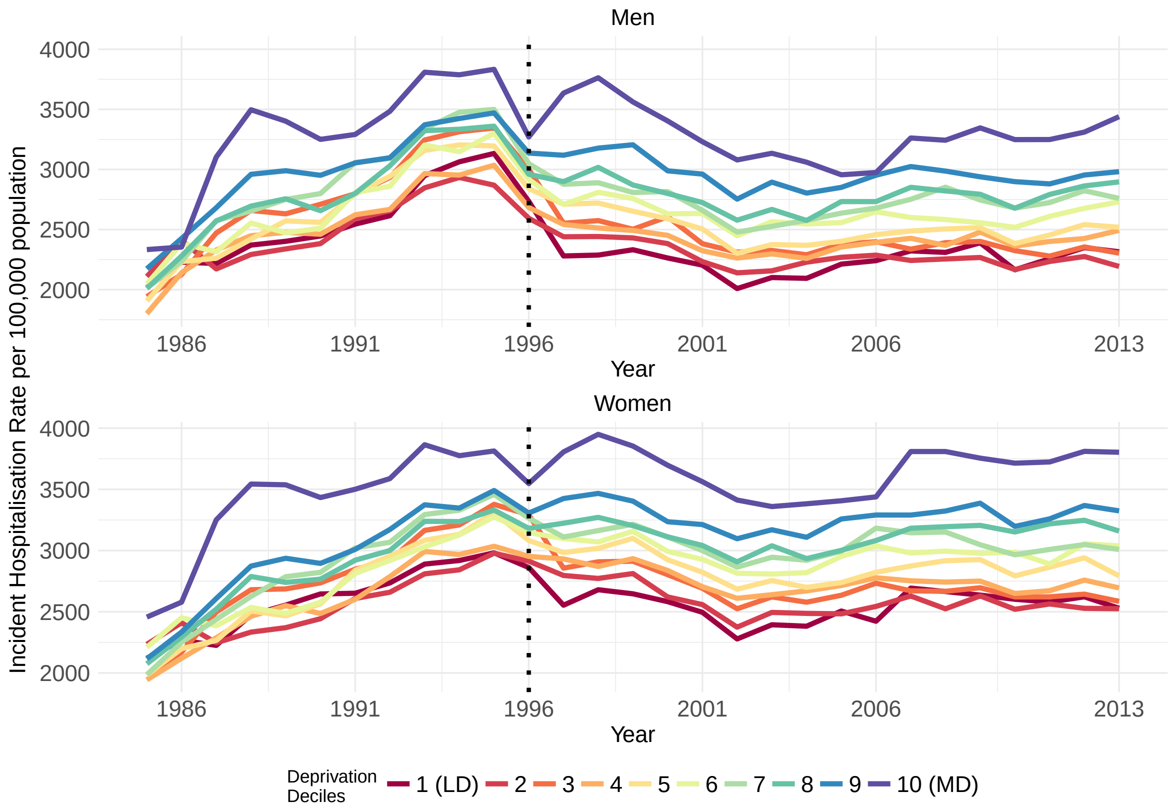


Figure 5.4: Age-standardised incident hospitalisation rates by deprivation decile: men & women, 1985 - 2013. The dashed lines indicates the introduction of ICD 10 for coding the main reason for hospitalisation

There is greater separation between the deprivation deciles in the later years of analysis, than in the first years. The decrease in incident hospitalisation rates in 1996 is experienced by all deprivation deciles for men, with the greatest declines occurring in the lesser deprived deciles. After 1996, the most deprived decile (decile 10) returned to much the same rate of incident hospitalisations than what was experienced before 1996.

The socioeconomic gradients can be further explored within the diagnosis groups, using Figures 5.5, 5.6 and 5.7.

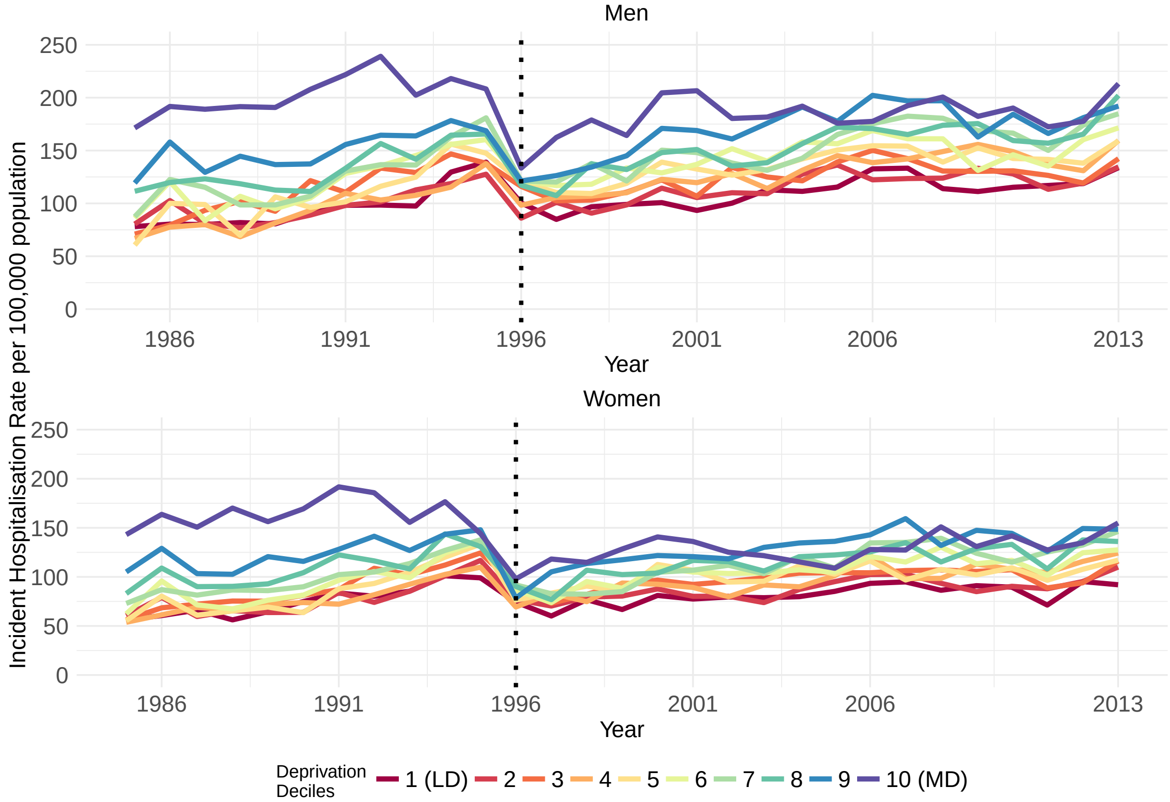


Figure 5.5: Age-standardised incident hospitalisation rates amenable through primary prevention by deprivation decile: men & women, 1985 - 2013. The dashed lines indicate the introduction of ICD 10 for coding the main reason for hospitalisation

Figure 5.5 describes the gradient in the incident hospitalisations of conditions from which death can be avoided through immunisations and improved hygiene conditions. The declines experienced in 1996 were experienced across the deprivation gradient in men and women. Incident hospitalisation rates appear to experience greater declines in the more deprived areas, than in the lesser deprived areas.

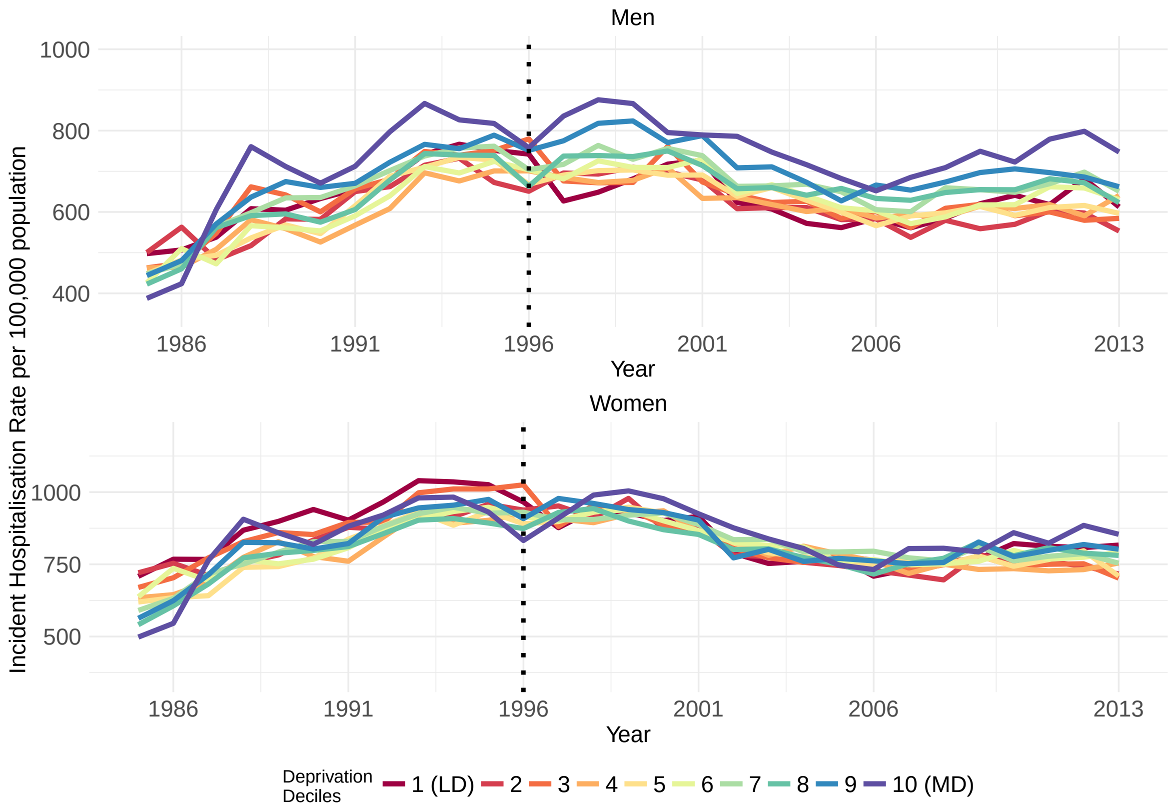


Figure 5.6: Age-standardised incident hospitalisation rates amenable through early detection and intervention by deprivation decile: men & women, 1985 - 2013. The dashed lines indicate the introduction of ICD 10 for coding the main reason for hospitalisation

Figure 5.6 describes the socioeconomic gradient in the rate of incident hospitalisations of conditions amenable to early detection and intervention. There is no large separation in incident hospitalisation rates for both sexes. Prior to 1996, women living in the least deprived decile (decile 1) experienced higher rates of incident cases, whilst for men, the highest incident hospitalisation rates were found in the most deprived areas (decile 10). After 1996, there appears to be very little gradient in female rates, whilst the gradient persists for men.

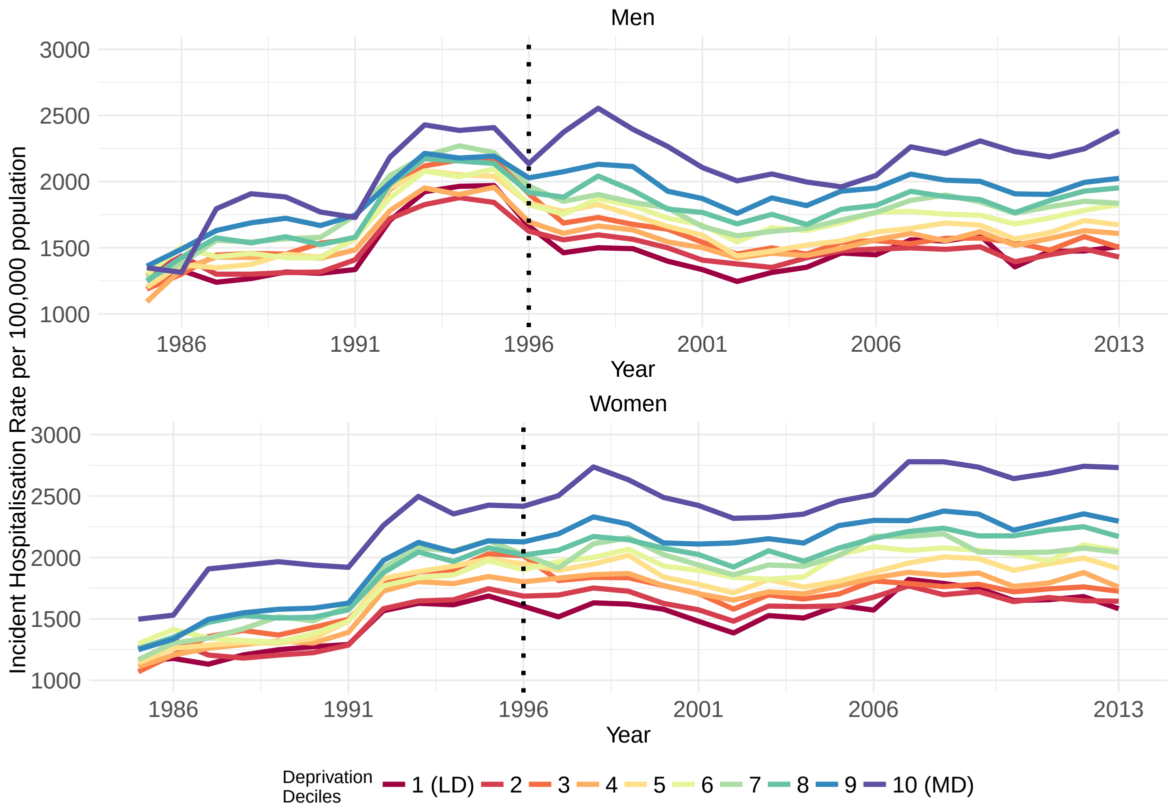


Figure 5.7: Age-standardised incident hospitalisation rates amenable through improved treatment and medical care by deprivation decile: men & women, 1985 - 2013. The dashed lines indicate the introduction of ICD 10 for coding the main reason for hospitalisation

The clearest separation across deprivation gradients in incident hospitalisation rates is for the ITMC group, shown in Figure 5.7, where rates in the most deprived areas (decile 10) are consistently larger, in both men and women. The rates appear to be increasing across all deciles for women.

Cause specific incident hospitalisation rates

The 13 conditions which had the highest proportion of cases within each year group are displayed in Table 5.2, along with the percentage of total cases each contributed.

Five of the 13 conditions did not contribute towards the 10 highest conditions for all of the years: appendicitis and peptic ulcers had large proportions in the first two year groups, and were replaced by Nephritis & Nephrosis, pneumonia, and malignant neoplasm of the skin in the latter years.

Table 5.2: Top 10 conditions (%) within each year group: men & women combined

Condition	1981-86	1987-96	1997-06	2007-13
All respiratory diseases (excl. pneumonia and influenza) $_{\text{ITMC}}$	11.4	9.9	7.8	7.8
Maternal conditions $_{\text{ITMC}}$	10.2	9.9	11.2	10.3
Perinatal conditions $_{\text{ITMC}}$	10.0	12.1	8.0	8.1
Benign tumours $_{\text{EDI}}$	8.8	9.9	11.5	9.5
Abdominal hernias $_{\text{ITMC}}$	7.7	7.4	9.6	9.9
Appendicitis $_{\text{ITMC}}$	4.7	3.0*	2.6*	2.5*
Cerebrovascular disease $_{\text{EDI}}$	4.6	4.8	4.6	3.9
Peptic ulcers $_{\text{ITMC}}$	4.4	3.3	2.7*	1.2*
Cholelithiasis and cholecystitis $_{\text{ITMC}}$	4.1	3.6	5.0	6.3
Obstructive uropathy and prostatic hyperplasia $_{\text{ITMC}}$	3.1	4.3	3.1	3.6
Nephritis & Nephrosis $_{\text{ITMC}}$	3.0*	3.9	1.8*	2.1*
Pneumonia $_{\text{ITMC}}$	2.6*	3.0*	4.1	5.2
Malignant neoplasm of the skin $_{\text{EDI}}$	2.1*	2.2*	3.5	4.3

$*$ Condition did not appear in the 10 largest percentages for this year set.

EDI: condition is considered amenable through early detection and intervention.

ITMC: condition is considered amenable through improved treatment and medical care.

In comparison to the conditions which contributed the largest proportions to overall amenable mortality (see Table 4.6), only 4 of the 13 conditions with high proportions of incident hospitalisations featured in the mortality list: cerebrovascular disease, perinatal conditions, pneumonia and peptic ulcers.

Conversely, 7 of the conditions which had high proportions of overall mortality did not have similarly high proportions of incident hospitalisations: breast, bladder and colorectal cancers, hypertensive disease, septicaemia, diabetes mellitus and COPD. In addition to the 13 conditions identified in Table 5.2, three further conditions were identified as being of interest for cause specific investigations owing to being a condition of interest (malignant neoplasms of the breast and COPD), or by experiencing large changes in the number of cases over the years (septicaemia). Owing to space, incident hospitalisation rates for 6 of the 16 conditions of interest will be discussed in the main body of this thesis, with plots for the remaining 10 conditions presented in Appendix C. Figures 5.8 to 5.19 describe the incident hospitalisation rates by sex and deprivation decile for breast cancers, COPD, obstructive uropathy and prostatic hyperplasia, perinatal conditions, pneumonia and malignant neoplasms of the skin.

The increasing incident hospitalisation rate of female breast cancers is illustrated in Figure 5.8. The rise in female rates is likely to be due to the increased coverage of screening programmes, able to detect more cases of breast cancer, at earlier times, than would be expected.

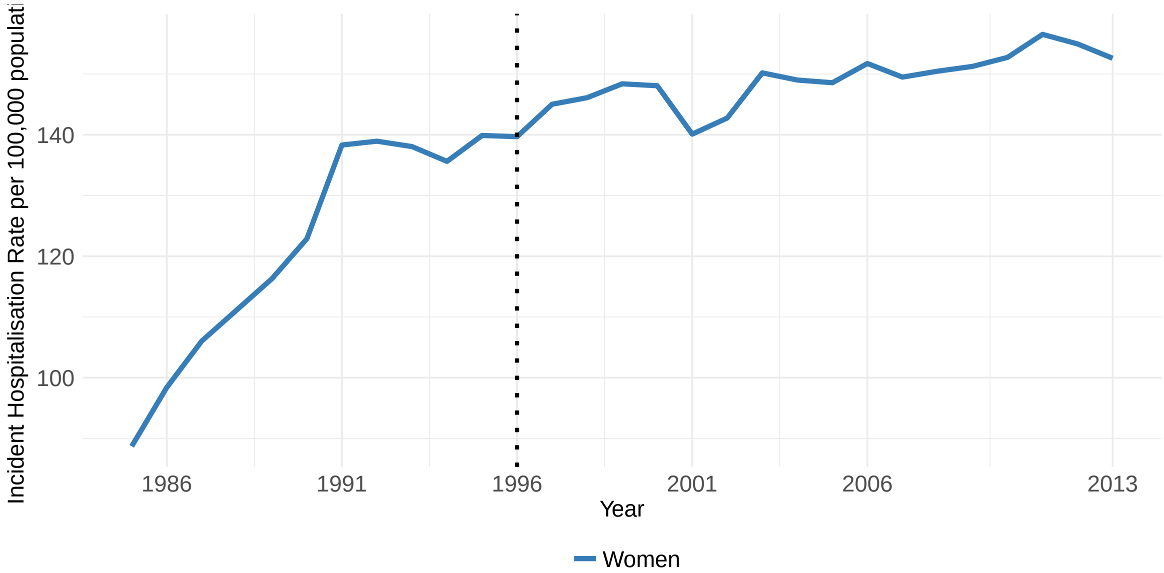


Figure 5.8: Incident hospitalisation rates of malignant neoplasm of the breast: women, 1985 - 2013. The dashed line indicates the introduction of ICD 10 for coding the main reason for hospitalisation

The gradient in female breast cancer incident hospitalisation rates is described in Figure 5.9. There is no clear separation between deprivation groups, however there is a suggestion of an inverse relationship, whereby women living in the least deprived areas of Scotland have a higher rate of incident hospitalisations for breast cancers, than women living in the most deprived areas.

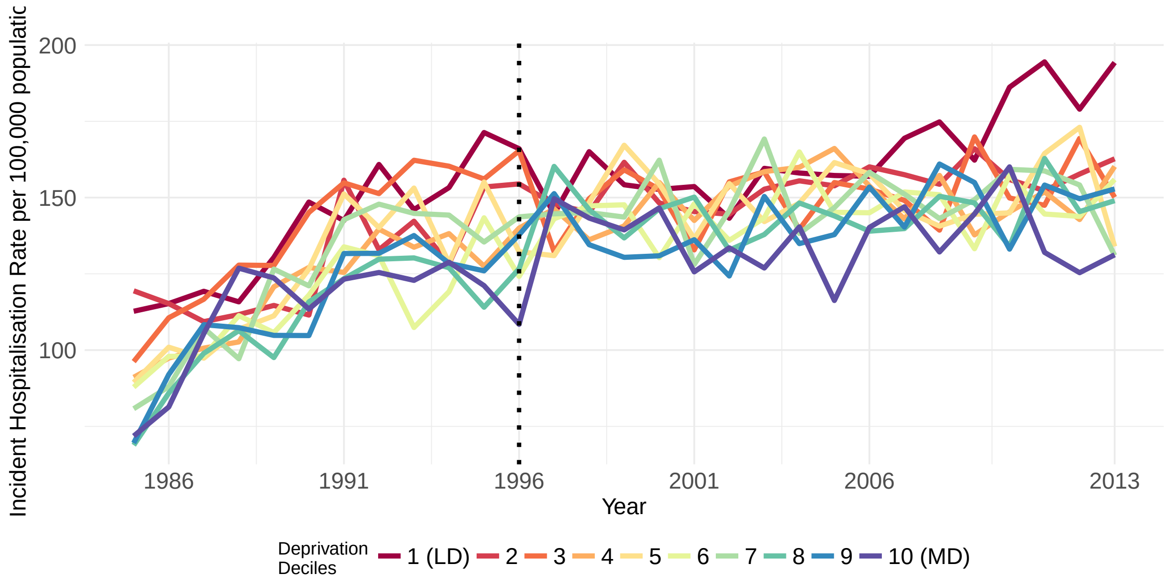


Figure 5.9: Incident hospitalisation rates of malignant neoplasm of the breast by deprivation decile: women, 1985 - 2013. The dashed line indicates the introduction of ICD 10 for coding the main reason for hospitalisation

The trends in incident hospitalisations of COPD are very different for men and women (see Figure 5.10). Male rates have declined over time, whilst female rates have increased, and exceeded male rates in 2003. Figure 5.11 depicts clear deprivation gradients in incident hospitalisation rates for both sexes. The increases in female rates are mainly driven by women in the most deprived areas.

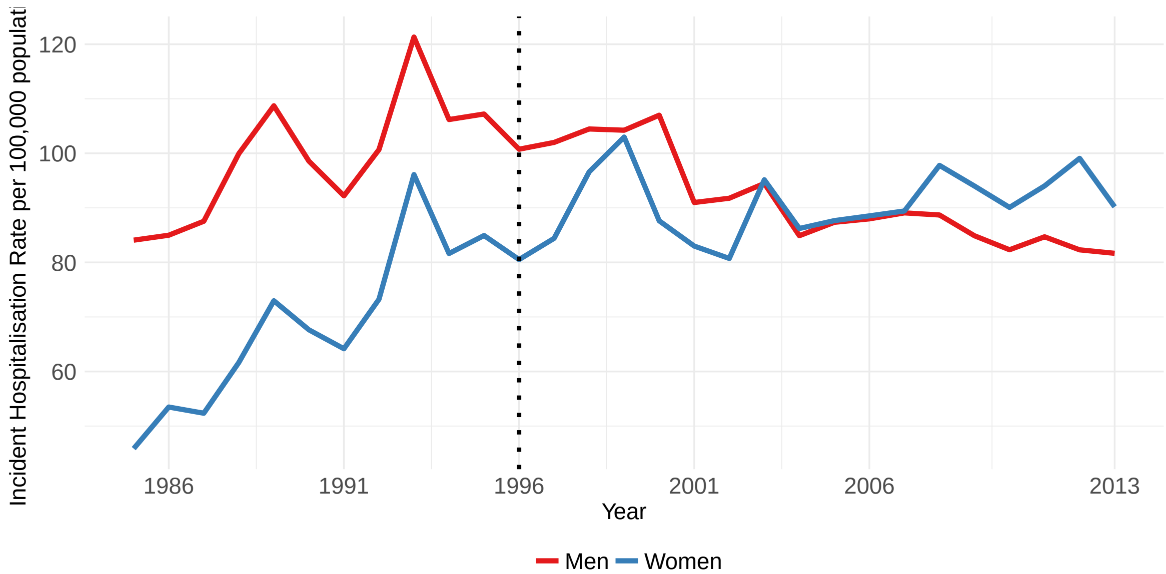


Figure 5.10: Incident hospitalisation rates of COPD: men and women, 1985 - 2013. The dashed line indicates the introduction of ICD 10 for coding the main reason for hospitalisation

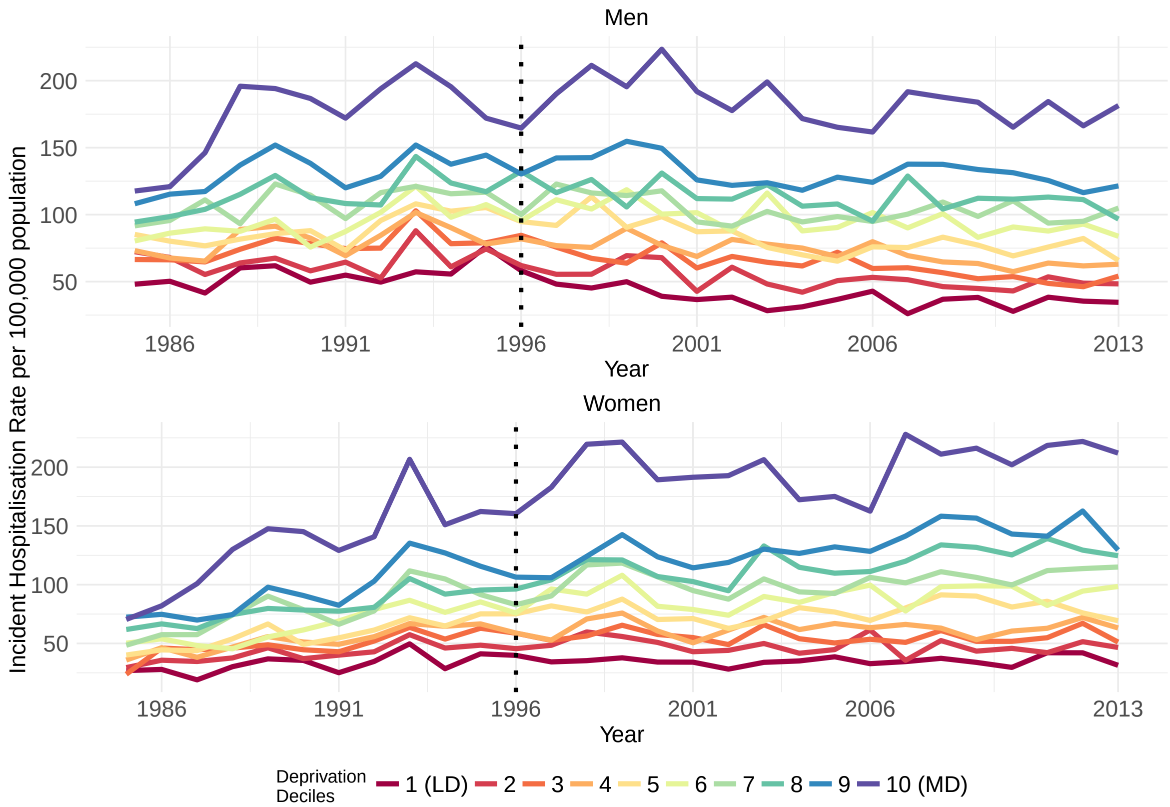


Figure 5.11: Incident hospitalisation rates of COPD by deprivation decile: men and women, 1985 - 2013. The dashed lines indicate the introduction of ICD 10 for coding the main reason for hospitalisation

Male incident cases of obstructive uropathy and prostatic hyperplasia, shown in Figure 5.12 appear to explain the large decline in male ITMC incident hospitalisation rates, that females did not experience (see Figure 5.3). Female rates are consistently increasing over time, and male rates have a similar trend following 1996. Breaking the incident hospitalisation rates down by deprivation decile, in Figure 5.13, indicates that men living in the least deprived areas of Scotland had higher incident hospitalisation rates pre-1996, whilst since then, there is much less of a gradient. Women in the more deprived areas consistently have higher incident hospitalisation rates.

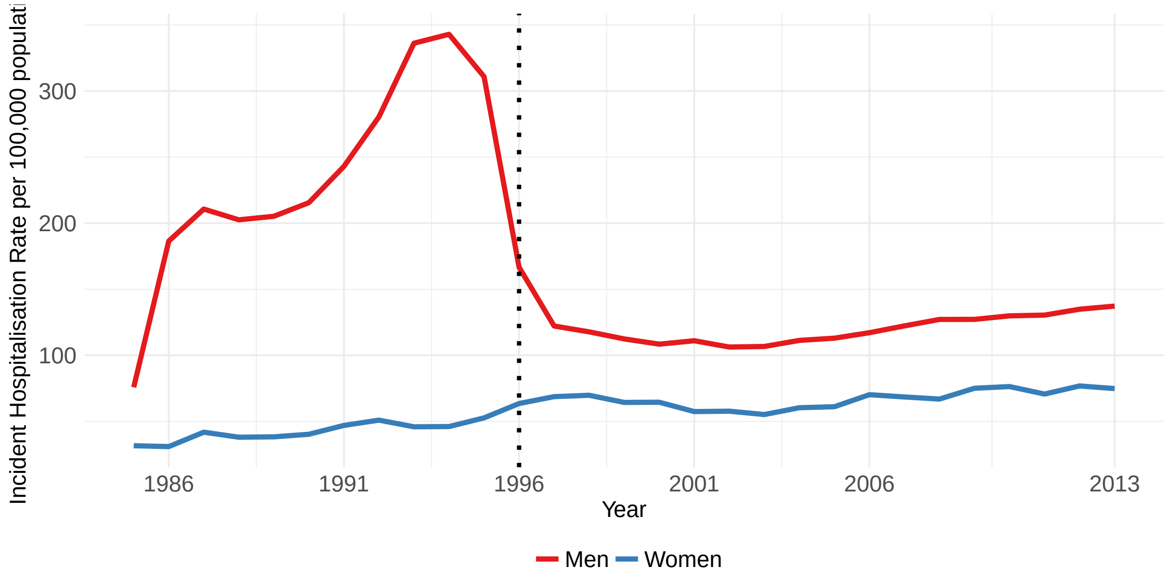


Figure 5.12: Incident hospitalisation rates of obstructive uropathy and prostatic hyperplasia: men and women, 1985 - 2013. The dashed line indicates the introduction of ICD 10 for coding the main reason for hospitalisation

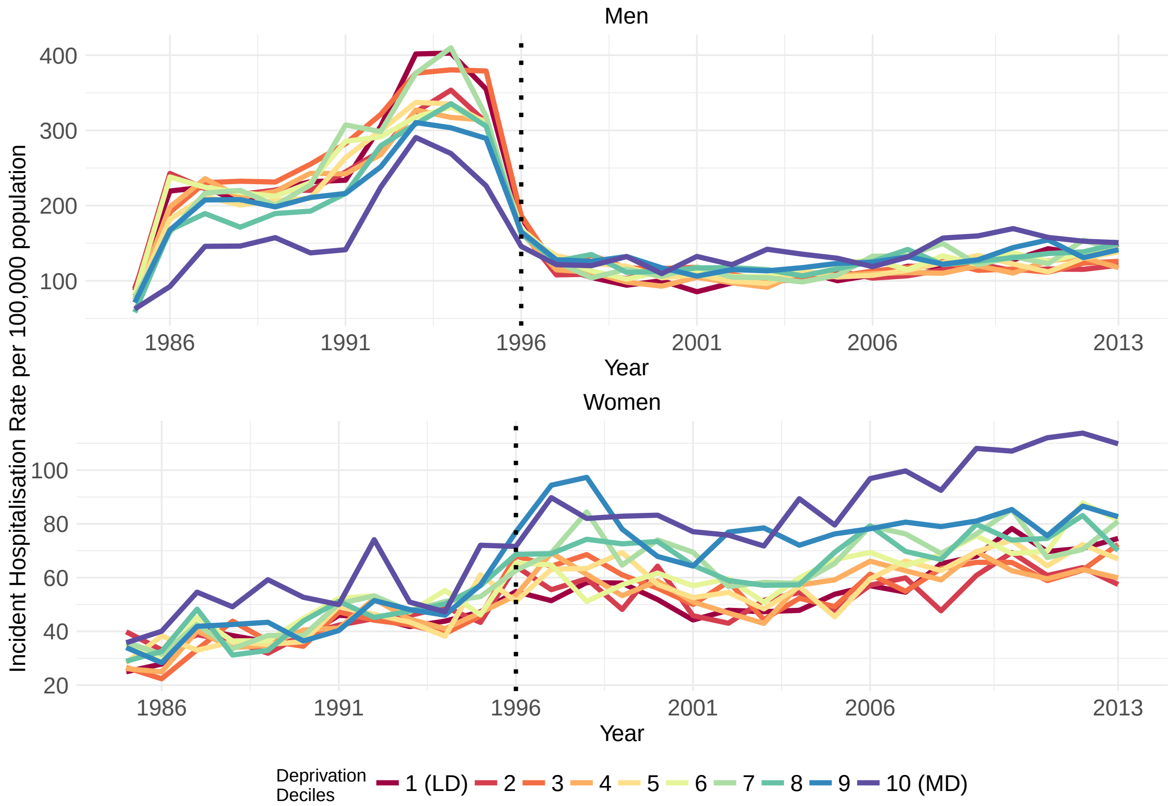


Figure 5.13: Incident hospitalisation rates of obstructive uropathy and prostatic hyperplasia by deprivation decile: men and women, 1985 - 2013. The dashed lines indicate the introduction of ICD 10 for coding the main reason for hospitalisation. Note: graphs are on different scales.

The increasing trend in overall incident hospitalisation rates in Figure 5.2 and the ITMC section of Figure 5.3 in the earliest part of the analysis period may be explained by the steep increase in the incident hospitalisations for perinatal conditions, shown in Figures 5.14 and 5.15. This increase occurs during the period where universal birth records were issued for every baby born in Scotland, and recorded type of birth as the main condition. Therefore, until 1992, the secondary diagnosed condition was used to identify amenable conditions. Further, there is a dip in rates occurring around 2002, coinciding with the introduction of the Scottish Birth Record, which superseded the SMR11 Neonatal Inpatients dataset (see section 5.3.1). These graphs provide a visual explanation of the impact changing recording practices can make.

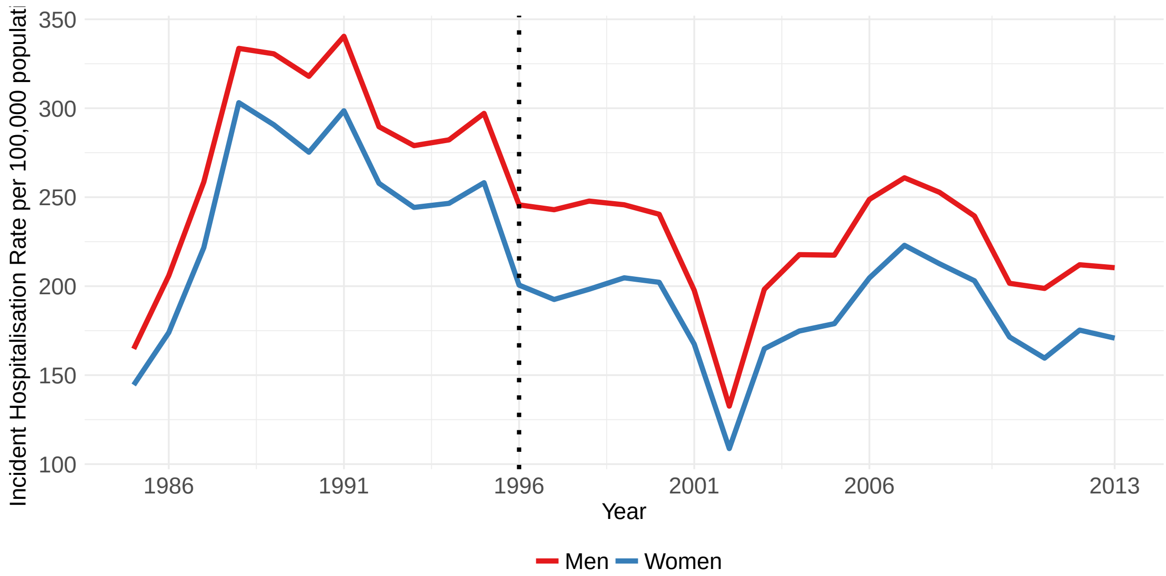


Figure 5.14: Incident hospitalisation rates of perinatal conditions: boys and girls, 1985 - 2013. The dashed line indicates the introduction of ICD 10 for coding the main reason for hospitalisation

The deprivation gradient in the incident hospitalisations for perinatal conditions after 1992 are interesting, in that the highest rates are occurring in the most and least deprived areas, whilst areas with median levels of deprivation have the lowest incident hospitalisations for perinatal conditions.

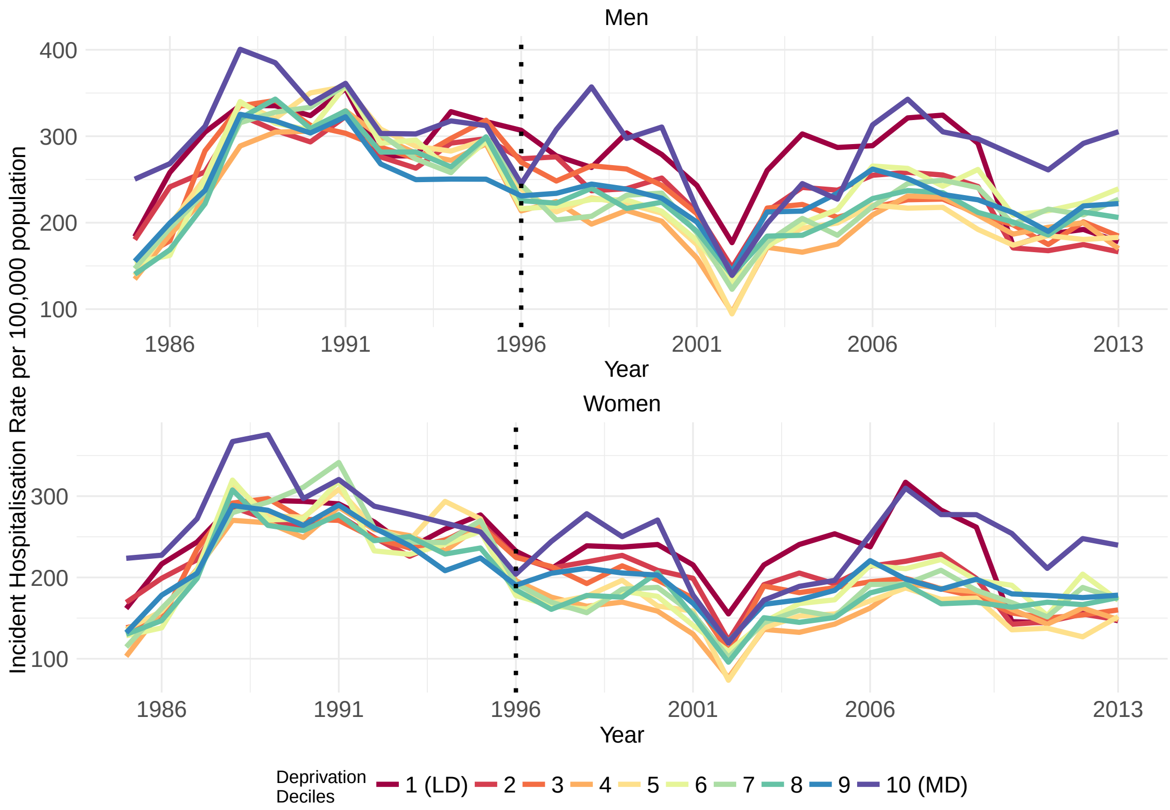


Figure 5.15: Incident hospitalisation rates of perinatal conditions by deprivation decile: boys and girls, 1985 - 2013. The dashed lines indicate the introduction of ICD 10 for coding the main reason for hospitalisation

When the mortality rates for pneumonia were plotted in Figure 4.15, the impact of the change in instructions for coding pneumonia deaths could be seen, with mortality rates decreasing by 47% for men and 51% for women between 1999 and 2000 (when ICD 10 was introduced for cause of death coding). Figure 5.16 shows there was no reciprocal change in the coding of hospitalisations during 1996 (when ICD 10 was introduced for SMR01 records). Incidence of hospitalisations for pneumonia has been increasing consistently over the analysis period, for both men and women.

When deprivation gradients in incident hospitalisation rates of pneumonia are plotted, in Figure 5.17, clear increasing gradients can be seen, with incident hospitalisation rates of pneumonia in the most deprived areas of Scotland (decile 10) being approximately 2 and a half times as large as those living in the least deprived areas (decile 1) in 2013 for both men and women.

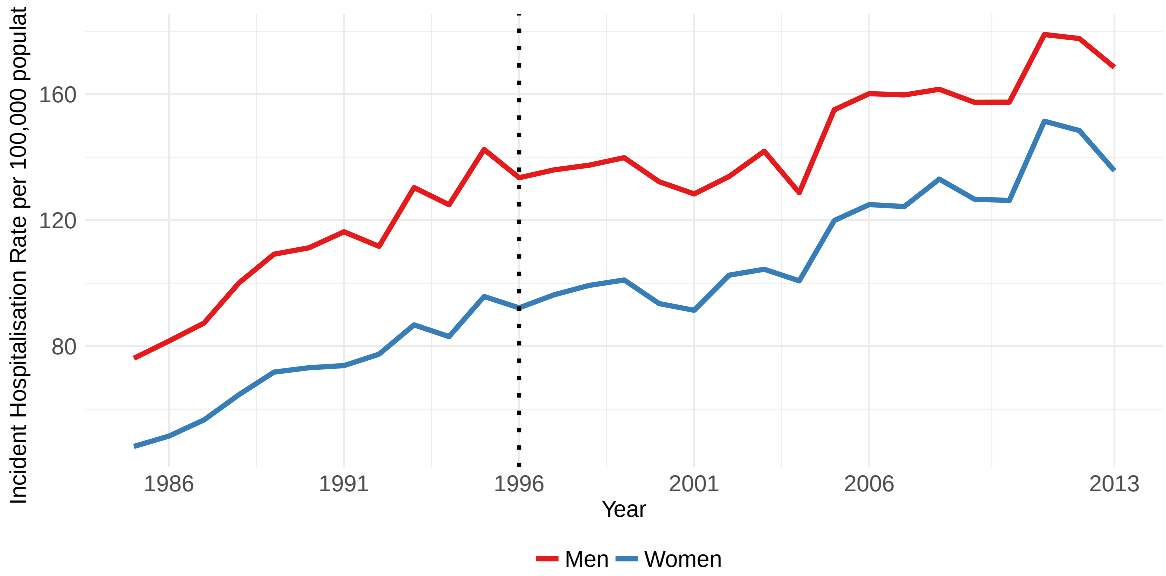


Figure 5.16: Incident hospitalisation rates of pneumonia: men and women, 1985 - 2013. The dashed line indicates the introduction of ICD 10 for coding the main reason for hospitalisation

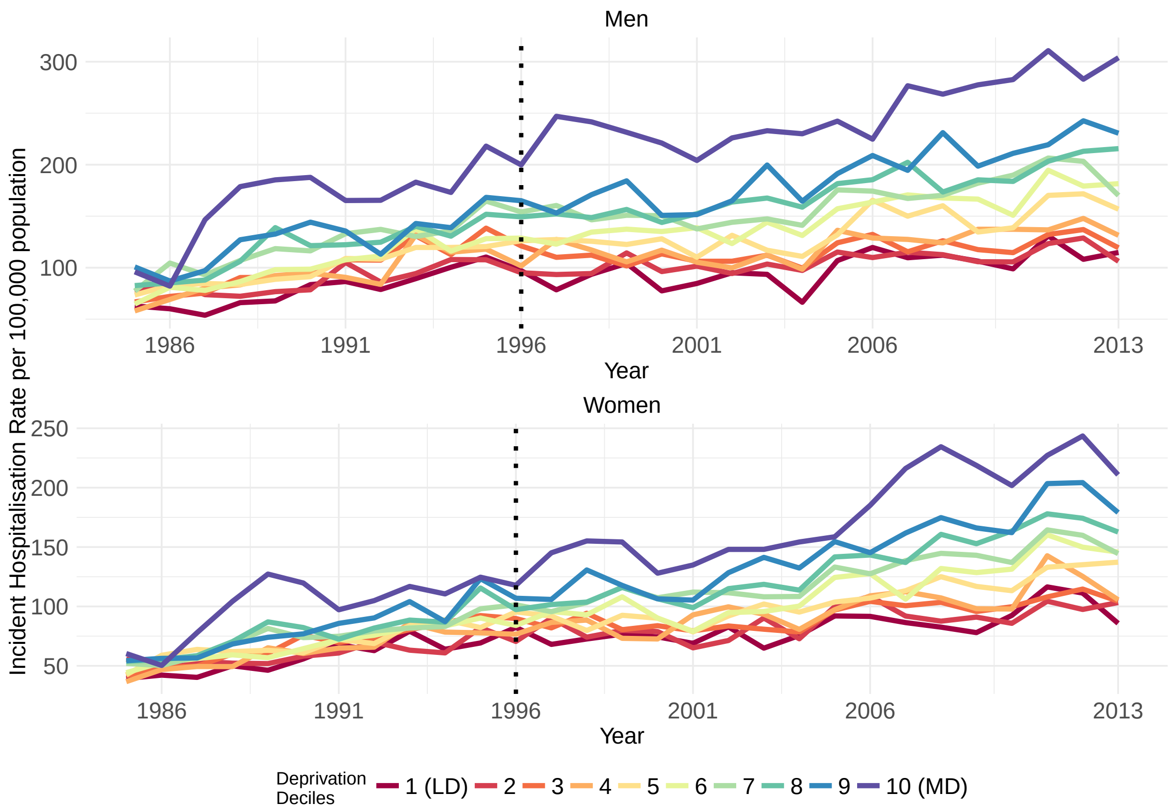


Figure 5.17: Incident hospitalisation rates of pneumonia by deprivation decile: men and women, 1985 - 2013. The dashed lines indicate the introduction of ICD 10 for coding the main reason for hospitalisation

Finally, rates of incident hospitalisations for skin cancer have also been increasing over the study period. Changes in ICD coding do not appear to have any observable effect on the incident hospitalisation rates in Figures 5.18 and 5.19.

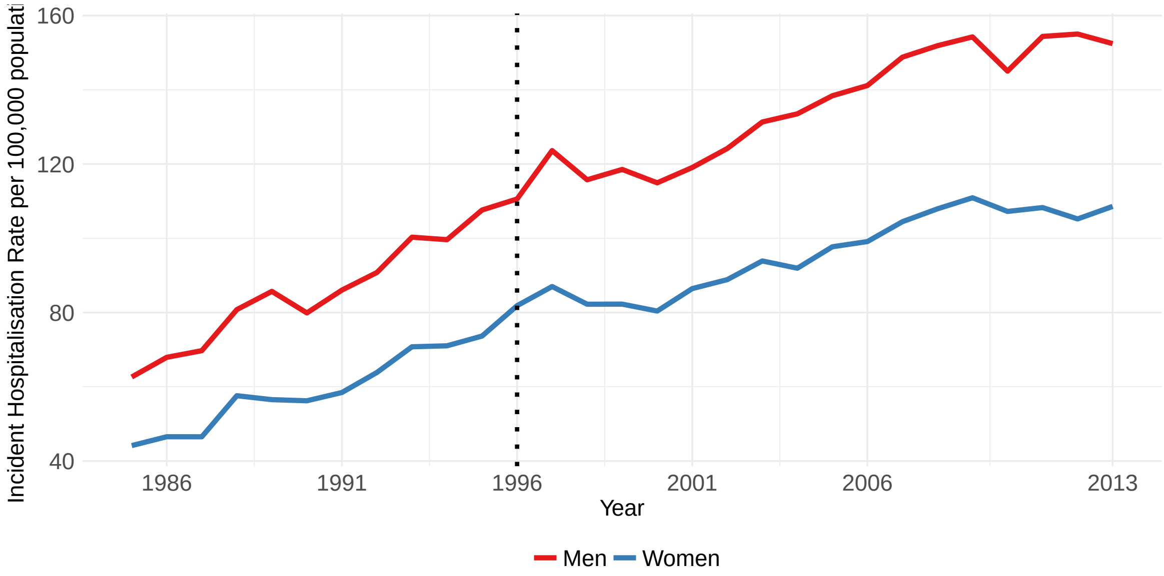


Figure 5.18: Incident hospitalisation rates of malignant neoplasms of the skin: men and women, 1985 - 2013. The dashed line indicates the introduction of ICD 10 for coding the main reason for hospitalisation

Much like breast cancer, there is an inverse gradient in the incident hospitalisation rates, where men and women living in the least deprived areas experience higher rates of incident hospitalisations than those living in the least deprived areas of Scotland. Rates in the least deprived areas (decile 1) have greater separation from the remaining deprivation deciles in more recent years.

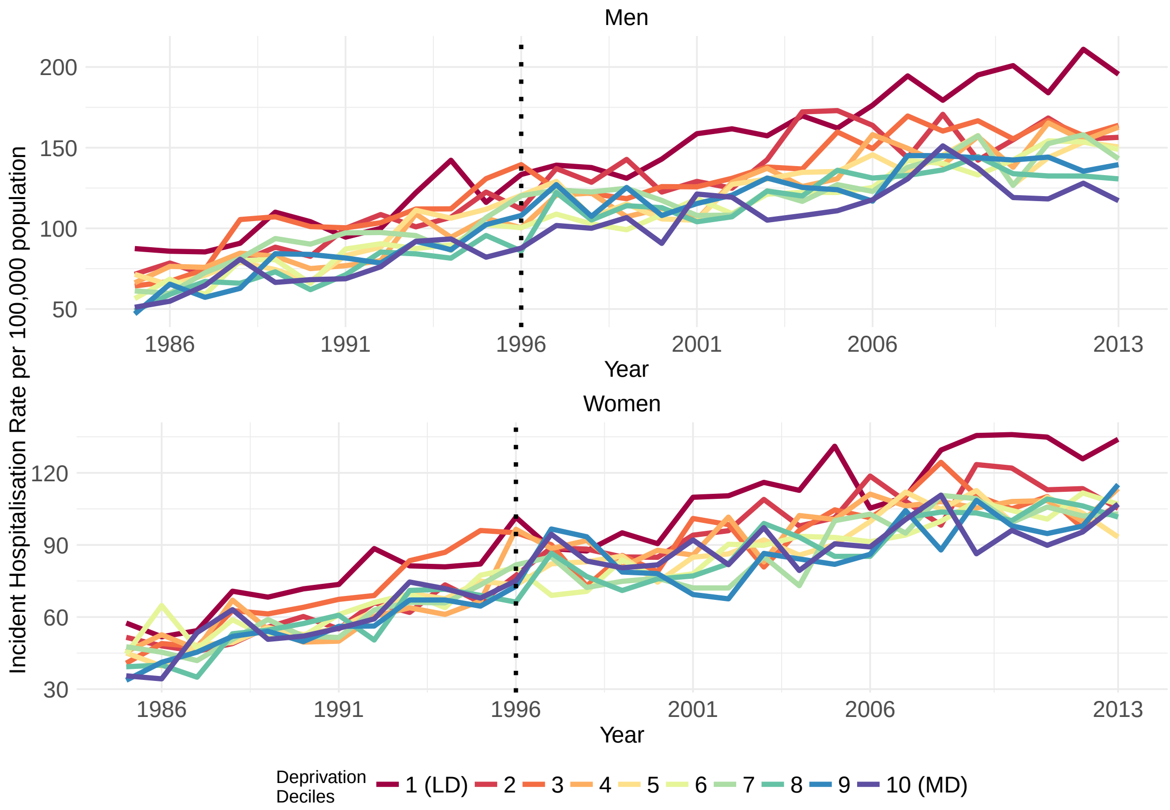


Figure 5.19: Incident hospitalisation rates of malignant neoplasms of the skin by deprivation decile: men and women, 1985 - 2013. The dashed lines indicate the introduction of ICD 10 for coding the main reason for hospitalisation. Note: graphs are on different scales

Age-specific incident hospitalisation rates

The greatest proportions of incident hospitalisation cases occurred in the youngest (0 to 14 years) ages, followed by the oldest (65 to 74 years). In 1985, 35.5% of male incident cases occurred in the youngest ages, and 17.4% at the oldest ages. By 2013, the percentage of male cases occurring at the youngest ages had decreased to 26.1%, and the oldest ages had increased to 25.1%. Within the female cases, the percentage of cases occurring at oldest ages increased by just 2%, from 16.8% in 1985 to 18.7% in 2013. The breakdown within the age groups by sex can be seen in Figure 5.20.

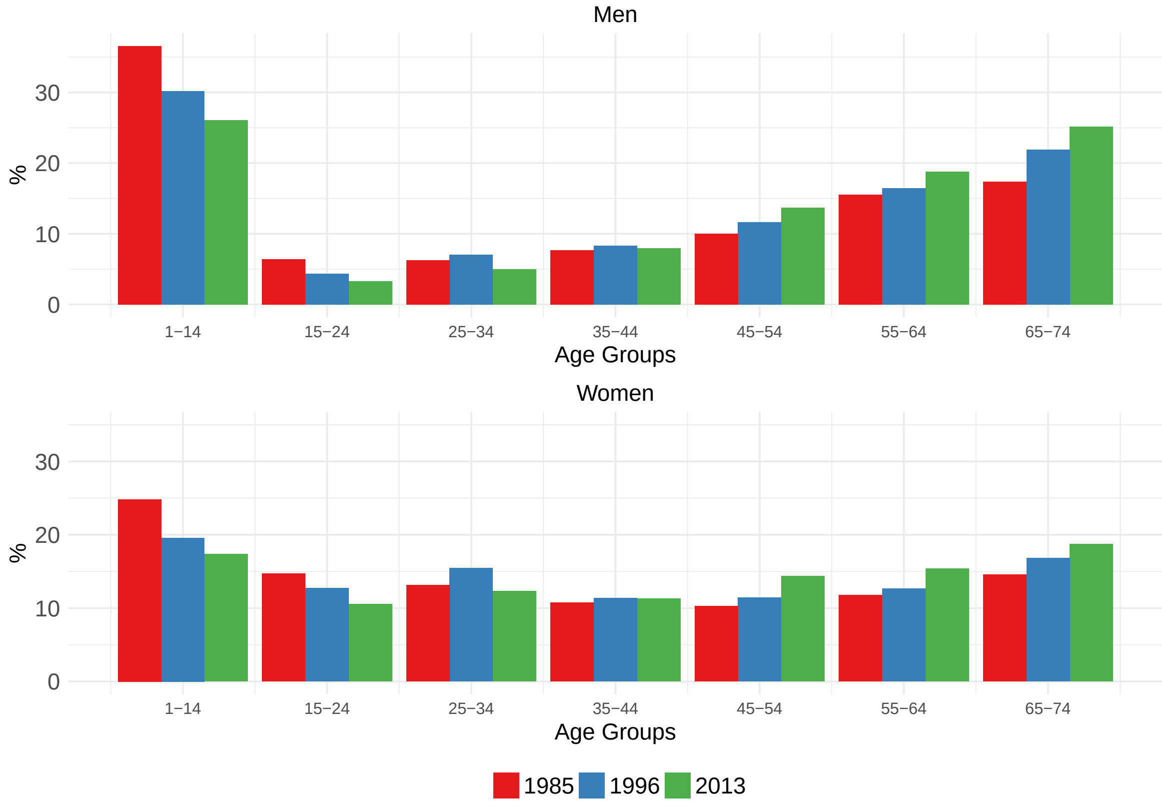


Figure 5.20: Percentage of amenable incident hospitalisation cases within each age group: 1985, 1996 and 2013

Compared to the female proportions, there is a much greater proportion of male cases in childhood (0 to 14 years), whereas the proportions in early adulthood (15 to 44 years) are lower. In older adulthood (45 to 74 years) there are increases in the proportions in both men and women, with men having a steeper gradient. The higher proportion of female cases in early adulthood are likely to be due to the inclusion of female breast cancers and maternal conditions, both of which will not affect men in this age group.

Over time, the proportion of cases during childhood is falling in both sexes, whilst the proportions in the oldest ages groups increase.

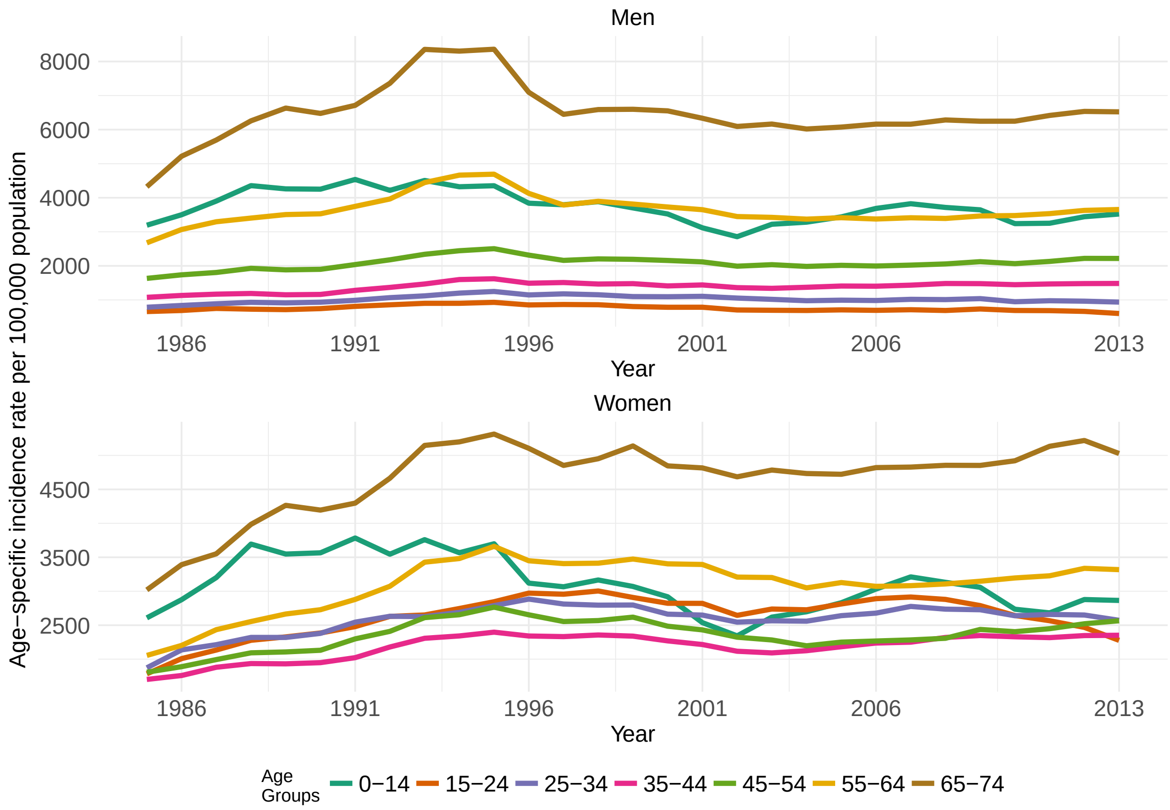


Figure 5.21: Age-specific incident hospitalisation rates: men & women, 1985 - 2013. Note: graphs are on different scales

Figure 5.21 describes the age-specific rates of incident hospitalisations for amenable conditions by sex. Whilst the oldest age group has the highest rates of incident hospitalisations in both sexes, the lowest rates differ. For men, the 15 to 24 year age group has the lowest incidence of hospitalisation for amenable conditions, whilst for women, the lowest rates occur between the ages of 35 and 45. The youngest age group for men remains fairly stable over the analysis period, and is of similar magnitude to the 55 to 64 year age group, whilst girls under 14 years experience more fluctuation over the analysis period.

5.4.3 Indices of inequality

Figure 5.22 contains the yearly relative indices of inequality for men and women. Relative inequalities ranged between 1.2 and 1.6 for both men and women. The lowest relative inequalities occur in 1996, at the start of the analysis period. The 2013 RII are interpreted as there being a 1.56 times higher risk of being diagnosed with an amenable condition for men living in the notionally most deprived areas, compared to those living in the least deprived areas.

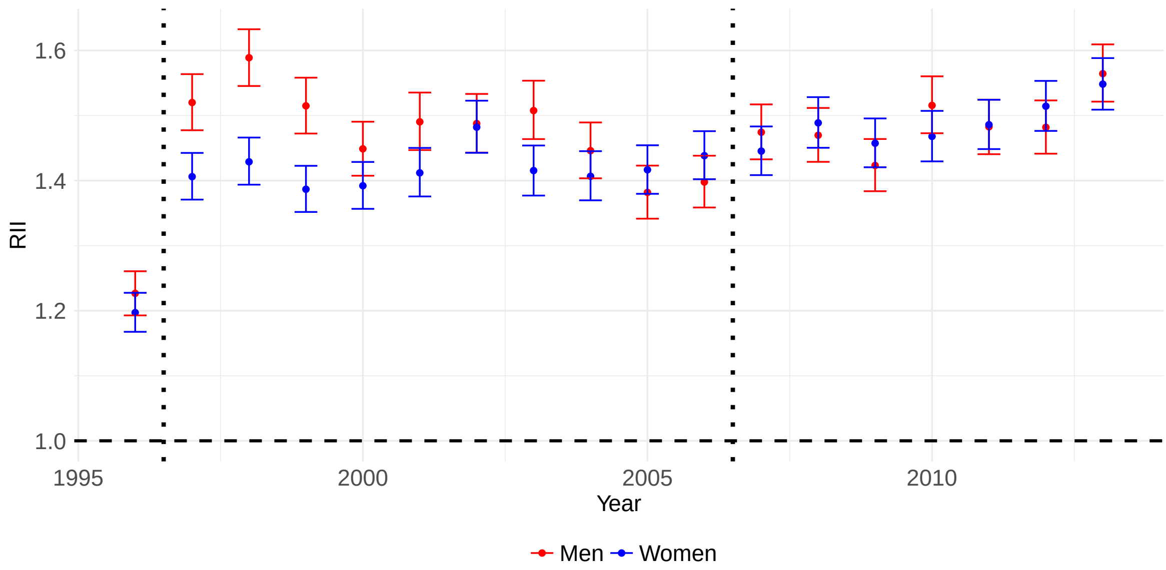


Figure 5.22: Relative Indices of Inequality: men & women, 1996 - 2013. The dashed line indicates the points in time where the Carstairs deprivation index version changes (1997 and 2007).

The Slope Indices of Inequalities presented in Figure 5.23 are absolute measure of inequalities, complimenting the relative measures presented in Figure 5.22.

Absolute inequalities in incident hospitalisation rates of amenable conditions between the notionally most and least deprived areas ranges between 590 and 1,280 per 100,000 for men, and 565 and 1,265 per 100,000 for women. Absolute inequalities within female incident hospitalisation rates of amenable conditions exceed those of males for the majority of the years within the analysis period.

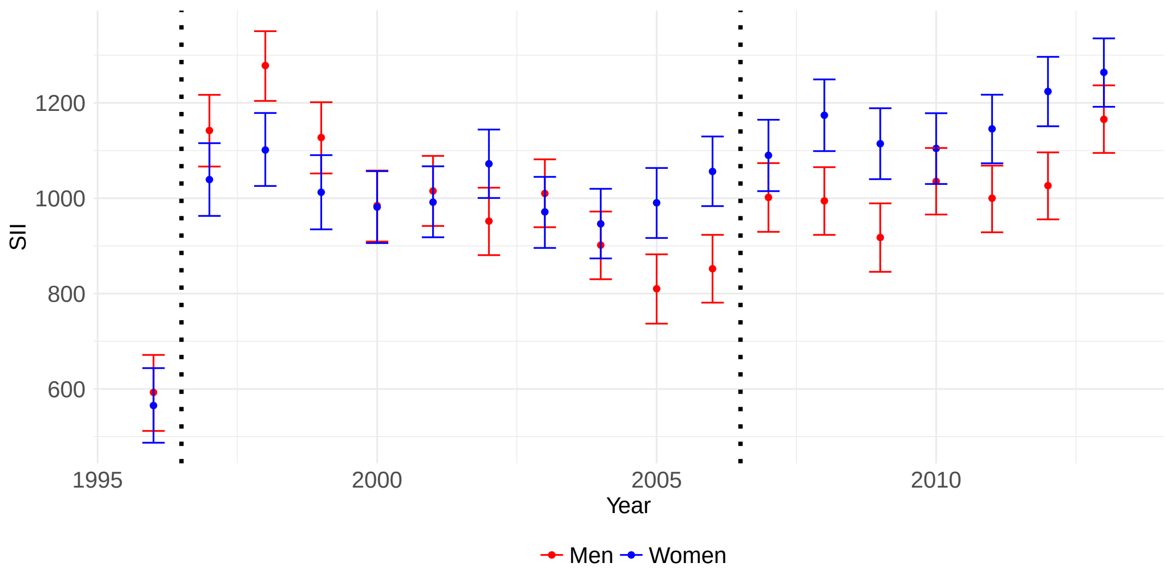


Figure 5.23: Slope Indices of Inequality: men & women, 1996 - 2013. The dashed line indicates the points in time where the Carstairs deprivation index version changes (1997 and 2007)

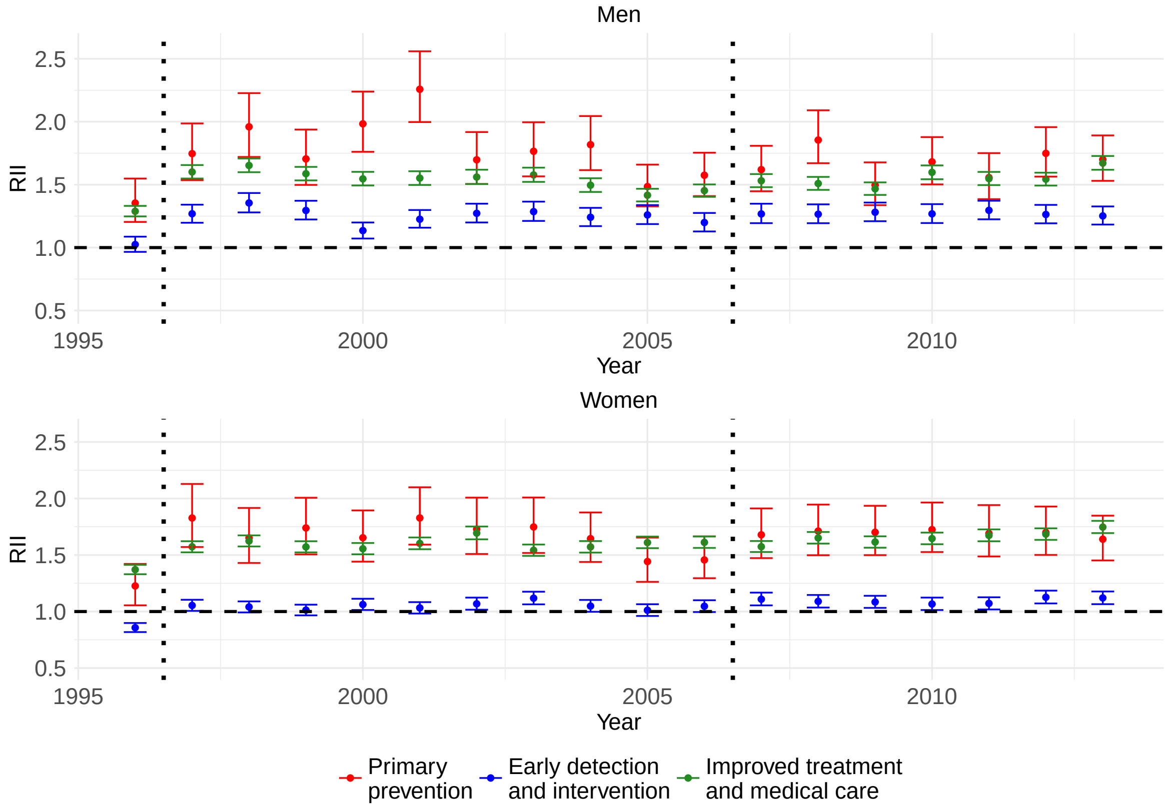


Figure 5.24: Relative Indices of Inequality by diagnosis group: men & women, 1996 - 2013. The dashed lines indicate the points in time where the Carstairs deprivation index version changes (1997 and 2007)

RII by diagnosis group and sex are presented in Figure 5.24. The relative inequalities in conditions amenable through PP are amongst the largest throughout the study period, for men and women, although there are more fluctuations than estimated for the remaining two diagnosis groups. In 1996, men living in the notionally most deprived areas of Scotland had incident hospitalisation rates for PP conditions 1.35 times those of men living in the least deprived areas. For women, the inequality in incident hospitalisation rates was approximately 1.23. By 2013, relative inequalities increased to approximately 1.70 and 1.64 in male and female rates of incident hospitalisations respectively.

The relative inequalities in conditions amenable through EDI for men are above 1 throughout the analysis period, and are significantly greater than 1 from 1997 onwards. Incident hospitalisation rates in the notionally most deprived areas were 1.02 (95% CI 0.97 to 1.09) times rates in the notionally least deprived areas (i.e. 2% higher) in 1996, increasing to 1.25 (95% CI 1.18 to 1.33) times in 2013 (i.e. 25% higher).

For women, relative inequalities in incident hospitalisation rates of conditions amenable through EDI in the notionally most deprived areas were not significantly different from rates in the notionally least deprived areas in 6 of the 18 years of analysis. Rates of incident hospitalisations for amenable conditions in the notionally most deprived areas were 0.86 (95% CI 0.82 to 0.90) times rates in the notionally least deprived areas (i.e. 14% lower) in 1996, increasing to 1.12 (95% CI 1.07 to 1.18) times in 2013 (i.e. 12% higher).

Relative inequalities in rates of mortality amenable through ITMC increased over the study period, and were significantly higher than 1, for both men and women. Rates of incident hospitalisations in the notionally most deprived areas were 1.29 times those of the least deprived for men, and 1.37 times for women in 1996. By 2013, the inequalities had increased to 1.67 and 1.75 respectively. Inequalities for women remained higher than those for men from 2004 onwards.

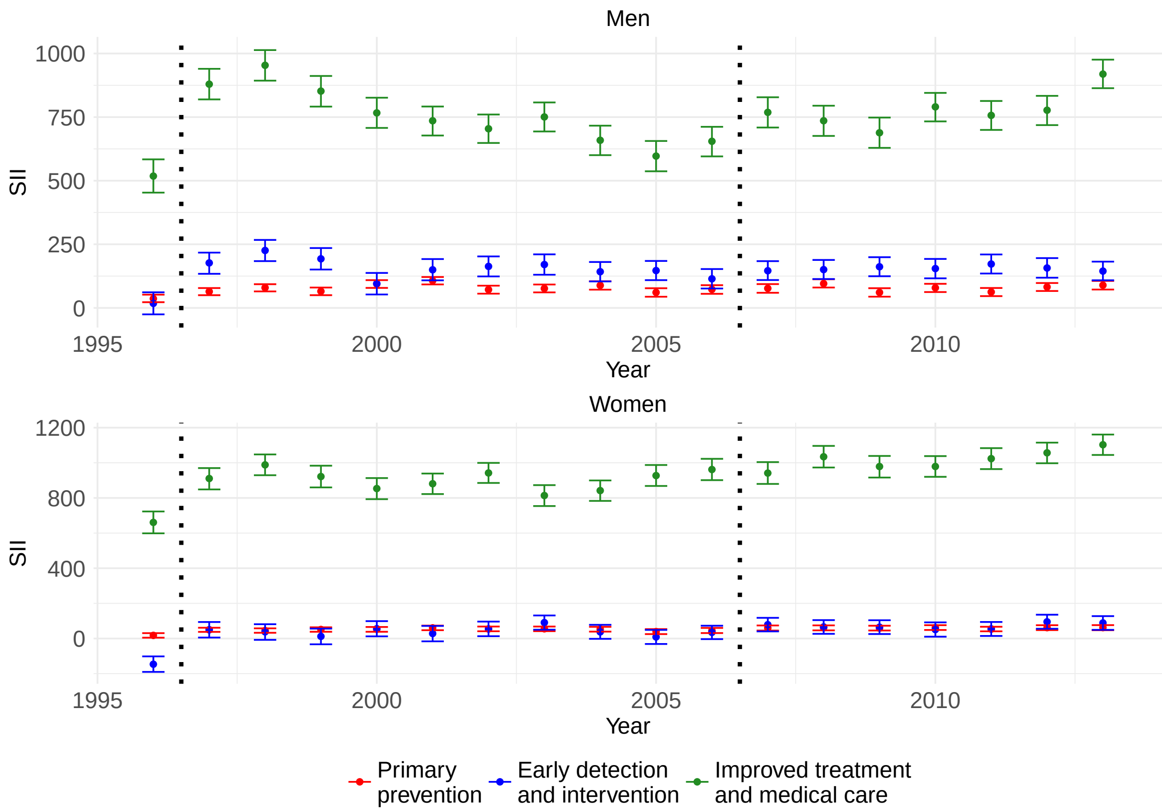


Figure 5.25: Slope Indices of Inequality by diagnosis group: men & women, 1996 - 2013. The dashed lines indicate the points in time where the Carstairs deprivation index version changes (1997 and 2007) Note: graphs are on different scales.

There is a different pattern in the absolute inequalities (Figure 5.25), compared to the relative inequalities in rates of incident hospitalisations. Absolute inequalities are largest in the ITMC group, for both men and women. SII for women generally increase over the analysis period, whilst there are more fluctuations in absolute inequalities in male incident hospitalisation rates. SII for the PP group remain fairly consistent over the analysis period.

Absolute inequalities in the EDI group for women are negative at the beginning of the analysis period, indicating that there was an inverse relationship between level of deprivation and incident hospitalisation rates. By the end of the analysis period, absolute inequalities in EDI incident hospitalisations were comparable to the PP group for women, and exceeded the inequalities for men.

5.4.4 Fractional Polynomials

Fractional polynomials were calculated for the model described in Equation 3.7. As the data used to generate the fractional polynomials were restricted to 1996 onwards, the Year_c variable was re-centred to equal Year - 1996. Table 5.3 describes the fractional polynomial transformations, centring and scaling applied to each variable, as well as the interactions.

Table 5.3: Fractional polynomial (FP) transformations of covariates: men

Covariate	FP	Transformation
Age (1)	0	$log_e(\frac{A}{10}) - 1.308$
Age (2)	1	$\frac{A}{10} - 3.7$
Year_c (1)	-2	$(\frac{Y_c+1}{10})^{-2} - 1.108$
Year_c (2)	-1	$(\frac{Y_c+1}{10})^{-1} - 1.053$
Decile (1)	0	$log_e(D) - 1.705$
Decile (2)	3	$D^3 - 166.375$
Age × Year_c (1)	-2	$(\frac{A \times Y_c+1}{1{,}000})^{-2} - 10.046$
Age × Year_c (2)	1	$\frac{A \times Y_c+1}{1{,}000} - 0.316$
Age × Decile (1)	0.5	$(\frac{A \times D}{100})^{0.5} - 1.427$
Age × Decile (2)	1	$\frac{A \times D}{100} - 2.035$
Decile × Year_c (1)	-0.5	$(\frac{D \times Y_c+1}{100})^{-0.5} - 1.447$
Decile × Year_c (2)	0.5	$(\frac{D \times Y_c+1}{100})^{0.5} - 0.691$
Age × Decile × Year_c(1)	0	$log_e(\frac{A \times D \times Y_c+1}{10{,}000}) + 1.754$
Age × Decile × Year_c (2)	0	$log_e(\frac{A \times D \times Y_c+1}{10{,}000})^2 - 3.077$

$Y_c = \text{Year}_c$ = Year - 1996
A = Age
D = Decile

Figures 5.26, 5.27 and 5.28 describe the shapes of the fractional polynomial transformations for the continuous variables of age, year and deprivation decile for men, as well as their interactions.

Figure 5.26 shows a sharp decline in incident hospitalisation rates after infancy (age 0 - 4 years), occurring at both the beginning and end of the analysis period, and for both of the extreme deprivation deciles. The age-specific rates in the least deprived decile (decile 1) remain lower than the most deprived decile (decile 10) for all ages after age 5 years, with the gap between the deprivation groups increasing with age.

Interestingly, the age-specific incident hospitalisation rates over the age range in the most deprived decile (decile 10) are almost identical at the two ends of the analysis period, suggesting that there has been no change in age-specific incident hospitalisation rates within the most deprived areas of Scotland over the analysis period, whilst the age-specific incident hospitalisation rates in the least deprived areas (decile 1) have decreased by 2013.

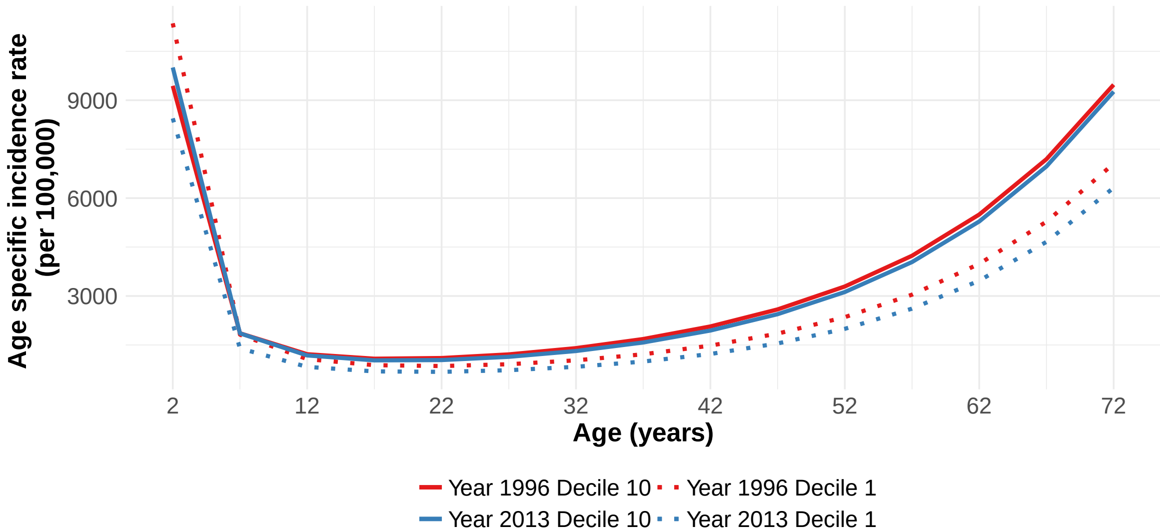


Figure 5.26: Age-specific incident hospitalisation rates by age: men, most and least deprived deciles, 1996 and 2013

The relationship of year of incident hospitalisation is represented in Figure 5.27, for two age groups. Age-specific incident hospitalisation rates are consistently lower for the younger age group (age 45 - 49), than the older age group (age 50 - 54), and lower in the least deprived decile, than in the most deprived.

The relationship between deprivation and year differs more at the beginning of the analysis period, where the least deprived deciles experiences a sharp decrease in the risk of being diagnosed with an amenable condition, whilst rates for men in the most deprived decile are smoother.

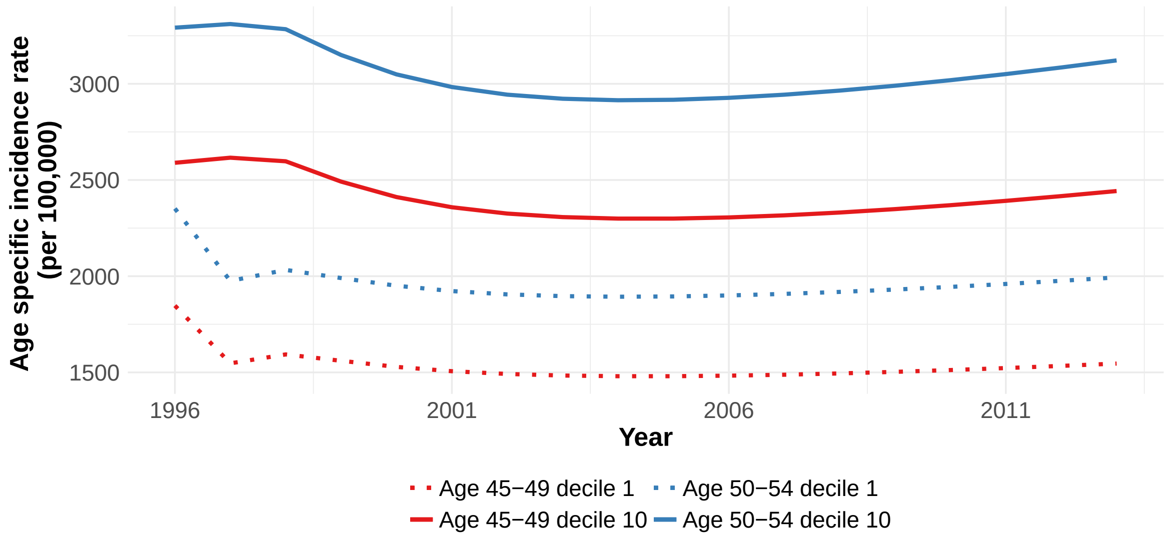


Figure 5.27: Age-specific incident hospitalisation rates by year: men, most and least deprived deciles, ages 45 - 54 years

Figure 5.28 describes the fractional transformation of the deprivation decile variable. The age-specific incident hospitalisation rates are lowest in the least deprived deciles (1), and highest in the most deprived deciles (10). The difference in age-specific incident hospitalisation rates between the start and end of the analysis period is greater in the lesser deprived areas, and smaller in the most deprived areas, echoing the conclusions drawn in Figure 5.26, where it appeared that there had been little to no improvements in the age-specific incident hospitalisation rates in the most deprived decile across the analysis period.

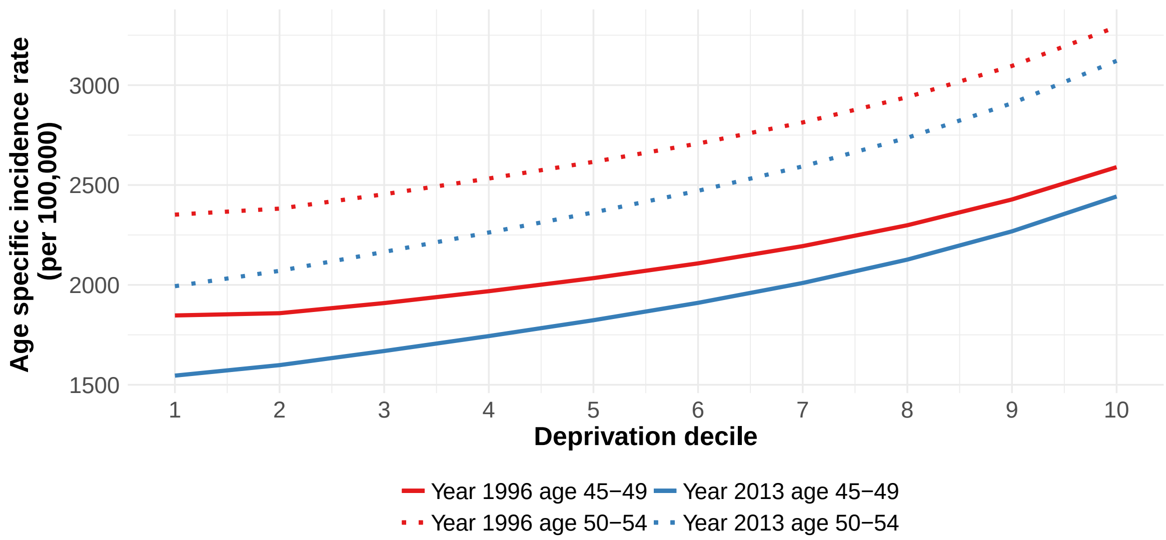


Figure 5.28: Age-specific incident hospitalisation rates by deprivation decile: men, ages 45 - 54 years, 1996 and 2013

The fractional polynomial transformations, centring and scaling applied to each main effect, as well as the interactions for women is described in Table 5.4.

Table 5.4: Fractional polynomial (FP) transformations of covariates: women

Covariate	FP	Transformation
Age (1)	-2	$(\frac{A}{10})^{-2} - 0.073$
Age (2)	3	$(\frac{A}{10})^{3} - 50.653$
Year_c (1)	3	$(\frac{Y_c+1}{10})^{3} - 0.857$
Year_c (2)	3	$((\frac{Y_c+1}{10})^{3} \times log_e(\frac{Y_c+1}{10})) + 0.044$
Decile (1)	0	$log_e(D) - 1.705$
Decile (2)	3	$D^3 - 166.375$
Age × Year_c (1)	2	$(\frac{A \times Y_c+1}{1{,}000})^{2} - 0.099$
Age × Year_c (2)	2	$((\frac{A \times Y_c+1}{1{,}000})^{2} \times log_e(\frac{A \times Y_c+1}{1{,}000})) + 0.115$
Age × Decile (1)	-1	$(\frac{A \times D}{100})^{-1} - 0.491$
Age × Decile (2)	-0.5	$(\frac{A \times D}{100})^{-0.5} - 0.701$
Decile × Year_c (1)	-2	$(\frac{D \times Y_c+1}{100})^{-2} - 4.386$
Decile × Year_c (2)	0.5	$(\frac{D \times Y_c+1}{100})^{0.5} - 0.691$
Age × Decile × Year_c (1)	-0.5	$(\frac{A \times D \times Y_c+1}{10{,}000})^{-0.5} - 2.404$
Age × Decile × Year_c (2)	0.5	$(\frac{A \times D \times Y_c+1}{10{,}000})^{0.5} - 0.416$

Y_c = Year_c = Year - 1996
A = Age
D = Decile

As with the men, plots of the transformations are more informative.

As seen with the men in Figure 5.26, there is a sharp decline in the incident hospitalisation rates for women after infancy, seen in Figure 5.29. However, unlike men, the age-specific incident hospitalisation rates in 1996 do not increase to the same extent at the older ages. The relationship in 2013 is much the same as it was for men, with the most deprived deciles having higher rates of incident hospitalisations at the older ages.

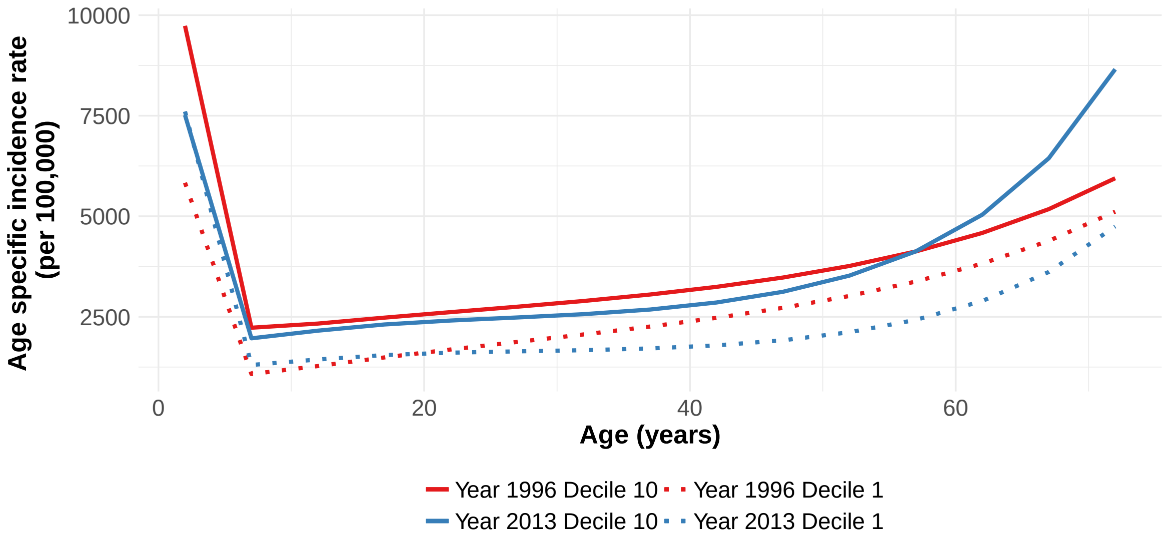


Figure 5.29: Age-specific incident hospitalisation rates by age: women, most and least deprived deciles, 1996 and 2013

Figure 5.30 describes the fractional polynomial transformations for the year within the analysis period. Women in the least deprived deciles see a much sharper decline after 1996 than the men experienced, in Figure 5.27. The incident hospitalisation rates in the least deprived deciles also decline over the years, whereas for the men, they remained fairly constant.

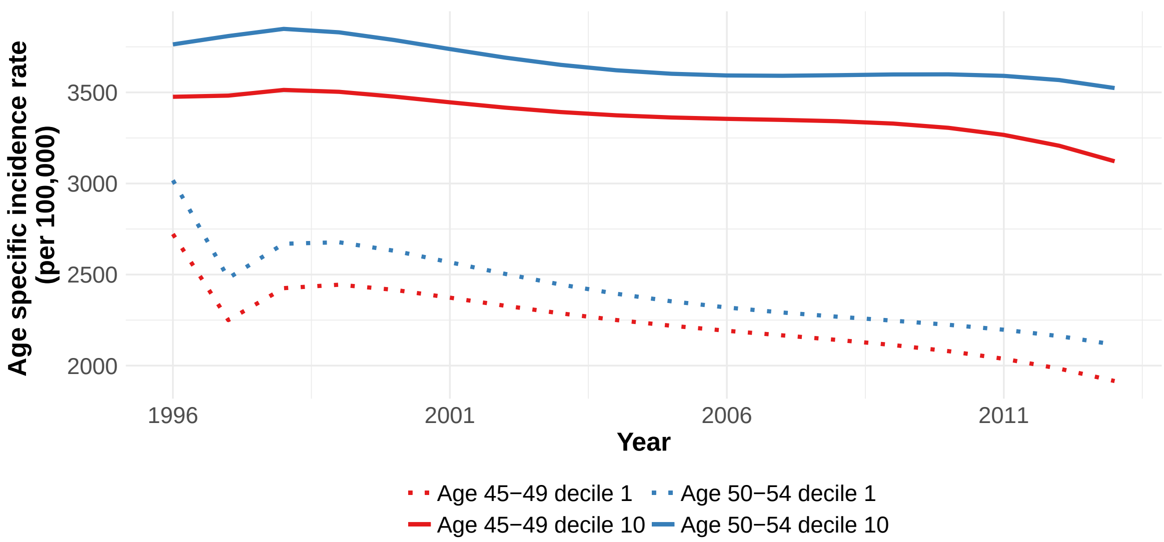


Figure 5.30: Age-specific incident hospitalisation rates by year: women, most and least deprived deciles, ages 45 - 54 years

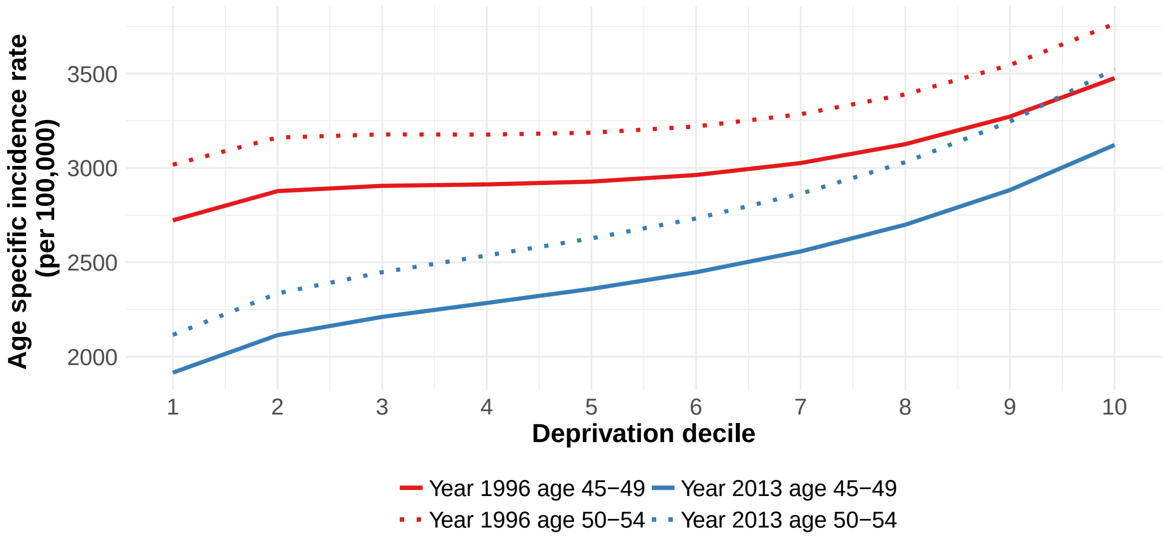


Figure 5.31: Age-specific incident hospitalisation rates by deprivation decile: women, ages 45 - 54 years, 1996 and 2013

Figure 5.31 describes the age-specific incident hospitalisation rates by deprivation decile for women. The difference in rates for the two age groups in 1996 is relatively constant over the deprivation gradient, whilst by 2013, the difference is greater at the more deprived deciles.

5.4.5 Multilevel Modelling

Prior to the transformations being applied to the data, minor cleaning and adjustments were made. Any record without a postcode sector, council code or local government district code was removed, as these are required in the multilevel model. There were 545,580 rows of data, containing 2,236,214 incident cases and a total population size of 85,939,680 between 1996 and 2013. Rows with at least one case, but no population size had their population sizes artificially increased to match the numbers of cases occurring in the area. This inflated the overall population size for the 18 years by 171 people, to 85,939,851.

There were 1,008,220 male, and 1,227,994 female amenable cases, distributed over 18 years and 1,987 unique area identifiers (combinations of postcode sectors and local government district/council codes). The sex-specific fractional polynomial transformations were applied to the multilevel model. The output for male incident hospitalisation data, along with the incidence rate ratios for each variable are displayed in Table 5.5.

Table 5.5: Incident Rate Ratios and 95% confidence intervals derived from multilevel modelling: men, 1996 - 2013

Men	FP	IRR	95%CI
Intercept		0.011	
FP age 1	0	0.153	(0.15 - 0.16)
FP age 2	1	2.244	(2.23 - 2.25)
FP year 1	-2	0.973	(0.97 - 0.98)
FP year 2	-1	1.203	(1.17 - 1.24)
FP decile 1	0	0.736	(0.71 - 0.76)
FP decile 2	3	1.000	(1.00 - 1.00)
FP age × year 1	-2	1.000	(1.00 - 1.00)
FP age × year 2	1	1.214	(1.18 - 1.25)
FP age × decile 1	0.5	2.973	(2.79 - 3.17)
FP age × decile 1	1	0.824	(0.81 - 0.83)
FP year × decile 1	-0.5	1.014	(0.99 - 1.03)
FP year × decile 2	0.5	1.306	(1.24 - 1.38)
FP age × decile × year 1	0	0.876	(0.86 - 0.89)
FP age × decile × year 2	0	0.987	(0.98 - 0.99)

FP: fractional polynomial
IRR: Incident rate ratio
95% CI: 95% confidence interval

Men	Coef.	s.e.	MRR
σ^2_{v0}	0.083	0.003	1.317
σ^2_{u0}	0.027	0.001	

Where σ^2_{v0} and σ^2_{u0} correspond to the variation at the area and year level respectively.

The median rate ratios for the morbidity data are much higher than those previously calculated for the mortality data (see Table 4.9). The median risk associated with an area with a higher incident hospitalisation rate, compared to an area with a lower rate, is associated with a 31.7% increased risk of being diagnosed with an amenable condition, within a given deprivation decile.

Table 5.6: Incident Rate Ratios and 95% confidence intervals derived from multilevel modelling: women, 1996 - 2013

Women	FP	IRR	95%CI
Intercept		0.022	
FP age 1	-2	1.091	(1.09 - 1.09)
FP age 2	3	1.002	(1.00 - 1.00)
FP year 1	3	1.200	(1.18 - 1.22)
FP year 2	3	0.795	(0.78 - 0.81)
FP decile 1	0	0.686	(0.67 - 0.70)
FP decile 2	3	1.000	(1.00 - 1.00)
FP age × year 1	2	0.440	(0.43 - 0.45)
FP age × year 2	2	7.184	(6.81 - 7.58)
FP age × decile 1	-1	1.056	(1.05 - 1.06)
FP age × decile 1	-0.5	0.501	(0.49 - 0.51)
FP year × decile 1	-2	0.999	(0.99 - 0.99)
FP year × decile 2	0.5	0.605	(0.58 - 0.63)
FP age × decile × year 1	-0.5	1.013	(1.01 - 1.01)
FP age × decile × year 2	0.5	4.021	(3.85 - 4.20)

FP: fractional polynomial

IRR: Incident rate ratio

95% CI: 95% confidence interval

Women	Coef.	s.e.	MRR
σ^2_{v0}	0.088	0.003	1.329
σ^2_{u0}	0.025	0.001	

Where σ^2_{v0} and σ^2_{u0} correspond to the variation at the area and year level respectively.

The median rate ratio for women, in Table 5.6 is slightly higher than that estimated for men at the area level - there is a 32.9% increased risk of being diagnosed with an amenable condition in areas with higher rates of incident hospitalisations for amenable conditions, compared to those with lower rates, within a given deprivation decile.

The fractional polynomials, as well as the interaction terms, make sensible interpretation of the IRR difficult. Figure 5.32 and 5.33 describe the predicted incident hospitalisation rates for men and women overall, and for the most and least deprived deprivation decile.

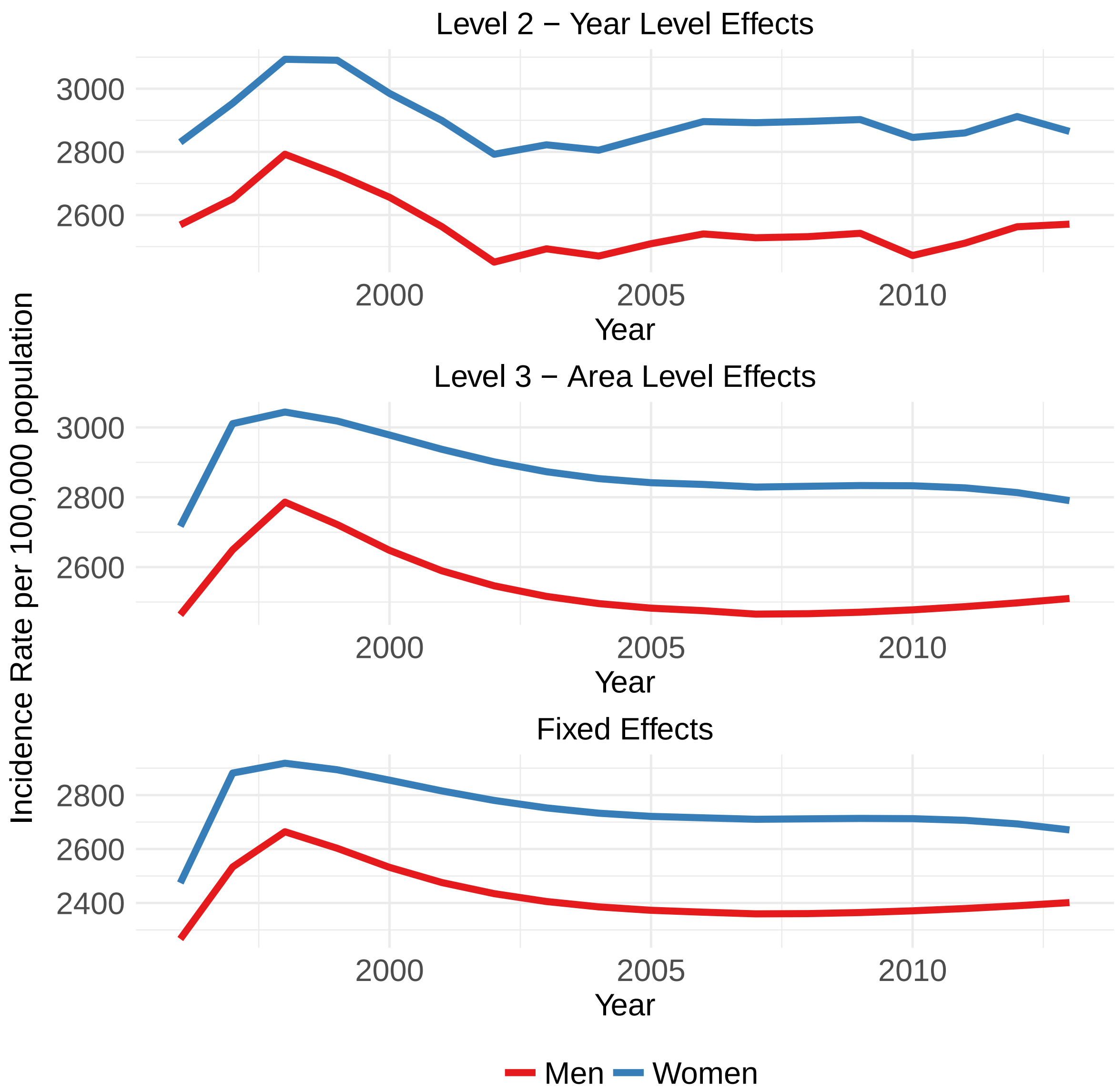


Figure 5.32: Predicted age standardised incident hospitalisation rates: men and women, 1996 - 2013

The level 2 effects in Figure 5.32 reflect the random effects of year in the data, whereas the level 3 effects reflect predictions made at the area level. The predicted rates at the area level are smoother than those of the year level, and are similar to the trend in the fixed effects. Predicted rates for women are consistently higher than those for men, as previously seen in the observed rates in Figure 5.2.

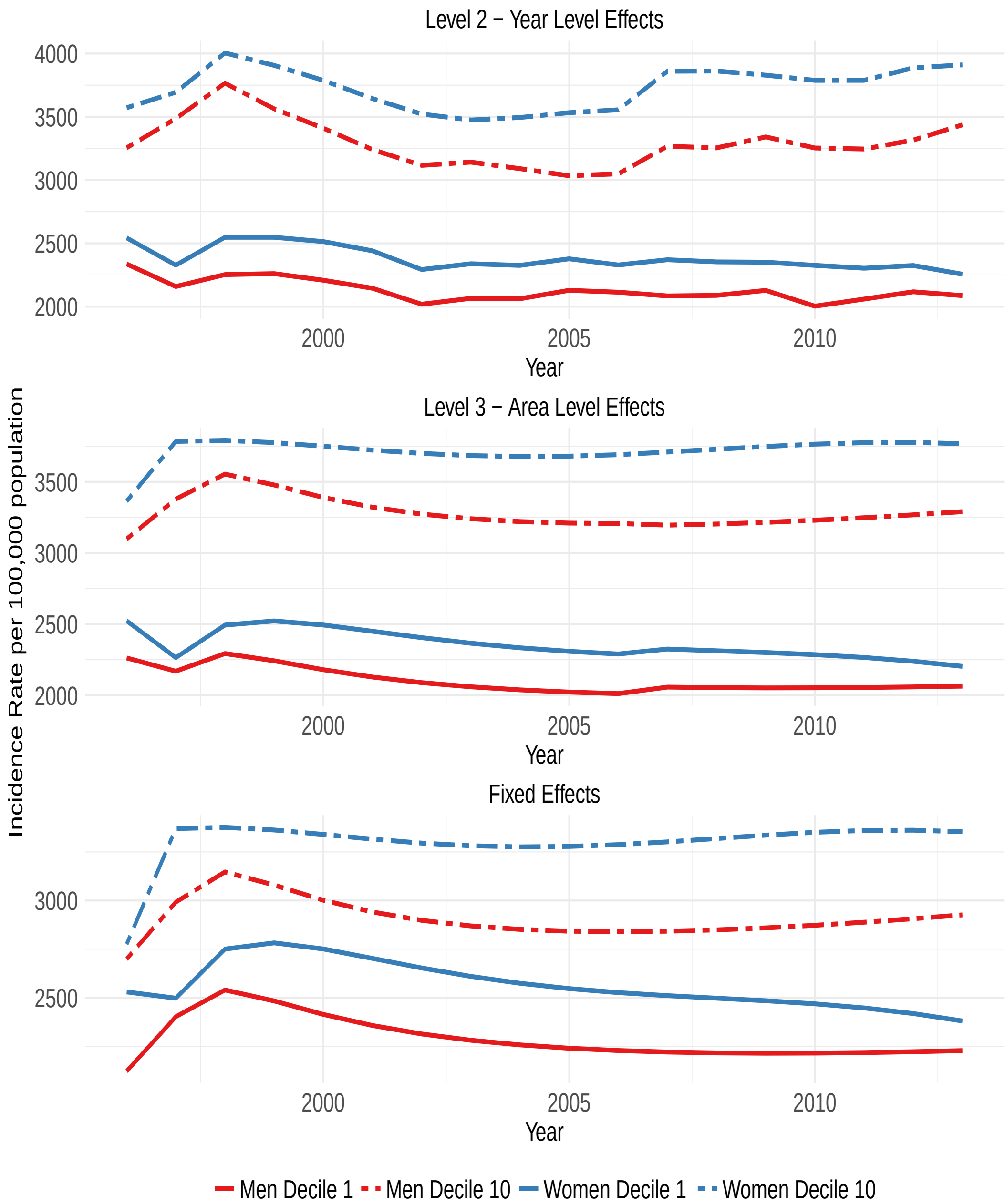


Figure 5.33: Predicted age standardised incident hospitalisation rates by deprivation decile: men and women, 1996 - 2013

Figure 5.33 describes the predicted incident hospitalisation rates for each sex in the most and least deprived deciles. The effects of the fractional polynomial transformations of decile, year and their interaction are clear - there was a sharp increase in predicted incident hospitalisation rates for both sexes in the most deprived at the beginning of the analysis period, whereas the least deprived deciles generally experienced decreases.

5.4.6 Sensitivity analyses

These sensitivity analyses aim to explore the effect of using a longer period of time in order for a case to be considered incident. In the main analyses, a 5 year limit was used, whereas these analyses will use a 7 year limit - identifying patients who had not been hospitalised for the same condition either earlier that year, or within the 6 years previously.

Descriptive statistics

Table 5.7 describes the distribution of cases across the years and diagnosis groups. In comparison to Table 5.1, the use of the 7 year period has decreased the overall number of cases by 280,289 (7.5%), mainly due to the exclusion of records generated in 1985 and 1986 as they now become part of the burn in period required to identify incident cases. The number of PP, EDI and ITMC cases decreased by 6.8%, 6.9% and 7.7% respectively.

Table 5.7: Sensitivity analyses: Numbers (%) of incident hospitalisation cases by year and diagnosis group, 1985 - 2013

Years	No. Years	PP	EDI	ITMC	Total
1987 - 1996	10	60,308 (4.5)	311,524 (23.5)	953,622 (71.9)	1,325,454
1997 - 2006	10	56,434 (4.6)	330,564 (26.8)	847,637 (68.7)	1,234,635
2007 - 2013	7	45,957 (5.0)	228,223 (25.0)	637,925 (69.9)	912,105
Total:	27	162,699 (4.7)	870,311 (25.1)	2,439,184 (70.2)	3,472,194

Age standardised incident hospitalisation rates

Figure 5.34 graphs the absolute difference between the 5 and 7 year incident hospitalisation rates. The 5 year incident hospitalisation rates are consistently larger than those calculated using 7 years to identify incident cases. The difference is greatest in the later years, whilst the early years are fairly similar. Women consistently have a greater rate difference, than men.

Breaking the overall counts down by age revealed little difference to results for the 5 year incidence presented in Figure 5.20, as are the trends in age-specific incident hospitalisation rates in Figure 5.21.

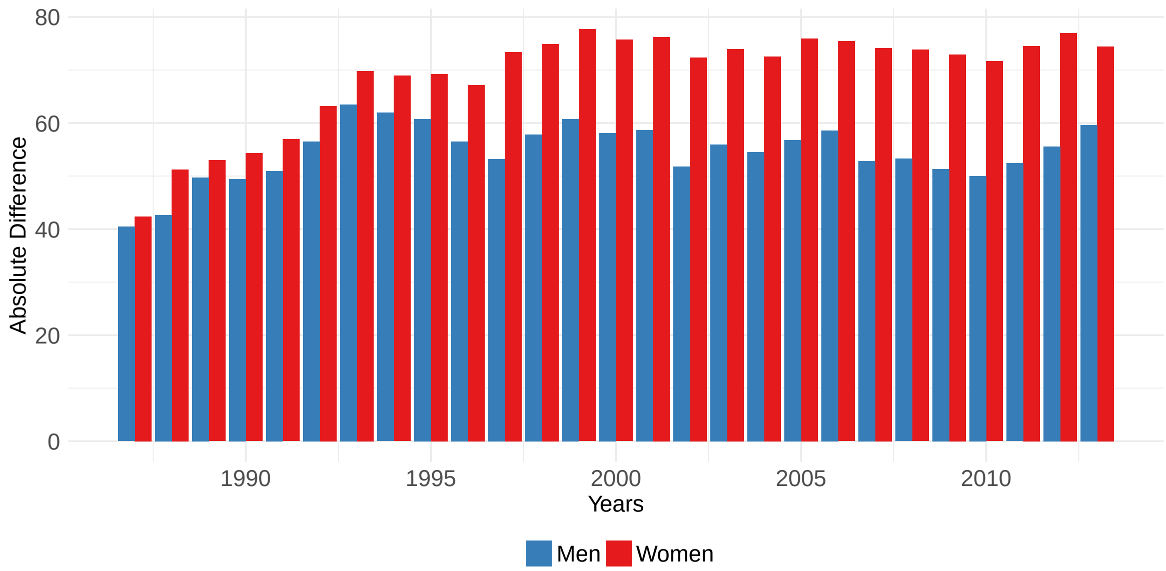


Figure 5.34: Sensitivity analyses: Absolute difference between 5 and 7 year incident hospitalisation rates (per 100,000 population): men and women, 1987 to 2013

Comparing the trends in cause specific incident hospitalisation rates between the two limits, the incident hospitalisation rates using the 5 year limit are higher than the 7 year limit for conditions which can result in multiple hospitalisations, such as diabetes, shown in Figure 5.35. Where amenable conditions are specific to a particular period, such as maternal and perinatal conditions, or can be cured through surgery, such as appendicitis, the incident hospitalisation rates are more likely to be the same for the two limits.

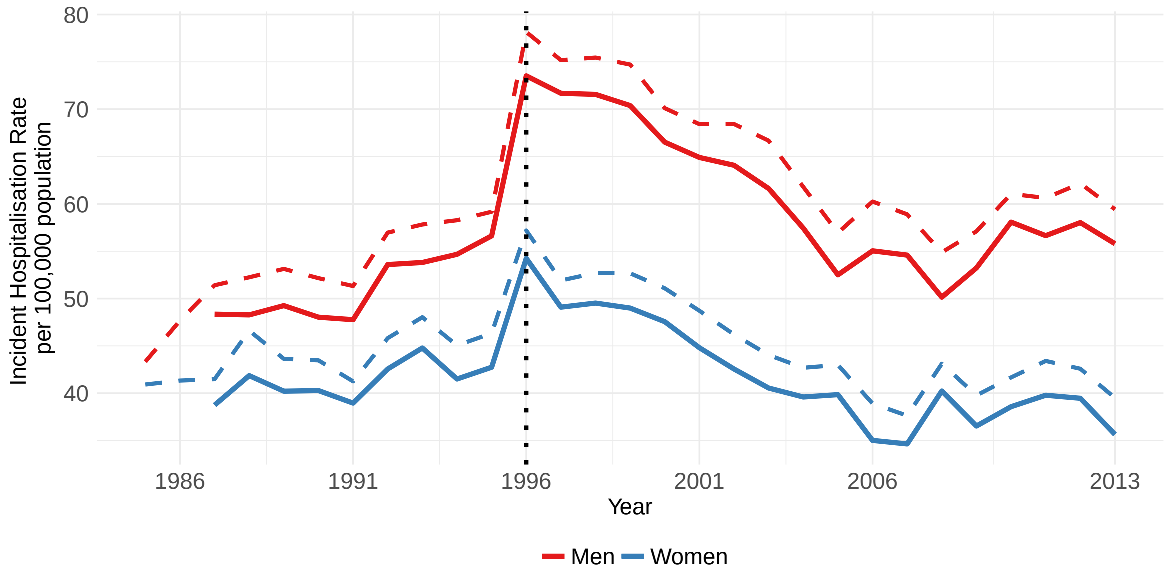


Figure 5.35: Sensitivity analyses: Incident hospitalisation rates using 5 year incidence (dashed lines) and 7 year incidence (solid lines) for diabetes mellitus: men and women, 1985 - 2013. The vertical dashed line indicates the introduction of ICD 10 to code the reason for hospitalisation

Fractional Polynomials

Fractional polynomial transformations were re-estimated for the 7 year incident data. For men, shown in Table 5.8, the transformations for age and deprivation decile, and one of their interactions were the same as before, however, the transformations chosen for year, and its interactions were different to those given in Table 5.3.

Table 5.8: Sensitivity analyses: Fractional polynomial transformations of covariates: men

Covariate	FP	Transformation
Age (1)	0	$log_e(\frac{A}{10}) - 1.308$
Age (2)	1	$\frac{A}{10} - 3.7$
Year_c (1)	-2	$(\frac{Y_c+1}{10})^{-2} - 1.108$
Year_c (2)	-2	$((\frac{Y_c+1}{10})^{-2} \times log_e(\frac{Y_c+1}{10})) + 0.057$
Decile (1)	0	$log_e(D) - 1.705$
Decile (2)	3	$D^3 - 166.375$
Age × Year_c (1)	0.5	$(\frac{A \times Y_c+1}{1{,}000})^{0.5} - 0.562$
Age × Year_c (2)	0.5	$((\frac{A \times Y_c+1}{1{,}000})^{0.5} \times log_e(\frac{A \times Y_c+1}{1{,}000})) + 0.748$
Age × Decile (1)	1	$\frac{A \times D}{100} - 2.035$
Age × Decile (2)	1	$(\frac{A \times D}{100} \times log_e(\frac{A \times D}{100})) - 1.446$
Decile × Year_c (1)	-0.5	$(\frac{D \times Y_c+1}{100})^{-0.5} - 1.447$
Decile × Year_c (2)	1	$\frac{D \times Y_c+1}{100} - 0.478$
Age × Decile × Year_c(1)	-2	$(\frac{A \times D \times Y_c+1}{10{,}000})^{-2} - 33.383$
Age × Decile × Year_c (2)	-1	$(\frac{A \times D \times Y_c+1}{10{,}000})^{-1} - 5.778$

Y_c = Year_c = Year - 1996
A = Age
D = Decile

Comparing the 7 year incident fractional polynomial estimates in Table 5.9 to the 5 year estimates in Table 5.4 for women, all three main effects, and the interactions between age and year, and age and decile have the same transformations applied to them, however, the interactions between decile and year, and the three way interactions have different transformations applied.

Table 5.9: Sensitivity analyses: Fractional polynomial transformations of covariates: women

Covariate	FP	Transformation
Age (1)	-2	$(\frac{A}{10})^{-2} - 0.073$
Age (2)	3	$(\frac{A}{10})^{3} - 50.653$
Year_c (1)	3	$(\frac{Y_c+1}{10})^{3} - 0.857$
Year_c (2)	3	$((\frac{Y_c+1}{10})^{3} \times log_e(\frac{Y_c+1}{10})) + 0.044$
Decile (1)	0	$log_e(D) - 1.705$
Decile (2)	3	$D^3 - 166.375$
Age $\times$ Year_c (1)	2	$(\frac{A \times Y_c+1}{1{,}000})^{2} - 0.010$
Age $\times$ Year_c (2)	2	$((\frac{A \times Y_c+1}{1{,}000})^{2} \times log_e(\frac{A \times Y_c+1}{1{,}000})) + 0.115$
Age $\times$ Decile (1)	-1	$(\frac{A \times D}{100})^{-1} - 0.491$
Age $\times$ Decile (2)	-0.5	$(\frac{A \times D}{100})^{-0.5} - 0.701$
Decile $\times$ Year_c (1)	0	$log_e(\frac{D \times Y_c+1}{100}) + 0.74$
Decile $\times$ Year_c (2)	0	$log_e(\frac{D \times Y_c+1}{100})^{2} - 0.546$
Age $\times$ Decile $\times$ Year_c (1)	0	$log_e(\frac{A \times D \times Y_c+1}{10{,}000}) + 1.754$
Age $\times$ Decile $\times$ Year_c (2)	0.5	$(\frac{A \times D \times Y_c+1}{10{,}000})^{0.5} - 0.416$

Y_c = Year_c = Year - 1996

A = Age

D = Decile

Multilevel Modelling

There were 545,580 rows of data, pertaining to 2,184,864 incident cases and a population at risk of 85,939,690 over 18 years and 1,987 areas. After increasing the population in areas with incident cases, but zero population, the new population size was 85,939,848.

There were 987,773 male incident records used in the multilevel analysis:

Table 5.10: Sensitivity analyses: Incident Rate Ratios and 95% confidence intervals derived from multilevel modelling: men, 1996 - 2013

Men	FP	IRR	95%CI
Intercept		0.011	
FP age 1	0	0.179	(0.18 - 0.18)
FP age 2	1	2.276	(2.27 - 2.28)
FP year 1	-2	1.052	(1.04 - 1.06)
FP year 2	-2	1.029	(1.02 - 1.03)
FP decile 1	0	0.861	(0.84 - 0.89)
FP decile 2	3	1.000	(1.00 - 1.00)
FP age × year 1	0.5	0.886	(0.85 - 0.92)
FP age × year 2	0.5	1.104	(1.08 - 1.13)
FP age × decile 1	1	1.177	(1.17 - 1.19)
FP age × decile 1	1	0.983	(0.98 - 0.98)
FP year × decile 1	-0.5	0.989	(0.97 - 1.00)
FP year × decile 2	1	1.064	(1.04 - 1.09)
FP age × decile × year 1	-2	1.000	(1.00 - 1.00)
FP age × decile × year 2	-1	0.999	(0.99 - 1.00)

FP: fractional polynomial

IRR: Incident rate ratio

95% CI: 95% confidence interval

Men	Coef.	s.e.	MRR
σ^2_{v0}	0.082	0.003	1.314
σ^2_{u0}	0.027	0.001	

Where σ^2_{v0} and σ^2_{u0} correspond to the variation at the area and year level respectively.

The MRR for the data using the 7 year incidence are approximately equal to those calculated for the 5 year incidence limit, despite the use of different fractional polynomials. Within a given deprivation decile, there is a 31.4% increased risk, in median, associated with an area with a higher incident hospitalisation rate, compared to an area with a lower rate.

Table 5.11: Sensitivity analyses: Incident Rate Ratios and 95% confidence intervals derived from multilevel modelling: women, 1996 - 2013

Women	FP	IRR	95%CI
Intercept		0.022	
FP age 1	-2	1.091	(1.09 - 1.09)
FP age 2	3	1.002	(1.00 - 1.00)
FP year 1	3	1.168	(1.15 - 1.19)
FP year 2	3	0.824	(0.80 - 0.84)
FP decile 1	0	0.695	(0.68 - 0.71)
FP decile 2	3	1.000	(1.00 - 1.00)
FP age × year 1	2	0.465	(0.45 - 0.48)
FP age × year 2	2	6.747	(6.40 - 7.11)
FP age × decile 1	-1	1.059	(1.06 - 1.06)
FP age × decile 1	-0.5	0.501	(0.49 - 0.51)
FP year × decile 1	0	0.777	(0.76 - 0.79)
FP year × decile 2	0	0.909	(0.90 - 0.92)
FP age × decile × year 1	0	0.934	(0.93 - 0.94)
FP age × decile × year 2	0.5	4.834	(4.56 - 5.12)

FP: fractional polynomial

IRR: Incident rate ratio

95% CI: 95% confidence interval

Men	Coef.	s.e.	MRR
σ^2_{v0}	0.080	0.003	1.309
σ^2_{u0}	0.027	0.001	

Where σ^2_{v0} and σ^2_{u0} correspond to the variation at the area and year level respectively.

The area level MRR for women using the 7 year incidence dataset is 30.9%. This is slightly lower than the MRR previously calculated using the 5 years (MRR = 32.9%).

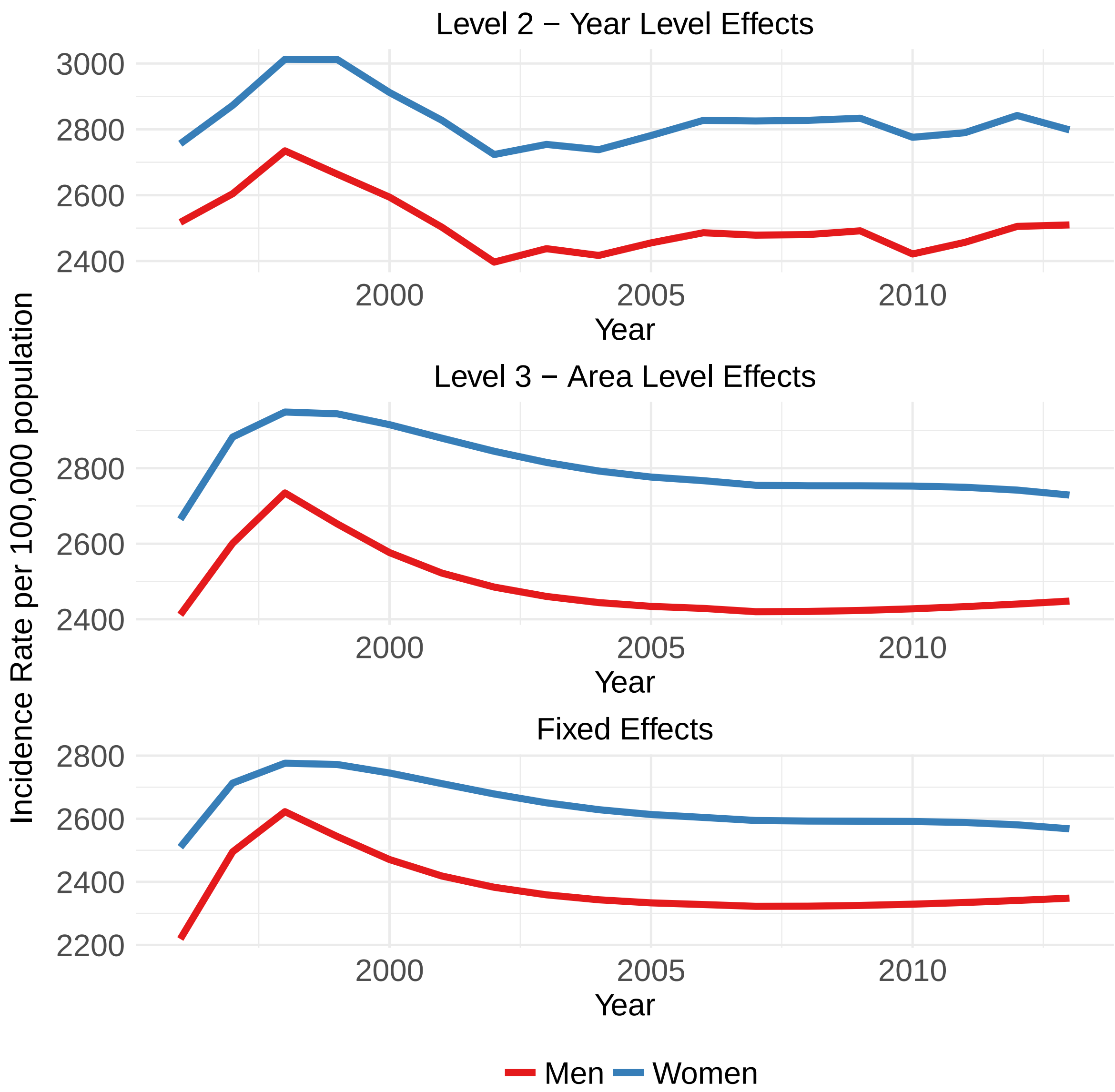


Figure 5.36: Sensitivity analyses: Predicted age standardised incident hospitalisation rates: men and women, 1996 - 2013

The predicted age standardised incident hospitalisation rates for men using the 7 year definition of incident hospitalisation cases appear to be fairly similar to those predicted using the 5 year definition, shown in Figure 5.32.

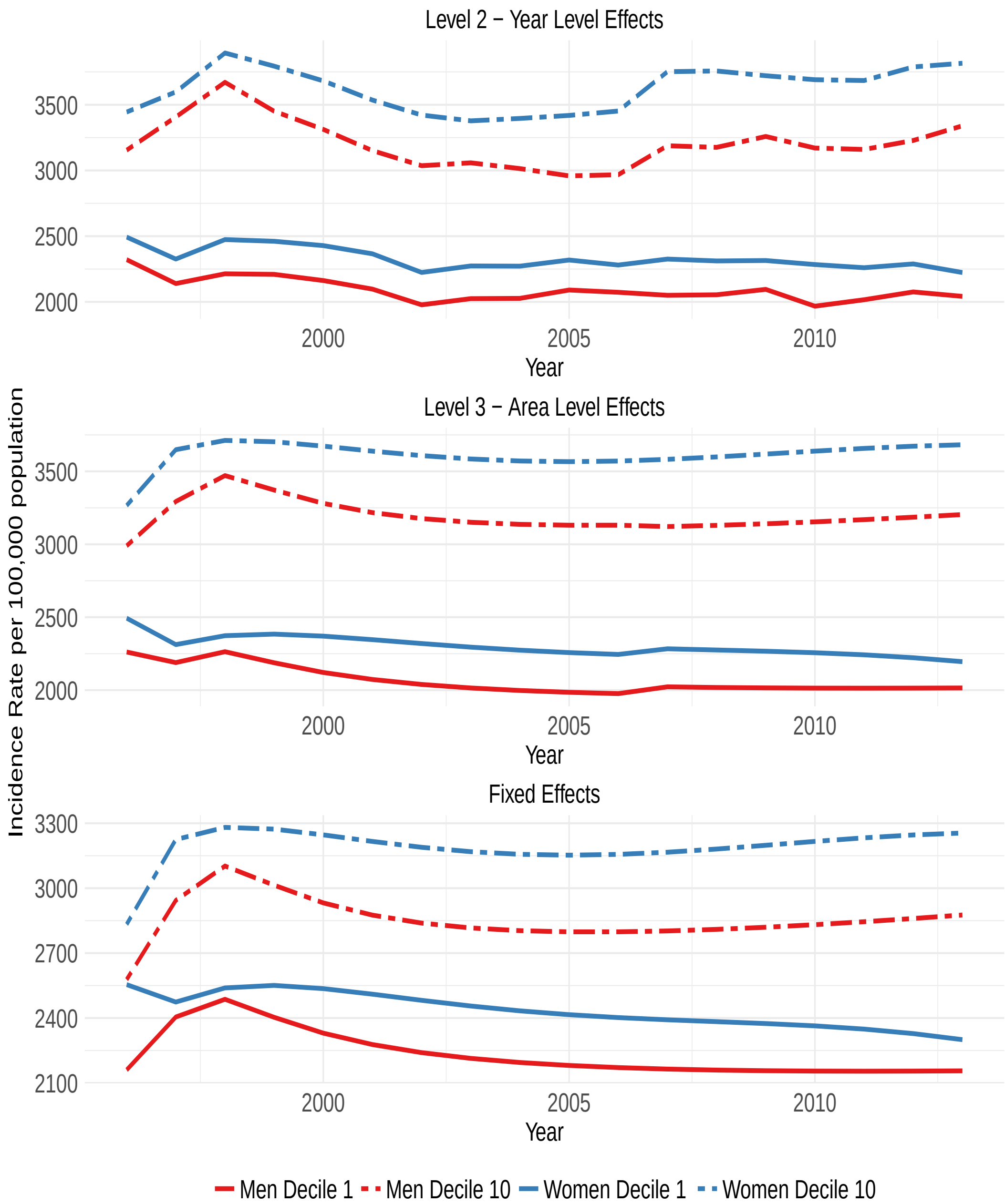


Figure 5.37: Sensitivity analyses: Predicted age standardised incident hospitalisation rates by deprivation decile: men and women, 1996 - 2013

Again, the predicted rates estimated for the 7 year incidence data in Figure 5.37 do not appear to be largely different to those previously estimated for the 5 year incidence data in Figure 5.33, for both men and women.

5.5 Discussion

This chapter has explored the incident hospitalisation rates of conditions which should not result in premature death, given timely access to health care. The rationale behind this investigation is the supposition that declines in rates of amenable mortality, as seen in chapter 4, may be reflecting declines in the incidence of the conditions, rather than improvements in the health care system.

5.5.1 Principal findings

This analysis revealed that the overall incident hospitalisation rates increased in both men and women prior to 1996, and that there was little difference in rates between the sexes. In 1996, male overall incident hospitalisation rates saw a sharp decline, owing to the large decline in the incident hospitalisation rates for obstructive uropathy and prostatic hyperplasia (see Figure 5.12). Female incident hospitalisation rates did not experience the decline to the same extent as male rates, given that prostatic hyperplasia is present only in men, introducing a greater separation between the sexes. From approximately 1998 onwards, the female incident hospitalisation rates have mirrored those of the males, with the lowest point reached in 2002, and a slow increase to 2013. This is in contrast to the consistent decline in mortality rates found in chapter 4 for both sexes. Therefore, the declines in rates of amenable mortality in Scotland are not solely reciprocal of declining rates of incident hospitalisations in the population.

The proportions of conditions amenable to health care within the three diagnosis groups differ between the mortality and incident hospitalisation rates; the ITMC group has a greater proportion of incident hospitalisations, whilst the EDI group has a greater proportion of the overall deaths. The trends in rates by sex also differ. The ITMC and EDI group have seen decreasing mortality rates over time, whereas incident hospitalisation rates have remained relatively constant, with a gradual increase within the ITMC group. The impact of the inclusion of female specific conditions, such as maternal conditions, is more evident in the ITMC group, where female rates of incident conditions exceed those of male, whereas the converse is true in the mortality rates.

Two of the individual amenable conditions selected for further exploration, breast and skin cancers, exhibited an inverse relationship with deprivation; whereby the lesser deprived individuals were experiencing higher rates of incident hospitalisations. Two possible explanations exist for this: differential screening and diagnosis rates, whereby those in the least deprived areas are more likely to attend screening programmes, and therefore have their cancers detected, or there is a true increased incidence of these cancers in the lesser deprived areas. If it were simply the latter case, it could be expected that mortality rates would reciprocally be higher in the lesser deprived areas, however, Figure 4.14 for breast cancer indicates no clear deprivation gradient, and Figure B.5 indicates that there were insufficient numbers of deaths within each deprivation decile to form a gradient in skin cancer mortality rates.

The impact of changes to recording practices, through both the changes made to neonatal and birth records, as well as changing from ICD 9 to 10 are evident in the majority of figures included in this chapter. Bridge coding between ICD 9 and ICD 10 was conducted in Scotland, whereby all deaths (at all ages) registered in Scotland in 1999 were coded twice, using both versions (General Register Office for Scotland 2001). A similar exercise was not performed for the morbidity records, however the change of ICD coding did not have the same effect on the incident hospitalisation rates of pneumonia as was seen in the mortality rates.

Comparing the proportions of each conditions' in contribution to the overall number of incident hospitalisations and deaths found 3 groups of conditions - those which had both high numbers of cases and deaths, those with high incident hospitalisations and low deaths, and, most of interest, those with low incident hospitalisations in hospital but high number of deaths. The third group includes cancers, which are amenable through early detection and intervention, and conditions which require long term medical care and management. The low incident hospitalisations but high numbers of deaths due to hypertensive disease, diabetes and COPD are indicative of a limitation of using secondary care records only in this analysis - these conditions are typically managed in a primary care setting, and so the incident hospitalisation rates are reflecting only the most severe cases which require hospitalisation, and not those who successfully manage their chronic conditions.

With regards to inequalities, relative inequalities in incident hospitalisation rates were much smaller than those estimated for the mortality rates, with a lower rate of increase over the study period. However, absolute inequalities were larger in the incident hospitalisation rates, due to the larger overall rates of incident hospitalisations compared to rates of deaths, and have been increasing over the last 10 years of the analysis period. The increasing absolute inequalities in incident hospitalisation rates are a contrast to the decreasing inequalities found in mortality rates. The opposing relationships mirror those of the overall mortality and incident hospitalisation rates. Within the diagnosis groups, the largest relative inequalities were found in both the primary prevention, and improved treatment and medical care group, although the confidence intervals around the latter were much tighter given the larger numbers of cases. The relative inequalities within the early detection and intervention group are the lowest in both sexes, and in women, there were 6 years in which there were no significant differences between incident cases in the most and least deprived areas. The inverse relationships noted in the individual plots of breast (Figure 5.9) and skin (Figure 5.19) cancers will be contributing towards this.

The fractional polynomials used to model the continuous variables of age, year and deprivation decile found that there was almost no change in the age-specific incident hospitalisation rates at the older ages in the most deprived deciles between 1996 and 2013, that there has been a slow increase in age-specific incident hospitalisation rates over the analysis period, and there was a greater decrease in age-specific incident hospitalisation rates between 1996 and 2013 within the least deprived deciles, than within the most deprived deciles. The multilevel modelling procedures found far greater area level variation in the incident hospitalisation rates than the mortality rates.

5.5.2 Strengths and limitations

This is the first analysis of incident hospitalisation rates of amenable conditions in Scotland, and one of just three analyses ever. Over 3 decades of hospital discharge, cancer registrations, birth and death records were obtained for analysis. An extensive range of analyses have been presented, along with sensitivity analyses exploring the effects of the time limit considered for incident conditions.

However, there are some limitations. This analysis used hospital discharge records, cancer registrations, birth and death records as a proxy measure for disease incidence. Variations in the quality of recording and in admissions policies, as well as multiple admissions have been previously identified as potential influences on the validity of this proxy (Treurniet et al. 1999). Variations in the quality or frequency of recording has been found to be fairly consistent, with the accuracy of main condition coding averaging 89%, and main operation coding averaging 94% between 1992 and 2014/15 for SMR01 records (Data Quality Assurance 2015). Similar audits for SMR06 have not yet been published. With regards to variations in admissions policies, this could have been adjusted for by using the total number of admissions as the denominator, rather than the population at risk. However, admission criteria may still vary for specific diagnoses. The impact of multiple admissions for the same diagnosis has been limited through the use of linked data and the 5 or 7 year limit to identify ‘first discharges’. The data will be most accurate for conditions which should require only one hospitalisation, such as appendicitis, and are reliant on the accuracy of the linkage process. As noted in the Data Cleaning section of this chapter, there were cases where records were linked incorrectly, however, these were minimal, and it can be assumed that multiple admissions for the same conditions have been removed from the final dataset.

The analyses presented in this chapter were based upon only using the primary diagnosis or cause of death to identify incident hospitalisations or cases. The datasets supplied by eDRIS included any record which had an amenable condition listed in any of the diagnosis categories, therefore there was the potential for more cases to be identified. The inclusion of the additional codes may have improved the estimates for conditions which do not routinely require hospitalisation, such as asthma or hypertension, however, additional codes are only included on health records if they co-existed with the main diagnosis, developed during the healthcare episode, or could affect the management of the patient's care (ISD Scotland, n.d.*a*). Therefore, the additional codes are unlikely to identify all cases within the population.

Limitations of the datasets used to identify incident cases themselves also need to be considered. The Scottish Morbidity Records are not a complete record of the incidence of all amenable conditions in Scotland. The datasets will naturally not include any person who has the disease, but has not received a formal diagnosis. The datasets will also not include a record of all persons diagnosed with amenable conditions which do not routinely require secondary health care (i.e. admission to hospital). Examples of these include measles, asthma, and diabetes. Only the most severe cases of these conditions will require hospitalisation, whilst the vast majority will be managed through primary care services. This underestimation was considered at the point of applying for access to the data. The Prescribing Information System dataset was considered for inclusion, as this would provide information on all medications that are prescribed and dispensed. However, individual patient linkage is not possible for data generated prior to April 2009 (Administrative Data Liaison Service n.d.*b*), and the dataset details only the medications prescribed and dispensed, rather than the patient diagnosis. Therefore this dataset was not considered a suitable source for these analyses. The Scottish Primary Care Information Resource[3] is a service which enables data extractions from primary care settings. As this resource is currently being phased in across Scotland, due for completion in 2017, future updates to this research may benefit.

5.5.3 Relations to other studies

As highlighted in the strengths section, as well as in the literature review, only two other published studies have explored the incident hospitalisations of amenable conditions in the general population; Bauer & Charlton (1986) and Treurniet et al. (1999).

The analyses conducted in England and Wales in 1974-78 by Bauer & Charlton were limited

[3]SPIRE: http://spire.scot/professional/

to a 10% sample of hospital discharge records, along with disease registries. The study did not have any record linkage, therefore is likely to have overestimated the SMRs calculated, due to over-counting people with multiple admissions over the study period.

The second analyses, conducted in the Netherlands, made use of linked hospital discharge data over a 10 year period, however did not use any disease specific registries. The 5 year limit to identify ‘first discharges’ used by Treurniet et al. was replicated in this analysis.

Both studies found that significant area level variation in amenable mortality rates remained after adjusting for the incidence of the conditions across the areas of interest.

5.5.4 Implications

The cause specific analyses conducted in this chapter, as well as in the previous chapter, highlight both well performing and problematic areas of the Scottish health care system. Breast, bladder and colorectal cancers were identified as contributing towards a large proportion of the overall amenable deaths in Table 4.6, however, this chapter found that they were not identified as having a large number of incident cases. These cancers are amenable through early detection and intervention, and the disparity between cases and deaths suggests that cases are not being identified early enough to prevent death. The same disparity was found for hypertensive disease, diabetes and COPD, however, the inability to include cases managed within primary care for these three conditions is likely to be a contributing factor. The successes of the health care system are found in those cases with high levels of incident hospitalisations, but low numbers of deaths. Seven of the nine conditions are amenable through improved treatment and medical care, and are generally those which require specialist care, such as surgeries. None of the conditions avoidable through primary prevention were identified as having particularly high incident hospitalisations within the Scottish population.

Given the universal health care system operating in Scotland, gradients and inequalities in rates of incident hospitalisations are difficult to assess and explain; differences in referral or admission policies, timely access to health care, or uptake of screening or immunisation services are all potential explanations for variation (McLaren & Bain 1998) across subgroups of the population.

5.5.5 Next steps

The previous two analysis chapters have explored gradients in the mortality and incident hospitalisation rates of amenable conditions in Scotland, using an area level deprivation. However, as discussed in section 3.5, the results found using a measure area level deprivation may be biased through ecological fallacy, whereby not all people living within a given area are experiencing the same levels of deprivation (Scottish Government 2008). Therefore, the next chapter of this thesis will explore individual level socioeconomic gradients in mortality rates, through the use of a longitudinal study sample of the Scottish population.

Results of this chapter will enable some comparison with other European countries which do not make use of area level measures of deprivation used in the previous and current chapters.

Chapter 6

Amenable mortality by individual measures of socioeconomic position

6.1 Introduction

This chapter makes use of individual level measures of socioeconomic position (SEP) collected in the Scottish Longitudinal Study (SLS) to measure the absolute and relative inequalities in amenable, non-amenable and all cause mortality between the most and least advantaged categories of each indicator.

Individual measures of socioeconomic position are commonly used to explore gradients in mortality in a number of European countries, made possible through the use of personal identifiers (McCallum et al. 2013). In Scotland, and the UK as a whole, population-wide personal identifiers are only available for linkage of health records, therefore we are typically reliant on unlinked study designs when including socioeconomic variables into the analyses. Linked longitudinal studies, containing a sample of the population, have made international comparisons possible, however, limitations on detail of information collected by the studies does introduce some challenges (Feinstein 1993).

The Scottish Longitudinal Study (SLS) has provided the means to study the socioeconomic patterning of rates of amenable mortality at the individual level for a representative sample of the Scottish population (objective 4 of this thesis, see section 1.1). The results will allow for an assessment of Scotland's position within Europe.

6.2 Individual measures of Socioeconomic Position

Candidate individual measures of SEP and demographic factors previously used to investigate gradients in amenable mortality were identified in the main literature review (see chapter 2). Explicit individual level measures of SEP such as education, occupation and income, as well as demographic groupings such as ethnicity and marital status have previously been identified as being closely linked to the successful utilisation of health care (Commission on Social Determinants of Health 2008), which is, in turn, linked to rates of mortality amenable to the health care systems.

Each of the candidate measures are assessed below; comprising a brief description and justification for its use in wider mortality studies, details of previous categorisations used, as well as a review of selected empirical studies relevant to this chapter.

Relevant studies were selected on the basis of whether they:

- explored gradients of individual measures of SEP within deaths either in a single or cross country comparison; or
- were of similar design to the Scottish Longitudinal Study i.e linked census-mortality studies.

6.2.1 Educational Attainment

Educational attainment is considered to be the most basic measure of SEP, given its influence over future occupation and income (Adler & Newman 2002). Over the years, it has remained a consistently popular measure, owing to its ease of measurement, applicability to both genders, and wide availability in many countries (Strand et al. 2007).

An advantage of using educational attainment is that the highest level of education attained by a given person is typically obtained in early adulthood, and thereafter remains stable over the life course for the majority of the population (Reques et al. 2014). Whilst this is attractive for studies that only collect data at baseline, suitable age ranges must be considered. The distribution of educational attainment across the age groups and sexes has shifted over the years; the proportion of people attaining higher levels of education has been seen to be increasing (Ostergren 2015).

Educational attainment has been used as a proxy measure of health awareness and literacy in many studies. These have shown that those with higher levels of education often have a better understanding of health promotion literature, are more effective users of the health care available, have a higher attendance at screening programmes and conduct more frequent self-examinations, especially where cancers are studied (Davey Smith et al. 1998, Adler & Newman 2002, Bautista et al. 2005).

Whilst there are many advantages of using educational attainment, there are several disadvantages. Cross country comparisons are reliant on being able to create consistent categories. This is relatively easy in countries that have similar schooling structures, however where the countries are further apart, attainment is difficult to compare. High levels of education are not necessarily associated with high levels of income, or better occupations, which have also been associated with lower rates of death (Martikainen et al. 2007), especially at the older ages (Huisman et al. 2005). Racial, ethnic and gender group differences may also impact the level of education a person is able to attain (Lynch & Kaplan 2000).

Measures of educational attainment

There are three main methods of measuring educational attainment: the most commonly used categorisation system is the level of schooling reached, typically measured using the International Standard Classification of Education (ISCE). This classification system is favoured as it can be applied to most cross-country comparisons, maximising the comparability between countries. The system's seven categories are typically collapsed into four categories: (1) pre-primary and primary school; (2) lower secondary education; (3) upper secondary education; and (4) tertiary ('post-secondary') education (Reques et al. 2014); however, categories (1) and (2) are also commonly amalgamated (Strand et al. 2007, Menvielle et al. 2008).

The second most commonly used measure of attainment is the educational qualifications obtained. This is used in the UK's Longitudinal Studies, and categorises schooling, college and university level qualifications. This allows for more detail than the ISCE's tertiary category contains, as apprenticeships and vocational training can be distinguished from college or university qualifications (Schwarz 2007).

Time measurements are the third method, however, they are not commonly used. Davey Smith et al. (1998) makes use of age at time of leaving full time education as the measure of educational attainment. The categories used are 12 - 14 years of age, 15 - 16, 17 - 18 and 19+, allowing for graduate levels of schooling. Time spent in education is an alternate measure (Lantz et al. 1998, Bautista et al. 2005, Elo & Drevenstedt 2006). Huong et al. (2006) categorised people in rural Vietnam according to whether they had no education (illiterate), up to five years, or over five years. The low cut off point reflects the level of compulsory education required in Vietnam (to primary school level only). Disadvantages of this measure of attainment include that they can be influenced by minimum school leaving age laws and employment opportunities at the time, therefore any effects found may be reflecting the impacts of changes to legislation (Davey Smith et al. 1998).

The type of categorisation used is heavily dependent on the level of detail available in the data. The education data collected in the SLS prior to 2001 only contain information on qualifications gained after the age of 18. Therefore, this variable could only be categorised into the two highest categories of the full ISCE (first and secondary stages of tertiary education).

Selected key results

Associations between educational attainment and mortality

The majority of cross-country mortality analyses that have investigated educational inequalities have been carried out by Mackenbach, Kunst, and the EU Working Group on Socioeconomic Inequalities in Health. European countries have been investigated in the majority of studies, however, New Zealand (Fawcett et al. 2005, Wamala et al. 2006), and the United States (Kunst & Mackenbach 1994, Mackenbach et al. 1999) have also been included in a number of comparisons.

Relative and absolute inequalities in all-cause mortality by educational attainment have been found to be increasing over time for many countries (Strand et al. 2014, Mackenbach et al. 2015). Strand et al. (2014) found significant increasing trends in the Relative Index of Inequality (RII) and Slope Index of Inequality (SII) for women, and in RII only for men, in all-cause mortality in the decades between 1960 and 2009 in Norway.

Borrell et al. (2008) analysed all-cause mortality in Barcelona over a 12 year period. Five categories of educational attainment were used to explore relative inequalities in mortality in four 3-year periods between 1992 and 2003, however, the youngest deaths included in the analyses (20 years) would not have had the opportunity to attain the highest level of education as yet. A large proportion of deaths corresponded to people with lower than primary-level education (>60% for men, >80% for women). Over the 12 year period, relative inequalities in all cause mortality remained constant (p >5%).

A number of countries now have linked census and mortality records, in order to explore socioeconomic gradients in deaths. Flanagan & McCartney (2015) found an inverse relationship between educational attainment and rates of mortality in 1971 to 2009, using the ONS LS. However, a large proportion of study members reported having ‘no [over age 18] education’ in the period before 2000, meaning that all results are likely to be imprecise.

Kulhanova et al. (2014) analysed data from 9 European countries, using census-linked studies, undertaken at either the national (n=5), regional (n=2), or urban (n=2) level. The years of analyses fall within the 1990's, but length of follow up differs across each study. Three categories of the ISCE were used in order to create comparable data. The results are reproduced in Table 6.1. Relative inequalities in all cause mortality were found to be between 1.4 and 2.2, and inequalities for men were greater in all countries, except for Sweden and Denmark.

Table 6.1: Relative index of inequality (RII) for total mortality by educational level, and corresponding 95% confidence intervals for nine European populations, 30-74 years

Country	All Cause mortality	
	Men RII (95%CI)	Women RII (95%CI)
Western Europe		
Belgium	1.97 (1.92 - 2.02)	1.73 (1.67 - 1.79)
Nordic Countries		
Sweden	1.79 (1.76 - 1.81)	1.84 (1.80 - 1.88)
Finland	2.20 (2.15 - 2.25)	1.84 (1.78 - 1.89)
Denmark	1.87 (1.82 - 1.93)	1.91 (1.84 - 1.99)
Norway	1.96 (1.92 - 2.00)	1.92 (1.87 - 1.98)
Southern Europe		
Italy (Turin)	1.80 (1.70 - 1.90)	1.40 (1.29 - 1.52)
Spain (Barcelona)	1.70 (1.62 - 1.77)	1.51 (1.40 - 1.62)
Spain (Madrid region)	1.65 (1.52 - 1.79)	1.40 (1.22 - 1.61)
Spain (Basque country)	1.77 (1.66 - 1.89)	1.44 (1.28 - 1.63)

Kulhanova et al., 'Why does Spain have smaller inequalities in mortality? An exploration of potential explanations', The European Journal of Public Health, 2014, 24(3), pp 370-377, by permission of Oxford University Press

The inequalities in all-cause mortality by educational attainment in the SLS have previously been explored by Popham & Boyle (2010), replicating analyses by Mackenbach et al. (2008), however, using shorter periods of analyses than are presented later in this chapter. They found that relative inequalities in Scottish all-cause mortality had increased over the period of analyses, that inequalities were greater than 15 of the 18 countries and regions explored for men (14 of the 18 for women), and that inequalities in both analysis periods exceeded the European average for both sexes.

Studies investigating associations in mortality for ages over 75 years have tended to find smaller, or no relative inequalities between educational groups, compared to younger age groups (Huisman et al. 2005). Explanations for this include a cohort effect (introduction of health education at school etc.), or that the effect of educational attainment diminishes with age (Feinstein 1993).

Amenable mortality and educational attainment
A number of studies have investigated educational inequalities in amenable mortality. Popham & Boyle (2010) also explored absolute inequalities in amenable mortality in the SLS, using educational attainment. For men and women in 1991 - 1999, the SII for amenable mortality were amongst the highest in Europe. The SII of 117 per 100,000 for men was closest to that of France (SII = 114), with the largest inequalities occurring in Lithuania (195) and Estonia (162). When inequalities are measured in female mortality, the SII of 67 per 100,000 for Scottish women is second largest, exceeded only by France with an SII of 82. The inequalities measured in 2001 - 2007 are not compared with other European countries, but are much lower, at 48 per 100,000 for men, and 55 per 100,000 for women.

Plug et al. (2012) explored amenable mortality in 14 European countries, using two levels of education to investigate inequalities in the mortality rates. The largest relative risks of all-cause, amenable, and non-amenable mortality were found in the Baltic region, as well as in Central and Eastern Europe. There was very little difference between the relative risks across the three groups of deaths, however, for Sweden, Finland, and Norway, the relative risk of amenable mortality was much larger than relative risks of all cause or non-amenable mortality.

Relative inequalities in a subset of amenable conditions were investigated for 16 European countries by Stirbu et al. (2010). The results, from 11 longitudinal studies, and 5 cross-sectional unlinked studies, are reproduced in Table 6.2. Relative inequalities in avoidable[1] mortality were greater than in all-cause mortality, in all countries analysed. The smallest inequalities were found in Southern Europe, however, only regions of these countries were included in the analysis. The largest educational inequalities for both all-cause and avoidable mortality are found in the Baltic region, and Central and Eastern Europe. Stirbu et al. adjusted all analyses for age and, unusually, sex. This makes comparisons between other studies difficult, where analyses are typically stratified for sex. The results in Table 6.2, could be compared with Table 6.1 in order to estimate sex-specific inequalities in mortality, however, it must be noted that Kulhanova et al. (2014) make use of a wider age limit than used by Stirbu et al. (2010).

[1] Stirbu et al. use the term 'avoidable', however, the ICD codes included in the definition are considered to be 'amenable', and do not include any 'preventable' deaths. Stirbu et al. exclude IHD, colorectal cancer and diabetes from the list of avoidable conditions.

Table 6.2: Relative indices of inequality for all cause and avoidable mortality by country, aged 30 to 64 years

Country	All Cause		Avoidable	
	RII	(95% CI)	RII	(95% CI)
Western Europe				
Belgium	1.95	(1.90 - 1.99)	2.10	(1.97 - 2.24)
Switzerland	2.28	(2.23 - 2.33)	2.72	(2.54 - 2.92)
Nordic Countries				
Sweden	2.01	(1.97 - 2.05)	2.26	(2.14 - 2.39)
Finland	2.42	(2.37 - 2.48)	2.78	(2.60 - 2.97)
Denmark	2.30	(2.23 - 2.37)	2.47	(2.24 - 2.72)
Norway	2.36	(2.30 - 2.42)	2.78	(2.57 - 3.01)
Southern Europe				
Italy (Turin)	1.66	(1.59 - 1.75)	1.81	(1.56 - 2.10)
Spain (Barcelona)	1.72	(1.65 - 1.79)	1.85	(1.64 - 2.10)
Spain (Madrid region)	1.56	(1.47 - 1.66)	1.70	(1.41 - 2.06)
Spain (Basque country)	1.37	(1.29 - 1.46)	2.04	(1.70 - 2.44)
Baltic region				
Estonia	2.90	(2.79 - 3.03)	3.46	(3.14 - 3.81)
Lithuania	3.50	(3.37 - 3.64)	4.08	(3.69 - 4.51)
Central and Eastern Europe				
Slovenia	2.29	(2.23 - 2.36)	2.97	(2.75 - 3.20)
Poland	4.07	(4.01 - 4.13)	4.61	(4.44 - 4.80)
Czech Republic	4.36	(4.26 - 4.47)	5.34	(4.99 - 5.71)
Hungary	4.21	(4.12 - 4.31)	5.35	(5.05 - 5.68)

Reproduced from Journal of Epidemiology and Community Health, Stirbu et al., 64(10), pp. 913-920, 2010 with permission from BMJ Publishing Group Ltd.

Schwarz (2007) explored amenable deaths in conjunction to individual causes of death in Austria. There was an absolute difference in amenable mortality rates between the most and least educated men of 136 per 100,000 (95%CI 113 - 160), and 82 per 100,000 (95%CI 56 - 109) for women. They found that amenable mortality contributed 21% of the overall mortality disparities in educational attainment for men aged 30-74 in 1991/2, whilst female amenable deaths contributed 32%.

6.2.2 Income

General health, as well as mortality, are considered to be influenced by income, as a larger income provides the opportunity for improved housing, diet, working conditions, as well as medical care in countries without universal health care systems (Lynch & Kaplan 2000). Income also represents a realised level of status, rather than the potential level that educational attainment represents (Sorlie et al. 1995).

However, there are several disadvantages of using income to explore gradients in population health. Causality, and health selection cannot be dismissed in many cases, as poor health may affect a person's ability to receive a better income (Kinge et al. 2015). Income is also not stable over the life course, unlike educational attainment. Therefore studies only able to use baseline data have limited accuracy.

Measurement

Income has been measured in several manners, depending on the data sources available. Studies conducted in Finland have made use of both net income, adjusting for the number of persons within a household (Lumme et al. 2012, McCallum et al. 2013), and consumption income (earned and capital income, as well as social security benefits), adjusted using a consumption weighting scale (Manderbacka, Peltonen & Martikainen 2014). Studies conducted in Norway have made use of similar measures (Kinge et al. 2015), whilst Kawachi & Kennedy (1997) used gross-income, unadjusted for household size, when computing a variety of income inequality indices for a US study.

The accuracy of this measure is dependent on the method of collection. Many countries may only allow the analysis of gross income, whilst others allow for the inclusion of social security benefits and other sources of income. Self-reported income is more prone to non-response and recall bias, due to the personal nature of household finances (Blakely 2001).

Fluctuations in gross or net income over time are influenced by promotions, retirement, and unemployment, whilst consumption income or expenditures are affected by changes in the household structure or by the economy (Lynch & Kaplan 2000, Blakely 2001). Asset wealth has been suggested as an indirect measure of income which may be a better long-term measure of a person's SEP (Lynch & Kaplan 2000). This may be especially useful in studies making use of self-reported, rather than government generated data, as the reporting of assets and house characteristics may be considered to be less invasive (Howe et al. 2012).

Cross-country comparisons using income are rare, owing to country-specific tax regimes, type of data available, and purchasing power (Blakely 2001).

Selected key results

Associations between income and mortality

Strong associations with all cause mortality have been found in countries which have income data available. Blakely et al. (2002) explored relative inequalities in income, education, and area level deprivation. They found that the highest inequalities in all-cause mortality were for income, and that inequalities were larger for men than for women ([2]$RII_{10:90}$ 2.22 and 1.77 respectively). The lowest inequalities were found for colorectal cancers, infections and pneumonia, and female breast cancers, all of which are amenable conditions.

Ostergren (2015) found that inequalities in all-cause mortality in Sweden have decreased between the top two income quintiles, however, the rate ratios between the top and bottom quintiles have significantly increased from 2.26 (95%CI 2.21 - 2.31) to 3.19 (95%CI 3.10 - 3.28) for men, and from 2.28 (95%CI 2.21 - 2.35) to 2.88 (95%CI 2.78 - 2.99) for women between the year groups 1990-94 and 2005-09.

Amenable mortality and income

Very few countries have explored gradients in amenable mortality by income level. The use of personal identifiers for the whole population, and linkages to annual tax statistics makes this possible. Lumme et al. (2012) and McCallum et al. (2013) used the previous year's family net income for adults aged 25 to 74 in Finland. Income was adjusted for family size, and those with no recorded income were assigned to the lowest income group. Table 6.3 details the risk ratios of total amenable mortality experienced by men in Finland over three time periods. The risk ratios increased over the three time periods, especially within the lowest two income quintiles. Ratios for women were smaller, but the gradient remained. Lumme et al. (2012) found little change in absolute inequalities in amenable mortality rates by income ventile (20^{ths}), however, relative inequalities increased with decreasing mortality rates.

[2] The $RII_{10:90}$ compares the 10^{th} percentile rank to the 90^{th} percentile rank, rather than the notionally most deprived, to the notionally least deprived

Table 6.3: Socioeconomic gradients in risk ratios for amenable mortality by income and cause of death, men aged 25-74

Quintile	1992 - 95		1996 - 99		2000 - 03	
	RR	95%CI	RR	95%CI	RR	95%CI
5 (Highest)	1.00		1.00		1.00	
4	1.20	(0.99 - 1.45)	1.46	(1.19 - 1.78)	1.35	(1.10 - 1.66)
3	1.46	(1.23 - 1.73)	1.68	(1.42 - 1.99)	1.65	(1.39 - 1.97)
2	1.90	(1.59 - 2.27)	2.31	(1.91 - 2.80)	2.43	(1.98 - 2.97)
1 (Lowest)	2.83	(2.40 - 3.33)	3.91	(3.27 - 4.68)	4.13	(3.37 - 5.06)

Reproduced from BMC Health Services Research, McCallum et al., 13(3), 2013 with permission from BioMed Central

A study conducted in Norway (Kinge et al. 2015), using equivalised household income, found there were greater absolute inequalities (as measured using the Corrected Concentration Index) in rates of preventable mortality, than in rates of amenable mortality between 1994 and 2011. The inequalities in rates of amenable death had little variation over the study period.

6.2.3 Occupational Social Class

Occupational social class (OSC) is seen as the link between educational attainment and income (Lynch & Kaplan 2000), and attempts to describe the community status, skills, and financial earnings of a person into a single measure (Sorlie et al. 1995).

Occupation explains a large part of the relationship between education, income, and mortality (Lynch & Kaplan 2000). However, OSC is a more complex variable to measure than education or income would be, given how occupations differ in status, required training or qualifications, rewards, and job characteristics, such as autonomy (Adler & Newman 2002). It was traditionally used as the indicator of socioeconomic position for cross-country analyses (Kunst & Mackenbach 1994), however difficulties with differences in classification systems and the exclusion of large parts of the population have lowered its popularity.

Its applicability to only those persons who are (recently) economically active introduces bias through the 'healthy worker' effect, whereby only healthy employees are enumerated, as people who contracted a disease or become injured, are either forced to quit working, or take up less strenuous occupations. Their deaths would be attributed to the 'economically inactive' category or latter occupation, rather than the former occupation in which the disease or injury was contracted (Sutherland 1947). In several studies, 'usual employment' has been used to minimise this (Blakely 2001).

Historically analyses were restricted to men, owing to a lack of women in paid employment (Marshall et al. 1993, Wood et al. 1999, Mackenbach et al. 2003). A selected number of studies have made use of husband's occupation, as reported on death certificates, in an attempt to include female mortality (Sutherland 1947, Mackenbach et al. 1989). This is undesirable due to the potential health selection associated with marriage, whereby healthy individuals are more likely to enter into marriage than those of ill health (Choi & Marks 2011). In recent years, with increasing numbers of women moving into paid employment, analyses performed on both sexes are possible, except when comparing historical data.

Measures of OSC

The Registrar-General's Social Class was first introduced in the UK in 1911 and comprised five main hierarchical classes, split according to the occupation's social and economic significance (Sutherland 1947). In 1990, this was renamed the Social Class based on Occupation (SC). Following criticisms of the validity and reliability of the SC classification system, the National Statistics Socio-economic Classification (NS-SEC) was introduced in 2001. It comprises eight main analytical classes, requiring occupational categories, size of company and employment status to be known in order to assign an individual to a class (Rose & Pevalin 2003).

Over the years, and in other countries, new occupational socioeconomic group measures have been introduced, however they are not widely used. Socio-economic groups (SEG) were introduced in the 1950s, and take into account employment status, employer size, as well as occupation rather than a measure of skill set (Rose & Pevalin 2003). The lack of clear guidance on how to collapse the 17 groups into a more useful analytical tool have meant that it has not been widely used (Rose & Pevalin 2003). The Erikson-Goldthorpe scheme has been used in several European analyses, however, due to its nominal nature, its 11 classes are typically collapsed into three categories: manual, non-manual and farmers (Mackenbach et al. 1997, Kunst et al. 1998). This was only applied to men, owing to the lack of comparable data for women. The Elley-Irving Scale was the most commonly used social class scales in New Zealand (Marshall et al. 1993). This scale assigns occupations to a level, using an equal weighting of median educational attainment and income. This scale is broadly comparable to the UK's SC. The New Zealand Socio-economic Index (NZSEI) has since superseded the Elley-Irving Scale (Blakely 2001).

Selected Findings

Associations between occupational social class and mortality

Due to the vast range of occupations, and the limited numbers of categories used in classifications, variation within the occupations of a class are of just as much interest as between classes. In 1947, using the then named Registrar-General's Social Class, Sutherland found that there was greater within class variation in standardised mortality ratios for influenza, than between class variation. This was found for both men, and married women (assigned to their husband's social class).

The gap in all cause mortality for men aged 35 - 64 years was found to be increasing between 1986-92 and 1997-99 in the ONS LS; the ratio of Social Class (SC) VI and V (Partly skilled and Unskilled) to classes I and II (Professional and Intermediate) increased from 1.69 to 1.75 (White et al. 2003). The opposite was found for women over the same analysis period, ratios decreased from 1.54 to 1.41.

In response to the high levels of within-class variation (White et al. 2008), the NS-SEC was introduced, and has since been used in many mortality studies across the UK. Figure 6.1 indicates that, whilst NS-SEC was not designed as an ordinal variable, an increasing gradient is evident in the age standardised mortality rates across the analytic classes for deaths in England and Wales.

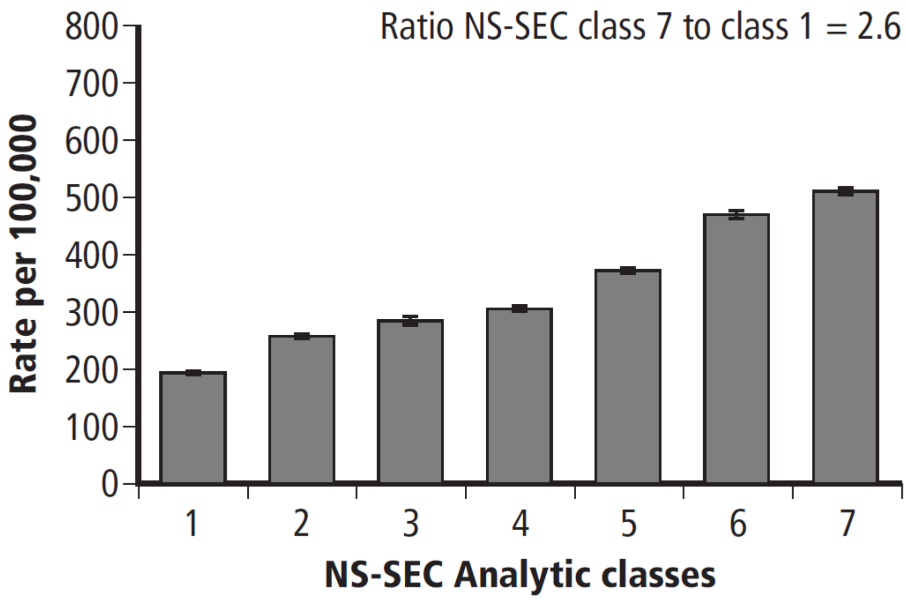


Figure 6.1: Age standardised mortality rates from all causes of death by NS-SEC, men aged 35-64, 2001-03. For key to analytic classes see Table 6.4 - note 1.1 and 1.2 are collapsed into a single class. Siegler et al. (2008) Contains public sector information licensed under the Open Government Licence v3.0.

The gradient is also evident in the ONS Longitudinal Study (LS), a database containing a linked 1% sample of residents in England and Wales. All-cause mortality rates for men are reproduced in Table 6.4. White et al. (2007) found that the rates calculated in the LS broadly follow the unlinked mortality rates shown in Figure 6.1, although for the latter categories, mortality rates are slightly underestimated. This may be due to the additional year of data included in the LS analyses.

Table 6.4: Age-standardised mortality rates by NS-SEC, men aged 25-64 from LS sample 2001-04

	NS-SEC analytic classes	Mortality Rate	(95% CI)
1.1	Large employers, higher managers	219	(176 - 272)
1.2	Higher professionals	210	(171 - 257)
2	Lower managerial, professional	249	(221 - 280)
3	Intermediate	251	(197 - 320)
4	Small employers, own account workers	285	(250 - 324)
5	Lower supervisory and technical	348	(307 - 395)
6	Semi-routine	409	(359 - 467)
7	Routine	443	(399 - 492)
	Never worked, long-term unemployed	989	(784 - 1,248)

White et al. (2007)

Amenable mortality and occupational social class

The first socioeconomic gradients in amenable mortality were explored through occupational social class in England and Wales (Mackenbach et al. 1989). They found that there were greater relative declines in the higher occupational classes of the SC, than in the lower occupational classes, over the period 1931 - 1961 for both men, and married women.

Since then, gradients have been explored in New Zealand (Marshall et al. 1993, Blakely 2001), provinces of Canada (Wood et al. 1999), and European countries (Mackenbach et al. 1989, Poikolainen & Eskola 1995). Only male deaths were included in almost all studies, owing to the “unreliable” classifications for women (Wood et al. 1999, p.1752).

Gradients in OSC mortality for men aged 15 - 64 years were analysed in New Zealand between 1975-77 and 1985-87, using the Elley-Irving scale (Marshall et al. 1993). Of the 731 deaths in the first period, 85% were allocated to a social class, along with 74% of the 567 deaths in the second period. Figure 6.2 reproduces the age standardised mortality rates for the two time periods. The rates for within each class have decreased between the two time periods, with greater absolute declines observed in the lowest social class (class 6).

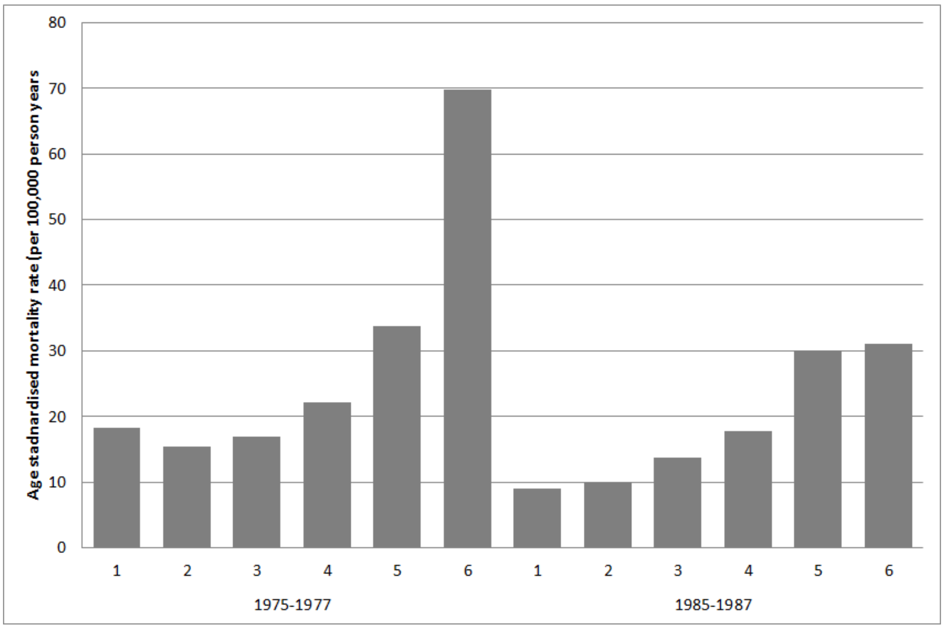


Figure 6.2: New Zealand male age-standardized mortality rates per 100,000 person years for causes of death amenable to medical intervention, by social class. Social class 1: high, Social class 6: low Marshall et al., 'Social class differences in mortality from diseases amenable to medical intervention in New Zealand', International Journal of Epidemiology, 1993, 22(2), pp 255-261, by permission of Oxford University Press

In 1999, Wood et al. investigated amenable deaths in British Columbia, Canada, using the UK's SC measure. They analysed 928 male deaths, aged 15-64, occurring between 1981 and 1991. 83% of these deaths could be assigned to a social class, along with 86% of the person years at risk. Significant rate ratios (greater than 1), comparing the highest to the lowest social classes, were found in the overall amenable causes category, but only within deaths due to pneumonia and bronchitis jointly (45.4% of total amenable deaths) when individual conditions were studied.

6.2.4 Composition and relationships within households

Social connections and support have long been known to positively impact health and mortality. The relationships within a household are the easiest way to measure social connections and support for a large sample. Marital status has been used to represent increased social support and shared economic advantage, over single people (Lund et al. 2002).

The association between mortality and relationships has been widely explored, using many different definitions of relationships over the years. It has previously been suggested that being married may positively impact timely contact with healthcare providers and encourage healthy behaviours (Somers 1979, Manderbacka, Peltonen & Martikainen 2014). Reductions in social isolation and increased engagement in social networks have been found to positively impact health, especially among men (Rosengren et al. 1989, Adler & Newman 2002).

The declining popularity of marriages and the increasingly common changes in marital status over the life-course make this a difficult measure to use, especially when collecting status at baseline only. Its limited ability as a measure of social support has also been identified, as the quality of relationship is not measured (Manderbacka, Peltonen & Martikainen 2014).

Measures of relationships within households

The most frequently used relationship statuses investigated are those between married, single, divorced, and widowed, with the latter three often being grouped together to form the 'unmarried' group when numbers are small. An 'ever married' vs 'never married' dichotomy was also introduced, accounting for those who were currently 'unmarried', but who had been married previously (Strand et al. 2007). This enabled the possibility of positive health selection for entering into marriage to be accounted for (Lillard & Panis 1996, Robards et al. 2012). Recently the categories have been expanded to allow for cohabiting couples and lone parents, reflecting the changes in the proportions of married people in the population, and changes in household compositions (Koskinen et al. 2007, Manderbacka, Peltonen & Martikainen 2014).

Classifying individuals to a group when not self-reported is a difficult process. Several studies require a less than 15 year age gap (Frisch & Simonsen 2013, Manderbacka, Peltonen & Martikainen 2014), therefore misclassifying any couples with a larger difference in ages. Misclassification can further occur when persons are identified as cohabiting with a member of the same sex. Statistics Finland did not classify these instances as being in a relationship (Manderbacka, Peltonen & Martikainen 2014), whereas same sex couples (homosexually married, divorced and widowed) could be identified in Denmark (Frisch & Simonsen 2013), following the implementation of a Registered Partnership Act in 1989.

Selected key results

Associations between household relationships and mortality

The positive relationships between health, use of health care and marital status has been well established (Somers 1979). The positive effects of being married for younger men was documented in 1957, where it was reported that death rates for married men aged 20-44 were approximately half of that of single men (Somers 1979).

Lund et al. (2002) compared three categorisations of relationship situations and their associations with mortality; cohabitation status (living alone vs living with others), living with or without a partner, and marital status. The three categorisations of social relations differed in terms of intimacy, and perceived 'legitimacy'. Higher rates of mortality were found in those living alone, those not living with a partner, and those not married, compared to their respective alternate categories. Comparing the three categorisations to each other, Lund et al. found that both cohabitation status, and living with or without a partner were strong independent predictors of mortality, and that cohabitation status was a better predictor of mortality than marital status was, among the 50 - 70 year olds in the Danish Longitudinal Health Behaviour Study.

Table 6.5 reproduces the unadjusted associations between household relationship and mortality in Finland (Koskinen et al. 2007). Relative risks were slightly attenuated by the inclusion of adjustments for education, occupation or employment status in models, however, all comparisons remained significant.

Table 6.5: Relative risks (95%CI) of mortality by living arrangement group in 1996-2000: men and women aged 30-64 years

Category	Men		Women	
Married	1.00		1.00	
Cohabiting	1.66	(1.59 - 1.72)	1.67	(1.57 - 1.77)
Persons living with someone other than a partner	2.91	(2.82 - 3.00)	1.72	(1.63 - 1.81)
Persons living alone	3.34	(3.15 - 3.32)	1.98	(1.90 - 2.07)

Koskinen et al., 'Mortality differences according to living arrangements', International Journal of Epidemiology, 2007, 36(6), pp 1255-64, by permission of Oxford University Press

The differences between using linked-census and unlinked records was explored in Lithuania (Shkolnikov et al. 2007) for seven causes of death between July 2001 and December 2004: Circulatory diseases, neoplasms, external causes (excluding alcohol poisoning), alcohol related deaths, infectious and respiratory system diseases, ill-defined causes of death, and other causes of death. The results, reproduced in Table 6.6, indicate the unlinked mortality estimates are generally equal to the linked mortality estimates, although the unlinked records tend to over-estimate the size of the rate ratios. The rate ratios are largest for those never married, compared to the married group, for both sexes, and in both the linked and unlinked cases.

Table 6.6: Poisson regression mortality rate ratios for ages 30-69 calculated from the census linked and unlinked mortality data

Sex	Category	Census-linked	Unlinked
Men	Married	1.00	1.00
	Divorced	2.19 (2.13 - 2.26)	1.84 (1.79 - 1.90)
	Widowed	2.24 (2.15 - 2.34)	2.31 (2.22 - 2.40)
	Never married	2.39 (2.31 - 2.46)	2.36 (2.29 - 2.44)
Women	Married	1.00	1.00
	Divorced	1.43 (1.37 - 1.50)	1.52 (1.46 - 1.59)
	Widowed	1.55 (1.49 - 1.61)	1.63 (1.57 - 1.70)
	Never married	1.84 (1.74 - 1.94)	2.03 (1.92 - 2.14)

Amenable mortality and relationships within households

Manderbacka, Peltonen & Martikainen (2014) found that total and amenable mortality rates were smallest in the married group, and larger in those living alone and lone parents within an 11% sample of persons aged 25-75 years living in Finland between 2000 and 2007. The results of the hazard ratios (HR) are reproduced in Table 6.7; including education, social class, economic activity, or income in the age-adjusted models attenuated, but did not completely remove the effects (not shown).

Table 6.7: HRs* (95% confidence intervals) of amenable mortality by living arrangement group in 2000-2007 among men and women aged 25-74 years

Category	Men		Women	
Married	1.00		1.00	
Cohabiting	1.45	(1.34 - 1.58)	1.30	(1.20 - 1.42)
Living alone	2.45	(2.33 - 2.58)	1.49	(1.42 - 1.57)
Lone parent	1.74	(1.49 - 2.03)	1.22	(1.12 - 1.33)
Other	3.72	(3.51 - 3.95)	3.06	(2.84 - 3.29)

∗ HRs adjusted for age and region, but not for education, social class, economic activity nor income quintile

Poikolainen & Eskola (1995) adjusted for marital status in a case-control study investigating differences in rates of amenable mortality by OSC. Married persons had a lower risk of amenable death than single, widowed or divorced, however no significant relative risks remained after adjusting for age, sex, social class and district of residence.

6.2.5 Ethnicity and Race

Disparities in health status and access to health care have been explored within racial and ethnic groups, with minorities experiencing a lower quality of health care, and greater difficulties in accessing care (*Unequal Treatment: Confronting Racial and Ethnic Disparities in Health Care* 2003). Differences in mortality rates between ethnic and racial groups have been explored over the years, in many countries (Manton et al. 1987). The associations between non-white races and lower levels of individual SEP measures have been used to explain the inequalities (Elo & Drevenstedt 2006).

Race and ethnicity have also been used to identify migrant populations within a country. In the case of amenable mortality, an interest in the mortality rates amongst migrants provides an indicator of how well the health care system of a country is used by migrants, and how well it can provide for the needs of marginalised populations (Makarova et al. 2015).

Categories

The definitions used to characterise and differentiate race or ethnic group are variable (Burchard et al. 2003), with race typically taken to be be dependent on biological or genetic differences, whilst ethnic groups are seen to reflect cultures or religions.

Self reported ethnicity or race are used in the main. Country of birth for a given person and their parents have also been used to identify migrants (Stirbu et al. 2006). In these situations, additional analyses taking into account duration of residence are included. This measure does not take ethnic identity, culture, language or ancestry into account.

The level of detail of race/ethnic group available for analysis can be context and time dependent, such as the introduction of options for ‘Gypsy or Irish Traveller’ and ‘Arab’ in the 2011 UK Census (Office for National Statistics 2012*b*). These persons would have previously self-identified to a different category.

Selected key results

Associations between ethnicity, race and mortality

Comparisons of US death rates have consistently shown higher mortality for blacks than for whites (Elo & Drevenstedt 2006).

Hummer et al. (1999) explored differences in all cause adult mortality by self-reported ethnicity, race and nativity in the US between 1989 and 1995, finding that, compared to native born, non-Hispanic whites, native born non-Hispanic black, and other Hispanic native born have significantly higher odds ratios of all cause death, whilst native born Asian Americans had significantly lower odds ratios. Foreign born non-Hispanic blacks, Asian Americans, other Hispanics and non-Hispanic whites all had significantly lower odds ratios of adult mortality (18-99 years), compared to native born whites. The only group to not have a significant difference was both foreign and native born Mexican Americans. Adjusting for education, income and marital status strengthened the odds ratios for the foreign born, but attenuated the relationships found in the native born.

Amenable mortality and ethnicity and race

Previous studies have reported higher rates of amenable mortality for blacks than whites (Elo & Drevenstedt 2006). The 'Australian and New Zealand Atlas of Avoidable Mortality' included comparisons by ethnicity or Indigenous status (see Table 6.8), finding that Indigenous persons in Australia had age-standardised amenable mortality rates over three times those of non-Indigenous persons, for both men and women (Page et al. 2006). In New Zealand, amenable mortality rates of Maori persons exceeded those of Pacific and European/other persons.

Table 6.8: Amenable mortality (0 - 74 years) by Indigenous status/ethnicity and sex, Australia and New Zealand, 1997 - 2001

Country	Indigenous status/ethnicity	Male ASR	Female ASR
Australia*	Indigenous	298.8	230.7
	Non-indigenous	78.4	59.1
New Zealand	Maori	211.0	184.9
	Pacific peoples	193.1	165.2
	European/others	90.3	72.8

* The Australian data are limited to four jurisdictions which were considered to have the most complete coverage of Indigenous deaths.

Reproduced from the Australian and New Zealand Atlas of Avoidable Mortality, Page et al. (2006), with permission from Public Health Information Development Unit (PHIDU)

The association between amenable deaths and migrant groups in the Netherlands was found to largely be attenuated through the control for demographic and socioeconomic factors (Stirbu et al. 2006). Many other studies have included ethnicity or race in their analyses (Marshall et al. 1993, Niti & Ng 2001, Tobias & Jackson 2001, Nolte et al. 2004, Elo & Drevenstedt 2006, Macinko & Elo 2009)

6.2.6 Place of residence

Whilst this is not a strictly individual level measurement of SEP, an individual's place of residence is associated with their health and mortality, through its physical location and attributes, as well as through the people sharing the locality. Within Scotland, given its large sparsely populated areas, this is known to be an issue which affects the equity in accessing health care and other essential services (Steel & Cylus 2012).

Using place of residence to measure relative deprivation requires that one can assume that households in the same neighbourhood have similar levels of SEP. This assumption is more likely to be met in large cities, than in smaller towns or rural areas (James et al. 2006).

Categories

There are many methods for comparing place of residence, and its relationship with mortality. Some make use of a simple remoteness measure, such as the Australian Standard Geographical Classification (ASGC) remoteness classification, which reflects the road distance required to travel to the nearest service centre (Page et al. 2006).

James et al. (2007) assigns an area level indicator of low income to deaths, whereby the areas are assigned to quintiles based upon the percentage of their population classified as having a 'low income'. Areas have also been defined on an urban-rural scale, however there is no universally accepted classification which defines where an area lies on the scale. Variants have made use of population size within an area, as accessibility (measured in time taken to drive to an area with a population of at least 10,000 people) (Scottish Government 2012).

Composite measures made up of data from multiple sources or domains are increasingly popular, as these are able to reflect the deprivation of the population of an area, relative to other areas, rather than its geographical location only. The Carstairs index (McLoone 2000, 2004, Brown et al. 2014) and the (Scottish) Index of Multiple Deprivation ((S)IMD) (Scottish Government 2016*a*, Department for Communities and Local Government 2015) are the two most commonly used composite measures in the UK. Descriptions of each are available in section 3.5. The Australian Index of Relative Socioeconomic Disadvantage (IRSD) comprises of 16 measures of disadvantage, including measures of income, education, and housing (Pink 2013). The New Zealand Deprivation (NZDep) index comprises nine census variables, including similar domains to the IRSD (Page et al. 2006). Several other countries have created their own version of these indices of relative deprivation (Rey et al. 2009, Nolasco et al. 2014).

Selected key results

Associations between place of residence and mortality

Chen & Yang (2014) used a composite measure of socioeconomic variables to define four levels of urbanisation in Taiwan. All cause mortality rates were found to be lower in more urbanised areas, with rates for individual causes generally agreeing with this. Rates of breast cancer in females was the only individual cause to be consistently higher in more urbanised areas throughout the study period.

England and Wales have two measures of place of residence, the Rural and Urban Area Classification (RUAC), and the Index of Multiple Deprivation (IMD). The RUAC is used in England and Wales, where areas are defined by their settlement type (>10,000 population, town, fringe, village, dispersed) and context (sparse, less sparse). A greater proportion of the rural areas are categorised into the least deprived quintile of the IMD, whilst a greater proportion of the urban areas are categorised in the most deprived quintile. Significantly lower all cause mortality rates were found in rural areas in both England and Wales, with the difference between urban and rural rates being smaller for women than for men (Gartner et al. 2008).

Amenable mortality and place of residence

Korda et al. (2007) used the Index of Disadvantage, aggregated at the small area level, to investigate avoidable causes of death, which includes ‘medical care indicators’. They found that relative inequalities in Australia increased over time, and that the increase in inequalities was greater in avoidable deaths, compared to non-avoidable ones. These trends were found for both men and women. Inequalities in medical care indicators were estimated to be lower than the those of remaining avoidable causes of death, and IHD.

Page et al. (2006) explored amenable mortality in Australia and New Zealand, using country-specific area level measures. Using the Australian IRSC, they found that rates of amenable mortality in the most deprived quintile were 1.67 and 1.54 times that of the least deprived quintile for men and women respectively. In New Zealand, using NZDEP, the rate ratios increased to 2.31 for men and 2.28 for women.

The earlier report of amenable mortality in Scotland explored the gradient in rates of amenable mortality using the SIMD (Grant et al. 2006). Figure 6.3 reproduces the plot, indicating a strong correlation with deprivation, which had declined over time. However, the ratio between the most and least deprived quintile remains approximately equal over the four years.

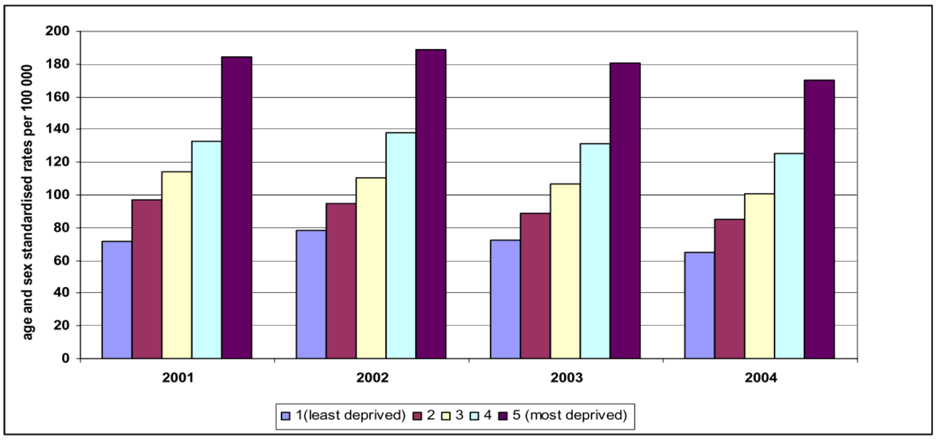


Figure 6.3: Age and sex standardised amenable mortality rates by SIMD quintiles: 2001 - 2004 Grant et al. (2006), 'Mortality amenable to Health Care in Scotland' by permission of Scottish Public Health Observatory

Grant et al. also explored changes to amenable mortality rates within Scottish Health Boards (n=15) between 1981 and 2004, by 5 5-year groups. Mortality rates in the West of Scotland Health Boards (Greater Glasgow, Ayrshire & Arran, Argyll & Clyde, and Lanarkshire) exceeded the overall Scotland rate for all 5 groups of years. All Health Boards saw a decrease in mortality rates over the analysis period, except for Orkney between 1981-85 and 1986-1990.

6.2.7 Conclusions

Three widely used measures of individual SEP and three demographic factors have been illustrated in this chapter's literature review. Educational attainment and measures of occupational social class were the most commonly used individual indicators used in both all-cause and amenable mortality studies.

As highlighted within each section, the individual measures which can be explored in the analysis section of this thesis are limited to the data collected within the census, and available within the SLS database: self-reported educational attainment, household relationships, ethnicity and residential address are directly collected, and occupational social class can be derived from questions based on employment.

Income is not asked within the census, and whilst methods exist to create a synthetic income variable within the SLS database (Clemens & Dibben 2014), this was not explored, as self-reported or externally validated measures were of interest.

6.3 Objectives

This chapter will meet objective 4 of this thesis (see section 1.1) by:

1. Exploring rates of amenable mortality in the Scottish Longitudinal Study at the individual level by:
   (a) educational attainment
   (b) social class (SC and NS-SEC)
   (c) living arrangements
   (d) race/ethnic group
2. Measuring the absolute and relative inequalities in mortality rates across each measure over time
3. Exploring the impact of adjusting for migrations to and from Scotland on person years at risk
4. Comparing sample to population, using the corresponding mortality findings in chapter 4 using the Carstairs index.

6.4 Methods

6.4.1 Data source

The Scottish Longitudinal Study[3] (SLS) provides the opportunity to investigate the effects of individual level measurements of socioeconomic position on amenable mortality within Scotland. The SLS is a large-scale linkage study which makes use of administrative data

[3] http://sls.lscs.ac.uk/

collected from the Censuses (first linked in 1991), vital events (births, deaths and marriages) and the NHS Central Register (NHSCR) for a 5.3% sample of the Scottish population (Hattersley & Boyle 2007). Study members are included into the sample if they were born on one of 20 semi-random birth dates[4], and have registered with the NHS. Therefore, the sample includes both persons born in Scotland, and those who have immigrated to Scotland, as long as they have registered with a GP. Entries and exits from the study are tracked through the registration and de-registration from the NHS (Boyle et al. 2009). As the completion of the Census, and the registration of vital events is compulsory in Scotland, at least 96% of the SLS sample have been traced and stored in the database (Hattersley et al. 2007, Hattersley & Boyle 2008, Boyle et al. 2009).

Information held by the SLS includes family and household structure, country of birth, ethnicity, educational attainment, occupation, and social class. New data from subsequent Censuses are linked to the sample in the years following a Census, however, vital events (births, deaths and marriages) are usually linked on an annual basis (Hattersley & Boyle 2007). At the time of submitting the application for use of the SLS database, Census records for 1991, 2001 and 2011 were linked in the study, however, only vital events up to 2010 were linked to study members. Therefore, only data from the 1991 and 2001 Censuses were included in the analyses.

Linkage methods

The Census records, vital events data, and NHSCR information are linked via the following steps, described in Hattersley & Boyle (2007)

1. Identify the sample: Persons are included in the sample if they were born on one of the 20 semi-randomly selected birth dates, spread throughout the calendar year.
2. Each member's Census data are then extracted from the electronic database of 1991 Census returns.
3. The original Census form for each member is then located in order to have access to their name (as the 1991 Census form guaranteed that 'Name and addresses will not be put into the computer' and names are needed to accurately link to other sources), and to get the 'difficult to code' Census information (eg. Occupation) as only 10% of these were electronically stored for the whole population.

[4]The four birth dates that are used to identify persons in the England and Wales LS are included in the 20 birth dates for the SLS. This enables part of the SLS sample to be analysed with the LS, if desired

4. Member name and demographic information was used to set flags in National Health Service Central Register (NHSCR) system. This register contains demographic details on all births and deaths in Scotland, as well as as for any person who has registered with a GP in Scotland. Once members are found on the register, they are assigned an SLS identifier, and can be traced. Persons that have completed the Census, but do not appear on the NHSCR are not traced (these are people that have immigrated to Scotland, but not yet registered with a GP. Once they do, they are assigned a SLS identifier, and traced). Other reasons for not tracing include differing dates of birth given on the Census and NHSCR. 98% of the 1991 sample were traced.

5. Vital events (births, deaths or marriages) to SLS members can now be linked. This is done through NHSCR electronically where possible. Once vital events are attached to the record, the member's names are stripped from the dataset, and returned to the SLS.

6. Records for 2001 and 2011 are collected in a similar manner, however, step 3 is no longer required as names and addresses were allowed to be electronically stored, allowing exact matching to be carried out, followed by probability matching and manual matching as required.

Outwith the Census linkage periods, new SLS members can enter the sample through birth or entering as an immigrant to Scotland once they are identified and traced through NHSCR.

6.4.2 Study exposures and covariates

The relevant measures of individual socioeconomic position or demographic variables which were identified in the literature review and could be derived from the 1991 and 2001 Census were:

1. Educational attainment
2. Social classes derived from occupation:
   (a) the Social Class based on Occupation (SC, previously Registrar-General's Social Class)
   (b) the National Statistics Socio-economic Classification (NS-SEC)
3. Household relationships
4. Race/Ethnic Group

In addition, area level deprivation was derived from the postcode sector of residence given on the Census returns.

Whilst education and occupational social class are both measures of SEP, they are not interchangeable. Educational attainment and social class, as well as other measures of SEP, are not necessarily positively correlated with each other, as they may be due to different causal processes (Geyer et al. 2006). Therefore, analyses will be repeated for each variable in order to explore their individual effect on rates of amenable mortality.

Educational attainment

Level of individual educational attainment was obtained from one question on each Census returns form, as can be seen in Appendix D. The 2001 Census allowed for the reporting of school level qualifications, whereas the 1991 Census collected data on educational qualifications attained after the age of 18.

In order to ensure comparability between analyses of the two Census periods, the 2001 variable was collapsed into the three categories available in the 1991 Census. The new categories are described in Table 6.9.

Table 6.9: Categories of Educational attainment by Census years

Categories	1991	2001
1	First degree and higher degree	First degree, higher degree, Professional qualifications
2	Other higher qualifications (non-degree)	HNC, HND, SVQ level 4 or 5 etc.
3	No over 18 qualifications	Higher grade etc ‘O Grade/Standard grade, GCSE etc. No qualifications
-	Not stated No Code Required (aged $<$18)	Not reported No Code Required (aged $<$18)

The number of categories available for analyses are smaller than the majority of the studies reviewed in Section 6.2.1. The 2001 variable could have been used to make a comparable variable, however, it was decided that the comparability within Scotland was of more interest, than between Scotland and other countries.

Social Class based upon Occupation

There are two measures of occupational social class available in the SLS database; the Social Class based on Occupation (SC), and the National Statistics Socio-economic Classification (NS-SEC). The NS-SEC was introduced in 2001, and was designed to supersede the SC. The SLS derives both variables for each Census, allowing for comparison.

The SC variable is an ordinal variable, with 5 major categories. Persons in the armed forces, with an inadequately described or missing occupation, or who had not worked in the previous 10 years were not assigned to a category. The categories used in the analyses are described in Table 6.10.

Table 6.10: Categories of the Social Class based on Occupation (SC)

Level	Label
1	Professional occupations
2	Managerial and technical occupations
3(N)	Skilled non-manual occupations
3(M)	Skilled manual occupations
4	Partly skilled occupations
5	Unskilled occupations

The NS-SEC was calculated using the reduced method (see Rose & Pevalin (2003) p.18) for both years, as no employment establishment size was collected at the 1991 or 2001 Censuses.

The NS-SEC was not designed to be an ordinal variable, due to the inclusion of an 'own account workers' (self-employed) category (Rose & Pevalin 2003). Rose & Pevalin state that the NS-SEC variable should only be regarded as ordinal when it is collapsed into three classes. Table 6.11 details the full 14 operational categories (L1 - 14), and 3 residual categories (L15 - 17) of the NS-SEC. The column of 'Ordered Positions' details the categories used in the analyses. The advised three classes for ordinal categorisations are made up of groups 1, 2, and the further collapsed group of 3, 4, and 5 of the Ordered Positions. It was decided for these analyses that we were interested in the 'tail' of the NS-SEC, and therefore the "Routine and manual occupations" made up of positions 3, 4 and 5 would be left as smaller groups.

Table 6.11: Categories of the NS-SEC

Level	Description	Ordered Position	Name
L1	Employers in large establishments	1	Managerial and professional occupations
L2	Higher managerial positions		
L3	Higher professional occupations		
L4	Lower professional and higher technical occupations		
L5	Lower managerial occupations		
L6	Higher supervisory occupations	2	Intermediate occupations
L7	Intermediate occupations		
L8	Employers in small establishments		
L9	Own account workers		
L10	Lower supervisory occupations	3	Lower supervisory and technical occupations
L11	Lower technical occupations		
L12	Semi-routine occupations	4	Semi-routine occupations
L13	Routine occupations	5	Routine occupations
L14	Never worked and long term unemployed		Not included in analyses
L15	Full time students		
L16	Occupations not stated or inadequately described		
L17	Not classifiable for other reasons		

There are no differences between how the 1991 and 2001 variables are coded, as both are calculated using the reduced method of the NS-SEC. Therefore, the two variables are comparable across the two Census periods.

Household Relationships

The literature review highlighted the limitations of analyses that make use of marital status only. In addition to marital status the Census forms collect information on the relationships between household residents. These relationships are defined by the person completing the Census form. The questions on the Census forms are listed in Appendix D.

The calculation of Hazard Ratios of amenable mortality between living arrangements conducted in Finland (Koskinen et al. 2007, Manderbacka, Peltonen & Martikainen 2014) were the original inspiration for the analysis of this variable. As the aim of this chapter was to compare inequalities in amenable mortality across different SEP or demographic measures, the categories used by Koskinen et al. (2007), Manderbacka, Peltonen & Martikainen (2014) had to be amalgamated into living in a consensual relationship, or not, as there was no natural order of increasing 'deprivation' in the original categorisations (see Table 6.5 and 6.7). The household relationships which make up each are described in Table 6.12.

Table 6.12: Categories of household composition variables by Census years

Analysis categories	1991	2001
Consensual relationship	Married couple* Cohabiting couple*	Married couple* Cohabiting couple*
Other	No families 1 person No families 2+ persons One family - lone parent** Other - 1+ dependent children Other - all pensioners Other	One person - pensioner One person - other One family - lone parent** One family - all pensioners Other - all student Other

* with no / 1+ dependent/ non-dependent children

** with 1+ dependent/ non-dependent children

Having children did not affect which category a SLS member was assigned to, as it has been found that having children did not negatively impact the health of their parents, whether they are in a married couple, or lone parents (Hughes & Waite 2002). The 2011 Census allowed for the identification of same sex couples (both married and cohabiting). As the relationships for the 1991 and 2001 Census were defined by the person completing the Census, it is likely that same sex couples for these Censuses are included in the Consensual relationships category.

Race/Ethnic Group

Whilst self-reported Race/Ethnic Group is collected in the Censuses, 84% of the study members who were enumerated in 2001, and had subsequently died of an amenable condition self-reported their race as ‘white’, and the vast majority of the remainder were recorded as ‘non-response’. There were insufficient variations within this category to continue analyses.

Area level deprivation

Published Carstairs indices are created using total population data collected from each Census. The indices are ordered and split into deprivation deciles. The decile each SLS member’s residence is assigned to is derived from the postcode recorded on the Census form. Decile 1 contains the least deprived 10% of the population, whilst decile 10 contains the most deprived. The 1991 and 2001 indices make use of slightly different variables (see subsection 3.5.1 for details). Otherwise, they are comparable.

Additional covariates

Additional demographic variables were used in the analyses.

Sex: A member’s sex is recorded up to four times within the dataset: in the Core dataset, at each Census, and at death. There were several SLS members for which the four records did not agree. In these cases, the sex recorded at the 1991 Census was taken to be the true sex, as this was manually coded from the hard copy of the Census return. If the SLS member was not present at the 1991 Census, the 2001 Census value was used.

Age: Age was recorded in three instances: at each Census and at death. Analyses were restricted to persons aged between 35 and 74 years (inclusive) at any point in the 10 years following a Census.

Dates of birth and death: Full date of birth is a restricted variable in the SLS, due to this being the manner of identifying SLS members for inclusion into the study. Therefore, only month and year of birth were available for analysis. This was used to cross-check the correct age was recorded at Census, and, along with month and year of death, to calculate person years at risk.

There were a small number of cases for which one or more of these additional covariates was either recorded as a non-response, or were implausible. In these cases, the SLS member was excluded from analysis (see Figure 6.4 for details).

Concluding Comments

Misclassification of a SLS member's demographic variables or category of SEP are possible. Results may be biased in two ways: reporting bias may occur if the SLS member reported incorrect or insufficient information on the Census form, and recording bias is possible through human error in the manual inputting of the 1991 Census, or computer error in the reading in of the 2001 Census.

6.4.3 Study Outcome

The outcome of interest for this study are deaths amenable to health care. These were identified from the vital events data linked to each SLS member, and were selected based on the causes of amenable deaths and associated age limits detailed in Appendix A. Deaths occurring between 21 April 1991 - 31 December 2000, and 29 April 2001 - 31 December 2010 (inclusive) and those occurring at ages 35 to 74 are included in analyses. Analyses were performed for amenable deaths, and repeated for non-amenable and all-cause deaths for comparison. Non-amenable deaths include Ischaemic heart disease, traffic accidents, suicides, lung cancers etc.

Deaths included in each analysis were required to have a value for the SEP variable of interest recorded at the previous Census. Therefore, the number of deaths analysed for each SEP variable are not equal across all measures due to varying non-response levels.

6.4.4 Person years at risk

Person years at risk was used as the denominator for all analyses. This was calculated for the whole sample over two periods, using the Census day as the start date: 21 April 1991 - 31 December 2000, and 29 April 2001 - 31 December 2010. The start and end dates of time at risk could be adjusted for individual SLS members - the start date was delayed until a birth or immigration into Scotland, and the end date was brought forward in the case of death, or emigration from Scotland. The time at risk for each study member was aggregated to 5 year age groups, therefore each member could contribute a maximum of 5 years 'at risk' within each age group to the denominator (Harding 1995, Flanagan & McCartney 2015).

The two overall periods of time at risk were split into three periods each, allowing for changes in inequalities to be measured over smaller periods of time. The time periods, along with examples of their respective dates are displayed in Table 6.13. The groups are numbered, whilst the years included within each group are lettered.

Table 6.13: Number of days making up each year group

Group	Year(s)	Start date	End date	Number of days
1	1991 - 1994	21/04/1991	31/12/1994	1,351
a	1991	21/04/1991	31/12/1991	255
b	1992	01/01/1992	31/12/1992	366
c	1993	01/01/1993	31/12/1993	365
d	1994	01/01/1994	31/12/1994	365
2	1995 - 1997	01/01/1995	31/12/1997	1,096
a	1995	01/01/1995	31/12/1995	365
b	1996	01/01/1996	31/12/1996	366
c	1997	01/01/1997	31/12/1997	365
3	1998 - 2000	01/01/1998	31/12/2000	1,096
4	2001 - 2004	29/04/2001	31/12/2004	1,343
5	2005 - 2007	01/01/2005	31/12/2007	1,095
6	2008 - 2010	01/01/2008	31/12/2010	1,096

The time periods typically consist of three full years of time at risk (as can be seen in Group 2: 1995 - 1997), except for the two groups which contain the Census year. Table 6.13 indicates that 1991 contributed a further 255 days (approximately 8 months) of time at risk to the first group, whilst 2001 contributes a further 247 days (not shown). Leap years were also taken into account.

The person years at risk used in the analyses was restricted to people aged between 35 and 74 during the two periods, and had a value recorded for the variable of interest. Therefore, the number of person years at risk for each SEP measure are not equal across all variables.

These analyses are not prone to numerator-denominator biases (see subsection 3.3.3), as the classifications for deaths and person years at risk are obtained from the same linked source.

6.4.5 Statistical Analyses

All deaths held in the SLS Vital Events dataset were extracted. These were categorised into amenable and non-amenable deaths. Analyses were repeated for all-cause deaths.

To be included in the numerator or denominator, it was required that the SLS member had to have been enumerated at the previous Census, in order to have a measure of their SEP or an assignment to a demographic group. An age requirement of being aged 26 or over at this Census was also used, as the highest level of education is typically achieved by this age. Social class based on occupation and household relationships are likely to fluctuate over the life time, so no further age restrictions were introduced. Rather than starting with a set cohort of 25 to 74 year olds at the Census, and losing cohort members each year to migration, death or ageing over 75, it was decided to limit the analyses to people aged 35 to 74 in a given year. This would allow new members to be introduced each year, whilst still losing members for the same reasons as before. Therefore, a study member aged 26 in 1991 would only be included in the analyses once they had turned 35 in 2000. Their SEP would be known from the 1991 Census.

Sex-specific age-standardised mortality rates were calculated for the three mortality groups for three smaller study periods within each Census period (1991: 1991 - 94, 1995 - 97, 1998 - 2000 and 2001: 2001 - 04, 2005 - 07, 2008 - 10). Each study period spans three full years, except for the two study periods at the start of each Census year, as these additionally include the remaining eight months of the year after the Census has been taken. The 2013 European Standard population was used to directly standardise all mortality rates. For standardisation methods see section 3.4.

For each of the three measures of individual SEP, household relationships and the area level deprivation measure, the Relative Index of Inequality (RII) and the Slope Index of Inequality (SII) were calculated using Poisson regression (Mackenbach et al. 2008), for each sex and study period separately. The methodology used to calculate these are outlined in section 3.7. Confidence intervals which contain 1 indicate that the mortality rates between the notionally most and least deprived areas were not significantly different (Allik et al. 2016).

Comparing sample to population

The Carstairs index is the only measure included in the SLS dataset which is also available, and accurately recorded for the whole population. The Carstairs indices available in the SLS are calculated based on the total population and not only the SLS members, hence the measures of deprivation, and the area assignments used in the SLS are equivalent to those of the population. Therefore, it is possible to compare the results calculated in each, in order to evaluate how likely the other individual measures will reflect the inequalities in the total population[5]. The results for the whole population were calculated using the 1991

[5] See section 6.7

population size and Carstairs index applied to all deaths in the 1991 census period, and the 2001 population size and Carstairs index was applied to all deaths in the 2001 census period. Therefore the results calculated for the whole population will differ slightly to the results presented in chapter 4, but will align with the assignments used in this chapter.

6.4.6 Sensitivity Analyses

The reliability and completeness of the migration data used to adjust the person years at risk is questionable, as this requires a SLS member to de-register with the NHS when emigrating from Scotland. GP registrations within the UK can be traced, therefore it is more likely that migrations outside of the UK are under-estimated (Boyle et al. 2009).

It was estimated that only 50% of all migrations were correctly reported in the ONS LS for people entering or exiting England and Wales (Flanagan & McCartney 2015). In these cases, persons who have emigrated from Scotland, without formally de-registering were still contributing towards the person years at risk, therefore artificially inflating the denominator and decreasing the mortality rate estimates (White et al. 2007).

In order to explore the impact of adjusting for migrations, a sensitivity analysis was run, repeating the calculations of the educational attainment RIIs and SIIs using person years at risk, and not correcting for migrations.

6.5 Results

There were 306,771 SLS members included in the sample. These include SLS members identified in the 1991 and 2001 census returns, as well as those linked through the NHSCR outwith the census periods. Between 21 April 1991 and 31 December 2010 there were 40,307 (13.1%) sample member deaths at all ages, of which 25,185 occurred before the age of 75. 6,462 (16.0% of all deaths and 25.7% of all deaths under age 75) were classified as being amenable to medical care and the remainder were classified as non-amenable deaths. Figure 6.4 describes the total size of each group of deaths. These are the maximum numbers of deaths that could be included into the analyses of each measure.

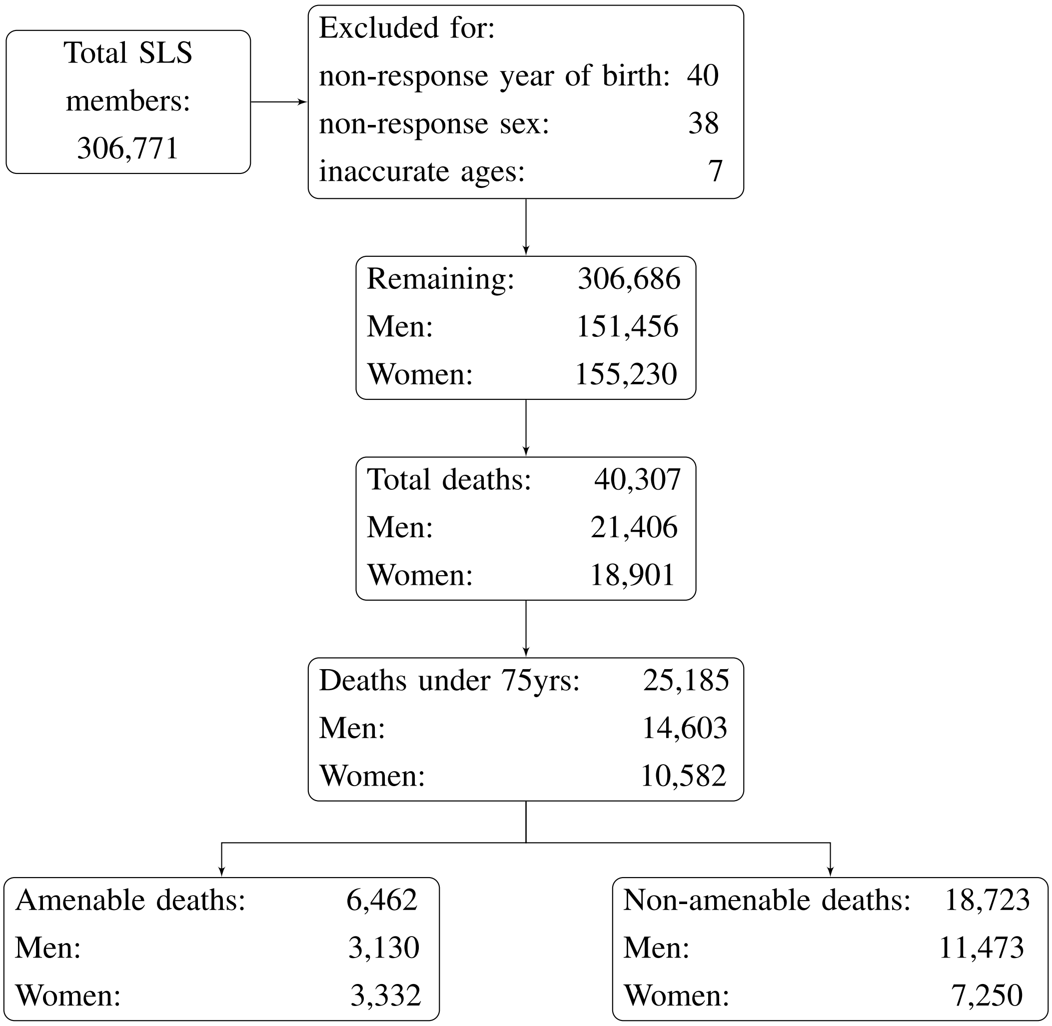


Figure 6.4: Flow diagram of the SLS sample included in analyses

The data for 85 (0.03%) SLS members were removed from the analyses due to having a non-response recorded for sex, date of birth, or having conflicting dates of birth and ages at a census. The person years at risk was calculated for the remaining 306,686 SLS members, of which 49.38% were male.

Results for each of the three measures of individual SEP, their household relationships and the area level deprivation measure are presented below.

6.5.1 Educational Attainment

Approximately 21.8% of all male deaths and 31.8% of all female deaths that had educational attainment recorded occurring between 1991 and 2010 were amenable to health care intervention. Table 6.14 details the distribution of deaths for each mortality group over the year groups, along with the person years at risk. The numbers of deaths within each study period decreases over time. See subsection 6.4.4 and Table 6.13 for explanation of decrease in deaths and person years at risk in the years following a census year group.

Table 6.14: Numbers of deaths and associated person years at risk for persons with a reported educational attainment (age 35 - 74 years) *Source: Scottish Longitudinal Study*

	Amenable	Non-amenable	All-cause	Person Years
Men				
1991-1994*	576	2,074	2,650	204,258.6
1995-1997	465	1,712	2,177	170,237.2
1998-2000	475	1,508	1,983	174,274.4
2001-2004*	418	1,564	1,982	213,115.1
2005-2007	354	1,270	1,624	176,237.2
2008-2010	316	1,223	1,539	175,636.7
Women				
1991-1994*	642	1,335	1,977	219,695.4
1995-1997	505	1,036	1,541	181,974.7
1998-2000	451	965	1,416	186,157.1
2001-2004*	459	991	1,450	230,455.6
2005-2007	341	836	1,177	191,979.8
2008-2010	382	774	1,156	192,630.2

* Contains census year

The three levels of educational attainment investigated are First degree and higher, Other higher qualifications, and No over 18 qualifications. In 1991 - 2000, approximately 93% of deaths within each of the three mortality groups occurred in persons who had gained no further qualifications after turning 18. This percentage decreased to approximately 86% in the second census period.

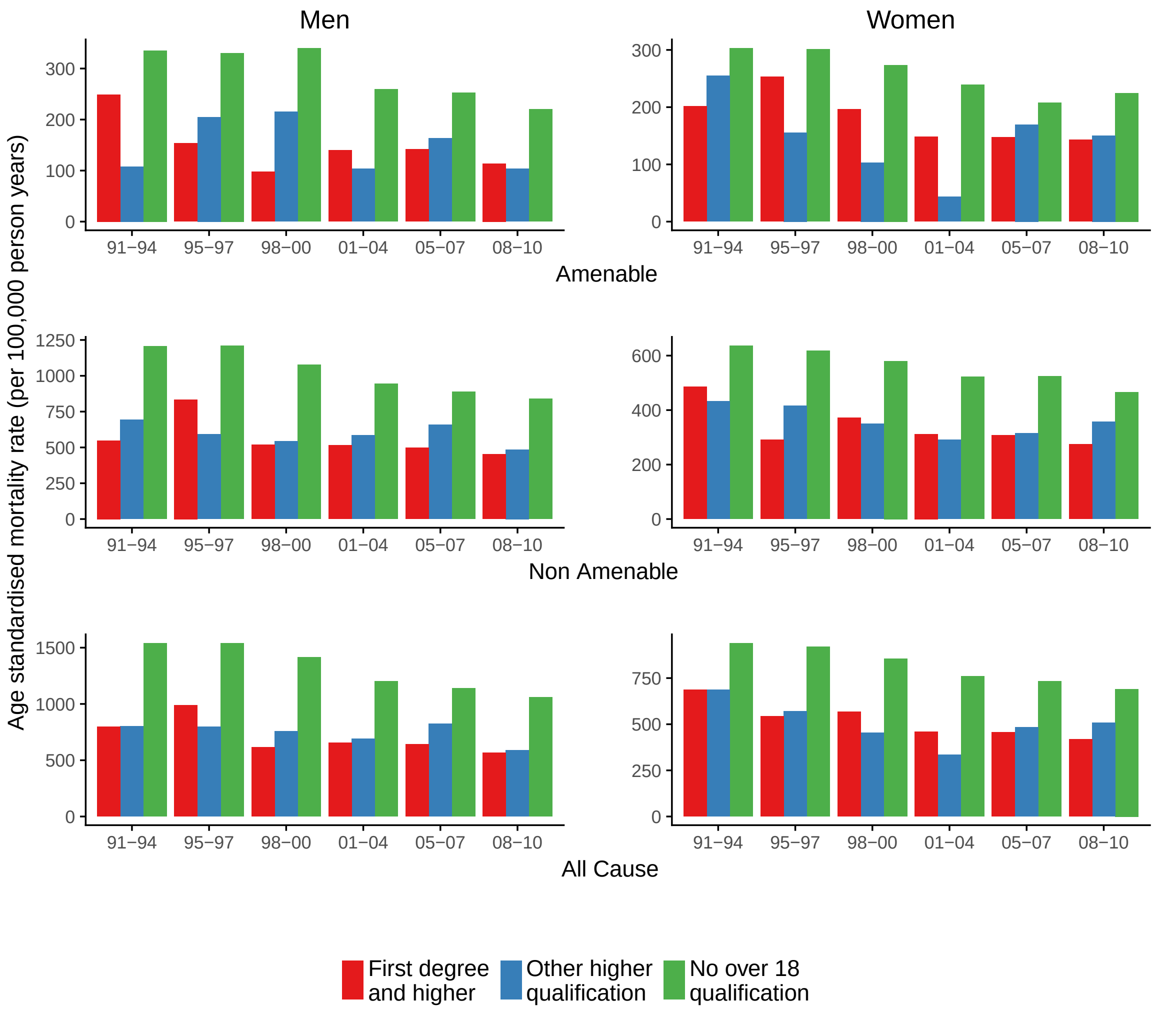


Figure 6.5: Age standardised mortality rates per 100,000 person years in educational attainment for Men and Women, aged 35-74 in 1991-2010. Note graphs are on different scales.
Source: Scottish Longitudinal Study

Age standardised mortality rates, displayed in Figure 6.5, are higher for men than they are for women, across all three mortality groups. Mortality rates between those who had a first degree and higher, and those that had some other higher qualification are approximately equal in the majority of years, and rates for those who had not attained any further educational qualifications after turning 18 are much larger.

Table 6.15 describes the relative inequalities across the levels of educational attainment in the three mortality groups. Inequalities are approximately equal across the three mortality groups, with inequalities in amenable mortality having the widest range, reflecting the smaller number of deaths contributing to the results.

Table 6.15: Relative inequalities in educational attainment *Source: Scottish Longitudinal Study*

	Amenable		Non-amenable		All-cause	
	RII	95%CI	RII	95%CI	RII	95%CI
Men						
1991-1994*	3.43	(1.87 - 7.46)	3.51	(2.52 - 4.99)	3.50	(2.62 - 4.79)
1995-1997	3.44	(1.83 - 7.66)	3.16	(2.26 - 4.68)	3.22	(2.37 - 4.55)
1998-2000	4.23	(2.30 - 9.17)	4.52	(3.11 - 6.91)	4.45	(3.21 - 6.37)
2001-2004*	3.80	(2.22 - 7.24)	3.49	(2.64 - 4.68)	3.55	(2.76 - 4.63)
2005-2007	3.43	(1.97 - 6.53)	2.85	(2.14 - 3.84)	2.96	(2.29 - 3.91)
2008-2010	3.48	(1.97 - 6.68)	3.37	(2.51 - 4.60)	3.39	(2.59 - 4.44)
Women						
1991-1994*	1.69	(0.98 - 3.27)	2.30	(1.50 - 3.70)	2.07	(1.47 - 3.02)
1995-1997	2.45	(1.31 - 5.24)	2.78	(1.77 - 4.73)	2.67	(1.83 - 4.03)
1998-2000	3.85	(1.98 - 9.17)	2.94	(1.83 - 4.97)	3.20	(2.19 - 4.90)
2001-2004*	2.58	(1.54 - 4.66)	2.66	(1.85 - 3.97)	2.64	(1.96 - 3.69)
2005-2007	2.00	(1.15 - 3.83)	3.08	(2.10 - 4.76)	2.70	(1.96 - 3.83)
2008-2010	2.25	(1.34 - 4.08)	2.61	(1.81 - 3.93)	2.48	(1.82 - 3.46)

* Contains census year

Over the twenty years, there are no significant increases or decreases in relative inequalities for men nor women within each of the mortality groups, however, there are fluctuations between each study period.

In 1991-94, amenable mortality rates for men with no over 18 education are approximately 3.4 times as large as men who had attained a university level education, rising to 4.2 times as large in 1998 - 2000. In the second census period, there was a small decrease in relative inequalities from the first study period (RII = 3.8) to the last study period (RII = 3.5). All confidence intervals overlapped, indicating that there were no significant changes over the six study periods. The relative inequalities in rates of amenable mortality for women are the smallest of all the mortality groups for both census periods.

Table 6.16 indicates that absolute inequalities in deaths for men are significantly lower for the amenable conditions, than the all-cause and non-amenable conditions. For women, the absolute inequalities in amenable mortality are lowest, however, they are not significantly different from the non-amenable conditions in the majority of year groups. As with the relative inequalities, there are no significant differences in absolute inequalities in amenable mortality for women in 1991-94.

Table 6.16: Slope Indices of Inequality in educational attainment for Men and Women, aged 35-74 in 1991-2010 *Source: Scottish Longitudinal Study*

	Amenable		Non-amenable		All-cause	
	SII	95%CI	SII	95%CI	SII	95%CI
Men						
1991-1994*	348.5	(191.9 - 484.9)	1,270.5	(984.9 - 1,520.0)	1,619.1	(1,305.9 - 1,909.5)
1995-1997	342.4	(182.7 - 478.9)	1,187.0	(884.7 - 1,481.1)	1,529.3	(1,182.7 - 1,861.2)
1998-2000	390.5	(248.7 - 507.9)	1,273.6	(1,024.5 - 1,492.1)	1,664.3	(1,379.6 - 1,916.0)
2001-2004*	270.1	(175.8 - 350.7)	939.1	(762.7 - 1,098.0)	1,208.9	(1,009.1 - 1,390.8)
2005-2007	247.3	(146.7 - 330.8)	770.5	(582.5 - 941.9)	1,017.4	(806.8 - 1,217.9)
2008-2010	214.9	(126.6 - 287.1)	802.0	(637.0 - 951.4)	1,016.8	(828.0 - 1,181.7)
Women						
1991-1994*	152.4	(-5.9 - 315.8)	486.1	(245.5 - 709.4)	635.2	(345.8 - 919.9)
1995-1997	243.6	(78.0 - 393.1)	556.8	(329.3 - 770.4)	800.4	(515.1 - 1,061.1)
1998-2000	301.8	(169.1 - 412.8)	543.0	(324.4 - 732.7)	845.9	(602.9 - 1,068.3)
2001-2004*	195.8	(94.4 - 286.6)	441.1	(289.9 - 580.3)	636.7	(457.8 - 811.7)
2005-2007	130.8	(27.6 - 229.6)	490.1	(340.3 - 627.4)	621.5	(438.5 - 792.6)
2008-2010	160.3	(60.9 - 253.2)	382.4	(246.2 - 509.7)	541.9	(371.2 - 702.9)

* Contains census year

6.5.2 Social class based on occupation

There are two measures of occupational social class available for analysis in the SLS: Social Class (SC), and NS-SEC. Within each measure, approximately 22% and 32% of all cause deaths are amenable to health care, for men and women respectively, amongst those who had an occupational social class measure available.

Table 6.17: Numbers of deaths and associated person years at risk for persons with a reported SC (age 35 - 74 years) *Source: Scottish Longitudinal Study*

	Amenable	Non-amenable	All-cause	Person Years
Men				
1991-1994*	344	1,389	1,733	184,797.8
1995-1997	335	1,300	1,635	158,398.3
1998-2000	359	1,233	1,592	164,503.4
2001-2004*	375	1,426	1,801	206,589.4
2005-2007	310	1,161	1,471	171,332.7
2008-2010	286	1,135	1,421	171,477.6
Women				
1991-1994*	251	471	722	155,407.3
1995-1997	259	486	745	139,106.1
1998-2000	260	552	812	149,516.6
2001-2004*	391	854	1,245	218,005.0
2005-2007	294	748	1,042	182,924.2
2008-2010	342	690	1,032	184,415.9

* Contains census year

8% of all male deaths in 1991 to 2000 occurred in the lowest category of SC, unskilled occupations. For women, 21.3% of all-cause deaths were in this category. There was little change for men in the second census period, but the percentage of female deaths decreased to 18.2%. The distribution was similar in the amenable and non-amenable mortality groups.

Table 6.18: Numbers of deaths and associated person years at risk for persons with a reported NS-SEC (age 35 - 74 years) *Source: Scottish Longitudinal Study*

	Amenable	Non-amenable	All-cause	Person Years
Men				
1991-1994*	344	1,391	1,735	185,490.6
1995-1997	334	1,307	1,641	159,137.4
1998-2000	360	1,236	1,596	165,313.2
2001-2004*	361	1,359	1,720	199,399.9
2005-2007	289	1,101	1,390	165,361.3
2008-2010	273	1,073	1,346	165,358.0
Women				
1991-1994*	251	471	722	154,546.6
1995-1997	258	482	740	138,231.2
1998-2000	260	550	810	148,431.8
2001-2004*	377	823	1,200	210,793.3
2005-2007	285	717	1,002	176,683.4
2008-2010	331	660	991	177,805.5

* Contains census year

When using the NS-SEC to classify SLS members, approximately 30% of all-cause deaths were categorised to the lowest level, routine occupations, in the first census period, decreasing to 28% in the second census period. Percentages were similar for men and women.

The overall numbers of deaths and person years at risk available for each of the social class analyses are not equal, however, the differences are small between the two, especially in the second census period. This is due to the two social class variables being derived from different variables recorded in the census.

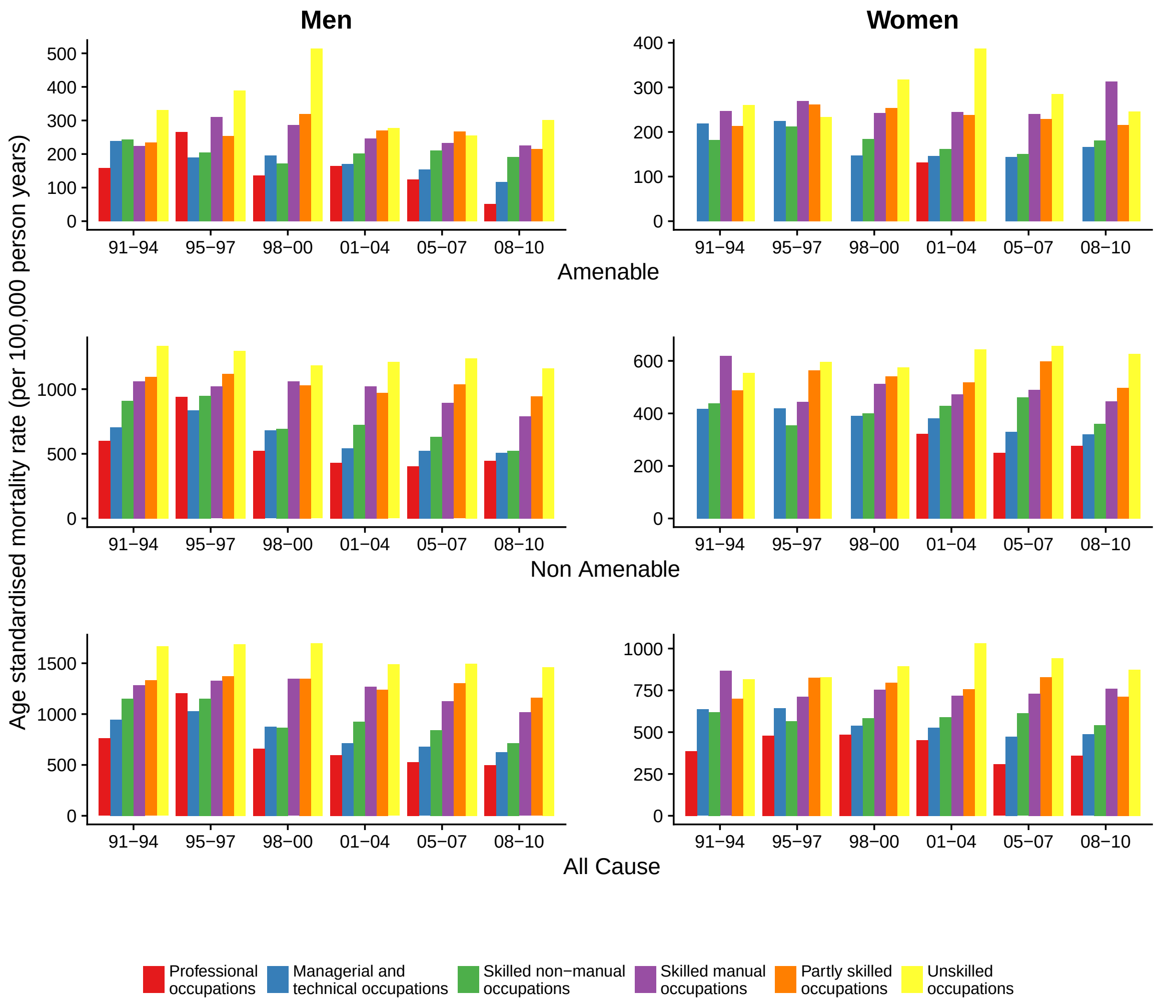


Figure 6.6: Age standardised mortality rates per 100,000 person years in SC for Men and Women, aged 35-74 in 1991-2010. Note graphs are on different scales.
Source: Scottish Longitudinal Study

A clear gradient across the all-cause deaths is evident in Figure 6.6 for the SC measure across the majority of the analysis periods. Mortality rates are higher for men than they are for women, across all mortality groups. The missing mortality rates for some of the time periods for women with professional occupations in the amenable and non-amenable mortality groups are due to being rates being suppressed by the SLS to ensure that the results are non-disclosive (see section 3.11 for further detail).

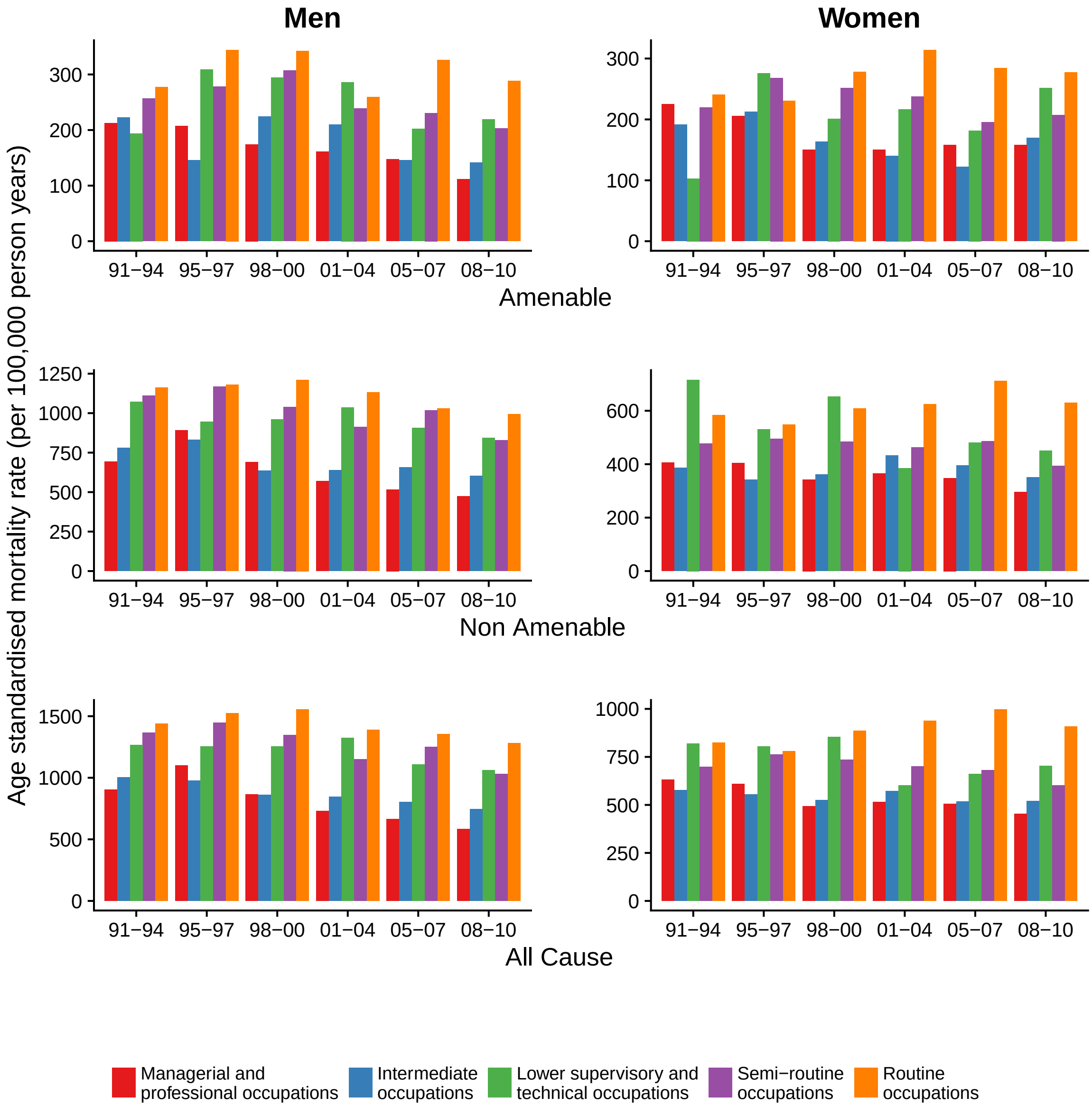


Figure 6.7: Age standardised mortality rates per 100,000 person years in NS-SEC for Men and Women, aged 35-74 in 1991-2010. Note graphs are on different scales.
Source: Scottish Longitudinal Study

The NS-SEC is not a strictly ordinal variable, unless it is collapsed to three categories, as described in section 6.4.2. However, increasing gradients in age standardised all-cause mortality rates are evident in the majority of the year groupings when five categories are used, especially for men (Figure 6.7). Analyses on the inequalities in mortality rates using NS-SEC presented in the remainder of this thesis make use of the five categories.

Table 6.19: Relative inequalities in SC *Source: Scottish Longitudinal Study*

	Amenable		Non-amenable		All-cause	
	RII	95%CI	RII	95%CI	RII	95%CI
Men						
1991-1994*	1.20	(0.88 - 1.88)	2.04	(1.70 - 2.47)	1.84	(1.57 - 2.21)
1995-1997	1.74	(1.18 - 2.54)	1.58	(1.31 - 1.93)	1.62	(1.36 - 1.92)
1998-2000	2.77	(1.90 - 4.11)	2.17	(1.78 - 2.63)	2.29	(1.91 - 2.73)
2001-2004*	2.12	(1.47 - 3.06)	2.81	(2.34 - 3.38)	2.65	(2.25 - 3.13)
2005-2007	2.37	(1.60 - 3.59)	3.20	(2.59 - 3.97)	3.01	(2.50 - 3.62)
2008-2010	3.30	(2.21 - 4.98)	2.85	(2.30 - 3.56)	2.93	(2.43 - 3.54)
Women						
1991-1994*	1.17	(0.79 - 1.96)	1.64	(1.13 - 2.16)	1.46	(1.10 - 1.87)
1995-1997	1.11	(0.72 - 1.71)	1.97	(1.42 - 2.75)	1.61	(1.23 - 2.08)
1998-2000	2.52	(1.62 - 3.98)	1.88	(1.39 - 2.53)	2.07	(1.61 - 2.66)
2001-2004*	3.15	(2.14 - 4.68)	1.94	(1.50 - 2.49)	2.26	(1.83 - 2.78)
2005-2007	2.51	(1.65 - 3.85)	2.54	(1.96 - 3.31)	2.53	(2.02 - 3.16)
2008-2010	1.97	(1.35 - 2.89)	2.26	(1.72 - 3.00)	2.16	(1.73 - 2.71)

* Contains census year

Relative inequalities in amenable mortality for men range from being non-significant in the first analysis period, to being 3.3 times higher for the theoretically lowest social class, compared to the highest social class, in the last analysis period (see Table 6.19). The range of relative inequalities for all-cause and non-amenable mortality are smaller, and all estimates indicate increasing inequalities over time.

There are no significant inequalities in amenable mortality for women in 1991 to 1997, however, the inequalities for 1998 to 2000 were largest of all three mortality groups. Female relative inequalities in amenable mortality appear to decrease during the second census period, whilst there is more fluctuation within the all-cause and non-amenable mortality groups.

Table 6.20: Relative inequalities in NS-SEC *Source: Scottish Longitudinal Study*

	Amenable		Non-amenable		All-cause	
	RII	95%CI	RII	95%CI	RII	95%CI
Men						
1991-1994*	1.49	(1.01 - 2.19)	2.13	(1.76 - 2.58)	1.99	(1.68 - 2.36)
1995-1997	2.32	(1.55 - 3.50)	1.65	(1.36 - 2.02)	1.78	(1.49 - 2.12)
1998-2000	2.45	(1.71 - 3.58)	2.41	(1.96 - 2.97)	2.42	(2.02 - 2.90)
2001-2004*	1.93	(1.36 - 2.77)	2.69	(2.22 - 3.27)	2.51	(2.12 - 2.97)
2005-2007	3.07	(1.98 - 4.80)	2.79	(2.26 - 3.46)	2.84	(2.34 - 3.44)
2008-2010	3.60	(2.34 - 5.59)	2.82	(2.27 - 3.50)	2.96	(2.43 - 3.60)
Women						
1991-1994*	1.19	(0.75 - 1.91)	1.72	(1.23 - 2.42)	1.51	(1.15 - 2.00)
1995-1997	1.12	(0.73 - 1.73)	1.83	(1.31 - 2.57)	1.54	(1.20 - 2.00)
1998-2000	2.46	(1.58 - 3.89)	2.28	(1.68 - 3.12)	2.34	(1.81 - 3.03)
2001-2004*	2.78	(1.88 - 4.14)	1.87	(1.45 - 2.42)	2.11	(1.72 - 2.61)
2005-2007	2.35	(1.49 - 3.74)	2.61	(1.98 - 3.47)	2.53	(1.99 - 3.22)
2008-2010	2.19	(1.47 - 3.28)	2.46	(1.85 - 3.30)	2.37	(1.87 - 3.01)

* Contains census year

When NS-SEC is used as the measure of occupational social class, relative inequalities are generally largest in rates of amenable mortality for men, with inequalities in non-amenable and all-cause deaths being broadly similar in magnitude. There is no clear difference between the female mortality groups, although there are no significant inequalities in amenable mortality in the first two time periods.

The absolute inequalities in amenable mortality for men, shown in Table 6.21 are lower for all study periods, when compared to inequalities in all-cause and non-amenable mortality. There are no significant inequalities in rates of amenable mortality for men in the first study period, and for women in the first and second study periods.

When using NS-SEC as the measure of occupational social class, only women in the first two study periods experience no significant inequalities in amenable mortality. The remaining indices in Table 6.22 are significant across all mortality groups and study periods.

Table 6.21: Slope Indices of Inequality in SC for Men and Women, aged 35-74 in 1991-2010 *Source: Scottish Longitudinal Study*

	Amenable		Non-amenable		All-cause	
	SII	95%CI	SII	95%CI	SII	95%CI
Men						
1991-1994*	39.1	(-26.8 - 129.1)	649.7	(490.9 - 803.2)	699.9	(525.9 - 891.3)
1995-1997	124.7	(38.5 - 200.5)	450.3	(265.3 - 631.3)	590.0	(378.8 - 791.7)
1998-2000	220.7	(145.8 - 286.3)	657.2	(502.1 - 801.3)	904.5	(723.6 - 1,069.8)
2001-2004*	142.8	(75.7 - 202.1)	784.4	(661.7 - 897.1)	946.1	(806.5 - 1,079.0)
2005-2007	150.6	(84.8 - 208.6)	811.4	(684.2 - 924.5)	983.4	(841.6 - 1,113.0)
2008-2010	171.2	(120.6 - 213.0)	678.5	(556.2 - 792.8)	872.3	(739.8 - 993.6)
Women						
1991-1994*	28.9	(-43.6 - 122.2)	230.3	(57.0 - 347.1)	258.1	(67.2 - 417.8)
1995-1997	20.8	(-68.2 - 107.5)	293.1	(156.3 - 419.3)	318.3	(140.0 - 479.1)
1998-2000	159.6	(87.4 - 221.2)	278.4	(149.7 - 394.2)	462.2	(309.2 - 604.0)
2001-2004*	193.5	(135.5 - 242.3)	296.4	(185.8 - 395.7)	517.2	(393.1 - 631.2)
2005-2007	139.9	(79.5 - 191.1)	408.0	(304.8 - 503.1)	566.0	(442.0 - 678.4)
2008-2010	116.1	(52.6 - 172.7)	315.5	(216.1 - 408.1)	445.4	(323.5 - 559.7)

* Contains census year

Table 6.22: Slope Indices of Inequality in NS-SEC for Men and Women, aged 35-74 in 1991-2010 *Source: Scottish Longitudinal Study*

	Amenable		Non-amenable		All-cause	
	SII	95%CI	SII	95%CI	SII	95%CI
Men						
1991-1994*	92.0	(3.3 - 175.3)	686.2	(523.4 - 836.9)	780.8	(597.3 - 955.8)
1995-1997	204.3	(110.4 - 285.3)	492.9	(303.1 - 674.7)	699.1	(492.4 - 904.2)
1998-2000	220.7	(136.9 - 296.0)	737.7	(577.8 - 884.6)	958.5	(781.5 - 1,124.2)
2001-2004*	140.3	(67.2 - 207.5)	746.4	(616.6 - 866.7)	890.3	(741.9 - 1,029.0)
2005-2007	205.1	(132.3 - 264.2)	718.5	(589.4 - 839.8)	923.7	(773.1 - 1,058.8)
2008-2010	203.1	(144.0 - 250.3)	660.5	(540.1 - 771.8)	864.3	(729.4 - 988.1)
Women						
1991-1994*	37.5	(-61.1 - 134.2)	249.8	(99.4 - 393.2)	279.9	(93.7 - 457.4)
1995-1997	27.2	(-72.7 - 125.2)	262.9	(119.9 - 394.0)	290.5	(123.0 - 453.6)
1998-2000	177.8	(94.2 - 249.3)	354.6	(230.3 - 467.2)	532.6	(382.9 - 670.7)
2001-2004*	193.1	(125.9 - 250.7)	278.0	(168.9 - 381.8)	475.1	(350.8 - 593.4)
2005-2007	147.5	(72.3 - 211.5)	413.3	(305.1 - 513.3)	560.8	(429.5 - 680.7)
2008-2010	148.2	(75.5 - 211.2)	339.4	(239.3 - 430.7)	487.5	(364.3 - 601.6)

* Contains census year

6.5.3 Household relationships

The numbers of deaths and person years at risk for persons with household relationships, displayed in Table 6.23 and recorded on the census form are the largest of all the individual level variables explored in this analysis. 83.5% of all male deaths and 87.5% of all female deaths between the ages of 35 and 74 years in the study cohort are included.

Of the all cause deaths, 22% and 32% are amenable to health care, for men and women respectively.

Table 6.23: Numbers of deaths and associated person years at risk for persons with a reported household relationship (age 35 - 74 years) *Source: Scottish Longitudinal Study*

	Amenable	Non-amenable	All-cause	Person Years
Men				
1991-1994*	590	2,158	2,748	209,790.5
1995-1997	486	1,769	2,255	174,372.10
1998-2000	482	1,563	2,045	178,110.5
2001-2004*	454	1,684	2,138	216,221.6
2005-2007	365	1,319	1,684	177,686.8
2008-2010	332	1,262	1,594	176,370.4
Women				
1991-1994*	679	1,368	2,047	229,369.6
1995-1997	524	1,106	1,630	189,601.4
1998-2000	480	1,018	1,498	193,434.9
2001-2004*	489	1,116	1,605	234,907.9
2005-2007	364	886	1,250	193,333.5
2008-2010	398	833	1,231	192,472.0

* Contains census year

In the first study period, 68.4% of the male amenable deaths occurred in men who were living in a consensual relationship, whilst in 2001 - 2004 this decreased to 40.5%. For women, the percentage of deaths for women living in a consensual relationship decreased from 64.1% to 37.3% for the same periods. For all-cause mortality, the percentage of deaths of men living in a relationship decreased from 70.6% to 43.9%. The equivalent percentages for women are 57.9% to 33.9%.

At the 1991 census, 80% of male and 70% of female years at risk were of those reported as living in a relationship. In 2001, this fell to 64% and 56% respectively.

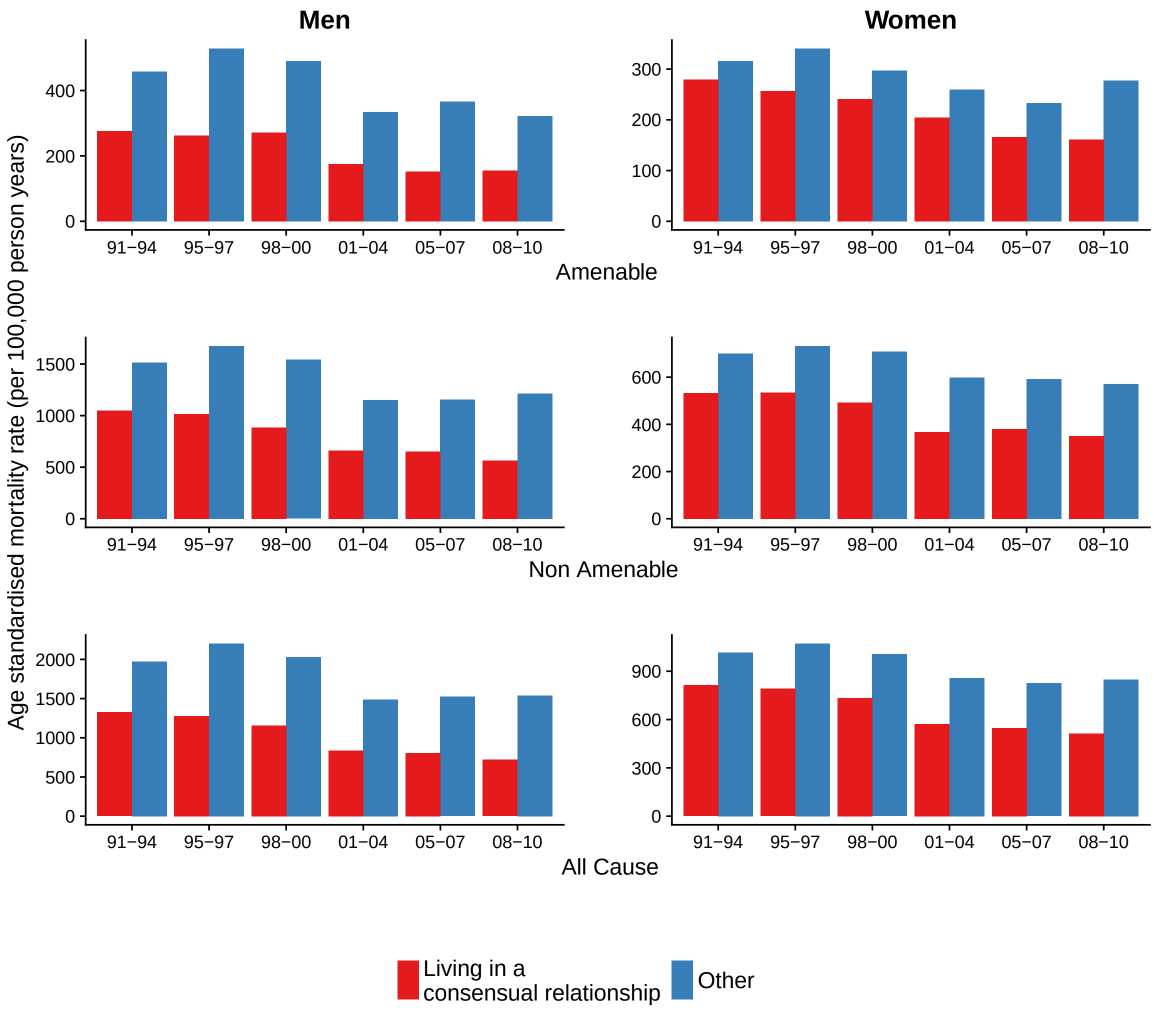


Figure 6.8: Age standardised mortality rates per 100,000 person years in household relationships for Men and Women, aged 35-74 in 1991-2010. Note graphs are on different scales.
Source: Scottish Longitudinal Study

It can be seen in Figure 6.8 that the age-standardised mortality rates for those living in consensual relationships are consistently lower than those who did not report as living with a partner, for both sexes. The smallest differences in rates between men and women occurred in the amenable mortality group, whilst male rates were approximately double those of females for the majority of the other two mortality groups. All mortality rates across all three mortality groups fell in the second decade of analyses.

Table 6.24: Relative inequalities in household relationships *Source: Scottish Longitudinal Study*

	Amenable		Non-amenable		All cause	
	RII	95%CI	RII	95%CI	RII	95%CI
Men						
1991-1994*	2.75	(1.91 - 3.93)	2.11	(1.74 - 2.54)	2.24	(1.89 - 2.64)
1995-1997	4.09	(2.77 - 5.95)	2.72	(2.21 - 3.32)	2.98	(2.47 - 3.58)
1998-2000	3.40	(2.26 - 4.98)	3.10	(2.46 - 3.86)	3.17	(2.61 - 3.85)
2001-2004*	4.82	(2.94 - 7.99)	3.35	(2.64 - 4.28)	3.61	(2.92 - 4.49)
2005-2007	6.55	(4.01 - 10.61)	3.52	(2.73 - 4.51)	4.03	(3.21 - 5.04)
2008-2010	4.42	(2.80 - 6.91)	4.62	(3.70 - 5.77)	4.57	(3.73 - 5.59)
Women						
1991-1994*	1.31	(0.96 - 1.78)	1.74	(1.39 - 2.16)	1.58	(1.32 - 1.89)
1995-1997	1.75	(1.21 - 2.51)	1.84	(1.44 - 2.36)	1.81	(1.48 - 2.22)
1998-2000	1.55	(1.05 - 2.24)	2.01	(1.56 - 2.59)	1.85	(1.50 - 2.28)
2001-2004*	2.07	(1.26 - 3.37)	2.72	(1.94 - 3.79)	2.49	(1.90 - 3.27)
2005-2007	2.11	(1.29 - 3.47)	2.73	(1.96 - 3.83)	2.53	(1.93 - 3.36)
2008-2010	2.93	(1.93 - 4.48)	2.74	(2.01 - 3.71)	2.80	(2.19 - 3.59)

* Contains census year

There were fairly large relative inequalities in rates of deaths for men over the two census periods, the largest occurring within the amenable mortality group. Results in Table 6.24 indicate that amenable mortality rates for men not living in a consensual relationship ranged between 2.8 and 6.6 times higher than for men living with a partner, over the twenty years of analysis.

Relative inequalities in amenable mortality for women remained the smallest among the mortality groups, except in the last study period. Overall, relative inequalities for both men and women increased over the study periods

When absolute inequalities are investigated in Table 6.25, we can see that there is a difference of approximately 300 amenable deaths per 100,000 person years, whilst the inequalities in non-amenable mortality are approximately three times that. For women, the difference between the two mortality groups is smaller, with absolute inequalities in non-amenable mortality being just over double those of the amenable mortality.

Again, there are no significant inequalities in rates of amenable mortality in women during the first study period.

Table 6.25: Slope Indices of Inequality in household relationships for Men and Women, aged 35-74 in 1991-2010 *Source: Scottish Longitudinal Study*

	Amenable		Non-Amenable		All-cause	
	SII	95%CI	SII	95%CI	SII	95%CI
Men						
1991-1994*	291.7	(195.9 - 371.2)	815.6	(620.1 - 995.4)	1,111.8	(896.8 - 1,312.0)
1995-1997	382.3	(295.4 - 448.6)	1,056.0	(860.6 - 1,227.2)	1,449.0	(1,234.7 - 1,642.3)
1998-2000	339.8	(240.8 - 414.4)	1,027.6	(848.8 - 1,182.4)	1,367.9	(1,173.4 - 1,546.7)
2001-2004*	314.7	(236.2 - 372.8)	945.7	(787.0 - 1,087.3)	1,261.8	(1,091.2 - 1,416.9)
2005-2007	332.0	(271.3 - 373.8)	905.7	(753.3 - 1,035.3)	1,250.4	(1,089.2 - 1,389.0)
2008-2010	253.2	(190.2 - 299.8)	970.3	(865.2 - 1,061.7)	1,223.6	(1,101.9 - 1,329.3)
Women						
1991-1994*	79.1	(-12.0 - 167.1)	323.1	(197.0 - 440.9)	404.7	(249.5 - 552.2)
1995-1997	155.4	(54.5 - 244.3)	355.5	(215.4 - 485.1)	511.0	(342.5 - 668.2)
1998-2000	111.6	(12.8 - 199.1)	371.7	(241.2 - 490.1)	485.7	(324.2 - 635.1)
2001-2004*	153.8	(51.4 - 238.5)	465.6	(323.4 - 587.1)	617.7	(449.5 - 769.5)
2005-2007	141.9	(50.9 - 219.3)	449.3	(313.8 - 566.5)	591.3	(432.8 - 738.3)
2008-2010	207.9	(134.0 - 269.0)	415.5	(300.1 - 514.5)	623.9	(490.8 - 743.5)

* Contains census year

6.5.4 Area level measures of deprivation: the Carstairs index

The sub-sample of persons used to investigate inequalities at the area level in the SLS sample has the second largest numbers of deaths and person years at risk of all the analyses. 83.7% of all male and 87.0% of all female deaths between the ages of 35 and 74 were included in this analysis.

Again, similar percentages to the individual level SEP measures are observed in the amenable and all-cause deaths.

Table 6.26: Numbers of deaths and associated person years at risk for persons with a residential Carstairs (age 35 - 74 years) *Source: Scottish Longitudinal Study*

	Amenable	Non-amenable	All-cause	Person Years
Men				
1991-1994*	606	2,180	2,786	210,914.3
1995-1997	498	1,785	2,283	175,237.8
1998-2000	500	1,577	2,077	178,965.2
2001-2004*	450	1,630	2,080	191,139.3
2005-2007	328	1,211	1,539	155,183.0
2008-2010	302	1,158	1,460	153,273.5
Women				
1991-1994*	696	1,402	2,098	230,410.0
1995-1997	533	1,113	1,646	190,307.0
1998-2000	483	1,027	1,510	194,116.6
2001-2004*	489	1,100	1,589	214,647.1
2005-2007	339	864	1,203	175,252.0
2008-2010	380	784	1,164	173,811.6

* Contains census year

Approximately 10% of the person years at risk in 1991 and 2001 were assigned to each Carstairs decile, for both men and women. Therefore the sample is a fair representation of the whole Scottish population. Approximately 13% of all cause deaths were for persons living in the most deprived decile.

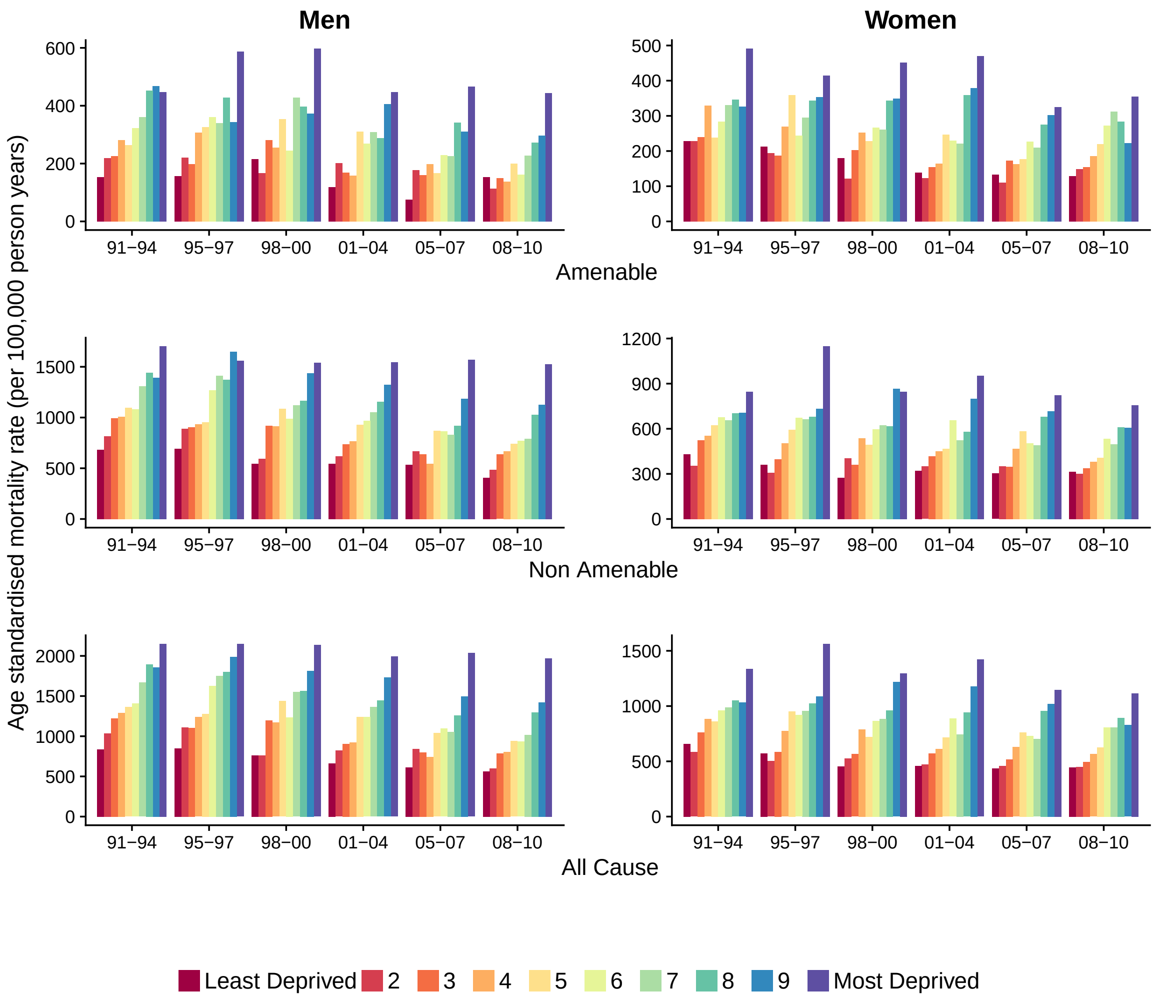


Figure 6.9: Age standardised mortality rates per 100,000 person years in area level deprivation for Men and Women, aged 35-74 in 1991-2010. Note graphs are on different scales.
Source: Scottish Longitudinal Study

Figure 6.9 illustrates the increasing gradient across the deprivation deciles, for all mortality groups and both sexes. Gradients are less smooth in the amenable mortality plots, owing to the smaller numbers of deaths. Rates of all-cause mortality decrease between the first and second census periods.

Table 6.27: Relative inequalities in area level deprivation *Source: Scottish Longitudinal Study*

	Amenable		Non-amenable		All-cause	
	RII	95%CI	RII	95%CI	RII	95%CI
Men						
1991-1994*	3.18	(2.36 - 4.25)	2.47	(2.11 - 2.89)	2.61	(2.28 - 3.00)
1995-1997	3.05	(2.22 - 4.20)	2.65	(2.23 - 3.16)	2.73	(2.34 - 3.17)
1998-2000	3.00	(2.19 - 4.20)	2.81	(2.35 - 3.36)	2.85	(2.44 - 3.34)
2001-2004*	3.60	(2.59 - 5.09)	2.95	(2.48 - 3.53)	3.08	(2.63 - 3.60)
2005-2007	4.15	(2.82 - 6.23)	2.79	(2.26 - 3.44)	3.03	(2.53 - 3.65)
2008-2010	3.53	(2.32 - 5.46)	3.47	(2.81 - 4.28)	3.48	(2.90 - 4.22)
Women						
1991-1994*	1.98	(1.50 - 2.62)	2.09	(1.73 - 2.54)	2.05	(1.75 - 2.40)
1995-1997	2.14	(1.57 - 2.94)	3.37	(2.69 - 4.20)	2.90	(2.43 - 3.48)
1998-2000	2.98	(2.13 - 4.16)	3.03	(2.43 - 3.82)	3.02	(2.51 - 3.63)
2001-2004*	4.45	(3.18 - 6.27)	3.07	(2.47 - 3.81)	3.43	(2.85 - 4.14)
2005-2007	3.17	(2.18 - 4.69)	2.89	(2.26 - 3.68)	2.96	(2.42 - 3.62)
2008-2010	2.73	(1.93 - 3.88)	2.74	(2.13 - 3.56)	2.73	(2.22 - 3.37)

* Contains census year

Relative inequalities in amenable mortality are consistently the largest for males compared to non-amenable and all-cause deaths, whilst for females, only during the second census period do relative inequalities in amenable mortality rates exceed those of non-amenable and all-cause mortality (see Table 6.27). There are no clear patterns of fluctuations across the study periods.

Whilst relative inequalities in rates of amenable deaths were largest for men, when absolute inequalities are compared in Table 6.28, the inequalities are the smallest across the three mortality groups. Absolute inequalities in amenable mortality for both men and women are consistently smaller than for non-amenable mortality for all study periods.

Table 6.28: Slope Indices of Inequality in area level deprivation for Men and Women, aged 35-74 in 1991-2010 *Source: Scottish Longitudinal Study*

	Amenable		Non-amenable		All-cause	
	SII	95%CI	SII	95%CI	SII	95%CI
Men						
1991-1994*	332.8	(258.2 - 395.3)	972.5	(819.8 - 1,113.9)	1,307.1	(1,142.2 - 1,464.8)
1995-1997	325.1	(243.6 - 395.5)	1,035.0	(871.2 - 1,189.5)	1,360.6	(1,179.1 - 1,527.0)
1998-2000	321.8	(239.9 - 396.0)	957.8	(813.0 - 1,092.0)	1,279.6	(1,116.1 - 1,434.7)
2001-2004*	291.5	(228.0 - 346.3)	911.3	(784.0 - 1,030.1)	1,203.5	(1,061.6 - 1,333.1)
2005-2007	271.4	(211.3 - 321.1)	773.9	(633.5 - 901.9)	1,049.5	(902.9 - 1,187.9)
2008-2010	223.9	(159.4 - 276.6)	844.3	(725.9 - 949.5)	1,068.2	(938.8 - 1,190.5)
Women						
1991-1994*	199.2	(120.4 - 271.2)	430.5	(325.0 - 530.1)	629.6	(500.2 - 751.9)
1995-1997	209.6	(128.7 - 283.4)	650.0	(550.0 - 738.0)	865.3	(741.1 - 983.5)
1998-2000	259.3	(188.6 - 319.7)	560.4	(462.8 - 650.2)	819.7	(702.3 - 928.1)
2001-2004*	301.7	(248.5 - 345.6)	546.5	(454.9 - 628.2)	852.1	(746.2 - 948.0)
2005-2007	209.3	(149.1 - 261.1)	497.4	(396.5 - 586.5)	707.0	(593.0 - 809.7)
2008-2010	204.0	(139.9 - 259.7)	425.2	(330.5 - 513.3)	629.1	(514.6 - 735.5)

* Contains census year

Comparing sample to population

The age-standardised amenable mortality rates are displayed in Figure 6.10. The amenable mortality rates calculated in the SLS, in the red, use the person years at risk for the denominator (per 100,000 person years), whilst the mortality rates calculated using the death register use the population size as the denominator (per 100,000 population). The rates within the deprivation deciles are plotted, but are not identified in separate colours, in order to simplify the comparison between the two data sources. The left most bars are the amenable mortality rates in the least deprived decile, whilst the right most bars are the most deprived deciles, within each data source.

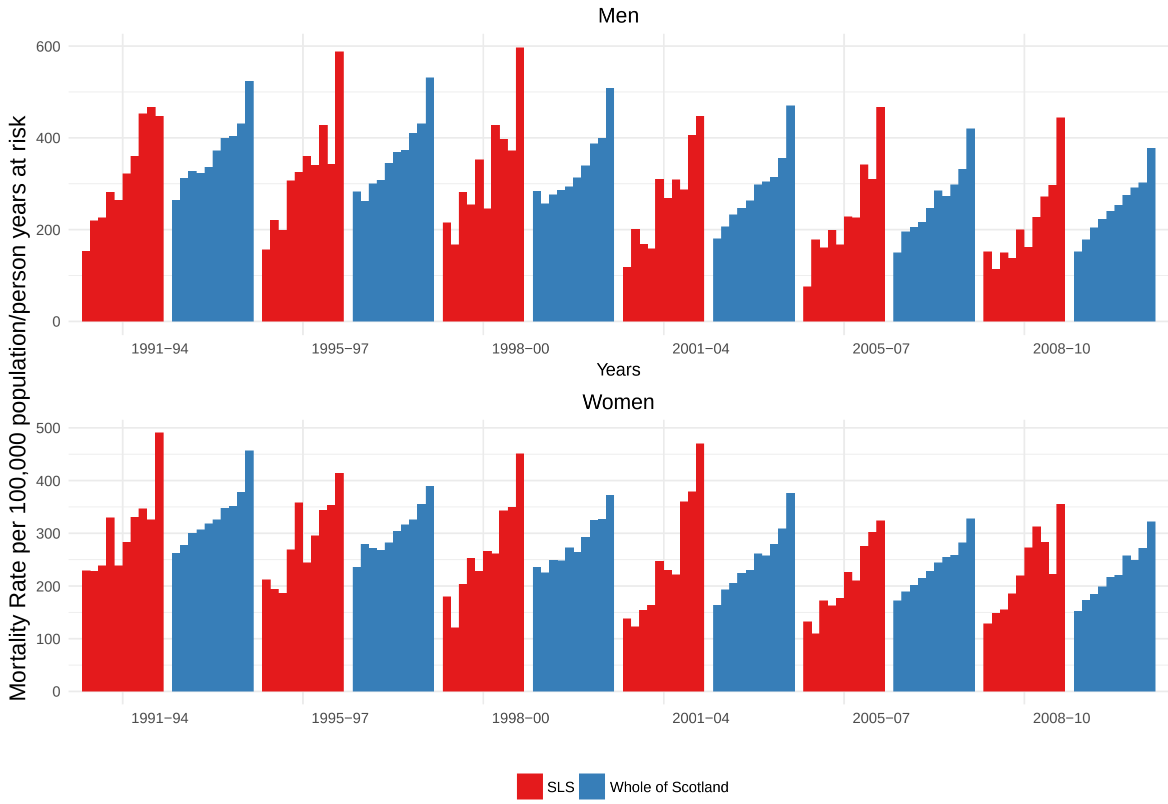


Figure 6.10: Age standardised mortality rates per 100,000 person years in area level deprivation for Men and Women, ages 35-74 in 1991-2010: SLS vs Whole of Scotland.
Source: Scottish Longitudinal Study

The age-standardised amenable mortality rates calculated for the whole Scottish population have a stricter gradient across the deprivation deciles, compared to the SLS amenable mortality rates, which do not strictly increase with increasing deprivation. The amenable mortality rates in the most deprived decile tend to be marginally larger in the SLS sample, than for the whole Scottish population.

Table 6.29 contains the relative indices of inequality calculated using each data source. The relative inequalities in amenable mortality rates calculated in the total population are all smaller than those estimated using the SLS dataset, except for women during the last year group, where inequalities are estimated to be similar. The majority of the 95% confidence intervals overlap, indicating that the inequalities calculated are not likely to be significantly different from each other (except for men in 1991-94, and women in 2001-2004).

Table 6.29: Relative inequalities in area level deprivation: SLS vs total population *Source: Scottish Longitudinal Study*

	SLS		Total Population	
	RII	95%CI	RII	95%CI
Men				
1991-1994*	3.18	(2.36 - 4.25)	1.91	(1.80 - 2.03)
1995-1997	3.05	(2.22 - 4.20)	2.09	(1.95 - 2.24)
1998-2000	3.00	(2.19 - 4.20)	2.04	(1.90 - 2.20)
2001-2004*	3.60	(2.59 - 5.09)	2.53	(2.37 - 2.70)
2005-2007	4.15	(2.82 - 6.23)	2.61	(2.42 - 2.83)
2008-2010	3.53	(2.32 - 5.46)	2.41	(2.22 - 2.61)
Women				
1991-1994*	1.98	(1.50 - 2.62)	1.69	(1.60 - 1.78)
1995-1997	2.14	(1.57 - 2.94)	1.61	(1.51 - 1.73)
1998-2000	2.98	(2.13 - 4.16)	1.72	(1.60 - 1.84)
2001-2004*	4.45	(3.18 - 6.27)	2.19	(2.05 - 2.33)
2005-2007	3.17	(2.18 - 4.69)	1.89	(1.75 - 2.04)
2008-2010	2.73	(1.93 - 3.88)	2.08	(1.93 - 2.25)

* Contains census year

Table 6.30: Slope Indices of Inequality in area level deprivation for Men and Women, aged 35-74 in 1991-2010: SLS vs total population *Source: Scottish Longitudinal Study*

	SLS		Total Population	
	SII	95%CI	SII	95%CI
Men				
1991-1994*	332.8	(258.2 - 395.3)	208.7	(189.3 - 227.6)
1995-1997	325.1	(243.6 - 395.5)	255.6	(233.4 - 277.5)
1998-2000	321.8	(239.9 - 396.0)	235.2	(212.5 - 257.4)
2001-2004*	291.5	(228.0 - 346.3)	225.0	(210.2 - 239.7)
2005-2007	271.4	(211.3 - 321.1)	232.5	(251.8 - 248.5)
2008-2010	223.9	(159.4 - 276.6)	204.6	(188.2 - 220.8)
Women				
1991-1994*	199.2	(120.4 - 271.2)	159.4	(142.6 - 176.1)
1995-1997	209.6	(128.7 - 283.4)	142.5	(123.3 - 161.9)
1998-2000	259.3	(188.6 - 319.7)	153.0	(134.3 - 172.1)
2001-2004*	301.7	(248.5 - 345.6)	168.0	(154.7 - 180.9)
2005-2007	209.3	(149.1 - 261.1)	146.0	(130.1 - 162.2)
2008-2010	204.0	(139.9 - 259.7)	157.6	(142.4 - 172.8)

* Contains census year

The comparison in absolute inequalities between the SLS and the total population, shown in Table 6.30, reveals that the absolute inequalities between the most deprived and the least deprived deciles are consistently lower than those estimated in the SLS, for all year groups and both sexes[6].

6.5.5 Sensitivity Analyses: educational attainment

As described in subsection 6.4.6, a sensitivity analyses was performed, investigating the effects of not adjusting the person years at risk for the migrations of SLS members. This was only explored for amenable deaths, using educational attainment as the measure of SEP.

The distribution of increased person years at risk used in the analyses are described in Table 6.31. Between 1991 and 2000, by not taking migration data into account, the person years at risk increases by between 0.3 and 1.0% in each of the study periods. After 2001, the increases range between 0.7 and 2.7%. The percentage increases are slightly higher for men than they are for women, across each study period.

[6]See section 6.7

Table 6.31: Sensitivity analysis: Increases (%) in person years at risk - persons with a reported educational attainment *Source: Scottish Longitudinal Study*

	Amenable deaths	New person years	Increase (%)
Men			
1991-1994*	576	205,150.94	892.30 (0.4)
1995-1997	465	171,473.29	1,236.06 (0.7)
1998-2000	475	176,092.44	1,657.41 (1.0)
2001-2004*	418	214,868.34	1,752.54 (0.8)
2005-2007	354	179,387.14	3,149.96 (1.8)
2008-2010	316	180,356.89	4,720.16 (2.7)
Women			
1991-1994*	642	220,388.85	693.49 (0.3)
1995-1997	505	183,042.48	1,067.79 (0.6)
1998-2000	451	187,604.19	1,275.53 (0.7)
2001-2004*	459	232,102.13	1,646.54 (0.7)
2005-2007	341	195,306.92	3,327.10 (1.7)
2008-2010	382	197,640.40	5,010.21 (2.6)

* Contains census year

Table 6.32: Sensitivity analysis: Relative and absolute inequalities in rates of amenable mortality, using educational attainment *Source: Scottish Longitudinal Study*

	RII	95%CI	SII	95%CI
Men				
1991-1994*	3.44	(1.86 - 7.31)	348.3	(191.0 - 481.0)
1995-1997	3.47	(1.87 - 7.77)	342.3	(188.4 - 478.0)
1998-2000	4.29	(2.30 - 9.27)	389.9	(246.8 - 504.8)
2001-2004*	3.86	(2.26 - 7.35)	271.0	(177.9 - 350.3)
2005-2007	3.52	(2.01 - 6.69)	248.4	(149.8 - 329.6)
2008-2010	3.60	(2.04 - 6.91)	215.8	(130.2 - 285.2)
Women				
1991-1994*	1.69	(0.97 - 3.23)	151.9	(-8.8 - 312.3)
1995-1997	2.46	(1.30 - 5.34)	242.9	(76.2 - 394.5)
1998-2000	3.85	(1.95 - 9.06)	300.2	(164.3 - 409.2)
2001-2004*	2.60	(1.55 - 4.69)	196.2	(95.4 - 286.2)
2005-2007	2.03	(1.17 - 3.89)	131.9	(30.2 - 229.0)
2008-2010	2.30	(1.37 - 4.19)	161.9	(64.8 - 252.4)

* Contains census year

The relative inequalities in educational attainment, when not adjusting for migration (Table 6.32), are slightly larger than when migrations have been accounted for (Table 6.15). All of the confidence intervals across the two tables overlap, suggesting that there is no significant difference in inequalities when migration is or is not adjusted for. There is a larger increase in the second census period, where the percentage increases in person years at risk were greatest.

When comparing the absolute inequalities, the inequalities in amenable mortality for the sensitivity analyses (Table 6.32) are smaller than the migration adjusted results (Table 6.16) in the first census period, but are larger in the second census period.

6.6 Discussion

This chapter aimed to investigate the social patterning of amenable mortality in Scotland, by individual measures of SEP and demographic factors, and to compare these to patterns found in all-cause and non-amenable mortality. Three measures of individual level SEP were used: educational attainment, social class and NS-SEC, and demographic differences were explored between living arrangements.

6.6.1 Principal Findings

In the first 10 years of analysis, when SEP measures from the 1991 Census are used, relative inequalities in amenable mortality were greatest when measured across educational attainment and living arrangements, and smallest when using the two occupational social class measures, for both men and women. In the years following the 2001 Census, there is less difference between the individual measures, and inequalities are generally greater than they were in 1991 - 2000.

Absolute inequalities in amenable mortality are greatest when using educational attainment, for both men and women, in 1991 - 2000, and smallest when the two occupational social class measures are used. In 2001 - 2010, living arrangements produce the greatest inequalities for men, whilst for women, all four measures are fairly similar.

In agreement with much of the literature reviewed in section 6.2, there are large inequalities in rates of all-cause, amenable and non-amenable mortality for those considered to be theoretically most disadvantaged - in educational attainment, occupational social class, or relationship status - compared to those considered to be most advantaged. Furthermore, none of the measures analysed found a consistent reduction in inequalities over time, despite overall rates decreasing.

In a universal health care setting, it could be expected that inequalities within amenable mortality would be smaller than all-cause, and non-amenable mortality. Absolute inequalities in amenable mortality were consistently smaller than all-cause and non-amenable although this is not surprising given that these are estimated based on the overall rates. In 1991-1994, the RIIs for amenable mortality are all lower than all-cause and non-amenable except for men measured using household relationships. By 2001-2004, the findings were less consistent, with RII for amenable mortality being the highest for men (educational attainment and living arrangements) and women (social class and NS-SEC).

Given the varied, and inconsistent results across the various measures of socioeconomic position, this thesis illustrates the importance and consideration required when selecting a SEP variable in future research, taking into account the likelihood of it dramatically changing over time, the relevance of the measure over time, as well as its availability.

6.6.2 Comparing sample to population

By including an analysis of area level deprivation within the SLS dataset, a comparison to the total Scottish population could be made.

The relative and absolute inequalities in rates of amenable mortality estimated in the sample over-estimated the inequalities calculated for the total population, for both men and women over the same periods of time. Whilst the methods used to calculate both sets of results are the same, the population estimates make use of population at risk as the denominator, whilst the SLS results were calculated using person years at risk. The RII and SII make use of a population fraction to account for changes to the structure of the denominator over time, although approximately 10% of the sample were allocated to each population decile, as was in the population. The age standardised mortality rates for sample and population were shown in Figure 6.10 indicated that higher rates of amenable deaths in the sample had occurred in the most deprived deciles, than observed in the total population. The Carstairs deprivation decile used in the sample analyses was the index associated with the SLS member's residence at the time of the Census, and not at the time of death. Therefore it is possible that study members may have moved to a more deprived area between completing the Census and death. Deprivation decile at time of Census, rather than at time of death, was used as all other individual measurements were taken at the same time.

In light of these findings, it could be assumed that the inequalities found in the individual measures may be over-estimated[7].

6.6.3 Sensitivity analysis

The sensitivity analyses indicate that making use of migration data to correct the person years at risk made little impact on the magnitude of inequalities found in the rates of amenable mortality for this analysis. However, as seen in Table 6.31, there was a greater percentage increase in person years in the later years of analysis. This could be either due to a better recording of migration, or there may have been a greater number of migrants moving to Scotland in the more recent years. Therefore future research should carefully consider the use of migration records, as further increases could have a greater impact on differences in inequalities.

6.6.4 Strengths and Limitations

The SLS is a large nationally representative sample of the Scottish population, with a high percentage of members linked across the censuses.

The vast majority of earlier studies had to make use of unlinked studies to investigate individual levels of socioeconomic position, therefore introducing numerator/denominator biases (Korda et al. 2007, Ezendam et al. 2008). This analysis makes use of person years at risk experienced by the SLS members as the denominator, removing the possibility of this bias.

Two measures of occupational social class were included in the analyses, allowing a comparison to be made between the current and superseded classification methods used in the UK. Despite the differing numbers of deaths and person years at risk in Tables 6.17 and 6.18, and a larger percentage of people being classified into the lowest category using the NS-SEC, the two methods of measuring occupational social class in the SLS largely agree with each other in terms of the magnitude of relative and absolute inequalities.

Through the use of RII and SII, comparisons between two census periods could be made. The changing distributions of the populations in each category are accounted for through the use of the population fraction, measuring the relative position and size of the population within each category (Schwarz 2007).

[7] See section 6.7

A large proportion of the deaths were not able to be categorised to one or both of the occupational social class measures. Only 66.1% and 52.9% of all male and female deaths under the age of 75 were assigned to a SC level, whilst 64.6% and 51.6% were assigned a NS-SEC classification respectively. These may be due to the SC and NS-SEC requiring multiple parts of the census to be answered, whilst the educational attainment and household arrangements can be ascertained in one question.

It is possible that the SLS vital events dataset is not complete, and not all member deaths have been linked to the full dataset. This could be due to delayed registrations of deaths, or unlinked deaths due to date of birth discrepancies (Popham & Boyle 2010). Any missing deaths in these cases will not affect the results presented here, as their missingness would not be related to their measures of individual socioeconomic position.

Less confidence can be put into results for the latter study periods within a census period, as SLS persons are classified based on their census responses up to 9 years previously. Whilst this is less likely to make a difference to the results using educational attainment, household relationships and occupational social class are much more likely to fluctuate between censuses (Boyle et al. 2009).

The assumption of the RII being calculated on a linear socioeconomic gradient in mortality rates for each measure was not always met. If a sufficient gradient was evident in the rates of all cause mortality, it was considered acceptable to continue analyses of the amenable and non-amenable deaths. A linear gradient in England for the 7 categories of the NS-SEC was reported by Siegler et al. (2008), keeping own account workers in their own category. This was attempted for these analyses, however, there was no smooth gradient across the seven categories. It was therefore decided to group the first four categories into two larger groups, and keep the tail of the smaller categories, in order to produce a linear gradient across five categories.

The relationships between individual SEP and specific causes of amenable mortality are not always clear cut (Feinstein 1993). There are several studies which have reported an association between decreasing deprivation and increasing rates of both breast and prostate cancers (Ezendam et al. 2008, Elstad et al. 2012). Confirmation of these findings in the SLS were not possible due to the small numbers of deaths available for individual causes of death in each study period and the potential for identifiability.

6.6.5 Relations to other studies

The comparability of these results with other countries is limited, due to the restricted number of categories available for many of the variables, as well as differences in methodologies. Relative inequalities in all cause mortality rates measured using educational attainment in the SLS sample are larger than all countries studied by Kulhanova et al. (2014) in Table 6.1. Whilst the methodologies used for calculating the RIIs are similar, Kulhanova et al. measured education using the ISCE categories, meaning that the inequalities measured in Scotland are equivalent to measuring inequalities within the highest category only (post-secondary or tertiary education).

The occupational social class measures are limited to comparisons with countries who have used the UK's social class measures. The age standardised mortality rates for men in the SLS are approximately 3 times larger within each category, compared to the results of the English LS analysed by White et al. (2007), reproduced in Table 6.4. Reasons for this include the generally higher mortality rates in Scotland as well as the older sample being used to calculate the SLS rates, than ages 25 - 64 used by White et al.

6.6.6 Future work

Two additional measures were identified as being of interest in the literature review: income and race/ethnic group. Income is not recorded on the census returns form, and therefore could not be included in this analysis. A STATA programme for creating a synthetic measure of income for SLS members has since been released, based on the work of Clemens & Dibben (2014), allowing for income inequalities in deaths to be investigated. This was not included in these analyses as self-reported measures were of interest.

Variables recording the race/ethnic group of the SLS members were requested for analyses, however, there were insufficient numbers of 'non-white' amenable deaths within each study period to perform valid analyses.

This thesis, and much of the literature, focuses on associations with one measure, adjusting for age and sex; less is known about their intersections (Manderbacka, Arffman, Sund & Karvonen 2014). Single measures of SEP do not exist in isolation, and the simultaneous analysis of multiple measures may reveal different influences on health than what would be found through the analysis of single measures (Hill 2015). The only study found to consider the effects of intersectionality on rates of amenable mortality was conducted in Finland by Manderbacka, Arffman, Sund & Karvonen (2014). They aimed to explore income inequalities in rates of amenable mortality, and how these were affected by social deprivation, regional deprivation and unemployment. Inverse income gradients were found in rates of amenable mortality, whereby those with higher reported incomes experienced lower rates of amenable mortality. Being unemployed and living alone (social deprivation) increased the risk of amenable mortality. Not living alone, and a high family income were found to act as 'buffers' to the negative effects of prolonged unemployment on rates of amenable mortality, as there were no increase in risk ratios across decreasing levels of income.

6.6.7 Next steps

Socioeconomic gradients in rates of amenable mortality in Scotland have been explored using both area and individual level measurements, in chapters 4 and 6. The two chapters following this go on to explore cross-country differences in rates of amenable mortality, comparing Scotland to England.

6.7 Correction - July 2018

Following the successful defence of this thesis in June 2018, it was discovered that the incorrect version of the Carstairs indices were supplied by the SLS for the analyses of the area level inequalities within the SLS sample, presented within subsection 6.5.4 - 'Comparing sample to population'.

Carstairs indices are calculated at the postcode sector level as standard, however, indices estimated at the output area level were supplied. Output areas have an average population size of 150 people, whereas postcode sectors have an average population of 5,000 people.

The initial results presented in subsection 6.5.4 (Tables 6.26, 6.27 and 6.28, and Figure 6.9) are correct, when interpreted in terms of inequalities at the output area level, rather than at the postcode sector level.

The comparison results between the SLS sample and the total population, presented in Figure 6.10, and Tables 6.29 and 6.30 are, however, now prone to the modifiable areal unit problem, whereby the results, and inferences, are sensitive to the definition of the area the data are collected and analysed at (Fotheringham & Wong 1991). Given that the populations residing within output areas are likely to be more homogeneous than within postcode sectors, any comparison of inequalities estimated at these different levels are likely to lead to incorrect inferences.

As the data used in this chapter are held within a Safe Haven, no re-analysis was possible in order to correct the results presented. If it can be assumed that the populations within output areas in Scotland are homogeneous in terms of area level deprivation measures, there will be greater variation in the Carstairs indices across all output areas. This greater variation is likely to lead to greater estimates of inequalities, such as those found in this chapter.

Chapter 7

A comparison of amenable mortality in Scotland and England: Devolution

The results presented in chapters 4 to 6 provided an illustration of the uses of the concept of amenable conditions to explore inequalities in rates of mortality and incidence within a country. Chapters 7 and 8 compare healthcare systems between countries in the face of large scale policy changes, using amenable mortality.

Scotland has been described as the "sick man of Europe" (Steel & Cylus 2012, p. 120), therefore comparisons with European countries are necessary in order to evaluate any improvements in rates of amenable mortality in Scotland.

Natural experiments are an ideal study design for country level comparisons, where the effects of large-scale population-level interventions are of interest (Craig et al. 2017), and assignments to intervention or control groups are outwith the control of the research team. The National Health System in the United Kingdom (UK) has previously been highlighted as an ideal setting for natural experiments (Greer 2016), given that the four countries were once controlled and financed by an overall UK Parliament (Desai et al. 2011). Therefore, differences between rates of amenable mortality in Scotland and England will be explored in the remaining two analysis chapters of this thesis.

This chapter, following objective 5 of this thesis (see section 1.1), explores the effect of the political devolution of Scotland in 2000 on rates of amenable mortality, compared to England. Given that devolution was not aimed to solely impact on the healthcare system in Scotland, this chapter provides insights into the potential indirect effects of policy changes on amenable mortality.

7.1 Introduction

The National Health Service was introduced in the UK in 1948. Whilst the Scotland Office was officially responsible for the management and organisation of this health service in Scotland (Commission on Scottish Devolution 2009), there was little divergence from the policies employed by the rest of the UK, led by a single Parliament at Westminster.

In 1997, a referendum for a separate Scottish Parliament received a majority vote, and following the Scotland Act of 1998, the Scottish Parliament and Scottish Executive (now Scottish Government) came into power on 1 July 1999. Amongst others, decisions on how to organise health care, and how funding would be allocated, were now devolved to a government elected by the Scottish people.

The NHS trusts, in Scotland, introduced prior to devolution in the UK's NHS were unified with NHS boards following the referendum, and the purchaser-provider split and internal market system, introduced in the early 1990s was removed in 2004.

There are several areas of policy where the two countries differ, and are particularly relevant to amenable conditions. The removal of prescription charges in Scotland, phased out from 2007 - 2010, could have had a considerable impact on the rates of amenable mortality, especially within the most deprived areas, as a large number of the conditions amenable to improved treatment and medical care require repeat prescriptions for medications for the management of chronic, long term conditions, such as asthma or epilepsy. However, in practice, a majority of prescriptions issued in Scotland prior to this, and currently in England are exempt from charges, such as those for diabetes, or those prescribed whilst in hospital (National Health Service England 2017).

The vaccination schedules for conditions amenable to primary prevention across the UK do not vary (NHS Choices 2016), however, screening policies for selected amenable cancers do differ between England and Scotland. Bowel cancer screening is offered 10 years earlier in Scotland - at ages 50 - 74 years, whilst England starts their screening at age 60 (Cancer Research UK 2015). Prior to 2016, Scotland had wider age limits for cervical cancer screening, starting at age 20, however, they have been recently brought in line with England's policy of starting screening at 25 years of age (Cancer Research UK n.d.).

The research aim of this chapter was to explore how rates of amenable mortality in Scotland were affected after the political devolution of Scotland from England.

7.2 Methods

7.2.1 Data

As described in Chapter 3, all deaths registered in Scotland between 1980 and 2013 were available for analysis. The variables extracted included age at death, sex, postcode sector and local government district (1981 - 1996) or council (1997 - 2013) of residence at time of death, the underlying cause of death (as coded by the International Classification of Diseases (ICD)), as well as the version of ICD used (version 9 or 10).

Equivalent registers of deaths occurring in England were already held, by the MRC/CSO Social and Public Health Sciences Unit, University of Glasgow, having been obtained from the Office of National Statistics (agreement 2315/2012), for the years 1990 to 2013. On the whole, the variables extracted from the English death register were the same as for Scotland, except for the residence at time of death variables. For this, the full postcode, as well as the electoral ward code, was extracted. All death records obtained from ONS had the 2011 version of the electoral ward code attached. English deaths were coded using ICD 9 until 2001, and ICD 10 from 2002 onwards, a year later than in Scotland.

Due to the narrower range of register data available for England at the time, the analysis period explored in this chapter was limited to 1990 to 2013.

7.2.2 Population sizes

Two sources of population sizes were available for this analysis. Population sizes at the small area level (postcode sectors for Scotland, electoral wards for England) were available for five-year age and sex group at the census years, as Census return forms allow for the most accurate estimations of the overall size and sex-age-breakdowns of a country's population. The Scottish population estimates were previously described in subsection 3.3.2. The equivalent English population size breakdowns were obtained from the Official Labour Market Statistics website (Nomis: Official Labour Market Statistics n.d.).

Annual mid-year estimates for the populations of England (Nomis: Official Labour Market Statistics n.d.) and Scotland (National Records of Scotland n.d.) were were available for sex and 5 year age group. The estimation of the midyear populations between the two countries is designed to be as similar as possible, however, there are slight differences in the data sources and methods used. These differences are described in detail elsewhere (Office for National

Statistics n.d.), but are essentially due to how 'special populations' (e.g. home/foreign armed forces and prisoners) are accounted for.

As population sizes at the area level are required to model rates of amenable mortality, using multilevel modelling, the proportions of each age-sex group observed within each area at the nearest Census year were applied to the total mid-year population for that country. This method has previously been described in subsection 3.3.2, and is used to estimate the yearly mid-year population sizes of each area in both countries.

7.2.3 Measures of deprivation

Chapter 6 reviewed previous investigations into socioeconomic gradients within rates of amenable mortality in other country settings using individual level measurements of socioeconomic position, such as education, income or occupation. In Scotland and England, individual NS-SEC classification is recorded when a death is registered, however this classification is known to have large discrepancies with the more accurate NS-SEC classification calculated from Census records (White et al. 2007). NS-SEC can also only be accurately assigned for those of working age, and who were (recently) employed. Therefore, area level proxy measurements were used for this analysis.

There is no routinely calculated, common measure of area level deprivation available across the UK. Carstairs scores, a measure of relative deprivation at the small area level, are currently used in Scotland (McLoone 2000), and were used in chapters 4 and 5. The indices are calculated using four variables, collected at the Census, previously described in Table 3.4.

As the Carstairs indices are not routinely calculated in England, a new combined Carstairs index was calculated for this chapter, combining the Census data from Scotland and England, to create a comparable measure of relative deprivation. Electoral wards in England were identified as a suitable spatial unit, as these are of comparable population size to Scotland's postcode sectors (see Table 7.1).

Table 7.1: Number of wards and postcode sectors available and included in analyses

Country	Year	Number of small areas	Number excluded	Small areas analysed	Median population	Range
England	1991	8,619	18	8,601	4,335	46 - 30,450
	2001	7,987	18	7,969	5,117	106 - 35,102
	2011	7,707	18	7,689	5,575	136 - 34,412
Scotland	1991	1,001	0	1,001	4,783	50 - 18,433
	2001	1,010	0	1,010	5,010	51 - 20,512
	2011	1,012	0	1,012	5,227	52 - 21,159

Each Census year, eighteen wards in England were excluded from the data sources as their population sizes were too small and published Census results would have been potentially disclosive. These wards were mainly located within the City of London.

Data for all Census years in England were downloaded from the Official Labour Market Statistics website (Nomis: Official Labour Market Statistics n.d.), the Scottish data for 1991 and 2001 were obtained from the published reports on the Carstairs scores (McLoone 2000, 2004), and the 2011 census Data Warehouse (Scotland's Census Data Warehouse n.d.). The calculation of the Carstairs score for Scotland has previously been described (McLoone 2000), but briefly:

1. For each small area in Scotland and England identify:
   (a) The proportion of economically active males seeking or waiting to start work
   (b) The proportion of all persons in private households which do not own a car
   (c) The proportion of all persons in private households with a density of more than one person per room
   (d) The proportion of all persons in private households with an economically active head with head of household in social class IV or V[1]
   (e) The total population
2. Calculate the population mean and standard deviation (SD) for each variable.
3. Standardise each variable to have a mean of zero and a variance of one. This is known as the z-score method (see Table 7.2).

[1]The social class variable was originally calculated using the Registrar-General's Social Class measure, however, after 1991, only NS-SeC is measured at the census. Social class IV or V was replaced with equivalent NS-SEC categories.

4. Sum the four z-scores for each area to form the Carstairs score.

5. Sort scores in ascending order.

6. Calculate approximate population sizes required to create population deciles, each containing 10% of the total population.

7. Assign the sorted scores to a decile, with the lowest scores indicating the least deprived areas, and the highest scores corresponding to the most deprived areas.

The Low Social Class component of the Carstairs score (item 1d) was amended in the combined Carstairs score for Scotland and England, as this variable normally requires a commissioned output table, as the data are not released for head of household as standard. This level of detail was not available for download for the English data, therefore the Social Class variable was amended in these analyses to include the proportion of all people (16+ for 1991, 16 - 74 years for 2001 and 2011 censuses) with low social class, rather than the proportion of households with an economically active head of household with low social class. This change was also made for Scotland, ensuring comparability. Figure 7.1 depicts the differences between the adjusted and published Z-scores for the 1991 social class component in Scotland. There does not appear to be a majority of points above nor below the reference line, indicating that there is no bias towards a particular method. The correlation between these two variables is high at 0.81, and the correlation for the overall Carstairs scores is 0.96, both close to +1, indicating strong, positive linear associations.

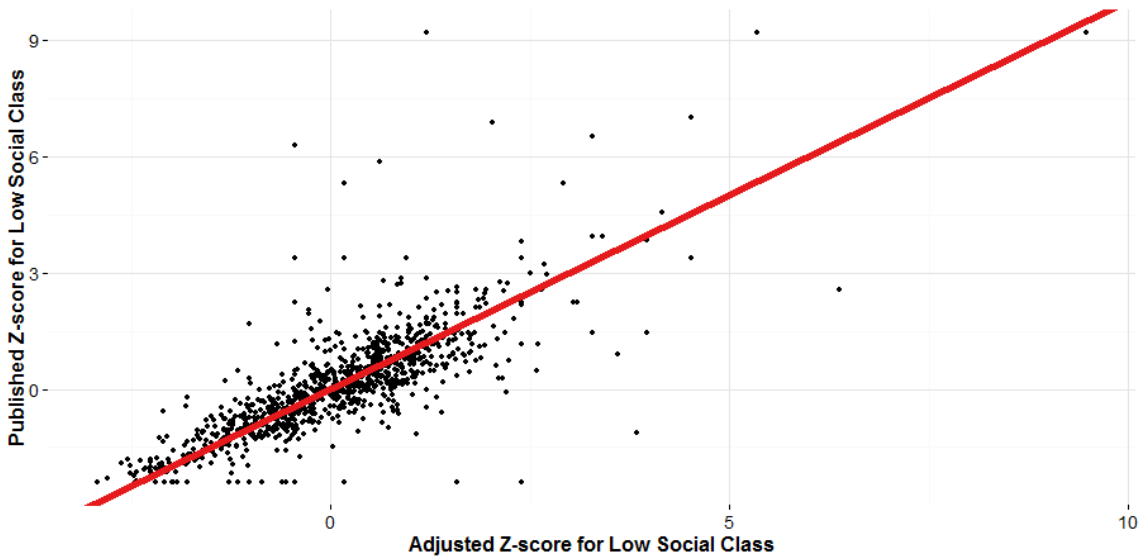


Figure 7.1: Adjusted vs published Z-scores for the 1991 Carstairs Scores. Red line indicates the line of equality.

Table 7.2: Example of calculating Carstairs score: Scottish Postcode sector G11 6 (1991)

Variable	Observed proportion	Population mean*	SD*	z-score
Male unemployment	0.203	0.114	0.069	(0.203 - 0.114) ÷ 0.069 = 1.29
No car ownership	0.401	0.135	0.071	(0.401 - 0.135) ÷ 0.071 = 3.75
Overcrowding	0.093	0.048	0.044	(0.093 - 0.048) ÷ 0.044 = 1.02
Low social class†	0.235	0.221	0.079	(0.235 - 0.221) ÷ 0.079 = 0.18
Overall Carstairs score for G11 6:				1.29 + 3.75 + 1.02 + 0.18 = **6.24**

* These are calculated for the populations of Scotland and England together.

† Amended variable: All persons with low social class

This process would normally be repeated for each Census year, however discontinuities in mortality rates within the most deprived decile of initial exploratory analyses (not shown) suggested that rates of amenable mortality within each country were highly sensitive to the change in version of deprivation decile used; occurring at the mid-point between each census (i.e. 1996/7, and 2006/7).

To investigate the changes between versions, the percentage of each country's population within each deprivation decile, for the three census years are displayed in Table 7.3. The rows labelled 'overall' are the percentages of total population within each decile, and these lie close to 10% as designed.

The English population make up a larger percentage of each deprivation decile, owing to its larger overall population size. The percentage of Scottish population within each of the 1991 indices deciles increases with increasing deprivation, indicating that the overall most deprived decile (10) contains a larger proportion of the Scottish population, than the least deprived decile (1) does (17.1% vs 4.8% in 1991).

Over time, we can see that the percentage of Scottish population in the most deprived decile (10) has halved, to 8.95%. This suggests that the Scottish population have become relatively less deprived, compared to the English population, over time.

In order to remedy the drastic changes in population dispersion, a yearly deprivation index was created, and areas were assigned to a deprivation decile based upon a linear extrapolation between each Census year, and after the 2011 Census. This allowed the change in percentages of Scottish population within the most deprived deciles to be less drastic. The re-assignment of the areas to deprivation decile were based upon the yearly mid-year population sizes, described in subsection 7.2.2.

Table 7.3: Percentages of each country's population within each decile, for the 1991, 2001 and 2011 Carstairs indices

Decile	Country	1991*	2001*	2011*
1	**Overall**	**10.01**	**10.00**	**10.00**
	England	95.24	94.62	94.30
	Scotland	4.76	5.38	5.70
2	**Overall**	**9.99**	**10.00**	**9.99**
	England	95.11	95.56	95.07
	Scotland	4.89	4.44	4.93
3	**Overall**	**10.00**	**9.99**	**10.00**
	England	95.61	94.46	92.74
	Scotland	4.39	5.54	7.26
4	**Overall**	**10.00**	**10.02**	**10.00**
	England	93.71	93.51	93.10
	Scotland	6.29	6.49	6.90
5	**Overall**	**10.01**	**10.06**	**10.00**
	England	91.35	92.55	90.47
	Scotland	8.65	7.45	9.53
6	**Overall**	**9.99**	**9.93**	**10.01**
	England	89.47	89.49	87.89
	Scotland	10.53	10.51	12.11
7	**Overall**	**9.99**	**10.00**	**10.00**
	England	88.39	88.26	86.92
	Scotland	11.61	11.74	13.08
8	**Overall**	**10.01**	**10.00**	**9.99**
	England	87.27	86.50	87.84
	Scotland	12.73	13.50	12.16
9	**Overall**	**10.08**	**9.99**	**10.01**
	England	84.47	85.70	89.85
	Scotland	15.53	14.30	10.15
10	**Overall**	**10.01**	**10.00**	**10.01**
	England	82.88	86.07	91.05
	Scotland	17.12	13.93	8.95

* Overall percentages may not add up to 100% due to rounding.

Within each of the new deciles, the Scottish areas were also further changed, moving up or down a decile, to attempt smoother extrapolations.

Table 7.4 illustrates the smoothing of the percentages of each country's population in the years between each Census for the most deprived decile. This decile required the greatest smoothing, as can be seen in Table 7.3.

Table 7.4: Smoothing of percentage of population within the most deprived decile (10). Census years are indicated in bold.

Year	England	Scotland
1990	82.56	17.44
1991	**82.88**	**17.12**
1992	83.21	16.79
1993	83.40	16.60
1994	83.69	16.31
1995	84.18	15.82
1996	84.39	15.61
1997	84.85	15.15
1998	85.03	14.97
1999	85.40	14.60
2000	85.63	14.37
2001	**86.07**	**13.93**
2002	86.61	13.39
2003	87.04	12.96
2004	87.57	12.43
2005	88.06	11.94
2006	88.64	11.36
2007	89.11	10.89
2008	89.60	10.40
2009	90.09	9.91
2010	90.67	9.33
2011	**91.05**	**8.95**
2012	91.62	8.38
2013	91.58	8.42

As described in subsection 7.2.1, the residential electoral wards listed on all death records for England were coded using the 2011 version of the ward code. The deprivation indices were calculated for the version of the ward code available at the time of the Census analyses (1991 ward codes and 2003 CAS codes). The ONS Ward History Database was initially consulted in order to obtain the mappings between each of the versions (Office for National Statistics 2013), however there were very few unique one-to-one mappings available between any two versions of the ward codes. An example of the ward mappings across the three versions of ward codes are displayed in Figure 7.2, but have been reduced for ease of viewing.

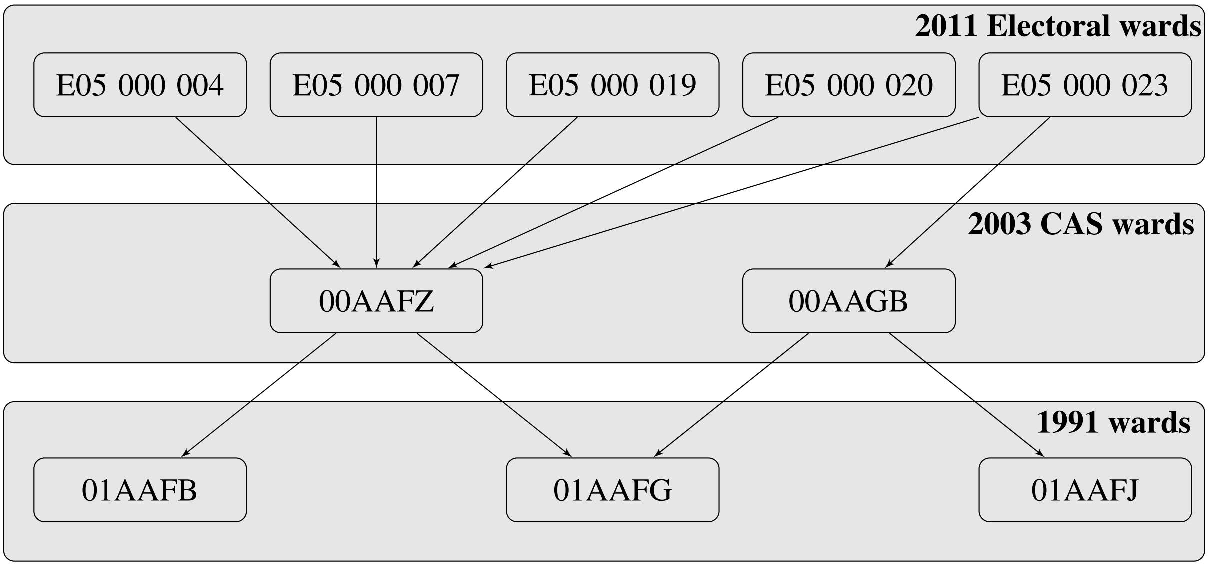


Figure 7.2: Flow diagram of the mappings of ward codes in England

As the electoral wards could not be back-coded to their previous version simply, the full postcode of the residential address recorded on each death record was used. Using the Ward History Database, the previous ward assignments of full postcodes could be then be identified, and attached to the death records.

Each death extracted from the register was assigned to the relevant Carstairs deprivation decile for their ward, or postcode sector, of residence. In a small number of cases (1,296, 0.1% see Table 7.5) deaths were assigned to the deprivation decile of a nearby ward or postcode sector, due to their area of residence not being assigned a deprivation decile. For each case, areas which were geographically adjacent were identified. The rate of amenable deaths within each identified candidate area's deprivation decile was calculated for the year of death and sex of the case. Cases were then assigned to an adjacent area with probability proportional to the area's rate of amenable death for that year. Therefore cases were more likely to be assigned to an area with higher rates of amenable deaths, than those with lower rates.

Table 7.5: Assigning deaths to deprivation deciles

Country	Years	Total Amenable Deaths	Not matched in first instance	Remaining after manual matching	Remaining after probability assignment
England	1990 - 1996	422,857	9	9	0
	1997 - 2006	491,071	1	1	0
	2007 - 2013	276,302	1	1	0
Scotland	1990 - 1996	55,019	876	66	0
	1997 - 2006	65,338	390	176	0
	2007 - 2013	38,379*	20	0	0

* Three records with missing sex have been removed

The large number of deaths requiring manual and probability matching in Scotland in Table 7.5 are due to there being a number of postcode reassignments in Scotland, mainly occurring within the Grampian councils between 1990 and 1996. Due to this, there are a number of postcode sectors which appear on a death record, but did not exist at the time of the census and therefore were not included in the deprivation calculations. Probability matching was applied to these, once the manual matching to census postcode versions had been completed as far as possible.

7.2.4 Statistical Analysis

Age Standardisation

Age-standardised amenable mortality rates for each country as a whole, and by deprivation deciles have been calculated for both sexes separately using the methods described in section 3.4.

Fractional Polynomials

The method of selecting fractional polynomials is described in section 3.8. The equation used in the estimation process was modified to take into account the two countries. Equation 7.1 describes these changes, with further explanation below.

$$\begin{aligned} log_e(deaths) &= age + post + country + year \\ &+ (post \times country) + (post \times year) + (country \times year) \\ &+ (post \times country \times year) \\ &+ decile_{Scot} + decile_{Eng} + (decile \times post) + (decile \times year) \\ &+ log_e(popn) \end{aligned} \tag{7.1}$$

Where:
Country = 1 (Scotland), with reference group = 0 (England)
Year = Year - 1999
Post = 0 ($<$ 2000), 1 ($\geq$ 2000)

Two decile variables ($decile_{Scot}$ and $decile_{Eng}$) were incorporated, one for each country. This allowed the effects of deprivation within each country to be modelled separately. As deprivation decile is defined within the range of 1 to 10, the decile for the other country was set to 5.5, rather than a null value of 0.

The year variable was centred on zero at 1999, the year of devolution. The centred year variable had a range of -9 (representing 1990) to + 14 (representing 2013). A 'post' indicator variable was included, coded as 1 from 2000 onwards, representing the years Scotland was devolved.

Interactions between post, country and year variables allowed for the evaluation of changes occurring within each country after devolution. Further interactions between decile and year allowed for the effects of deprivation to change over time, and after devolution, with the inclusion of an interaction with the post variable.

The counts of death were modelled using a Poisson regression model, with the constant population sizes used as the offset.

Variables were selected into the model with a nominal p-value of 0.05, except for the country variable, as well as the interactions between country, post and year. These were forced to be included in the model, as these were required for the research aims. All indicator variables (country and post) and their interactions were required to be modelled linearly. The continuous variables of age, deprivation decile and year were allowed to be modelled using fractional polynomials.

Multilevel modelling

There exists a natural hierarchy within the dataset. Figure 7.3 describes this structure, and the four levels within. The fourth level - Country - cannot be used in practice, as there are only two units of measurement - England and Scotland - which do not provide sufficient power for analyses (Rasbash et al. 2012*a*).

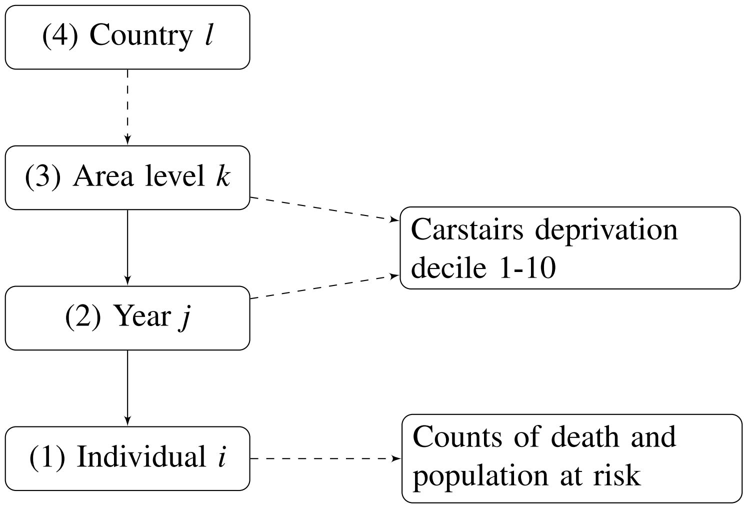


Figure 7.3: Multilevel nature of data

Therefore, the multilevel structure used within this chapter is the same as previously described in section 3.9.

There are 26,242 units at the area level (unique combinations of postcode sectors and local government districts or councils, as well as electoral wards) and between 4 and 24 years of data within each area. There should be 15 counts of death and population sizes within each year - for each age group, however, age groups with both zero population and zero deaths have been removed. Models are run separately for each sex.

The transformations produced by the `mpf` procedure in Stata were applied to each variable prior to the inputting of the variables into MLwiN. Equation 7.2 describes the full Poisson regression model possible, where each of the age, year and deprivation decile variables can have up to two fractional polynomial transformations applied in order to best model its relationship (as indicated with the -1 and -2 suffixes to each variable). However, reductions to the model are possible if only one transformation is suggested. The *i, j* and *k* subscripts indicate which level of the model the variable is observed at.

$$
\begin{aligned}
log_e(deaths_{ijk}) = {} & \beta_{0jk}constant + age1_{ijk} + age2_{ijk} \\
& + post_{jk} + country_k + year1_{jk} + year2_{jk} \\
& + (post \times country)_{jk} + (post \times year)_{jk} + (country \times year)_{jk} \\
& + (post \times country \times year)_{jk} \\
& + decile_{Scot}1_{jk} + decile_{Scot}2_{jk} + decile_{Eng}1_{jk} + decile_{Eng}2_{jk} \\
& + (decile \times post)_{jk} + (decile \times year)1_{jk} + (decile \times year)2_{jk} \\
& + log_e(popn_{ijk})
\end{aligned}
\tag{7.2}
$$

Where

$$
\begin{aligned}
&\beta_{0jk} = \beta_0 + v_{0k} + u_{0jk} \\
&\begin{bmatrix} v_{0k} \end{bmatrix} \sim N(0, \Omega_v) : \Omega_v = \begin{bmatrix} \sigma^2_{v0} \end{bmatrix} \\
&\begin{bmatrix} u_{0jk} \end{bmatrix} \sim N(0, \Omega_u) : \Omega_u = \begin{bmatrix} \sigma^2_{u0} \end{bmatrix} \\
&var(deaths_{ijk}|\pi_{ijk}) = \pi_{ijk}
\end{aligned}
$$

σ^2_{v0} and σ^2_{u0} represent the additional area and year level variation not accounted for by the model. σ^2_{v0} is used to estimate the median rate ratio of the area level. π_{ijk} represents the mean, and the variance of the Poisson distribution.

7.3 Results

Age standardised rates for each sex, within each country, are displayed in Figure 7.4, for the years 1990 - 2013.

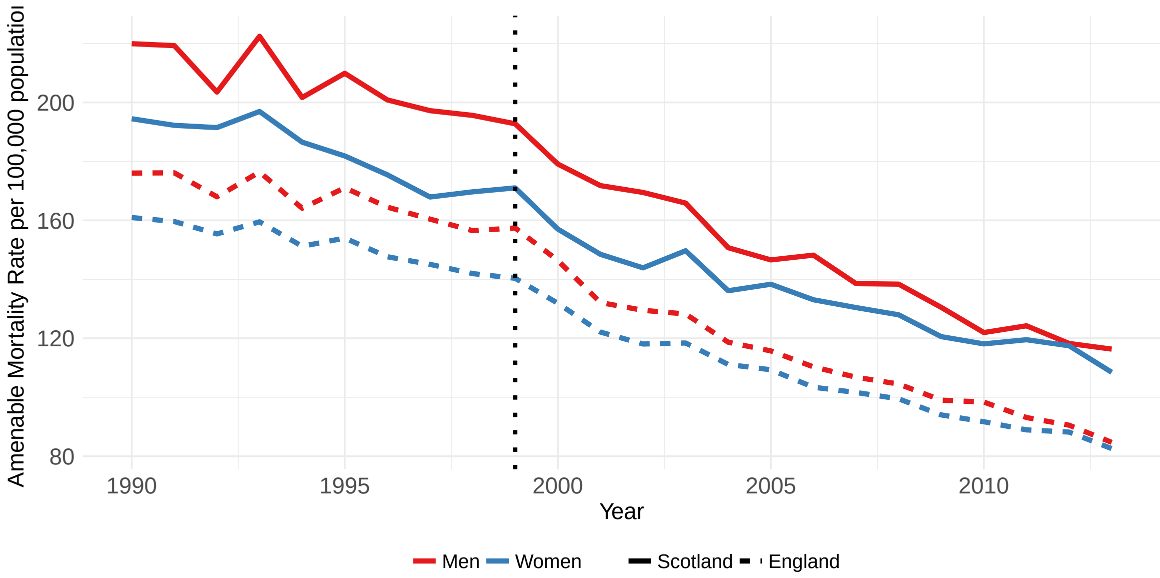


Figure 7.4: Age-standardised amenable mortality rates for men and women in Scotland (solid) and England (dashed), 1990 - 2013. The vertical dashed line indicates 1999, the year of devolution.

The largest absolute increases in mortality rates for both sexes and in both countries occurred in 1994 (England: 9.68 and 5.66 per 100,000, Scotland: 9.81 and 5.75 per 100,000 for men and women respectively). The largest absolute decreases in mortality rates occurred in 2007, again for both sexes and in both countries (6.52 and 5.22 per 100,000 for men and women in England respectively, 7.69 and 4.90 per 100,000 for Scottish men and women respectively).

Age-standardised rates of amenable mortality by deprivation decile in each country are illustrated in Figure 7.5. Mortality rates within each deprivation decile in Scotland appear to predominantly exceed those in England, for both sexes.

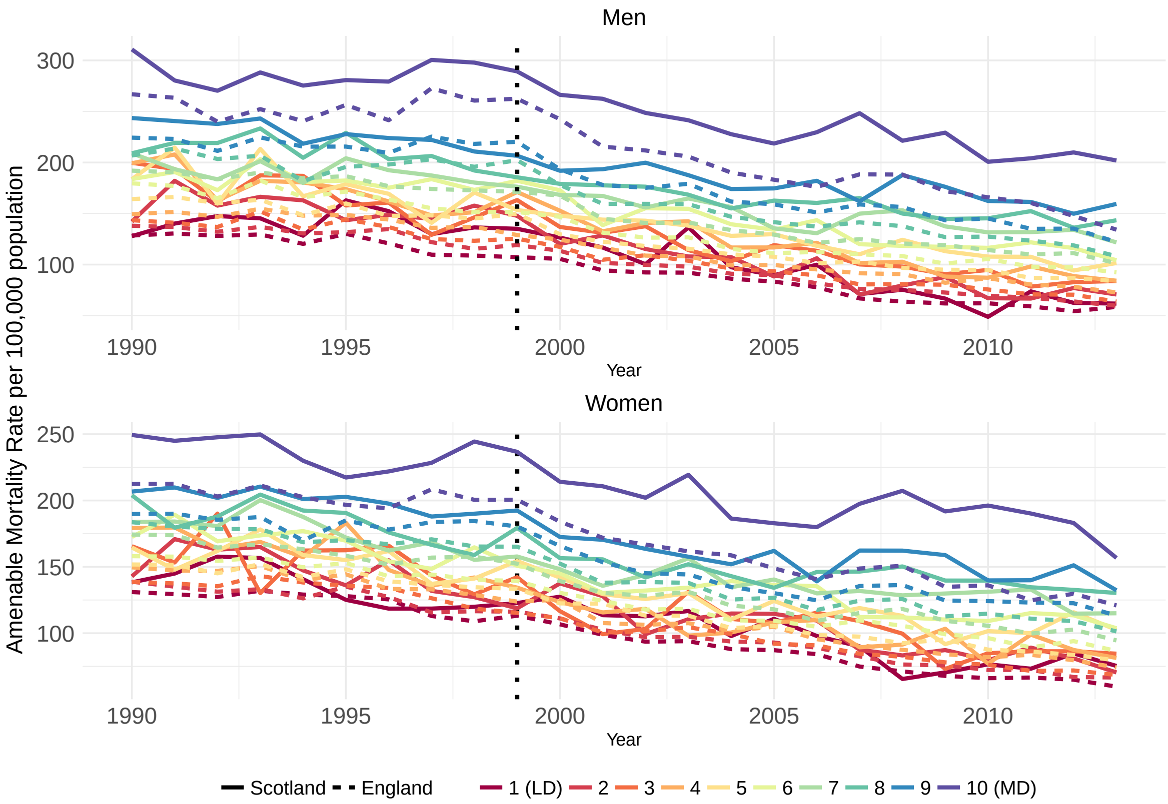


Figure 7.5: Age-standardised amenable mortality rates by deprivation decile for men and women in Scotland (solid) and England (dashed), 1990 - 2013. The vertical dashed line indicates 1999, the year of devolution. Note: graphs are on different scales

As the deprivation decile assignments were made across both countries, people within the same decile are intended to have similar levels of material deprivation. The fact that Scotland has higher rates of amenable mortality within each decile suggests that: health care services in Scotland are not successfully averting these amenable deaths to the same level as in England, regardless of deprivation level; that there are different underlying patterns of incidence and disease severity in Scotland than in England; and/or that people living within equally deprived areas across Scotland and England are heterogeneous at individual levels of deprivation, and the Scottish populations are more deprived on this individual scale.

The `mfp` procedure was run using Equation 7.1, and returned the transformations for the models for men and women in Tables 7.6 and 7.7 respectively.

Table 7.6: Multivariable fractional polynomial (FP) model: men, Scotland and England, 1990-2013

Variable	FP	Transformation
Age 1	0	$log_e(\frac{A}{10}) - 1.308$
Age 2	1	$\frac{A}{10} - 3.7$
Post	1	-
Country	1	-
Year 1	2	$(\frac{Y_C-10}{10})^2 - 1.563$
Year 2	3	$(\frac{Y_C-10}{10})^3 - 1.953$
Post $\times$ Country	1	-
Post $\times$ Year	1	$(P \times Y_C) - 4.375$
Country $\times$ Year	1	$(C \times Y_C) - 1.25$
Post $\times$ Country $\times$ Year	1	$(P \times C \times Y_C) - 2.188$
Decile $_{\text{Scot}}$ 1	-1	$D_S^{-1} - 0.182$
Decile $_{\text{Scot}}$ 2	3	$D_S^3 - 166.375$
Decile $_{\text{Eng}}$ 1	0	$log_e(D_E) - 1.705$
Decile $_{\text{Eng}}$ 2	2	$D_E^2 - 30.25$
Decile $\times$ Post	1	$(D \times P) - 3.208$
Decile $\times$ Year 1	2	$(\frac{(D \times Y_C)+91}{100})^2 - 1.097$
Decile $\times$ Year 2	3	$(\frac{(D \times Y_C)+91}{100})^3 - 1.149$

A = Age; 2, 7, 12, ..., 72. Y_c = Year_c = Year - 1999; -9, -8, ..., +14.
P = Post; 0 (<2000), 1 ($\geq$ 2000) C = Country; 0 (England), 1 (Scotland)
D = Decile; 1, 2, ..., 10. D_S and D_E represent Scottish and English deciles respectively.

All variables were scaled and centred, using the transformations described in Table 7.6. Post, Country and their interaction are not transformed by the `mfp` procedure as they are indicator variables. The continuous variables of age, year, decile and the decile $\times$ year interaction are best modelled with two fractional polynomial transformations each.

The transformations applied to the deprivation decile variables for England and Scotland are different, indicating a differing relationship between the risk of amenable death and deprivation within each country.

Table 7.7: Multivariable fractional polynomial (FP) model: women, Scotland and England, 1990-2013

Variable	FP	Transformation
Age 1	-1	$(\frac{A}{10})^{-1} - 0.270$
Age 2	1	$\frac{A}{10} - 3.7$
Post	1	-
Country	1	-
Year 1	2	$(\frac{Y_C - 10}{10})^2 - 1.563$
Year 2	3	$(\frac{Y_C - 10}{10})^3 - 1.953$
Post $\times$ Country	1	-
Post $\times$ Year	1	$(P \times Y_C) - 4.375$
Country $\times$ Year	1	$(C \times Y_C) - 1.25$
Post $\times$ Country $\times$ Year	1	$(P \times C \times Y_C) - 2.188$
Decile $_{\text{Scot}}$ 1	-1	$D_S^{-1} - 0.182$
Decile $_{\text{Scot}}$ 2	3	$D_S^3 - 166.375$
Decile $_{\text{Eng}}$ 1	1	$D_E - 5.5$
Decile $_{\text{Eng}}$ 2	3	$D_E^3 - 166.375$
Decile $\times$ Post	1	$(D \times P) - 3.208$
Decile $\times$ Year 1	2	$(\frac{(D \times Y_C)+91}{100})^2 - 1.097$
Decile $\times$ Year 2	3	$(\frac{(D \times Y_C)+91}{100})^3 - 1.149$

A = Age; 2, 7, 12, ..., 72. Y_c = Year_c = Year - 1999; -9, -8, ..., +14.
P = Post; 0 (<2000), 1 ($\geq$ 2000) C = Country; 0 (England), 1 (Scotland)
D = Decile; 1, 2, ..., 10. D_S and D_E represent Scottish and English deciles respectively.

The age and decile variable transformations chosen for women in Table 7.7 are different to those selected for men in Table 7.6, indicating differing relationships for age and deprivation between the sexes.

The relationships of each continuous variable with two fractional polynomials can be plotted against the rates of age-specific mortality. Figure 7.6 shows the fractional polynomial shapes of the age variables, for England and Scotland, at the most and least deprived deciles. Both figures are based on data for the year 1999.

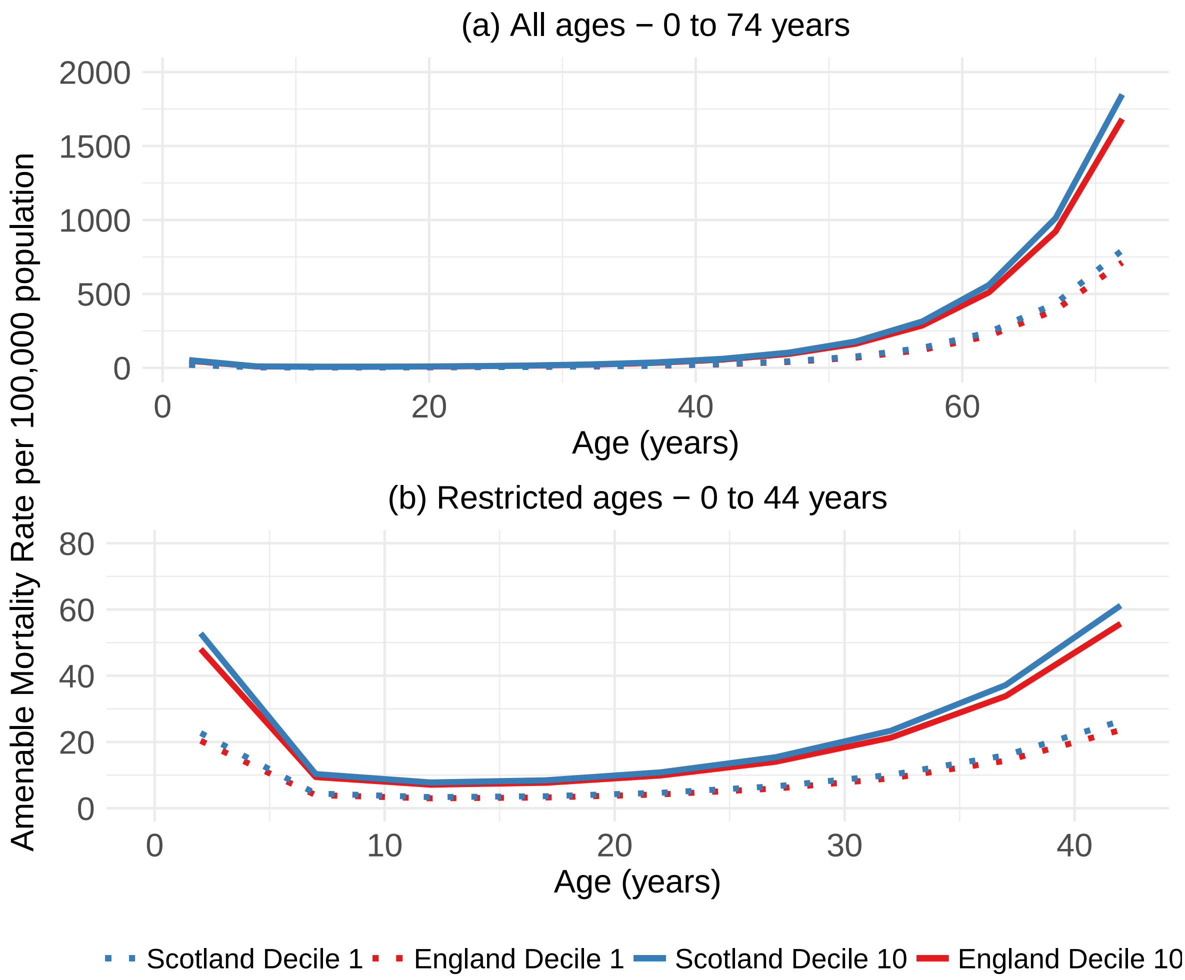


Figure 7.6: Fractional polynomial of: (a) the age variable, and (b) a magnified plot of the age variable, restricted to ages 0 to 44 years, plotted against the age-specific mortality rate for Scotland and England, at the most and least deprived deciles, for men at the year 1999.
Note: graphs are on different scales

The age specific mortality rates are higher in the most deprived (decile 10, solid lines), than in the least deprived (decile 1, dashed lines). The fractional polynomial relationship at the youngest ages appears flat in the upper half of Figure 7.6. In order to inspect this relationship at the younger ages, the axes presented in the lower half of Figure 7.6 were limited in order to magnify the plot. This indicates that there is a sharp decrease in the rate of amenable death after infancy (age 0 to 4 years), and that the rate of death does not exceed this initial level until after age 40.

The age-specific mortality rates of Scotland and England appear very similar between 5 and 24 years of age, especially within the least deprived decile. The greatest differences in age-specific mortality rates occur at the oldest ages, regardless of deprivation level.

Figure 7.7 depicts the fractional polynomial shapes for the male deprivation measures described in Table 7.6. The deprivation deciles are plotted for two age groups at the year 1999.

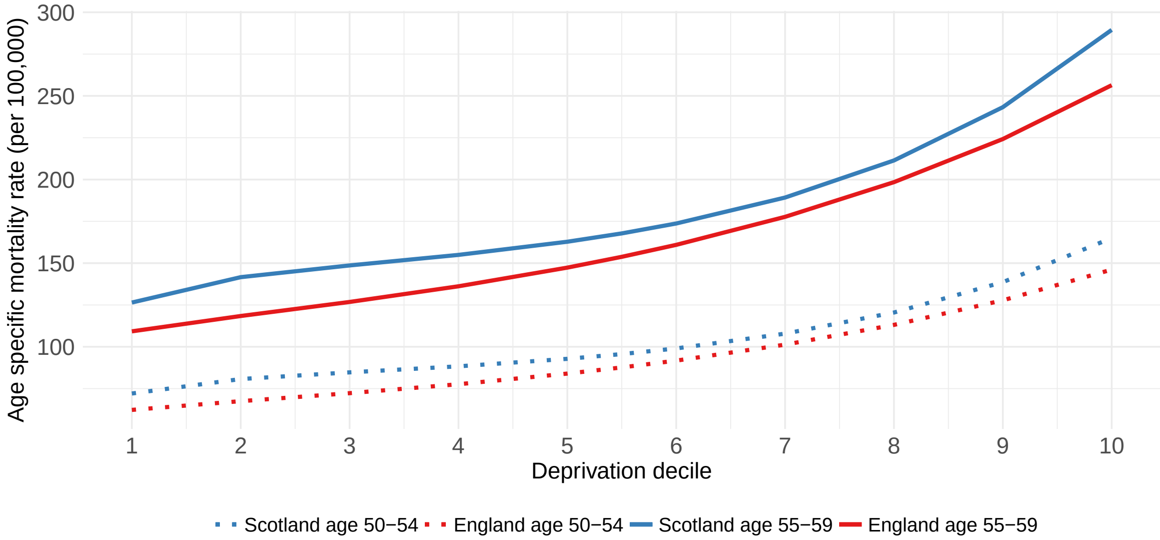


Figure 7.7: Fractional polynomials of the deprivation variables, plotted against the age-specific mortality rate for Scotland and England, for men aged 50-59 years at the year 1999

There is a sharper increase in age-specific mortality rates for men in deciles 1 to 2, and 9 to 10 in Scotland, than in England. The country differences in age-specific mortality rates appear to be smallest within the 7^{th} and 8^{th} deprivation decile, and within the younger age group (50-54 years), compared to the older age group (55-59 years).

Finally, the fractional polynomial transformations applied to the year variables can be plotted. Figure 7.8 describes the age-specific mortality rates for men aged 50-54 years in Scotland and England, at the most and least deprived deprivation levels, over the 24 year analysis period.

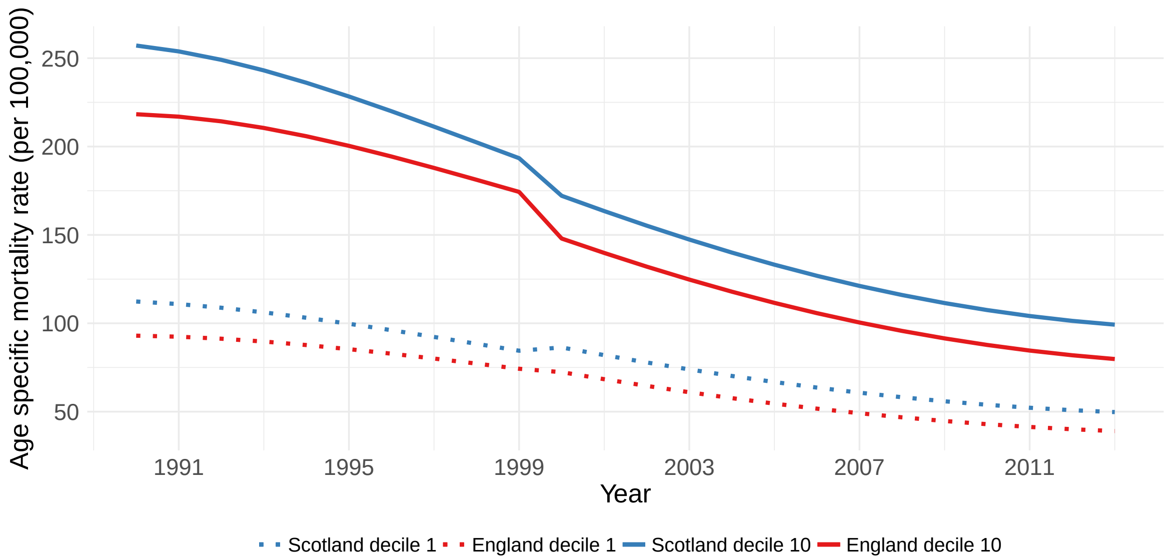


Figure 7.8: Fractional polynomials of year of death, plotted against the age-specific mortality rate for Scotland and England, for men aged 50-54 in the most and least deprived deciles

The sharp declines in 1999 to 2000 in the most deprived deciles, and the small increase in Scotland at the same time, are due to the inclusion of the post indicator, and its interaction with the year of death variable. Overall, trends in age-specific mortality rates have been declining in both countries.

The resultant incident rate ratios (IRR) from the multilevel models, run with the fractional polynomial transformations, are displayed in Tables 7.8 and 7.9.

Table 7.8: Incident Rate Ratios (IRR) and 95% confidence intervals (95%CI) for the multilevel model: men

Variable	FP	IRR	95% CI
Intercept		0.00018	
Country	1	1.086	(1.06 - 1.11)
Post	1	1.032	(1.01 - 1.06)
Year 1	1	0.728	(0.70 - 0.75)
Year 2	1	1.079	(1.07 - 1.09)
Post × Country	1	1.081	(1.05 - 1.11)
Post × Year	1	0.989	(0.98 - 0.99)
Country × Year	1	0.996	(0.99 - 0.99)
Post × Country × Year	1	1.007	(1.00 - 1.01)
Age 1	0	0.154	(0.15 - 0.16)
Age 2	1	4.340	(4.32 - 4.36)
Decile $_{\text{Scotland}}$ 1	-1	0.783	(0.73 - 0.84)
Decile $_{\text{Scotland}}$ 2	3	1.001	(1.00 - 1.00)
Decile $_{\text{England}}$ 1	0	1.089	(1.08 - 1.10)
Decile $_{\text{England}}$ 2	2	1.007	(1.01 - 1.01)
Decile × Year 1	2	1.372	(1.31 - 1.44)
Decile × Year 2	3	0.905	(0.89 - 0.92)
Decile × Post	1	0.985	(0.98 - 0.99)

FP: fractional polynomial

Men	Estimate	Std Error	MRR
σ^2_{v0}	0.032	0.001	1.185
σ^2_{u0}	0.005	0.001	

Where σ^2_{v0} and σ^2_{u0} correspond to the variation at the area and year level respectively.

The coefficients in Table 7.8 and Figure 7.8 indicate that the rates of amenable death have been decreasing over time in both countries. Rates in Scotland were approximately 8.6% (95% CI 6 to 11%) higher than those in England, and the difference remained roughly similar following devolution, with Scotland's rates remaining 8.1% (95% CI 5 to 11%) higher than England. There were significant changes in trends in each country at the point of devolution, the year 2000. Scotland experienced a 0.7% lesser decrease than in England, given the positive rate ratio for the post × country × year variable.

The relationship between rates of amenable deaths and deprivation also lessened after 2000, by approximately 1.5%. The MRR indicates that, within a deprivation decile, there is an 18.5% increased risk in median, between areas with higher and lower rates of male amenable mortality in Scotland and England.

Table 7.9: Incident Rate Ratios (IRR) and 95% confidence intervals (95%CI) for the multilevel model: women

Variable	FP	IRR	95% CI
Intercept		0.00027	
Country	1	1.060	(1.03 - 1.09)
Post	1	1.016	(0.99 - 1.04)
Year 1	2	0.749	(0.73 - 0.77)
Year 2	3	1.065	(1.06 - 1.07)
Post $\times$ Country	1	1.041	(1.01 - 1.07)
Post $\times$ Year	1	0.997	(0.99 - 1.00)
Country $\times$ Year	1	0.996	(0.99 - 0.99)
Post $\times$ Country $\times$ Year	1	1.011	(1.01 - 1.02)
Age 1	-1	1.960	(1.95 - 1.97)
Age 2	1	2.640	(2.63 - 2.65)
Decile $_{\text{Scotland}}$ 1	-1	0.887	(0.84 - 0.94)
Decile $_{\text{Scotland}}$ 2	3	1.001	(1.00 - 1.00)
Decile $_{\text{England}}$ 1	1	1.043	(1.04 - 1.05)
Decile $_{\text{England}}$ 2	3	1.000	(1.00 - 1.00)
Decile $\times$ Year 1	2	1.249	(1.19 - 1.31)
Decile $\times$ Year 2	3	0.939	(0.92 - 0.96)
Decile $\times$ Post	1	0.988	(0.98 - 0.99)

FP: fractional polynomial

Women	Estimate	Std Error	MRR
σ^2_{v0}	0.020	0.001	1.143
σ^2_{u0}	0.003	0.001	

Where σ^2_{v0} and σ^2_{u0} correspond to the variation at the area and year level respectively.

Unlike the model for men, there were no significant changes in trends in England at the point of devolution for women, however, Scotland experienced a lower decrease than in England, given the positive rate ratio for the post $\times$ country $\times$ year variable. The MRR indicates that, within a deprivation decile, there is an 14.3% increased risk in median, between areas with higher and lower rates of female amenable mortality in Scotland and England.

The predicted mortality rates for each sex at each level of the data's hierarchy are plotted in Figures 7.9 (men) and 7.10 (women).

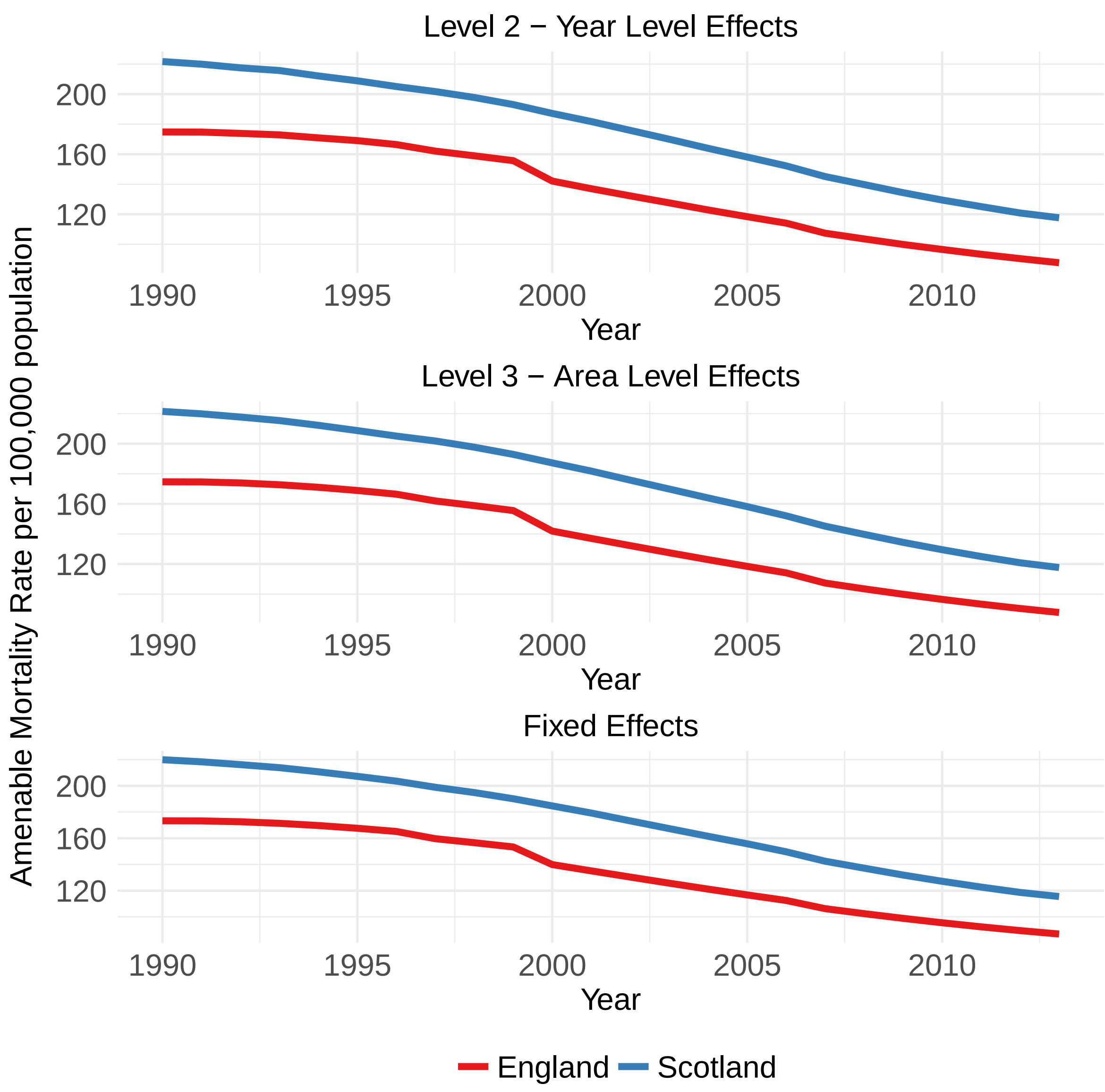


Figure 7.9: Predicted rates at the year and area level, as well as the fixed effects for men

Figure 7.9 describes a stronger step decline in mortality rates in England than in Scotland following devolution for men, however similar declines are seen for women in Figure 7.10. The age-standardised amenable mortality rates for women also indicate a decline in Scotland between 2006 and 2007 - potentially an artefact of the data, and evidence of unsuccessfully smoothing the population sizes for women in Scotland over the years.

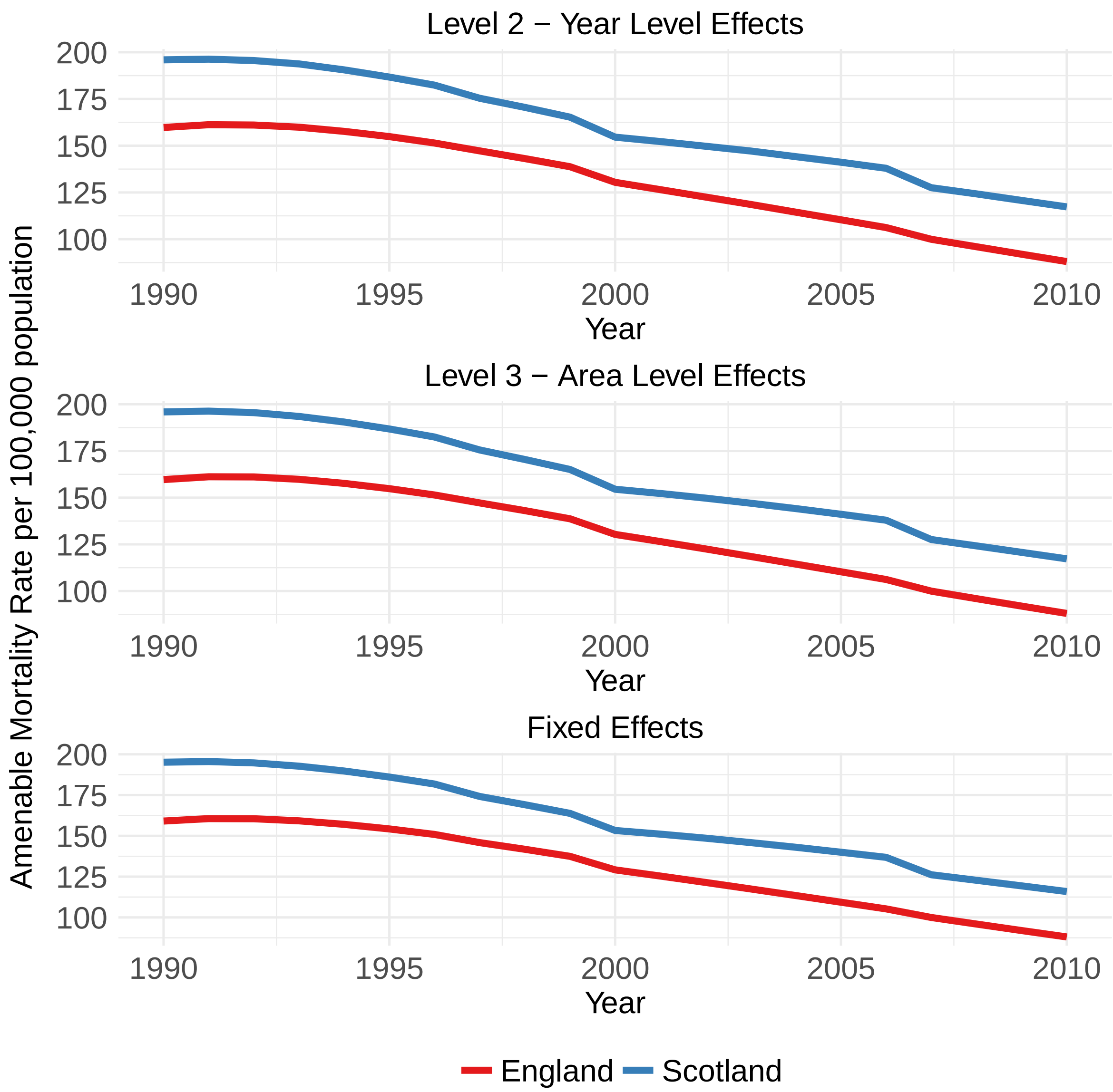


Figure 7.10: Predicted rates at the year and area level, as well as the fixed effects for women

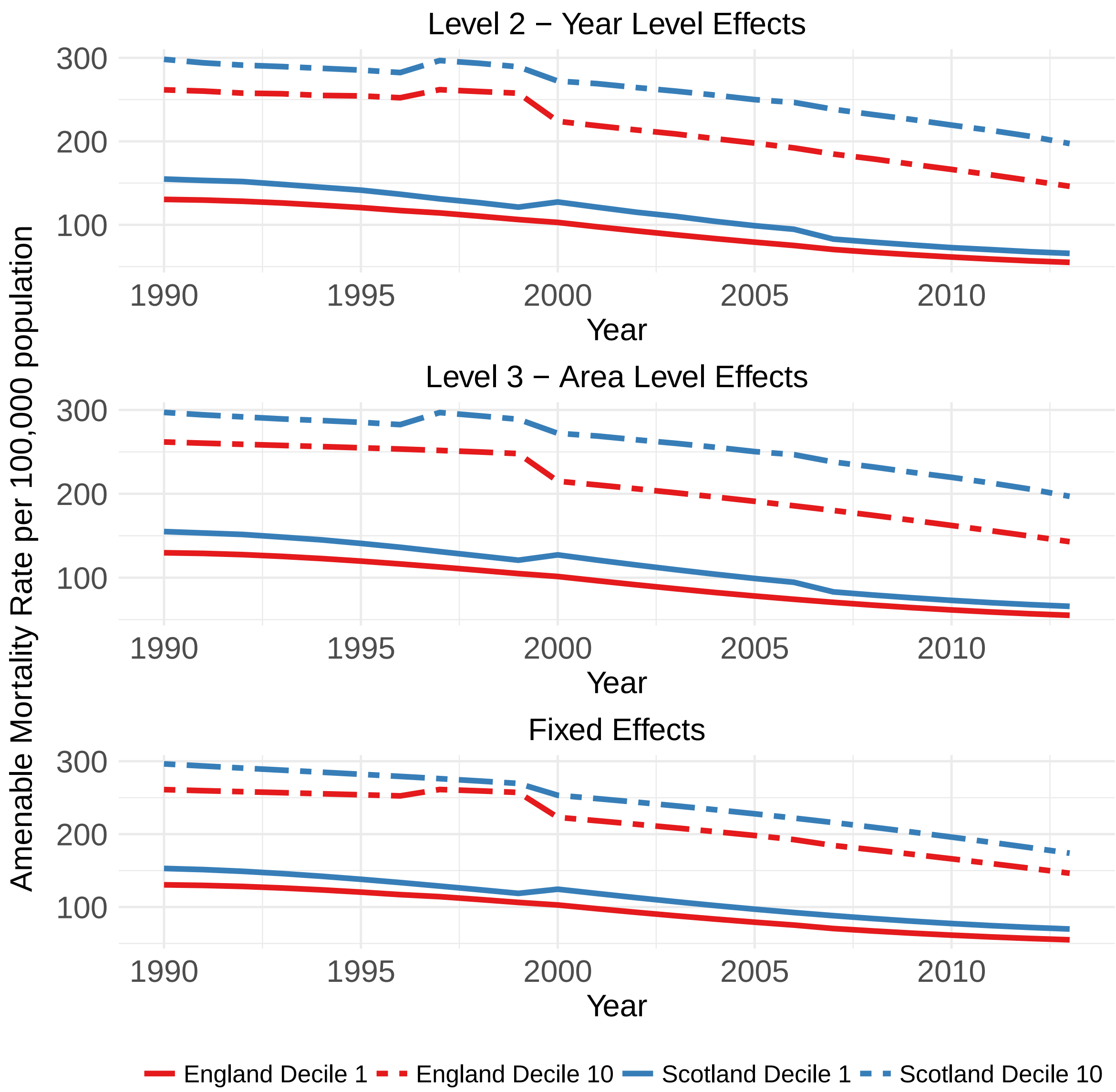


Figure 7.11: Predicted rates by deprivation decile at the year and area level, as well as the fixed effects for men

Potential evidence of unsuccessful attempts at smoothing the population sizes and deprivation deciles for men and women are evident when the predicted rates by deprivation decile are plotted for men and women in Figures 7.11 and 7.12. Discontinuities are stronger for at 1996/97, than at 2006/07 seen previously, and are stronger in the most deprived decile (10).

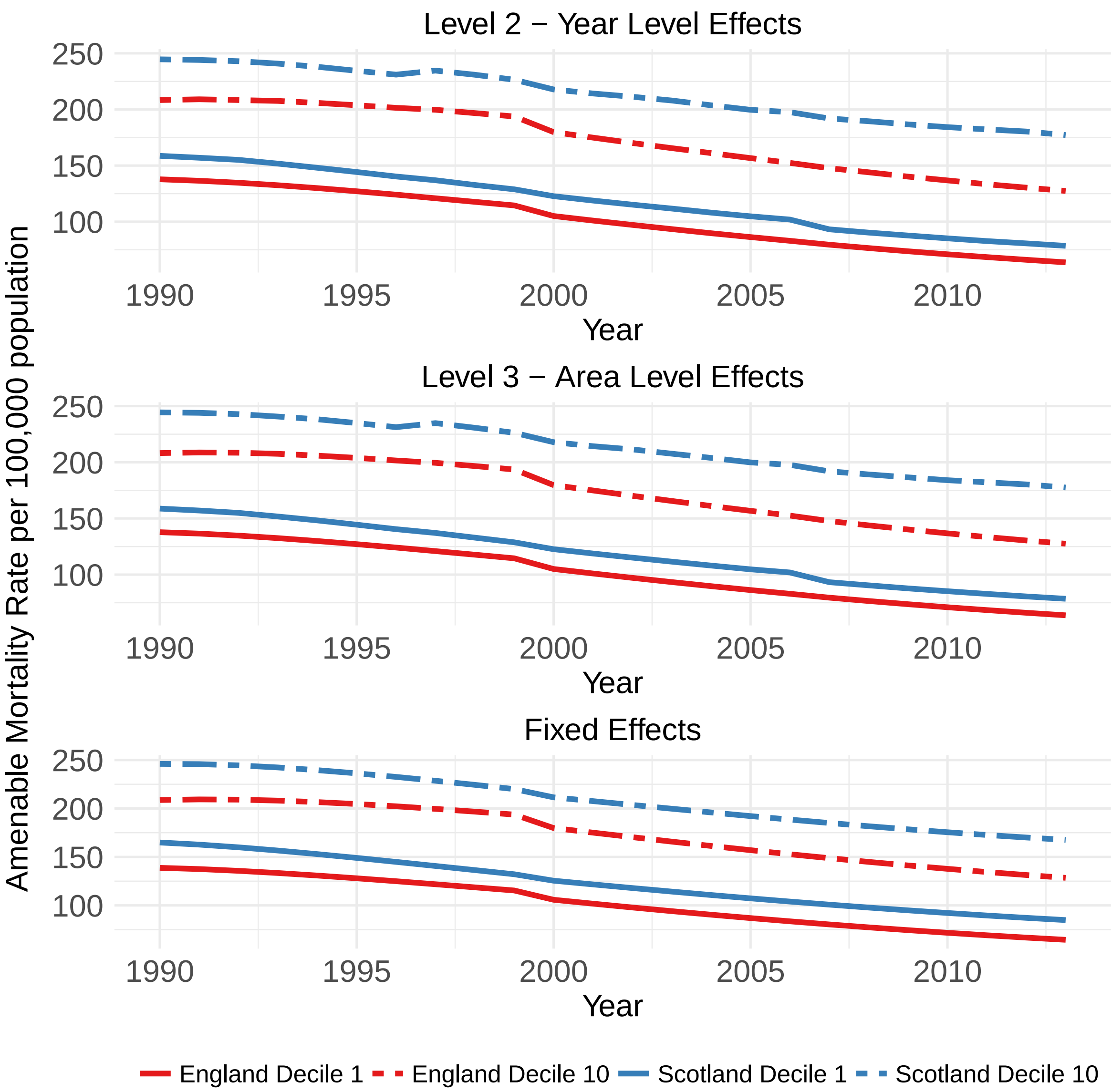


Figure 7.12: Predicted rates by deprivation decile at the year and area level, as well as the fixed effects for women

7.4 Discussion

This chapter aimed to compare rates of amenable mortality in England and Scotland over time, with special interest into any effects of the devolution of Scotland from England in 2000.

7.4.1 Principal findings

Age-standardised mortality rates in Scotland exceeded those of England throughout the 24 year analysis period, and male rates exceeded those of females in both countries, although the difference can be seen to be decreasing in the later years of analysis. There does not appear to be any change in the differences between countries, within sexes.

There have been declines in rates of amenable mortality in both England and Scotland, for men and for women. Prior to devolution, men and women in England had lower rates of amenable mortality than in Scotland, although mortality rates were decreasing faster per year in Scotland, than in England (Scotland had further declines of 0.4% per year for both men and women). After devolution, men and women in Scotland experienced a lower rate of decline in amenable mortality, when compared to the rate in England.

7.4.2 Strengths and limitations

Twenty-four years of high quality mortality data were available for this analysis for both countries. In order to take the relative level of material deprivation of each country into account, and the differing compositional structures in measures of socioeconomic position between England and Scotland, adjusting estimates for deprivation was necessary. An adjusted Carstairs index was therefore calculated. The Social Class component of this Carstairs index had to be amended to reflect the level of detail available in the census data, however, the correlation with the published scores remained high (0.96), therefore results should be unaffected by this change.

Multilevel modelling was used to take advantage of the hierarchical structure in the data, allowing for the measurement of variation between areas and across time. Fractional polynomials were employed to model the non-linear relationships between risk of amenable death and age, deprivation, and year of death.

There are, however, several limitations to consider. Firstly, this analysis, unrealistically, explored whether there was an change in amenable mortality immediately following devolution. An improved analysis plan could have explored whether there were any differences after a longer period, given that changes to the way the healthcare system in Scotland was organised and delivered were unlikely to occur immediately following devolution. Secondly, the measure of relative deprivation used may not be a suitable measure of deprivation in the most recent years of analysis, given that the Carstairs index of multiple deprivation was first calculated in Scotland in the 1980s. The components used to create the score are either decreasing in relevance - such as overcrowding, or reflect the necessities of living in a remote location, rather than deprivation, such as car ownership (this can be seen by the relatively high proportion of households without access to a car in Table 7.2, within a city-based post-code sector). The use of only male unemployment is also questionable, given the increasing number of women in employment since the score's creation in the 1980s (Brown et al. 2014). Allik et al. (2016) proposed a new measure of material deprivation, updating the Carstairs score to allow for greater applicability across small areas in Scotland. The new measure replaces male unemployment with overall unemployment (men and women), decreases the number of categories in the Low Social Class designation, and includes housing tenure and educational attainment in place of overcrowding and car ownership. Finally, the predicted rates of death were not able to be satisfactorily smoothed, especially when studying the deprivation deciles. Several attempts to remove the discontinuities were made, as discussed, but were on the whole, unsuccessful.

7.4.3 Relations to other studies

Pre- and post-devolution trends in amenable mortality between the four countries of the UK have previously been investigated, finding that the differing health policies employed in each of the devolved countries has had little effect on rates of amenable mortality (Bevan et al. 2014). Improvements to their analyses are made in this chapter, by including a measure of relative deprivation to account for differing socioeconomic statuses in each country, as well as including the hierarchical structure into the models.

Desai et al. (2011) assessed the absolute change in rates before and after devolution using linear regression, for all four countries of the UK. They found large decreases in mortality rates for all countries by 2009. When relative change was examined they found a lower annual rate of decline for men and women in England, than in Scotland for the period 1990 - 1999 (2.68% vs 2.79% for men, 2.53% vs 2.90% for women), however in 1999 - 2009, the rates of decline were comparable (3.55% vs 3.52%) for men, but greater for women in England (3.19% vs 2.98%). Note, that their analysis may not be a strict comparison, as 50% of IHD deaths were included, which have been excluded from this analysis.

Following the cessation of this analysis, comparisons of all-cause mortality rates have been made between countries in the UK. Abel et al. (2016) published an adjusted IMD, allowing for England, Wales, Scotland and Northern Ireland to be compared using a single index, using data sources generated between 2010 and 2015. Whilst this method could not have been used in this analysis, as IMD were not calculated prior to 2000, future comparisons of amenable mortality by deprivation in England and Scotland may benefit from its use. Two further studies have used Carstairs deprivation scores to compare all-cause mortality rates in Scotland and England and Wales. Firstly, McCartney et al. (2017) calculated the deprivation scores for each country separately. This was not considered suitable in this analysis, as this assumes that there are not deprivation gradients between countries (i.e. people who live in the 10% most deprived areas of Scotland are experiencing the same levels of deprivation as those who live in the 10% most deprived areas in England and Wales) (Abel et al. 2016). Schofield et al. (2016) created a combined Carstairs index for Scotland, England and Wales, similar to that calculated in this thesis, but limited analyses to the three years surrounding each census, therefore avoiding any of the discontinuities found when including all years between censuses.

7.4.4 Implications

Future studies should explore alternative measures of deprivation, given the difficulties encountered with the Carstairs scores created for this analysis. As identified above, future work should explore the use of the adjusted, UK wide IMD, as proposed by Abel et al. (2016).

7.4.5 Next steps

Chapter 8 continues to make use of a natural experiment study design to investigate the effects of a population-level intervention. In this case, the introduction of the Health and Social Care Act in England, which may directly affect rates of amenable mortality, through reforms to the health care system. Scotland is used as a control.

Chapter 8

Amenable mortality in Scotland and England: the Health and Social Care Act

This final analysis chapter details another natural experiment study, comparing Scotland and England, as in chapter 7. The intervention of interest is the introduction of the Health and Social Care Act (2012) in England. The Department of Health introduced the proposed reforms in a White Paper, published in 2010, outlining a long-term plan for the NHS, and concluding that changes would start "at the earliest opportunity - rather than waiting until 2013" when the Act would come into force (Department of Health 2010*a*, p.50). This meant that the intervention date for this natural experiment is not as easily defined as it was in chapter 7, and that the pace of change would vary across England.

8.1 Introduction

In 2010, the Department of Health published a White Paper, 'Equity and Excellence: Liberating the NHS' (Department of Health 2010*a*), introducing the greatest changes the English NHS has experienced in its history (Edwards 2013). The reforms stated intentions were to improve health service quality and efficiency, as well as increase patient choice (Asthana 2011). Immediately after the unexpected announcement of this health system reorganisation, NHS structures in England started to change rapidly - prior to the Health & Social Care Act (HSCA) coming into force (Timmins 2012). Although these reforms have been hugely controversial (Kmietowicz 2012), there have only been two quantitative studies published on their effect on population health: the first investigates whether there has been a change in the numbers of hospitalisations and specialist visits (Lopez Bernal et al. 2017), using Scotland as a control. The second explores the effects of spending constraints on all-cause mortality rates and Potential Years of Life Lost (PYLL) from causes considered to be amenable to health care in England only (Watkins et al. 2017).

Amenable mortality is a widely used measure of health system performance that reflects deaths which should not occur in the presence of timely and effective health care (Nolte & McKee 2003). It has been used to measure the effectiveness and quality of health care delivered in England for many years (Charlton et al. 1983, Mackenbach et al. 1990, Nolte & McKee 2003, Wheller et al. 2007), was used as part of the justification for the reforms (Department of Health 2010*a*) and has consistently been included as an overarching indicator of NHS performance (Department of Health 2010*b*). Watkins et al. (2017) found that PYLL from causes considered to be amenable to health care significantly increased for women in 2011-2014, but not for men in 2011-2012, after the annual increase in Public Expenditure on Health (PHE) was limited in 2009/10.

In order to improve on the analysis conducted by Watkins et al., a natural experiment design has been used to compare trends in health outcomes in England and Scotland. The Scottish health system has been devolved since 2000, and after removing the purchaser/provider split in 2004, has undergone very little reform making it a well-suited comparator for evaluation purposes (Bevan et al. 2014).

This chapter aims to evaluate the impact of the introduction of major health system reforms on the ability of the English NHS to provide effective health care to its population, as assessed by total amenable mortality and its underlying components. The introduction of the reforms is taken to occur in 2010, in agreement with Watkins et al.

8.2 Methods

8.2.1 Study Design

The introduction of the HSCA within England allows for a natural experiment design, comparing amenable mortality rates before and after the publication of the White Paper, with Scotland as a control country. A difference in differences (DID) approach was taken for the analyses (Dimick & Ryan 2014), investigating whether within country differences in rates of amenable mortality before and after the reforms were different from each other. The primary hypothesis was that there would be a step-change in rates of amenable mortality in England, compared to Scotland, due to the publication of the White Paper, and associated changes in the organisation of the English NHS.

Assumptions

The DID analysis requires two assumptions to be met: (1) the treated (England) and control (Scotland) units should have parallel trends prior to the treatment (publication of the White Paper), and (2) both the treatment and control should be equally affected by other phenomena occurring during the periods of analysis (Ryan et al. 2014).

The 'parallel trends' assumption is tested by investigating whether the linear pre-treatment trends are significantly different between the units of analysis (Ryan 2009). Table 8.1 indicates that this assumption has been met, and prior to the publication of the White Paper, there was no statistically significant difference in the trends between England and Scotland for men nor women. Therefore, it can be assumed that any difference in differences in the outcome between the countries can be attributed to the White Paper's publication and subsequent reform implementations.

Table 8.1: Checking the assumptions of parallel trends between England and Scotland prior to the publication of the White Paper.

Model	Estimate	Std Error	p-value
Men	0.000006	0.0001	0.952
Women	-0.00002	0.00008	0.979

The secondary assumption of 'common shocks' essentially attempts to ensure that the estimate of any differences found is due to the intervention of interest (i.e. the White Paper introducing HSCA), rather than an unrelated event. This assumption cannot be statistically tested so must be assumed to be met, following consideration. The selection of a suitable control may be difficult in light of this, as it must be assumed that the control group has undergone the same macro level 'shocks' as experienced by England.

The NHS is mainly financed through general taxation (Steel & Cylus 2012). As the Tax system is a reserved matter, controlled by the UK Government, it can be assumed that similar protective measures were taken in both Scotland and England during and following the financial crisis in 2007/8. Therefore, both experienced similar 'shocks'.

8.2.2 Data

Records of all deaths in England and Scotland occurring between 2000 and 2013 were obtained from the Office for National Statistics and the National Records of Scotland respectively. The variables extracted from the death records included year of death, sex, age, residential electoral ward code (England) or postcode sector (Scotland), final underlying cause of death (classified according to the International Classification of Diseases (ICD)), and the version of ICD used (9 or 10). Deaths occurring in England were classified using ICD 9 until 2000 and ICD 10 from 2001, whilst Scotland introduced ICD 10 coding in 2000. The population at risk for each country was based on official mid-year population estimates by sex and 5-year age bands, as described in Section 7.2.2.

Outcomes

The main outcomes of interest were rates of mortality amenable to medical care in Scotland and England. These were identified using the ICD codes detailed in Appendix A.

Two additional outcomes of interest were identified. As in previous chapters, the three subgroups of amenable mortality - deaths amenable to primary prevention, early detection and intervention, and improved treatment and medical care (ITMC) were also explored. The ITMC subgroup was of particular interest as it was hypothesised that this group was the most likely to change within a short time period as a consequence of health system reform. The second additional outcome of interest was deaths due to surgical or medical misadventure, which fall within the ITMC subgroup. These were examined more closely as these deaths are a direct result of contact with, and care received from a health care system. They cannot be explained by delays to patients seeking care in the same manner that many other amenable causes of death can be. These deaths should be minimal within an effective, high quality health care system.

8.2.3 Statistical Analyses

Quasi-Poisson regression, taking account of over-dispersion, was used to investigate whether there was a step change in the rates of amenable mortality in England, compared to Scotland, in 2010. Over- (and under-) dispersion occurs when the Poisson distribution assumption of the mean being equal to the variance is violated (Faraway 2006). Quasi-Poisson regression allows the variance to be proportional, rather than equal, to the mean count of deaths. Equation 8.1 describes the DID equation used. Raw counts of amenable deaths were modelled adjusting for five-year age group, country and year of death. Mid-year population sizes, by 5 year age group and sex, were used as the offset. The year variables were centred around 2009 i.e. the year prior to the White Paper's publication. The post indicator variable indicated whether the year was 2010 and after or not. Sex specific models were run for total amenable mortality, as well as for each subgroup.

$$\begin{aligned} log_e(deaths) &= age + England + (age \times England) \\ &+ year + (year \times England) \\ &+ post + (post \times England) \\ &+ log_e(popn) \end{aligned} \tag{8.1}$$

Where:
Age = 1,...,15, with reference group = 5 (ages 20 - 24 years)
England = 1, with reference group = 0 (Scotland)
Year = Year - 2009
Post = 0 ($<$ 2010), 1 ($\geq$ 2010)

The interactions in Equation 8.1 allowed for the possibility of differing age distributions in each country, as well as differing rates of decline over the years. The coefficient for the interaction between post and country is the DID estimate, which estimates the average effect of the publication of the White Paper on the rates of amenable mortality within the English population (Ryan et al. 2014). The predicted number of excess deaths occurring in England in the years of the intervention (2010 - 2013) were estimated by setting the $post \times England$ interaction term to zero, that is, modelling a situation where the intervention (post) did not occur in England.

Sensitivity analyses

Scotland may not be an adequate control group for the whole of England, due to differences in socioeconomic, demographic and morbidity characteristics. In order to strengthen causal inference, the possibility that underlying socioeconomic factors might explain any differences found was considered. Analyses were repeated, using the North of England as the intervention group, compared to Scotland. The North East of England is often selected as a comparator for the devolved countries of Scotland, Wales and Northern Ireland, owing to its similar size, socioeconomic, demographic and morbidity characteristics (Bevan et al. 2014). By restricting analyses to the North of England, two geographical areas where socioeconomic differences were minimal were able to be compared. Electoral wards within the North East and North West of England were identified using the Office for National Statistics

Postcode Directory 2013. The population estimates created using the Directory were lower than official estimates of the North East and North West of England population. Analyses were performed using the lower population estimates, as this allowed for some certainty that all deaths occurring within the selected wards were included in the analyses.

Analyses were also repeated for 'other' mortality, that is, all deaths, excluding those conditions considered here to be amenable, as well as excluding IHD (hereafter referred to as non-amenable mortality). If smaller or no step increases were found in rates of non-amenable deaths in England, compared to Scotland, this would imply that there was an effect of the reforms to the health care system on amenable mortality and the effects found were less likely to be due to changes in something other than HSCA.

Lastly, the analyses were repeated for IHD deaths only (ICD 9: 410-414, ICD 10: I20-I25). Deaths due to IHD were excluded from the main analyses due to their large numbers (see subsection 3.2.1 for further detail). Following Nolte & McKee (2004), and McCallum et al. (2013)[1], IHD deaths were analysed separately. As there were very few deaths due to IHD before the age of 20, the age range was restricted to 20 to 74 years.

8.3 Results

Between 2000 and 2013 there were 600,388 amenable deaths in England, and 82,071 in Scotland. Numbers of deaths within each subgroup of amenable mortality are displayed in Table 8.2. Just over 50% of the total amenable deaths occurred in women, in each of the three regions, and numbers of deaths within each year decreased over time.

Table 8.2: Number (%) of amenable deaths within England, North England, and Scotland

Area	Total Amenable	Primary Prevention	Early detection & intervention	Improved treatment & medical care
England	600,388 (100)	3,707 (0.6)	340,180 (56.7)	256,501 (42.7)
North of England	133,543 (100)	775 (0.6)	71,793 (53.8)	60,975 (45.7)
Scotland	82,071 (100)	369 (0.4)	43,881 (53.5)	37,821 (46.1)

The age standardised rates of mortality within each area, by sex are plotted in Figure 8.1. The dashed line indicates the year 2010, when the White Paper was published. Rates are highest in Scotland for both sexes and over the whole period of analysis, followed by the North of England.

[1]These were two of the five original publications from which the overall amenable conditions used in this thesis (see Appendix A) were based upon.

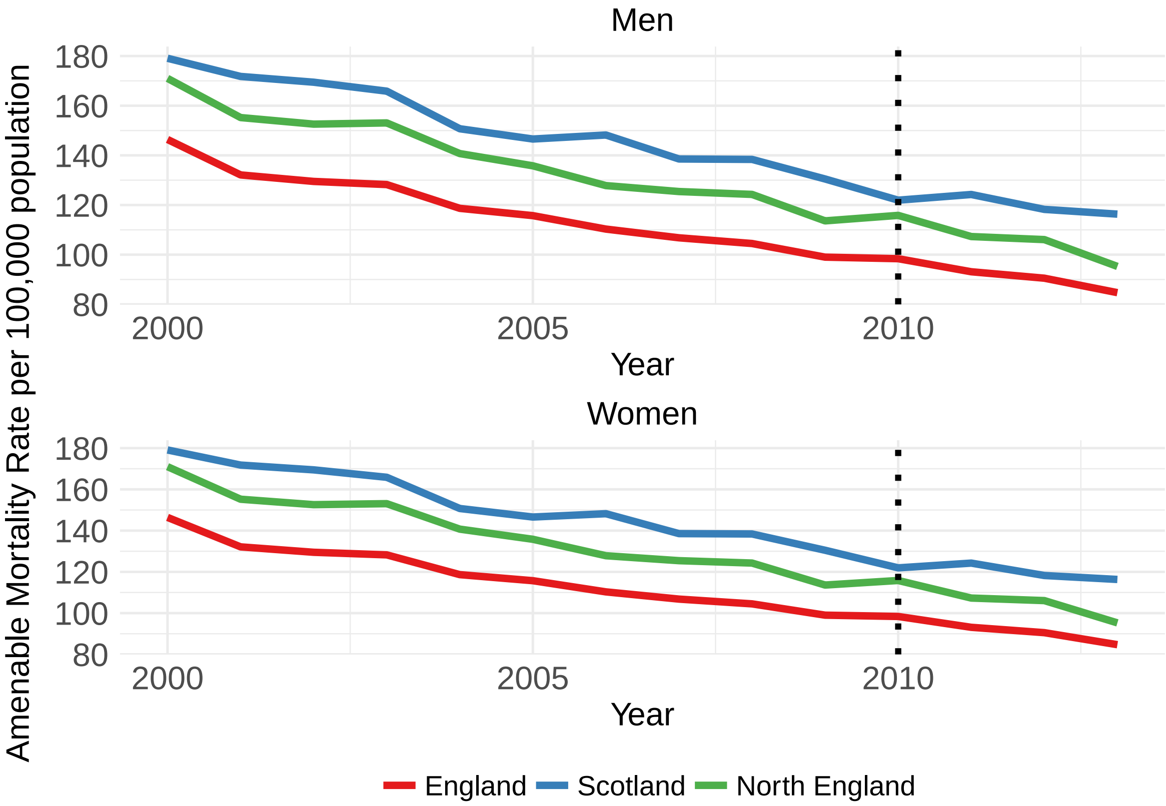


Figure 8.1: Age standardised amenable mortality rates for men and women in England, North England and Scotland, 2000 - 2013. The dashed vertical lines indicate the introduction of the White Paper.

The rate ratios for each variable in the model for men and women are displayed in Table 8.3. The male age variables indicate that for ages 5 - 19, the amenable mortality rates are below the reference ages of 20 - 24 years, and the remaining age groups are associated with a higher rate of death. The age group × England interaction allowed for differing age distributions in the deaths between countries. The youngest age group has a significantly lower rate of amenable mortality in England than in Scotland, whilst the remaining age groups do not differ significantly from the rate ratios estimated for Scotland.

England has an overall 10.3% decreased risk of amenable death for men, compared to Scotland. There is a 3.2% decrease in the risk of amenable death for men in Scotland per year, whilst for England there is a 3.9% decrease. Following the publication of the White Paper in 2010, there was a 3.7% (95%CI -2.1 to 9.8%) step increase in the amenable mortality rate for men in England, compared to Scotland.

Compared to women in Scotland, women in England had a 9.1% decreased risk of amenable death. The rate of decline was 3.3% and 2.5% per year in England and Scotland respectively. There was a smaller step increase of 0.5% (95%CI -4.1 to 5.4%) in the rate of amenable mortality for women in England, compared to Scotland, than the men experienced.

Table 8.3: Model estimates and 95% confidence intervals for England vs Scotland: men and women

Variable	Men		Women	
	Estimate	95% CI	Estimate	95% CI
(Intercept)	0.00007		0.00006	
Ages 0 - 4	9.770	(7.75 to 12.50)	9.119	(7.37 to 11.41)
Ages 5 - 9	0.282	(0.16 to 0.46)	0.319	(0.20 to 0.49)
Ages 10 - 14	0.446	(0.29 to 0.67)	0.450	(0.30 to 0.65)
Ages 15 - 19	0.769	(0.54 to 1.08)	0.755	(0.55 to 1.04)
Ages 25 - 29	1.555	(1.16 to 2.09)	1.501	(1.15 to 1.96)
Ages 30 - 34	2.283	(1.75 to 3.01)	2.637	(2.08 to 3.37)
Ages 35 - 39	3.107	(2.42 to 4.04)	4.592	(3.69 to 5.78)
Ages 40 - 44	4.918	(3.87 to 6.33)	7.745	(6.28 to 9.67)
Ages 45 - 49	7.536	(5.98 to 9.65)	11.994	(9.76 to 14.93)
Ages 50 - 54	13.248	(10.57 to 16.88)	19.538	(15.95 to 24.26)
Ages 55 - 59	22.734	(18.19 to 28.88)	29.192	(23.86 to 36.2)
Ages 60 - 64	42.328	(33.94 to 53.67)	46.693	(38.21 to 57.84)
Ages 65 - 69	74.876	(60.10 to 94.85)	74.459	(60.98 to 92.18)
Ages 70 - 74	133.314	(107.09 to 168.77)	130.716	(107.12 to 161.73)
Ages 0 - 4 × England	0.303	(0.23 to 0.39)	0.313	(0.25 to 0.39)
Ages 5 - 9 × England	1.600	(0.97 to 2.78)	1.451	(0.93 to 2.36)
Ages 10 - 14 × England	0.997	(0.65 to 1.56)	1.053	(0.71 to- 1.59)
Ages 15 - 19 × England	0.990	(0.69 to 1.43)	1.002	(0.72 to 1.41)
Ages 25 - 29 × England	0.852	(0.62 to 1.16)	1.040	(0.78 to 1.37)
Ages 30 - 34 × England	0.852	(0.64 to 1.13)	0.990	(0.77 to 1.27)
Ages 35 - 39 × England	0.937	(0.71 to 1.22)	0.978	(0.77 to 1.23)
Ages 40 - 44 × England	0.908	(0.70 to 1.17)	0.945	(0.75 to 1.18)
Ages 45 - 49 × England	0.926	(0.71 to 1.18)	0.924	(0.73 to 1.15)
Ages 50 - 54 × England	0.860	(0.67 to 1.09)	0.877	(0.70 to 1.09)
Ages 55 - 59 × England	0.863	(0.67 to 1.09)	0.874	(0.70 to 1.08)
Ages 60 - 64 × England	0.824	(0.64 to 1.04)	0.839	(0.67 to 1.04)
Ages 65 - 69 × England	0.821	(0.64 to 1.04)	0.838	(0.67 to 1.04)
Ages 70 - 74 × England	0.860	(0.67 to 1.08)	0.844	(0.68 to 1.04)
England	0.897	(0.71 to 1.15)	0.909	(0.74 to 1.14)
Year	0.968	(0.96 to 0.97)	0.975	(0.97 to 0.98)
Year × England	0.993	(0.99 to 0.99)	0.992	(0.99 to 0.99)
Post	0.987	(0.93 to 1.04)	1.003	(0.96 to 1.05)
Post × England*	1.037	(0.98 to 1.10)	1.005	(0.96 to 1.05)

* DID estimate

Table 8.4 contains the observed, predicted and estimated additional deaths for men and women in England, compared to Scotland. The predicted deaths were obtained from the model described in Equation 8.1. The column labelled 'No White Paper' was calculated using the predicted rates with the value of the Post $\times$ England interaction set to zero. The results suggest that the publication of the White Paper in England in 2010 resulted in on average an additional 670 deaths per year for men, and 106 additional deaths per year for women, between 2010 and 2013.

Table 8.4: Predicted additional deaths in England, compared to Scotland

Year	Country	Observed deaths	Predicted deaths	No White Paper	Additional deaths	95% confidence interval
Men						
2010	England	19,904	19,641.5	18,947.3	694.2	(-456 to 1,780)
2011	England	19,077	19,106.3	18,431.0	675.3	(-457 to 1,740)
2012	England	18,863	18,730.6	18,068.6	662.0	(-457 to 1,715)
2013	England	17,986	18,351.6	17,703.0	648.6	(-459 to 1,690)
Women						
2010	England	19,870	19,994.9	19,886.0	108.9	(-878 to 1,049)
2011	England	19,488	19,548.2	19,441.7	106.5	(-867 to 1,033)
2012	England	19,642	19,236.9	19,132.1	104.8	(-862 to 1,024)
2013	England	18,705	18,924.9	18,821.8	103.1	(-858 to 1,017)

The model outputs for the diagnosis subgroups of amenable mortality have been restricted. Whilst age and age$\times$England interaction terms were included in the models, they are not displayed in Tables 8.5, 8.7 and 8.9. The variables exhibited similar patterns to those seen in Table 8.3.

Table 8.5: Model estimates for England vs Scotland, Men and Women: deaths amenable to primary prevention

Variable*	Men		Women	
	Estimate	95% CI	Estimate	95% CI
England	1.119	(0.37 to 5.00)	0.671	(0.17 to 2.63)
Year	0.982	(0.92 to 1.05)	1.032	(0.97 to 1.10)
Year × England	0.999	(0.93 to 1.07)	0.952	(0.89 to 1.02)
Post	1.125	(0.61 to 2.09)	0.725	(0.41 to 1.27)
Post × England†	0.913	(0.48 to 1.72)	1.388	(0.77 to 2.50)

* Model adjusted for age and age×England interactions

† DID estimate

The subset with the smallest number of deaths (see Table 8.2) is Primary prevention. This results in estimates with large confidence intervals, as can be seen in Table 8.5. Rates of deaths amenable to primary prevention for men in England were 11.9% higher than in Scotland, whilst rates for women were 32.9% lower in England, compared to Scotland. The DID estimates suggest an 8.7% (95% CI -52.2 to 72.3) step decrease for men - resulting in 12 fewer male deaths per year on average in England (Table 8.6), and a 38.8% (95% CI -23.0 to 150.4%) step increase for women in England compared to Scotland, resulting in 35 additional female deaths per year on average in 2010 to 2013.

Table 8.6: Predicted additional deaths in England, compared to Scotland: primary prevention

Year	Country	Observed deaths	Predicted deaths	No White Paper	Additional deaths	95% confidence interval
Men						
2010	England	131	134.9	147.7	-12.8	(-150 to 58)
2011	England	139	133.9	146.6	-12.7	(-150 to 58)
2012	England	143	133.5	146.2	-12.7	(-151 to 58)
2013	England	122	132.7	145.3	-12.6	(-152 to 58)
Women						
2010	England	129	127.3	91.7	35.6	(-41 to 77)
2011	England	123	126.4	91.1	35.3	(-41 to 77)
2012	England	129	126.3	91.0	35.3	(-42 to 77)
2013	England	125	125.9	90.7	35.2	(-43 to 77)

Table 8.7: Model estimates for England vs Scotland, men & women: deaths amenable to early detection and intervention

Variable*	Men		Women	
	Estimate	95% CI	Estimate	95% CI
England	1.040	(0.67 to 1.73)	1.253	(0.83 to 2.00)
Year	0.961	(0.95 to 0.97)	0.967	(0.96 to 0.97)
Year × England	1.000	(0.99 to 1.01)	1.000	(0.99 to 1.01)
Post	0.989	(0.93 to 1.06)	1.036	(0.98 to 1.09)
Post × England†	1.021	(0.95 to 1.09)	0.959	(0.91 to 1.02)

* Model adjusted for age and age×England interactions

† DID estimate

Tables 8.7 and 8.8 relate to deaths amenable to early detection and intervention. Rates of death amenable to these causes were 4% higher for men, and 25.3% higher for women in England, compared to Scotland prior to 2010. Following the publication of the White Paper, there was a 2.1% (95% CI -4.8 to 9.4%) step increase in rates of male deaths, but a 4.1% (95% CI -9.4 to 1.6%) step decrease in rates of female deaths. The step increase in male rates of mortality, shown in Table 8.8, equates to just under 200 additional deaths per year on average in England compared to Scotland, whilst the step decrease in rates of female mortality is associated with approximately 500 fewer deaths in England per year on average in 2010 to 2013.

Table 8.8: Predicted additional deaths in England, compared to Scotland: early detection and intervention

Year	Country	Observed deaths	Predicted deaths	No White Paper	Additional deaths	95% confidence interval
Men						
2010	England	10,052	9,775.6	9,579.0	196.6	(-511 to 855)
2011	England	9,454	9,511.5	9,320.2	191.3	(-503 to 834)
2012	England	9,256	9,328.0	9,140.4	187.6	(-500 to 826)
2013	England	8,995	9,141.9	8,958.1	183.8	(-497 to 815)
Women						
2010	England	12,325	12,460.6	12,987.5	-526.9	(-1,306 to 206)
2011	England	12,131	12,191.1	12,706.7	-515.6	(-1,283 to 208)
2012	England	12,314	11,991.3	12,498.4	-507.1	(-1,269 to 210)
2013	England	11,665	11,792.1	12,290.8	-498.7	(-1,256 to 213)

As described in the Methods section, it was expected that the earliest impacts of the health reforms would be found in the improved treatment and medical care group. Results in Table 8.9 indicate that rates of mortality were 15.4% and 20.6% lower in England, compared to Scotland, for men and women respectively. In 2010 there was a 5.6% (95% CI -3.0 to 14.9%) step increase in rates for men, and a larger step increase of 7.6% (95% CI -1.0 to 16.9%) for women.

Table 8.9: Model estimates for England vs Scotland, men & women: deaths amenable to improved treatment and medical care

Variable*	Men		Women	
	Estimate	95% CI	Estimate	95% CI
England	0.846	(0.64 to 1.14)	0.794	(0.61 to 1.06)
Year	0.974	(0.97 to 0.98)	0.985	(0.98 to 0.99)
Year $\times$ England	0.987	(0.98 to 0.99)	0.980	(0.97 to 0.99)
Post	0.982	(0.91 to 1.06)	0.963	(0.89 to 1.04)
Post $\times$ England†	1.056	(0.97 - 1.15)	1.076	(0.99 to 1.17)

* Model adjusted for age and age×England interactions

† DID estimate

The step increases in rates of death due to ITMC translates to approximately 495 excess deaths per year on average in England for men between 2010 and 2013, and 507 deaths per year on average for women (Table 8.10).

Table 8.10: Predicted additional deaths in England, compared to Scotland: improved treatment and medical care

Year	Country	Observed deaths	Predicted deaths	No White Paper	Additional deaths	95% confidence interval
Men						
2010	England	9,721	9,730.7	9,217.9	512.8	(-327 to 1,282)
2011	England	9,484	9,460.8	8,962.3	498.5	(-326 to 1,253)
2012	England	9,464	9,269.2	8,780.8	488.4	(-327 to 1,233)
2013	England	8,869	9,077.2	8,598.9	478.3	(-329 to 1,216)
Women						
2010	England	7,416	7,407.1	6,884.7	522.4	(-94 to 1,087)
2011	England	7,234	7,230.5	6,720.5	510.0	(-97 to 1,066)
2012	England	7,199	7,119.3	6,617.1	502.2	(-102 to 1,055)
2013	England	6,915	7,007.1	6,512.9	494.2	(-108 to 1,045)

Deaths due to surgical or medical misadventure are considered to be amenable to improved treatment and medical care. The rates of death due to this, plotted in Figure 8.2, have been age- and sex-standardised as there should be no difference between the sexes. The rates plotted are limited to 2001 to 2013, ensuring that comparable ICD 10 codes were used in each country. Between 2001 and 2013, there were 2,243 and 272 deaths due to surgical or medical misadventure recorded in England and Scotland respectively.

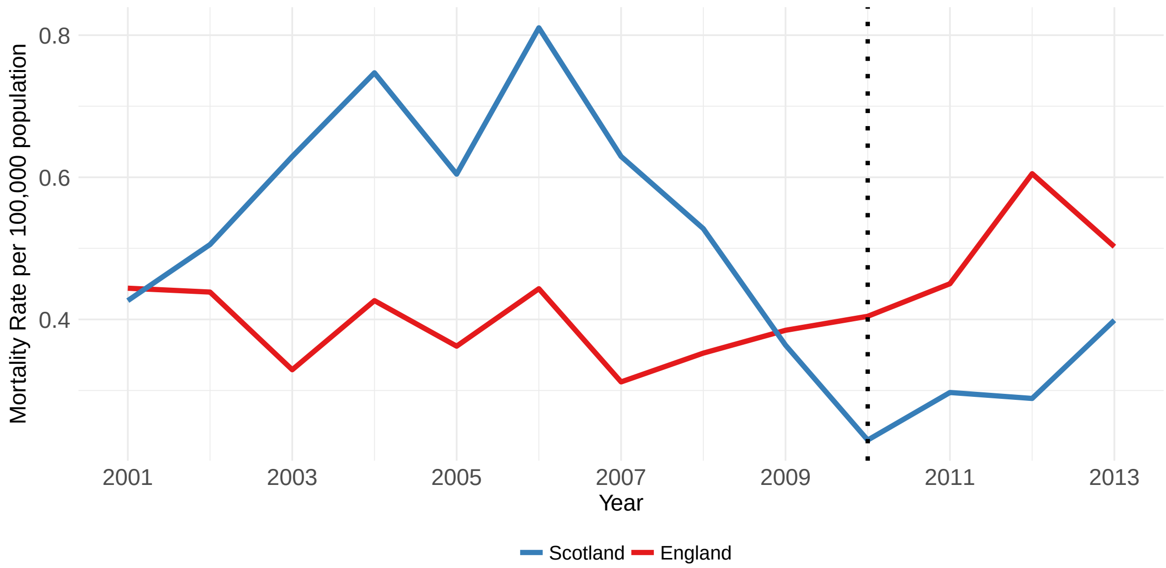


Figure 8.2: Rates of death due to Surgical or Medical Misadventure in England and Scotland, 2001 - 2013. The dashed line indicates the introduction of the White Paper.

Until 2009, age-sex-standardised rates of death due to misadventure were higher in Scotland than they were in England. From 2007, rates in Scotland have been decreasing, whilst rates in England have been increasing, over taking those of Scotland in 2010 - the year of the White Paper's publication. Insufficient numbers of death occur within each age group to gain reliable estimates from the DID analyses as performed on total amenable mortality and the subsets. The assumption of parallel trends prior to the intervention is also violated for these trends.

8.3.1 Sensitivity Analyses

The first sensitivity analysis explores the effects of the introduction of health care system reforms on the North of England, compared to Scotland. The trends in mortality rates between North of England can be seen in Figure 8.1, showing that mortality rates in the North of England are closer to those of Scotland, for both men and women. Rates of amenable mortality in Scotland remain highest throughout the analysis period.

Table 8.11 contains the model estimates investigating the difference in differences between North of England and Scotland, for all amenable deaths, as well as the three subgroups, for men and women.

Table 8.11: Model estimates for North of England (N.England) vs Scotland, men & women, for amenable mortality and its three subgroups

Variable*	Men		Women	
	Estimate	95% CI	Estimate	95% CI
All amenable mortality				
N.England	1.020	(0.82 to 1.28)	0.970	(0.79 to 1.20)
Year	0.968	(0.96 to 0.97)	0.975	(0.97 to 0.98)
Year × N.England	0.992	(0.99 to 0.99)	0.994	(0.99 to 0.99)
Post	0.987	(0.95 to 1.03)	1.003	(0.97 to 1.04)
Post × N.England†	1.034	(0.98 to 1.09)	1.016	(0.97 to 1.06)
Primary prevention				
N.England	0.134	(0.01 to 1.00)	0.473	(0.09 to 2.59)
Year	0.982	(0.92 to 1.04)	1.032	(0.97 to 1.10)
Year × N.England	0.983	(0.91 to 1.06)	0.967	(0.90 to 1.04)
Post	1.125	(0.66 to 1.94)	0.725	(0.43 to 1.23)
Post × N.England†	0.952	(0.49 to 1.83)	1.337	(0.70 to 2.54)
Early detection and intervention				
N.England	1.039	(0.64 to 1.72)	1.211	(0.77 to 1.94)
Year	0.961	(0.95 to 0.97)	0.967	(0.96 to 0.97)
Year × N.England	0.993	(0.98 to 1.00)	0.999	(0.99 to 1.01)
Post	0.989	(0.93 to 1.05)	1.036	(0.99 to 1.09)
Post × N.England†	1.048	(0.97 to 1.13)	0.974	(0.92 to 1.04)
Improved treatment and medical care				
N.England	1.042	(0.81 to 1.35)	0.895	(0.69 to 1.16)
Year	0.974	(0.97 to 0.98)	0.985	(0.98 to 0.99)
Year × N.England	0.991	(0.98 to 0.99)	0.987	(0.98 to 0.99)
Post	0.982	(0.92 to 1.04)	0.963	(0.91 to 1.02)
Post × N.England†	1.022	(0.95 to 1.10)	1.075	(0.99 to 1.16)

* Models adjusted for age and age×N.England interactions

† DID estimates

The step changes found for total amenable mortality in the North of England, compared to Scotland are of similar magnitude to the whole of England comparisons for men - a step increase of 3.4% is estimated, whilst for women, the step increase is approximately three times larger than that estimated in the whole of England (1.6% vs 0.5%) compared to Scotland.

The direction of the step change remains the same for the North of England, compared to Scotland, as the whole of England comparison. The step increase for male deaths amenable to ITMC has decreased from 5.6% to 2.2% whilst the step increase for women remains approximately equal at a 7.5% step increase.

The second sensitivity analysis explores whether there are step changes in non-amenable mortality. Table 8.12 indicates that there are step decreases of 1.8% (95% CI -8.2 to 5.1%) for men, and 1.8% (95% CI -6.7 to 3.4%) for women in England, compared to Scotland.

Table 8.12: Model estimates for England vs Scotland, men & women, non-amenable mortality

Variable*	Men		Women	
	Estimate	95% CI	Estimate	95% CI
N.England	0.630	(0.55 to 0.79)	0.697	(0.60 to 0.81)
Year	0.984	(0.98 to 0.99)	0.994	(0.99 to 0.99)
Year × England	1.001	(0.99 to 1.01)	0.996	(0.99 to 1.00)
Post	0.970	(0.91 to 1.03)	0.982	(0.94 to 1.03)
Post × England†	0.982	(0.92 to 1.05)	0.982	(0.93 to 1.03)

* Model adjusted for age and age×England interactions

† DID estimate

These step decreases are associated with approximately 975 and 650 fewer male and female deaths per year respectively in England, compared to Scotland, from 2010 to 2013.

Table 8.13: Predicted additional other deaths in England, compared to Scotland

Year	Country	Observed deaths	Predicted deaths	No White Paper	Additional deaths	95% confidence interval
Men						
2010	England	56,175	54,191.6	55,167.0	-975.4	(-4,963 to 2,741)
2011	England	55,591	54,043.6	55,016.3	-972.7	(-4,983 to 2,763)
2012	England	55,388	54,158.5	55,133.3	-974.8	(-5,032 to 2,802)
2013	England	49,462	54,222.3	55,198.2	-975.9	(-5,081 to 2,843)
Women						
2010	England	36,862	35,678.2	36,324.0	-645.8	(-2,617 to 1,222)
2011	England	36,288	35,742.7	36,389.6	-646.9	(-2,638 to 1,240)
2012	England	36,574	36,019.6	36,671.5	-651.9	(-2,678 to 1,267)
2013	England	33,981	36,264.5	36,920.9	-656.4	(-2,718 to 1,295)

Finally, the analyses were performed on IHD deaths only, restricting the ages further to 20 to 74 years. Table 8.14 details the step increases in rates of IHD deaths for men of 2.2% and 6.4% for women. These step increases were associated with approximately 304 and 275 additional male and female deaths (see Table 8.15) from IHD in England per year in 2010 - 2013 respectively.

Table 8.14: Model estimates for England vs Scotland, men & women, IHD

Variable*	Men		Women	
	Estimate	95% CI	Estimate	95% CI
N.England	1.100	(0.34 to 6.24)	1.021	(0.22 to 14.08)
Year	0.940	(0.93 to 0.95)	0.930	(0.92 to 0.94)
Year $\times$ England	0.992	(0.98 to 1.00)	0.990	(0.98 to 1.00)
Post	1.001	(0.93 to 1.08)	0.967	(0.88 to 1.07)
Post $\times$ England†	1.022	(0.94 to 1.11)	1.064	(0.96 to 1.18)

* Model adjusted for age and age×England interactions

† DID estimate

Table 8.15: Predicted additional IHD deaths in England, compared to Scotland

Year	Country	Observed deaths	Predicted deaths	No White Paper	Additional deaths	95% confidence interval
Men						
2010	England	15,280	15,196.6	14,867.7	328.9	(-908 to 1,470)
2011	England	14,075	14,360.7	14,049.9	310.8	(-868 to 1,397)
2012	England	13,726	13,665.7	13,369.9	295.8	(-837 to 1,339)
2013	England	13,136	12,993.9	12,712.7	281.2	(-807 to 1,283)
Women						
2010	England	4,949	5,021.4	4,718.7	302.7	(-228 to 779)
2011	England	4,524	4,674.9	4,393.1	281.8	(-217 to 729)
2012	England	4,522	4,398.5	4,133.4	265.1	(-209 to 690)
2013	England	4,237	4,137.2	3,887.8	249.4	(-202 to 653)

8.4 Discussion

8.4.1 Principal findings

We found no significant evidence that health care reforms introduced in the English NHS in 2010 coincided with changes in rates of amenable mortality for men and women in England, compared to Scotland. Whilst the direction and size of the estimates are suggestive of step increases in amenable mortality rates in England, compared to Scotland, the 95% confidence intervals around the DID estimates included the null value of 1, therefore there was insufficient evidence of an effect.

When assessing more specific outcomes which would be expected to be more sensitive to change in response to the reforms, step increases in rates of death which were avoidable through improved treatment and medical care were found, however these again failed to reach significance, and are consistent with no effect. Trends in death rates due to surgical misadventure diverged following the reforms, with rates increasing in England compared to the continuing declines within Scotland, however there were insufficient numbers of deaths to perform any formal analyses.

Estimates for non-amenable mortality, whilst also non-significant, were in the opposite direction to the DID estimates for amenable mortality, suggesting that there was a differential impact of the reforms on amenable and non-amenable causes of death.

8.4.2 Strengths and limitations

Our findings make use of 14 years of mortality records, along with full population estimates. The use of subgroups of amenable mortality, as well as a tracer condition (deaths due to surgical and medical misadventures) enabled the impacts on specific parts of the health service to be estimated, focusing on those which were anticipated to be affected earliest, thereby strengthening causal inference (Craig et al. 2017). Due to the small numbers of deaths due to surgical and medical misadventures, estimating the effect of the introduction of the HSCA was not possible, however the plot suggests continued increasing rates in England.

The use of the DID analyses, and the use of Scotland as a comparator, not relying on a simple pre-post study design, allowed for changes in already decreasing rates of amenable mortality to be examined whilst accounting for unmeasured confounding differences between the intervention and control (Dimick & Ryan 2014). The effects of socioeconomic differences between the two countries were explored in the sensitivity analyses, using the North of England as the intervention group compared to Scotland. These found similar effect sizes for men in the whole of England (approximately 3.4% step increase in rates of amenable mortality), and a step increase approximately 3 times as large for women (1.6% vs 0.5%). The two further outcomes of interest, ITMC and deaths due to surgical or medical misadventure, experienced step increases in both England and North of England, compared to Scotland, for men and women.

Quasi-Poisson regression models were used to account for over-dispersion, allowing the variance to be proportional, rather than equal to the mean. The models were adjusted for differing age structures in each country, as well as differing rates of decline prior to the reforms.

In order to evaluate whether the changes in amenable mortality rates in England were due to the introduction of the HSCA, trends in non-amenable mortality were explored. These were expected to not have been affected by the reforms in England. Step decreases in mortality rates in England, compared to Scotland, were found. The opposing directions of the impacts on rates of amenable verses non-amenable mortality are suggestive of the HSCA having some differential effect on amenable deaths.

There are several limitations of this analysis to consider. First, defining the exact start of the intervention is problematic because reforms began prior to the implementation of the legislation (Katikireddi et al. 2014). A pre-defined implementation date for the intervention was used, informed by prior policy analysis and in agreement with previous research (Watkins et al. 2017) but it is possible that some of the time period for which England was classified as being exposed to the reforms should in reality be considered unexposed. The likely impact of this bias is that the impact of these reforms on rates of amenable mortality in England have been underestimated. Second, the results found were inconclusive, and would be consistent with no effects of the reforms to the English NHS. This is an early investigation into the effects of health care reform. Although the magnitude and direction of the estimated effects in both overall amenable mortality and the ITMC subgroup were indicative of increased numbers of deaths, these did not reach significance using the traditional threshold of 0.05. As such it cannot be concluded that these results did not arise due to chance. The power to detect a significant change when evaluating natural experiments increases with the number of years' data following intervention, and this study highlights the challenges of using these methods to investigate population wide impacts, especially where there is a policy need for the early evaluation of such changes (Lagarde 2012). Third, although rates of amenable mortality have been used previously to measure the quality and effectiveness of a health care system, there remains some uncertainty as to how well they reflect the current state of health care delivered (Pérez et al. 2014). They are now considered as indicators of the need for further investigation, and this analysis indicates such a need. Without such a detailed investigation, the possibility that the English reforms led to increased avoidable deaths cannot be dismissed. This is important not only for England, given ongoing debates about the future of the NHS, but also for countries that may consider similar reforms in the future. Fourth, the upper age limit of 75 does not suggest that deaths after this age are no longer preventable; rather it reflects the increasing presence of multiple co-morbidities at the older ages, which can reduce the accuracy of the underlying cause of death recorded on death records (Mackenbach, Kunst, Looman, Habbema & van der Maas 1988). The upper age limit is also used as many clinical effectiveness trials for the treatments offered exclude older patients, and therefore there is little evidence of many treatments' effectiveness at the older ages (New Zealand Ministry of Health 2010). Finally, there may be a larger proportion of delayed and under-reported deaths in England, rather than Scotland. Of the deaths occurring in 2012, 4.4% were registered a year later in England, compared to 1.2% in Scotland. Deaths occurring in 2013 in England, but not registered until 2014 are not included in these analyses, whereas these deaths are included for Scotland. The effect of this under-reporting is likely to result in an underestimate of the impact of the reforms. There were only three years of mortality data available for analyses after the introduction of health system reforms; therefore, our results are reflecting the early effects. The longer term impacts are unknown.

8.4.3 Relations to other studies

As described in the Introduction, two previous studies have investigated the effects of the latest health care system reforms leading to the HSCA in England (Watkins et al. 2017, Lopez Bernal et al. 2017).

Watkins et al. conducted a time trend analysis, exploring the effects of spending constraints introduced in 2009/10 on rates of all-cause mortality, and, as a validation, on PYLL due to conditions considered amenable to health care. The main analyses found that there was no immediate significant difference between observed and predicted numbers of deaths occurring in 2011 for men and women, however, from 2012-14, significant rate ratios (above 1) were found, suggesting an excess of between 8,148 (2012) to 18,324 (2014) deaths per year after the restricted increase in Public Expenditure on Health. The validation exercise, using PYLL from causes considered amenable to health care intervention, found significant rate ratios (above 1) between predicted and observed PYLL for women in all years 2011-2014, however, only 2012-14 for men. The definition of amenable conditions used by Watkins et al. follows the ONS's revised definition (Olatunde et al. 2016), and includes deaths due to HIV/AIDS and all IHD deaths. No cross-country comparisons were made to control for any impacts which may not be due to the reforms.

An interrupted time series analysis explored whether GP-lead commissioning of care services, introduced through HSCA, would result in a decrease in hospitalisation rates and specialist outpatient visits in England, using Scotland as a control (Lopez Bernal et al. 2017). Quarterly hospitalisation data were obtained between 2007 and 2015, for comparable admissions between the two countries, although analyses were performed using data from April 2010 onwards due to coding errors. The intervention was hypothesised to have occurred following the enactment of the HSCA, and a year-long (April 2012 - March 2013) phase-in period was allowed for. Slopes, rather than step changes, were modelled, with slopes in both countries being similar prior to 2012. Between April 2010 and March 2012, total specialist visits in England increased by 0.5% per quarter (no equivalent result reported for Scotland), and after 2013, increased to 1.4% (95%CI 0.6 to 2.1%) per quarter, after controlling for trends in Scotland. There was no equivalent increase in inpatient hospitalisations after 2013. Whilst this study potentially used a more supported intervention date of April 2012, this analysis, and that of Watkins et al. (2017) suggest that reforms may have begun in 2010, the start of the analysis period used by Lopez Bernal et al. In addition, no sex-specific analyses were presented (sex was adjusted for, along with age), however, there is likely to be a differential in the rates at which men and women seek medical care.

Bevan et al. (2014) compared rates of amenable mortality in England, North East England and Scotland between 2000 and 2010 in a larger assessment of the progress of health care systems within the devolved countries of the UK. They included 50% of IHD deaths in the definition of amenable mortality, and so are not directly comparable with these results. Rates in North East England were found to be most similar to Scotland, although the North East did experience higher rates of decline between 2000 and 2010. Bevan et al. also examined trends in amenable mortality at the older ages (65 - 74 years). Relative declines of 32%, 21% and 30% in rates of amenable death was found for men in England, North East England, and Scotland respectively between 2000 and 2010. Desai et al. (2011) compared England and Wales, to Scotland from 1990 to 2009, ending their analyses a year prior to the publication of the White Paper. In the second decade of analysis (after devolution in 1999), the rate of decline of amenable death in England and Wales exceeded that of Scotland, coinciding with increased spending per head on health care in England.

8.4.4 Implications

The step changes for rates of amenable and other mortality were estimated to be in different directions, following 2010. Therefore rates of amenable mortality are not simply reflecting rates in other mortality, as has been previously suggested.

Whilst these findings are indicative of the health system reforms having no effect on the ability of the NHS to avoid these deaths from occurring, these analyses are based upon the final stage of potentially long periods of illness and extensive contact with the health care system. No allowance for time lag was made, nor possible due to the limited post-intervention data available. Any early effects of health care system reforms, in England, and other countries, may be best detected using alternative health outcomes or measures of health care supply.

8.4.5 Next steps

The analyses performed in this chapter have found a potentially important adverse impact of the NHS reforms in England but many questions remain unanswered. Rates of mortality amenable to health care intervention were studied, but further analysis of a broader range of health outcomes is needed. Health system reforms are complex, involving multiple components which may be implemented at different times, or in different manners, across multiple locations. While the short-term impacts of the health care reforms in England appear potentially null, long-term impacts have yet to be investigated.

Chapter 9

Discussion and conclusions

9.1 Novel contributions

This thesis provides the most up-to-date analysis of amenable mortality in Scotland. Whilst not the first study conducted on overall amenable mortality in Scotland (Carstairs 1989, 1993, Grant et al. 2006), it is the first to report socioeconomic differences over an extended period of time, by the type of intervention (primary prevention, early detection and intervention, and improved treatment and medical care), to measure both absolute and relative inequalities in mortality and incident hospitalisation rates within these cause groups, and uses the broadest range of amenable conditions since amenable mortality was first conceived as an indicator of the quality of medical care (Rutstein et al. 1976).

A core contribution of this thesis is the exploration of relative and absolute inequalities in rates of amenable mortality over a 34 year period, finding that relative inequalities had increased, whilst absolute inequalities experienced some decline. The narrowing of absolute inequalities is encouraging, as it reflects a smaller difference in rates between the most and least deprived areas. However, the increasing relative inequalities suggest that the mortality rates in the least deprived areas are decreasing faster than the most deprived areas. This points to areas of improvements required in the delivery, access, compliance and/or effectiveness of healthcare available in these areas.

The exploration of the incidence rates of amenable conditions in the general Scottish population, detailed in chapter 5, aimed to address a consistently identified limitation within the literature: that the declines in rates of amenable mortality may be confounded by declines in the incidence of these conditions within the population, and follows smaller studies conducted by Bauer & Charlton (1986) and Treurniet et al. (1999). The use of both full hospital discharge and cancer registers over 33 years allows this to be the most comprehensive measure of the incidence of amenable conditions, and the socioeconomic gradients within.

Combining the results of chapters 4 and 5, it can be concluded that the decline in rates of amenable mortality in Scotland are not solely due to any changes in the incidence of these conditions within the general population, rather, whilst incident hospitalisation rates remained relatively stable over the last 10 years of analysis, mortality rates continued to decline. Inequalities in each of these rates also differ - absolute inequalities were largest within the rates of incident hospitalisations, whereas relative inequalities were higher in the mortality rates. The disparity within the absolute inequalities is not concerning, given that these are based on the observed rates, and the incident hospitalisation rates were much larger than the mortality rates. In terms of relative inequalities, the 2013 RIIs in male mortality rates are approximately double those within the incident hospitalisations rates, and are about 40% larger for women. This suggests that there are greater inequalities in dying from these amenable conditions than in being diagnosed with one. Using the subgroups of amenable mortality, the inequalities can be more closely studied to identify possible shortcomings. For men and women, relative inequalities in mortality rates are greater in both the early detection and intervention, and improved treatment and medical care groups, compared to the relative inequalities in the incident hospitalisation rates. In EDI, relative inequalities in dying are approximately 60% and 40% larger than being diagnosed, for men and women respectively, whereas within the ITMC groups, male inequalities in mortality rates are 140% larger (125% for women). Therefore, there is a considerable difference between being diagnosed with a condition considered amenable through improved treatment and medical care, and dying as a result. There are several potential sources for this disparity: firstly, patients from higher socioeconomic backgrounds are generally less likely to have multiple co-morbidities and unfavourable risk factors which may complicate the interventions available, and are more likely to be compliant with treatment plans (Mackenbach 2006). Therefore, whilst these do not necessarily prevent a diagnosis of an amenable condition, these factors do improve the risk of death, resulting in mortality rates in the lesser deprived areas declining faster, and thereby increasing the relative inequalities. Alternatively; not all of the amenable conditions are fully contributing towards the incident hospitalisation rates (i.e. conditions mainly treated or managed within primary care settings, mainly those classified as ITMC), therefore relative (and absolute) inequalities within the incident hospitalisation rates may be underestimated.

The investigation of individual-level inequalities within rates of amenable mortality in Scotland, using educational attainment and the Scottish Longitudinal Study has previously been investigated (Popham & Boyle 2010), however, the results presented in chapter 6 extend the analysis period, and include alternative measures of individual socioeconomic position, such as occupational social class. The effects of accounting for migration within the sample were explored, as well as a comparison of area level inequalities found in the sample, to those found in the population.

Both chapters 7 and 8 make use of natural experiment study designs to evaluate large policy changes which may have affected the ability of each country's health care service to deliver the timely and effective interventions required to avert a death resultant of an amenable condition. The lack of officially produced common measures of area level deprivation across Scotland and England available for routine analysis necessitated the calculation of an adjusted Carstairs index in chapter 7. The use of the adjusted score removed the potential for the results to be confounded by differences in the socioeconomic patterning within rates of amenable mortality between Scotland and England, however was ultimately unsuccessful. The analyses presented in chapter 8 illustrate the potential for harm associated with the introduction of large scale policy changes.

In terms of novel methodology, this is the first study of amenable mortality to include fractional polynomial terms to allow for the flexible modelling of mortality and incidence rates in population. Whilst numeric representations of fractional polynomials can be difficult to interpret when used in conjunction with interactions, the plots of the predicted rates provide valuable visual descriptions of associations over time.

9.2 Summary of principal findings

This thesis aimed to explore the use of mortality amenable to health care intervention as an indicator of the equity of a health care system, and as a comparator between health systems. The following objectives were identified, and met within each of the 5 results chapters:

Chapter 4

1. Analyse the trends in rates of amenable mortality in Scotland, by individual and groups of causes.
2. Explore the socioeconomic gradient in rates of amenable mortality, using area level deprivation, and the extent to which this gradient has changed over time.

Chapter 4 illustrates the historical and recent trends in rates of amenable mortality in Scotland, from 1980 until 2013. Male mortality rates exceeded those of females for all years, although the gap between the sexes has decreased in recent years. Given the vast range of interventions required of the health care system to prevent deaths from these amenable conditions, rates of amenable mortality were divided according to the type of intervention: primary prevention, early detection and intervention, and improved treatment and medical care. The numbers, and therefore rates, of deaths due to failures in primary prevention are small, and highly variable over the 34 year period. The rates of deaths amenable through early detection and intervention were the largest at the start of the analysis period, and have seen the greatest reductions over time. Rates of amenable mortality for women were greater than for men, owing to the inclusion of female-specific cancers. The final group, deaths amenable through improved treatment and medical care, include the largest number of causes. Mortality rates for men declined at a faster rate than women.

This thesis aimed to use rates of amenable mortality as an indicator of the equity of the Scottish health care system: these amenable conditions should not result in death in the majority of cases, given the universal health care system available, and their effective cures or treatments. If there were no inequalities, there would be no gradients in the rates of death, regardless of the measure of socioeconomic position used. As Scotland has no individual level indicator of SES which can be accurately and appropriately assigned to the whole population, the use of area-level proxy indicators for SEP was necessary. Strong gradients in the mortality rates were found using the Carstairs index, a measure of relative material deprivation, for both men and women. Mortality rates within the most deprived areas exceeded those of the least deprived areas of Scotland throughout the study period, for overall amenable mortality, and two of the three subgroups. Both absolute and relative inequalities in mortality rates were calculated, as these may reflect differing relationships over time. Relative inequalities were found to be increasing over the 34 year period, for overall amenable mortality, and within two of the three subgroups, whilst absolute inequalities were more varying, but overall declining over time.

Chapter 5

> Examine the trends and socioeconomic gradients in the incidence of selected amenable conditions in the Scottish population.

Chapter 5 aimed to address a consistently identified limitation in the study of rates of amenable mortality: that declines in the mortality rates could be a simple reflection of declines in the incidence of these conditions within the study population, rather than as a result of improvements in the care delivered. This chapter made use of hospital discharge records, cancer registrations, birth and death records to investigate the changing patterns of disease incidence within the Scottish population between 1985 and 2013.

Rather than the consistent declines seen in mortality rates, incidence rates of total amenable conditions were found to rapidly increase between 1985 and 1996. This increase coincides with a change in recording system for perinatal conditions. Other possible explanations for the increase in rates of the remaining conditions, other than a true increasing incidence, is changes to hospital admissions policies, or in health seeking behaviours. In 1996, the introduction of ICD version 10 to code diagnoses saw a change in trend, from rapidly increasing, to one of relatively little change following an initial decrease, especially in male rates. Female incidence rates exceeded those of males after 1998 - contrasting to the relationship seen within the death rates. Analyses of the three subgroups revealed that female mortality rates exceeded those of males in both the early detection and intervention group, and the improved treatment and medical care group. This is likely due to the inclusion of female specific cancers in the former, and maternal causes of death in the latter.

Relative inequalities in incidence rates of amenable conditions were smaller than those calculated for mortality rates, and did not increase to the same extent over the analysis period. RII's were also fairly similar between the sexes within the incidence rates, whilst the mortality rates saw greater inequalities in male deaths. The patterns in absolute inequalities in incidence and mortality rates differed; absolute inequalities decreased in mortality rates, whilst they have been increasing since 2005 in the incidence rates. Absolute inequalities in the incidence rates were far larger than those in mortality rates, owing to the greater overall incidence rate. Women experienced the greatest absolute inequalities in incidence rates, contrasting to mortality rates, in which men exceeded those of women.

Chapter 6

> Investigate socioeconomic patterning of amenable mortality by individual characteristics such as education and occupational social class.

Three measures of individual level socioeconomic position, as well as living arrangements, were used to explore socioeconomic patterning in rates of amenable, non-amenable and all cause mortality within the SLS. Data from two censuses were used to assign individuals to categories: 1991 and 2001, each with a 10 year follow-up period. During 1991 - 2000, relative inequalities in rates of amenable mortality were greatest when measured using educational attainment and living arrangements, for both men and women. There was less difference between the four measures in the second period of follow-up, between 2001 and 2010, although the inequalities measured were generally higher.

Absolute inequalities were greatest in all-cause mortality, given the larger numbers of deaths and therefore higher mortality rates. When relative inequalities were estimated, no clear relationship was apparent across the four measures, over time. Relative inequalities for men in the last three years of follow-up for each period (1998 - 2000 and 2008 - 2010) tended to be greatest within rates of amenable mortality, whereas for women, the greatest relative inequalities were patterned across the three (non-exclusive) mortality groups, and the years of analysis.

Inequalities in rates of amenable mortality were also explored using the Carstairs index, in order to compare the SLS sample to the population estimates previously calculated in chapter 4. The inequalities calculated in the sample were found to over-estimate the inequalities calculated for the total population, implying that the inequalities calculated using the four individual level measurements may be over-estimating the true inequalities within the total population[1].

Chapters 7 and 8

> Investigate the effects of policy changes to health system organisation and management on rates of amenable mortality, through comparisons between Scotland and England.

The concept of amenable mortality has long been used as a method of evaluating health care systems between countries. The first study, published in 1986 by Charlton & Velez (1986), compared improvements in mortality rates for conditions amenable to health care intervention, across six developed countries. Since then, many more comparisons have been made, mainly within Europe (see subsections 2.4.1 and 2.4.6 for further detail).

The final two analysis chapters of this thesis presented comparisons of Scotland and England, with the further aim of using rates of amenable mortality to evaluate the impacts of population wide policy interventions on the ability of a health care service to continue to provide timely and effective health care. These were conducted using natural experiment study designs, as no randomisation to intervention nor control groups could be applied.

The first, investigating whether amenable mortality rates in Scotland were affected by the political devolution in 1999, using England as a control. Mortality rates declined in both countries throughout the analysis period, with Scotland consistently experiencing higher rates. Following devolution, the rate of decline slowed in Scotland, compared to England. Attempts were made in the chapter to account for differences in the distribution of area level deprivation between the two countries, however, this was ultimately unsuccessful, given the discontinuities found within the predicted mortality rates.

[1] See section 6.7

The second, chapter 8, explored whether the introduction of the Health and Social Care Act in England had an adverse affect on the English NHS' ability to prevent deaths amenable to the healthcare system. Step increases, although statistically non-significant, in rates of amenable mortality were found for men and women in England, compared to Scotland, for overall amenable mortality, and within the improved treatment and medical care subgroup. These analyses were limited by 3 years of data following the announcement of the reforms, as well as an unclear implementation date.

Both of these chapters highlight potential difficulties which may be encountered when comparing health care systems across countries, given that these are natural experimental settings over which most investigators have little control of: differing levels of deprivation; impacts from changes other than the intervention of interest, and limited comparable data. Whilst these do impact the overall findings of these two chapters, this thesis did find that Scotland experienced consistently larger amenable mortality rates, compared to England, over the whole analysis period, and this points to the potential for further improvements in the prevention of amenable deaths.

9.3 Strengths and limitations

9.3.1 Concept and analyses of amenable mortality

The continued use of rates of amenable mortality as a indicator of the equity of a health care system is strengthened by many advantages. The calculation of the overall indicator, and its subgroups, is relatively inexpensive, as routinely collected data are readily available for analysis in the majority of countries, and are released with little delay.

The usefulness of the concept of amenable mortality was further enhanced in this thesis through the study of subgroups of amenable conditions. These were grouped according to the type of intervention required by the health care system. As the amenable mortality indicator was designed to highlight areas of weakness, this further division of the overall indicator allows for faster identification of these potential problems.

A limitation of the overall concept, identified by Page et al. (2006), amongst others, was the need for the list of amenable conditions to be updated. This thesis combined five of the most recently published lists of amenable conditions into one, making it the most comprehensive, up-to-date and inclusive collection of causes of death which are considered to be amenable to health care intervention. In general, there was a considerable amount of overlap between the five lists, especially within the early detection and intervention (8 of the 13 conditions achieved consensus from all lists). The final number of conditions included in the study (n=51 + IHD), exceeds that of all publications since its original conception (Rutstein et al. 1976). The list of conditions deemed to be amenable was used throughout the analysis period, which does affect the interpretations of the high rates in the beginning of the analysis period, and their subsequent declines. Many of the conditions on the list may not have been considered as amenable to medical care in the 1980s as they are deemed now, due to advances in medical care and knowledge over time (Andreev et al. 2003). The AMIEHS study included a section reviewing the literature on the introduction of specific health care innovations which should have resulted in improvements in rates of amenable mortality (Plug et al. 2011). The majority of the innovations introduced in the UK (data not analysed for Scotland separately) occurred during the 1980s, with new treatments for colorectal cancer introduced in 1995, Hodgkin's disease in 1999, and acute strokes in 1998. As these occurred prior to devolution, it can be assumed that these innovations were available in Scotland at similar times. There were a small number of causes of death which were relatively rare. Whooping cough, Rubella, Scarlatina, Erysipelas, Measles, Malaria and Streptococcal Pharyngitis had no, or very few deaths each year. In the incidence study (Chapter 5), there were 5 or less incident cases of Legionelliosis, Scarlatina, or Erysipelas requiring hospital treatment, or resulting in death. In previous studies, these conditions would have been removed due to their low counts (e.g. Office for National Statistics (2012*a*)). However, these were retained in this thesis in order to continue the use of rates of amenable mortality as a warning system.

A further previously identified limitation of the concept was that declines in mortality rates were reflecting declines in the incidence or severity of amenable conditions within the population, rather than improvements of the health care delivered (Castelli & Nizalova 2011). This thesis provides evidence of opposing trends in mortality and incidence rates, although cannot comment on the effects of changes to disease severity.

This thesis used an overall upper age limit of 75 years throughout the analysis process, based upon life expectancy and the assumption of these deaths being 'premature', as well as the increased numbers of co-morbidities in the elderly. In 1980, male life expectancy in Scotland was 69.1 years (Office for National Statistics 2016), and thus, the male amenable deaths used in these analyses may have been identified inappropriately in the earlier years of analysis. Life expectancy for women at the start of analysis was 75.3 years. The upper age limit of 75 years was retained in order to maximise comparability of these results with those previously published. The prevalence of multi-morbidity has previously been explored in Scotland, using a representative sample of the population (Barnett et al. 2012). Forty conditions (either physical or mental) were identified as being a morbidity, and the presence of two or more was deemed a 'multi-morbidity'. The selected morbidities included amenable conditions, such as hypertension, strokes, recent cancer diagnoses, diabetes and epilepsy. Of the 1.75 million patients included in the sample, 42.2% had at least one of the conditions, and 23.2% had two or more. More than half of those with multi-morbidities were aged under 65 years, and the prevalence of patients with multi-morbidities in the most deprived decile (as measured using the Carstairs index) was double that of the least deprived until age 59. From age 60 onwards, the gap decreased, and inverted at ages over 85 years. This study highlights potential difficulties in assigning the final underlying cause of death, which may result in some deaths being wrongly attributed to an amenable, or otherwise, condition (Schwarz 2007).

The declines in mortality rates seen in both men and women throughout the analysis period are suggestive of improvements in health care. Improvements to the safety and quality of care delivered in Scotland, such as the introduction of individual disease guidelines and care audits, previously discussed in section 4.5, are likely to have aided the declines in recent years.

9.3.2 Data

Secondary, administrative data sources were used in the analyses presented in this thesis. The use of secondary data presents many advantages and disadvantages.

The large, population wide coverage of the death and health care records used to identify primary outcomes in this thesis are a great strength. These are representative of real world activity, given that they were generated from clinical interactions (Chan & McGarey 2012). Research conducted using secondary data are generally cheaper to conduct and are available faster, as they are routinely collected, unlike primary data.

Individual mortality records for the total resident populations of Scotland between 1980 and 2013, and for England between 1990 and 2013 were used in this thesis. These are routinely collected by the National Records of Scotland, and the Office for National Statistics for England, and both are considered to be the most accurate records of deaths within the country (Administrative Data Liaison Service n.d.*a*, Office for National Statistics 2015).

The hospitalisation records, birth records and disease registries used in chapter 5 are collected in order to generate reports on health care needs, as well as service planning, provision and management (ISD Scotland 2010). The datasets are expected to be largely complete, given that care provided in hospital settings in Scotland are almost entirely accessed through the NHS, rather than the private sector (Steel & Cylus 2012). However, these data are limited in that they are mainly collected for purposes other than research. Research conducted using secondary data is restricted by the level and type of data that are collected, as well as not being able to return to the patient for further information or clarifications.

These morbidity records are not entirely adequate for the measuring of the incidence of all amenable conditions within the population. Conditions which do not routinely require hospitalisation for treatment, such as asthma, diabetes and hypertension are likely to have their incidence underestimated within the Scottish population. These conditions were only identified as incident cases where they had reached a sufficiently serious stage, requiring hospitalisation (which may perhaps reflect problematic areas of primary care settings), and so the overall incidence within the population is not accurately estimated. A prescription based database was considered for inclusion, however, it did not allow for individual linked records before 2009.

Death records are collected by the National Records of Scotland, and have been coded using an automated system since 1996[2]. Bridge coding exercises were conducted for the update of ICD version 9 to version 10. The main diagnoses, used in chapter 5 as the primary outcome measure are coded according to Scottish Clinical Coding Standards[3], which have been in place since May 1996 (coinciding with the introduction of ICD version 10 for morbidity records). Experienced coders accurately translate the discharge summaries completed by clinicians, and therefore the main outcomes used are reliant on accurate information being provided[4]. Little information is available on the standards used prior to 1996.

The assignment of 32 deaths (0.013%) to the address of the postbox of Ninewells Hospital in Dundee, as described in chapter 4, identified a potential source of measurement bias. Area level measures of deprivation are assigned according to the residential address listed on the death certificate, therefore these 32 deaths potentially had the wrong deprivation decile assigned to them. This issue was found to mainly occur in children under the age of 1. No further deaths were identified as being assigned to a different hospital's address.

9.3.3 Measures of socioeconomic classification

The Carstairs index was used throughout this thesis as a proxy measure of socioeconomic position, using the published scores in chapters 4, 5 and 6, and an adjusted score in chapter 7. The Carstairs index was designed to reflect access to material resources (Carstairs & Morris 1991), whilst making use of readily available data sources (population censuses). There

[2]https://www.nrscotland.gov.uk/files/statistics/vital-events/coding-causes-of-death.pdf
[3]http://www.isdscotland.org/Products-and-Services/Terminology-Services/Clinical-Coding-Guidelines/
[4]http://www.isdscotland.org/Products-and-Services/Terminology-Services/Useful-Links-and-Downloads/national-health-information-leaflet-160202.pdf

have been debates as to how well the score and its components reflect modern day levels of deprivation, given it was originally conceived in 1991. Chapter 7 described the limitations associated with the Carstairs index, along with alternative measures (Allik et al. 2016).

Individual level measures of socioeconomic position were explored in chapter 6, allowing for a level of comparison with other European countries which are able to use individual level measures as standard. International comparisons remain difficult, as the comparability of data collected across countries remains imperfect, where definitions or categorisations differ. Analyses using individual measures are also reliant on a high percentage of non-missing data (Ontario Agency for Health Protection and Promotion 2013). In chapter 6, the numerators and denominators used in each individual measure differed, as there were different rates of missingness for each component. This may have limited the direct comparability between any two measures, however, this was done in order to use the maximum number of deaths possible.

The potential for ecological fallacy, whereby associations found at the area level do not reflect those of the individual level, was explored using the SLS in chapter 6. Although the magnitudes of the inequalities found at the individual level differed to those at the area level, the directions of the relationships were similar. An alternative area based measure, the Scottish Index of Multiple Deprivation (SIMD), could have been used to reduce the small area population sizes, increasing homogeneity within, and therefore decreasing the chance of ecological fallacy, however, this index was not routinely calculated in Scotland until 2000.

An attempt was made to derive a measure of deprivation which could be used across both Scotland and England in chapter 7, however, it was essentially unsuccessful in creating a score which was consistent over time. Alternative measures have since been published since this analysis, and are described in subsection 7.4.3.

Both the area and individual level measurements relied on decennial censuses for updating. For the area level, the Carstairs scores were applied to the 10 years surrounding, and not following a census. This limits the time interval between the index being calculated, and the earliest/latest year of its application (Carstairs indices are applied a maximum of 4 years prior to a census year, and 5 years after a census year). In the case of the individual measures, the reported SEP level for each of the variables was applied to the 10 years following the census only. This assumes that a given individual's status remains constant until the next census; an assumption which may be appropriate when using educational attainment (Reques et al. 2014), but less so for occupational social class or relationship status, which may be more likely to change over the life course (Davis et al. 1992).

9.3.4 Methodology

Sensitivity analyses were conducted in each of the analysis chapters in this thesis, each demonstrating that relationships found in the main analyses were robust, and consistent. This allows for increased confidence in the accuracy, generalisability and replicability of the reported results.

Both relative and absolute measures of the inequalities in mortality rates were presented, as the conclusions drawn from each can be opposing. The relative and slope indices of inequality were used to measure the inequalities over time, as these take the relative size of each group, as well as the whole socioeconomic distribution into account (Mackenbach et al. 2008), rather than only the most and least deprived groups, as used in rate ratios and rate differences. RII and SII are dependent on measures of SEP which have natural orderings of increasing disadvantage (Ontario Agency for Health Protection and Promotion 2013). This was possible in all analysis using the Carstairs score, as the deprivation deciles are assigned based on increasing levels of deprivation. Within the individual level measures, this was more difficult to justify, especially within the NS-SEC analyses, as the 14 operational categories were not designed to be ordinal or hierarchical. In these analyses, the categories were collapsed into five classes, and the presence of a gradient in the all-cause mortality rates was taken to be sufficient justification for the use of the RII and SII within the smaller subgroup of amenable mortality. Monte-Carlo 95% confidence intervals were simulated for each RII and SII, as the intervals estimated during the modelling process assume sampling error is present, which is not the case when using register-based sources of the total population.

Fractional polynomials were used to model the non-linear relationships of age, year of death/incidence and deprivation level with risk of amenable mortality or diagnosis of amenable condition. Fractional polynomials improve over singular polynomial transformations (such as quadratic or cubic curves) as they offer greater flexibility in modelling, often with more biologically plausible relationships (Royston et al. 1999). The fractional polynomial models estimated in this thesis were limited in their numeric interpretability (in table form) owing to the use of interaction terms, and up to two fractional polynomials chosen for each relevant variable, however, interpretations were able to be made graphically.

The hierarchical nature of the data; counts of deaths or incidences of conditions per year, nested within areas, allows for multilevel modelling to be performed. This technique partitions the variation in counts of amenable deaths into years of death, and residential areas. The area MRR indicated that men experienced a greater risk of amenable death, in median, compared to women when comparing areas with higher mortality rates to those with lower rates, within the same deprivation decile. The multiple response multilevel model partitioned this further, finding that the median increased risk is higher for the ITMC group, than the EDI group, for both men and women.

9.4 Future research

A comparison of the trends in rates of amenable mortality presented in chapter 4 to those of all-cause mortality would be a worthwhile addition to future research. This would allow for the investigation of whether rates of amenable mortality were declining at a faster rate than those of all-cause mortality. This was not attempted in chapter 4 for the total population due to the potentially large number of deaths requiring postcode sector amendments or probability matching in order to be assigned to a deprivation decile (see Table 4.4). Future research may consider the exclusion of unmatched deaths, and a narrower analysis period. Chapter 6 included some attempt at a comparison of rates of amenable mortality to those of non-amenable and all-cause deaths, however, given that the analyses were presented in grouped years, and by socioeconomic positions, it is difficult to conclude whether there was a difference in the overall trends.

This thesis explored rates of premature deaths for selected, amenable causes. The upper age limit of 75 years was used as this reflected the life expectancy in many countries, including Scotland, as well as uncertainty as to how effective the treatments and interventions required to avert a death would be in an older population. There has been previous discussion as to whether a separate age limit should be introduced for men and women, given that female life expectancy tends to exceed that of males. As sex-specific mortality rates and analyses were used throughout this thesis, differing upper age limits could be incorporated in future work, however this may limit comparability with other studies.

A potential recommendation for future work which would have been proposed in this thesis has since been implemented. The ONS publishes an annual report of avoidable mortality in England and Wales, a similar report would have been proposed for Scotland. NRS published the first description of rates of avoidable and amenable mortality in Scotland between 2014 and 2016 in August of 2017. This report describes the numbers of avoidable, amenable and preventable deaths by council and Health Board, but does not present any mortality rates, nor include any analysis of socioeconomic gradients. Given Scotland's reputation of large inequalities, the inclusion of such analyses in future reports would allow for the continued monitoring of the results presented here.

The annual reports of avoidable mortality, published by ONS, present rates of avoidable mortality according to ICD chapters, such as all avoidable cancers. This replaces the three groups of conditions used in this thesis, categorising by type of intervention required. Mortality rates presented by ICD chapter may be of interest in future work, however, it must be noted that there will be chapters with very small numbers of death (e.g. Conditions considered to be amenable to primary prevention are almost solely contained within Chapter I: Certain infectious and parasitic diseases ICD 10: A00 - B99), and therefore trends in mortality rates may not be helpful.

The results by the three groups of conditions presented in this thesis, split according to the type of intervention required in order to avert the death, were introduced by Lumme et al. (2012) and McCallum et al. (2013). A further split, by place of intervention could also be of interest in future work.

Two places of intervention were suggested in their previous research: Primary Care and Specialist Care. Primary Care included the conditions in the primary prevention, early detection and intervention, and a portion of improved treatment and medical care categories. The remaining conditions in the improved treatment and medical care group, which typically require surgical intervention are grouped into the Specialist Care category. This simplistic distinction will require further evaluation to determine its suitability in a Scottish setting before being implemented in future work, however, it may be able to offer further insights as to which areas of the health care system are introducing the greatest inequalities in mortality rates.

Following a consultation on the revision of the definition of avoidable mortality, conducted by ONS, a children and young persons indicator of avoidable mortality was incorporated for future reports. A version of this indicator, applied to amenable conditions, could be of interest. The number of amenable deaths in Scotland occurring before the age of 20 years fell to 149 deaths in 2013, down from 647 in 1980. This small number of deaths does mean that trends in cause-specific or diagnosis group analyses are unlikely to be helpful, however, the overall mortality rates will highlight any changes. The smaller number of deaths also allows for the opportunity to perform individual case file investigations into potential failures in the delivery of health care, as originally outlined by Rutstein et al. (1976).

The Scottish Index of Multiple Deprivation (SIMD) is favoured over the Carstairs index by policy makers, as it can be updated more regularly, providing a current measure of deprivation within a small area level (Ralston et al. 2014). SIMD was not used in this thesis as it was considered more important to be able to provide a full historic description of trends in amenable mortality in Scotland from 1980 onwards, rather than limit the analyses to starting from 2000. Future work should make use of this measure of deprivation to explore continuing inequalities in rates of amenable mortality.

In this thesis, inequalities in rates of amenable mortality were assessed on the basis of background disparities in risk, such as socioeconomic or demographic factors. The literature review (section 2.4.7) identified other sources of variations in rates, such as the accessibility and supply of healthcare services. Research into variations in healthcare access across socioeconomic groups in Scotland has been explored in general, however it may be of interest to investigate whether, and when, healthcare services were accessed by individual patients prior to their deaths from amenable causes, and how these differed across the socioeconomic gradient. The hospitalisation records used in chapter 5 could have been used to identify patient who had recent contact with a healthcare service prior to their death.

As identified in chapter 5 and in the limitations section above, the incidence of conditions which are not routinely treated within a hospital setting are likely to have been underestimated within the Scottish population. SPIRE, the resource containing primary care data extractions previously discussed in subsection 5.5.2, may prove a useful resource for more accurate future estimations of the incidence of amenable conditions in the Scottish population.

Chapters 7 and 8 made use of natural experiment study designs to explore the effects of policy changes on rates of amenable mortality in Scotland and England. More studies such as this may be possible with other European countries, such Sweden, Denmark and Norway, where health reforms have already occurred, and Finland, which will be undergoing reforms in the coming years (Government Communications Department 2017).

9.5 Conclusion

In summary, the analyses presented in this thesis have demonstrated that rates of amenable mortality in Scotland have declined, for both men and women, whilst incidence rates of the same conditions have remained relatively constant in recent years. Inequalities in both mortality and incidence rates were estimated, using individual level measures of socioeconomic position, and area level proxies. Relative inequalities in both the incidence and mortality rates, and using both levels of SEP measures have been increasing over time, whilst absolute inequalities in mortality rates have declined, reflecting the declines in rates of amenable mortality over time.

Previous work into amenable mortality has expected the indicator to be a definitive measure of health care quality, or even just a warning system of problematic areas. This thesis has demonstrated that it can be used to monitor inequalities in causes of death which should not be occurring, given the universal health care system operating in Scotland. Relative inequalities in mortality rates for amenable conditions were found to be increasing, which is indicative of unequal access, quality or supply of health care in more deprived areas of Scotland, compared to less deprived areas. The declining overall trend in absolute inequalities in rates of amenable mortality is encouraging (Mackenbach 2015), however, overall this thesis concludes that more work is needed.

The Scottish Government has previously stated that health inequalities cannot be reduced through health care systems alone (Scottish Government 2008), however the health care system is a key determinant of health with regards to conditions amenable to medical intervention. The inequalities found in the causes of death for which the health care system has the most responsibility, and ability to prevent, indicate that improvements are required. The continued investigation of inequalities in rates of amenable mortality, and their incidence, in countries with universal health care systems may enable the identification, and resulting improvement, of disparities in the provision, access and usage of health care services.

Appendix A

Amenable Causes

Primary Prevention			
Cause of Death	Age	ICD-9	ICD-10
Intestinal Infections	0-14	001-009	A00-A09
Other infections (Diphtheria, Tetanus, Poliomyelitis and Varicella)	0-74	032, 037, 045, 052	A35, A36, A80, B01
Whooping cough	0-14	033	A37
Scarlatina	0-74	034.1	A38
Meningococcus	0-74	036	A39
Erysipelas	0-74	035	A46
Measles	0-14	055	B05
Rubella	0-74	056	B06
Malaria	0-74	084	B50-B54
Streptococcal pharyngitis	0-74	034.0	J02.0
Cellulitis	0-74	681-682	L03

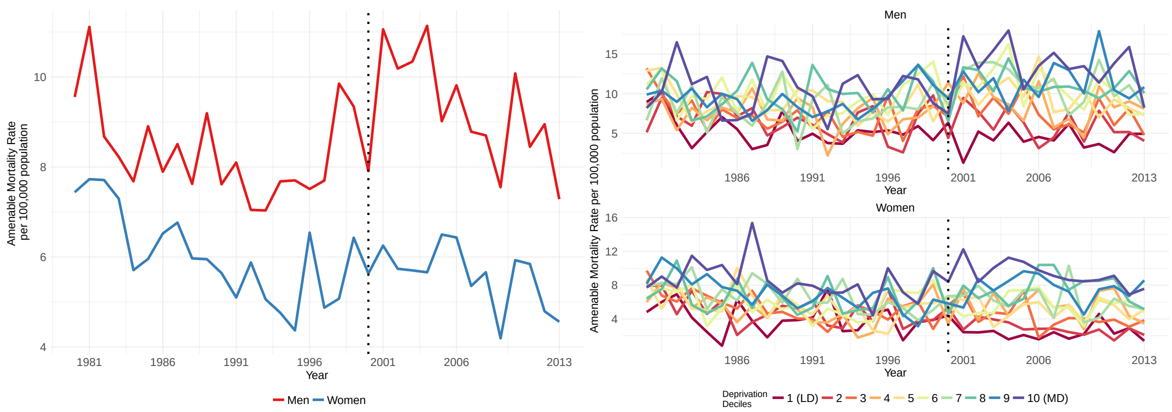
Early detection and intervention			
Cause of Death	Age	ICD-9	ICD-10
Tuberculosis	0-74	010-018, 137	A15 - A19, B90
Malignant neoplasm of colon and rectum	0-74	153,154	C18-C21
Melanoma of skin	0-74	172	C43
Malignant neoplasm of skin	0-74	173	C44
Malignant neoplasm of breast	0-74	174	C50 (Women only)
Malignant neoplasm of cervix uteri	0-74	180	C53
Malignant neoplasm of unspecified parts of uterus & body of uterus	0-44	179,182	C54, C55
Malignant neoplasm of bladder	0-74	188	C67
Neoplasm of Thyroid	0-74	193	C73
Benign tumours	0-74	210-229	D10-D36
Hypertensive disease	0-74	401-405	I10-I13, I115
Cerebrovascular disease	0-74	430-438	I60-I69
Bacterial Meningitis	0-74	320	G00, G03

Improved treatment and medical care			
Cause of Death	Age	ICD-9	ICD-10
Septicaemia	0-74	038	A40, A41
Legionelliosis	0-74	482.84	A48.1
Malignant neoplasm of testis	0-74	186	C62
Hodgkin's disease	0-74	201	C81
Leukaemia	0-44	204-208	C91-C95
Diseases of the thyroid	0-74	240-246	E00-E07
Diabetes mellitus	0-74	250	E10-E14
Epilepsy	0-74	345	G40,G41
Rheumatic and other valvular heart disease	0-74	390-398	I01-I09
Nephritis and nephrosis	0-74	580-589, 591	N00-N08, N17-N19
All respiratory diseases (excl. pneumonia / influenza)	0-14	460-478, 494, 495, 500-519	J00-J06, J20-J22, J30-J39, J47-J99
Influenza	0-74	487, 488	J09-J11
Pneumonia	0-74	480-486	J12-J18
Chronic obstructive pulmonary disease	45-74	490-492, 496	J40-J44
Asthma	0-44	493	J45, J46
Peptic ulcer	0-74	531-534	K25-K28
Appendicitis	0-74	540-543	K35-K38
Abdominal hernia	0-74	550-553	K40-K46
Cholelithiasis and cholecystitis	0-74	574-575.1	K80-K81
Other diseases of the gallbladder	0-74	575.2-575.9	K82
Other diseases of the billary tract	0-74	576	K83, K91.5
Diseases of pancreas	0-74	577	K85,K86
Obstructive uropathy and prostatic hyperplasia	0-74	592, 593.7, 594, 598.0-598.1, 598.8-598.9, 600	N13, N20-N21, N35, N40

Maternal death	0-74	630-676	O00-O99
Perinatal deaths (all causes excl. Still-births)	0-74	760-779	P00-P03, P05-P95, A33, A34
Congenital cardiovascular anomalies	0-74	745-747	Q20-Q28
Misadventure to patients during surgical and medical care	0-74	E870-E876, E878-E879	Y60-Y69, Y83-Y84

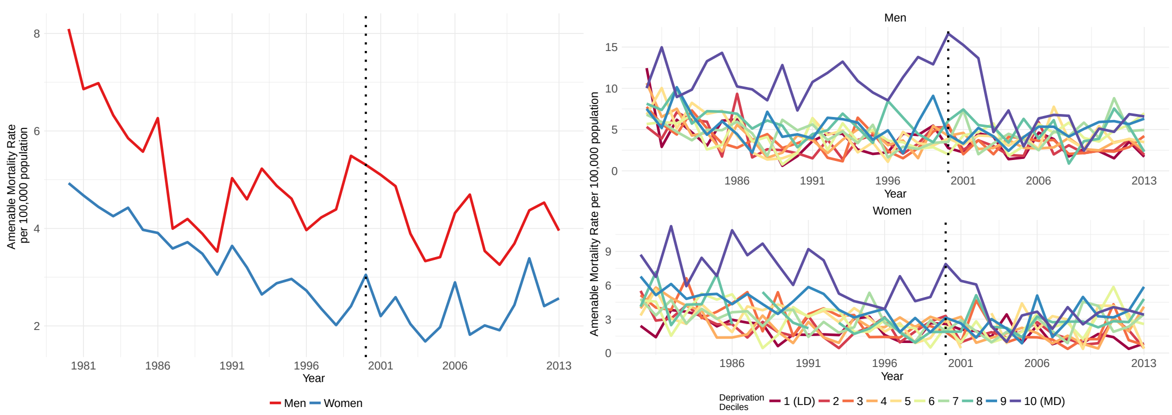
Appendix B

Cause specific mortality rates



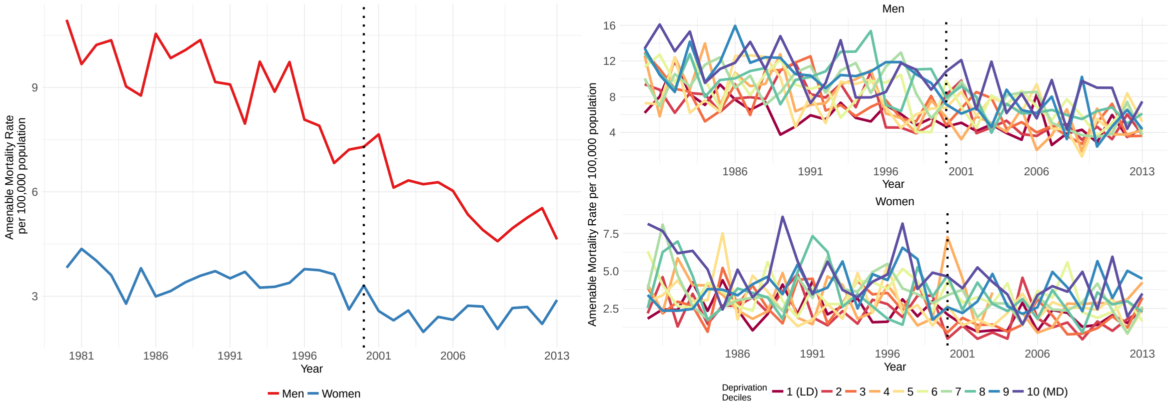
(a) (b)

Figure B.1: Mortality rates of diabetes mellitus: (a) by sex and (b) by deprivation decile



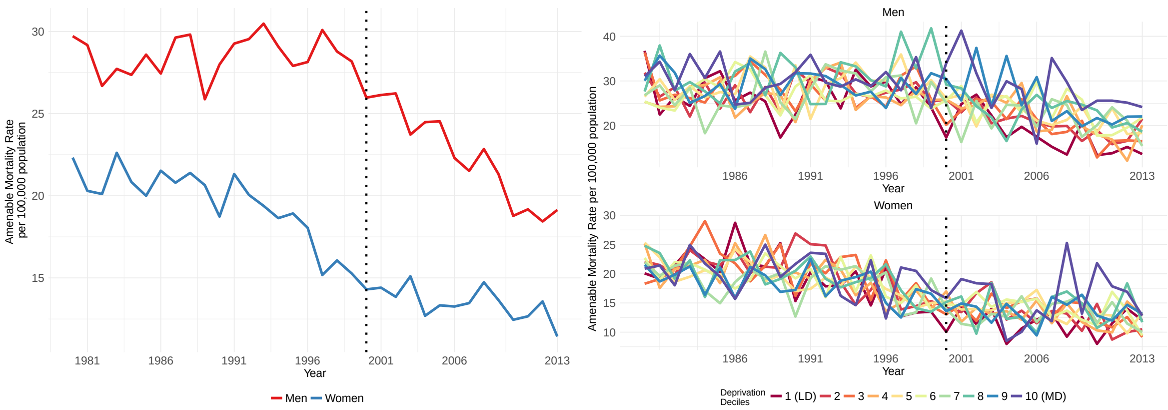
(a) (b)

Figure B.2: Mortality rates of Hypertensive Disease: (a) by sex and (b) by deprivation decile



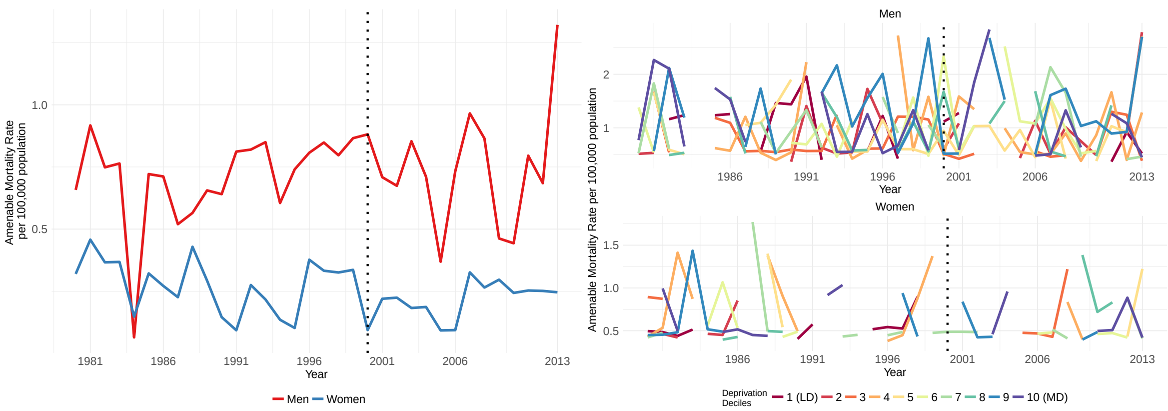
(a) (b)

Figure B.3: Mortality rates of malignant neoplasms of the bladder: (a) by sex and (b) by deprivation decile



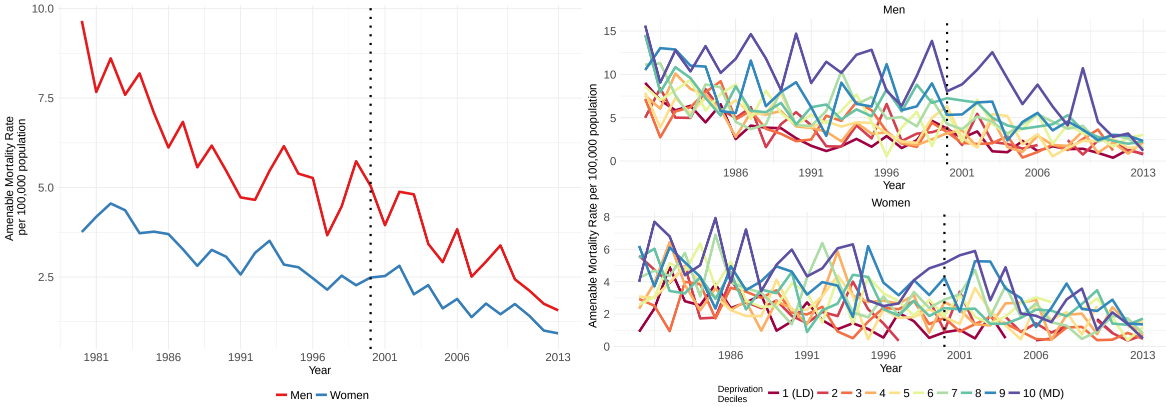
(a) (b)

Figure B.4: Mortality rates of malignant neoplasms of the colon and rectum: (a) by sex and (b) by deprivation decile



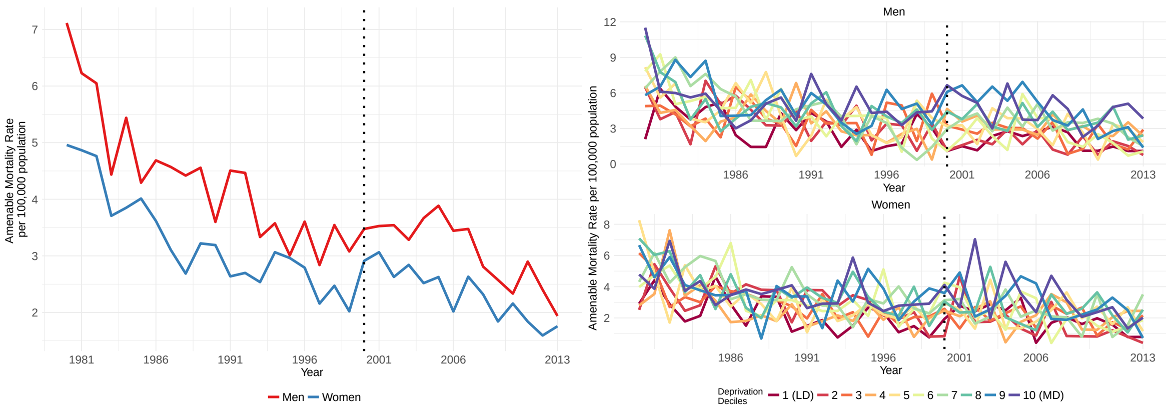
(a) (b)

Figure B.5: Mortality rates of malignant neoplasms of the skin: (a) by sex and (b) by deprivation decile



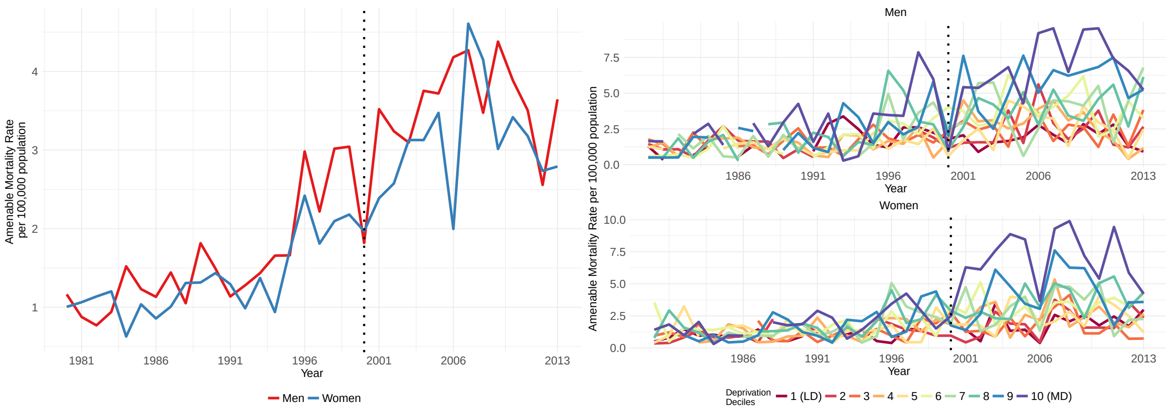
(a) (b)

Figure B.6: Mortality rates of peptic ulcers: (a) by sex and (b) by deprivation decile



(a) (b)

Figure B.7: Mortality rates of perinatal conditions: (a) by sex and (b) by deprivation decile

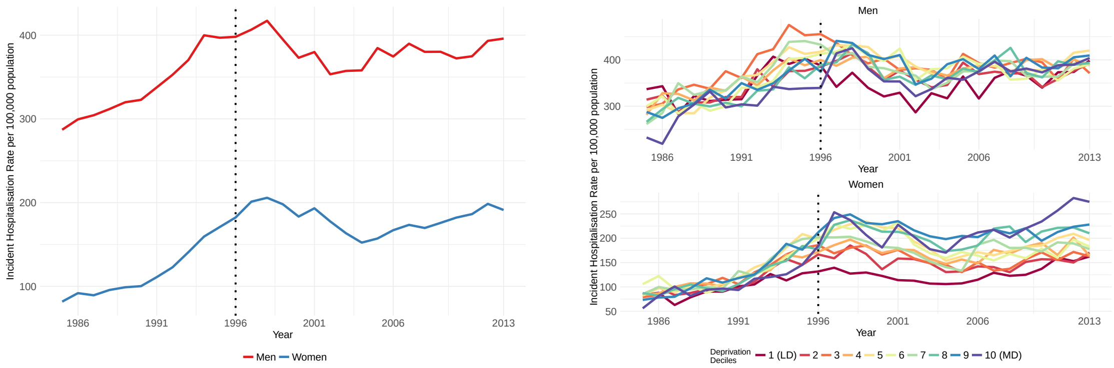


(a) (b)

Figure B.8: Mortality rates of septicaemia: (a) by sex and (b) by deprivation decile

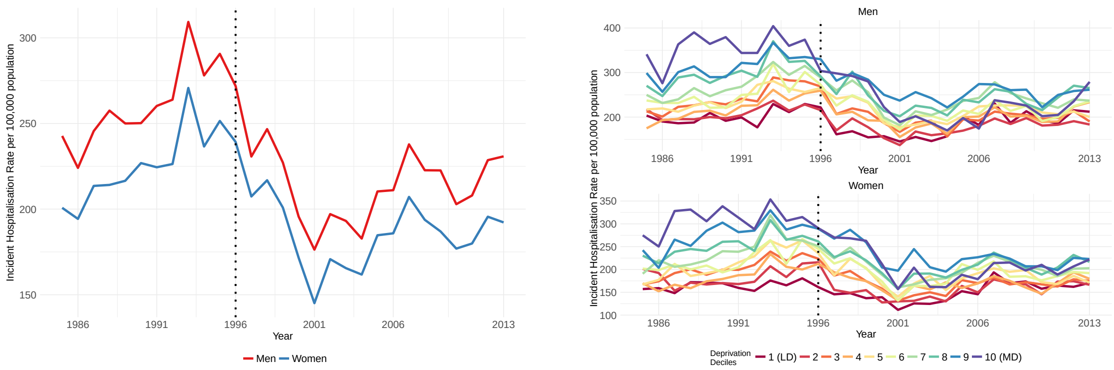
Appendix C

Cause specific incidence rates



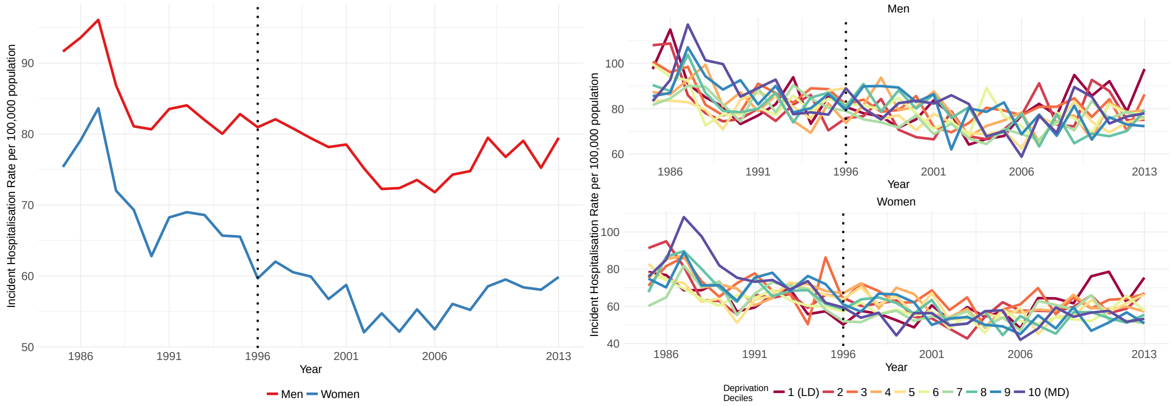
(a) (b)

Figure C.1: Incidence rates of abdominal hernias: (a) by sex and (b) by deprivation decile



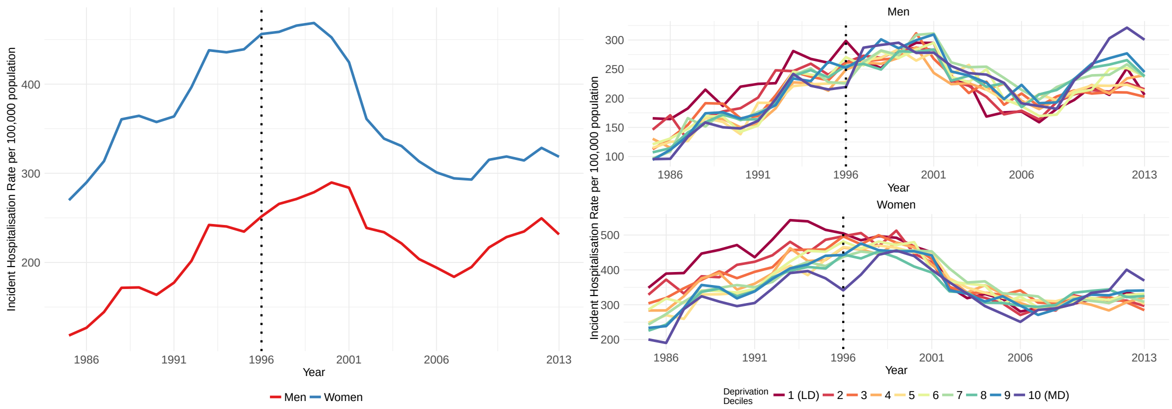
(a) (b)

Figure C.2: Incidence rates of all respiratory diseases (excluding pneumonia and influenza): (a) by sex and (b) by deprivation decile



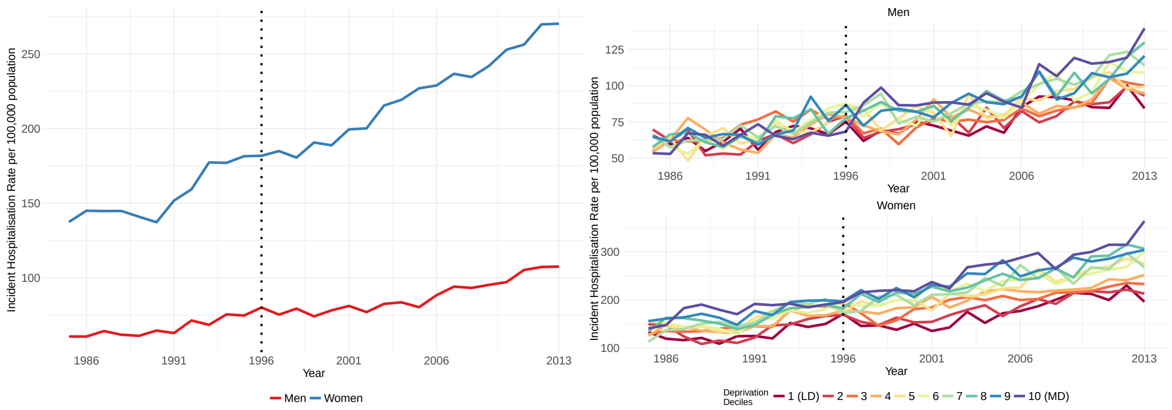
(a) (b)

Figure C.3: Incidence rates of appendicitis: (a) by sex and (b) by deprivation decile



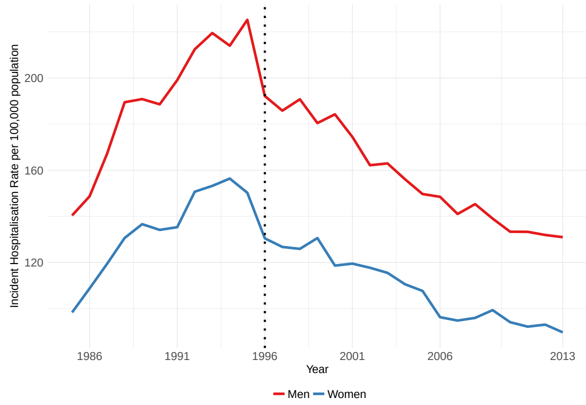
(a) (b)

Figure C.4: Incidence rates of benign tumours: (a) by sex and (b) by deprivation decile

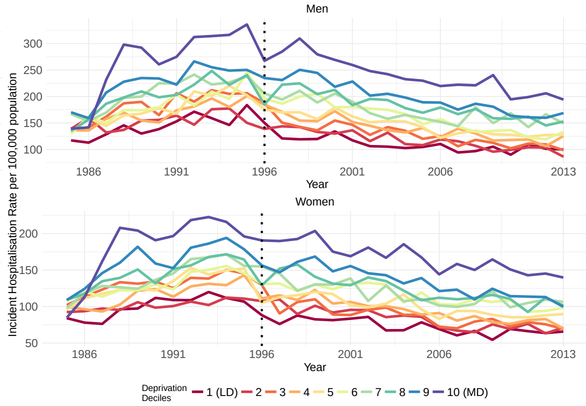


(a) (b)

Figure C.5: Incidence rates of cholelithiasis & cholecystitis: (a) by sex and (b) by deprivation decile

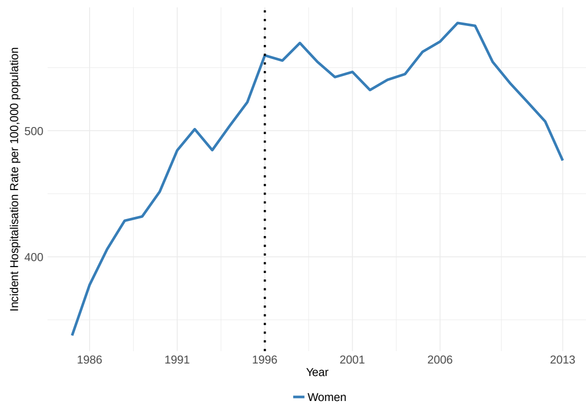


(a)

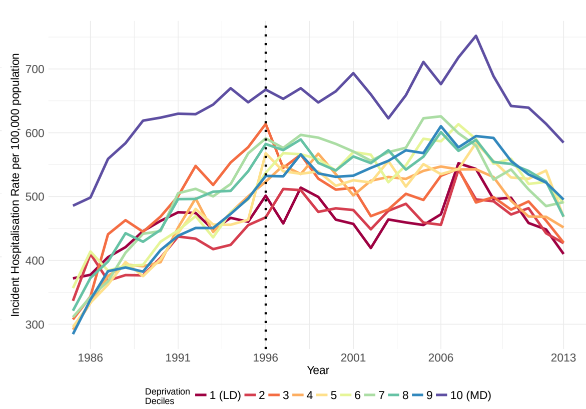


(b)

Figure C.6: Incidence rates of cerebrovascular disease: (a) by sex and (b) by deprivation decile

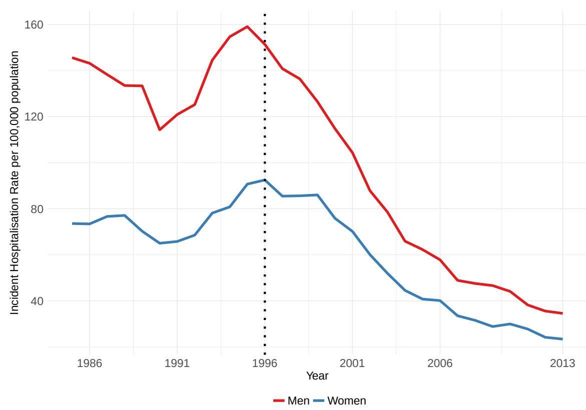


(a)

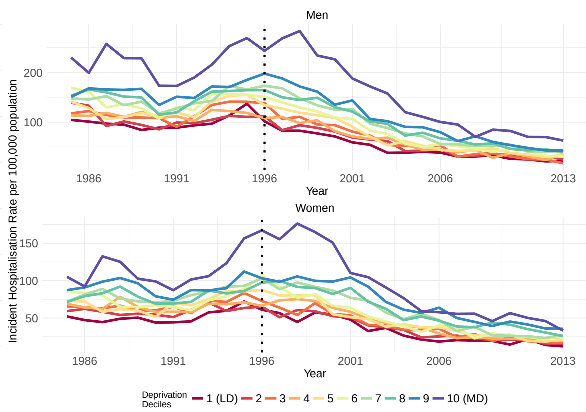


(b)

Figure C.7: Incidence rates of maternal conditions: (a) women only and (b) by deprivation decile

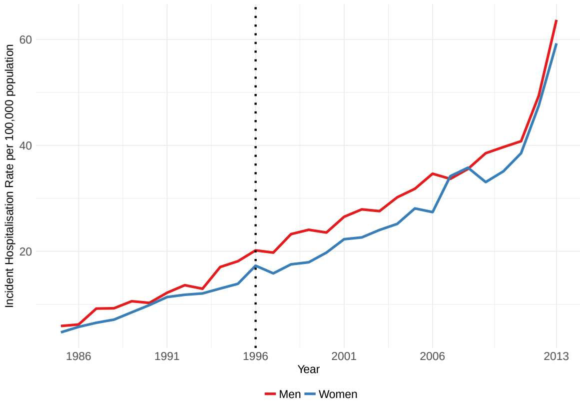


(a)

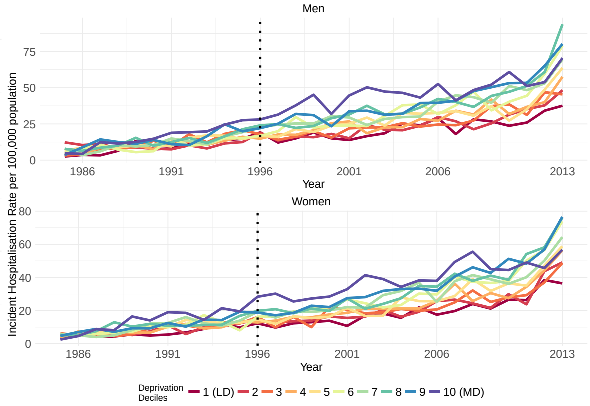


(b)

Figure C.8: Incidence rates of peptic ulcers: (a) by sex and (b) by deprivation decile



(a)



(b)

Figure C.9: Incidence rates of septicaemia: (a) by sex and (b) by deprivation decile

Appendix D

Census Questions

Table D.1: 1991 and 2001 Census Question: Educational Attainment

1991	2001
Have you obtained any qualifications after reaching the age of 18 such as: □ Degrees, diplomas, HNC, HND □ Nursing qualifications □ Teaching qualifications □ Graduate or corporate membership of professional institutions □ Other professional, educational or vocational qualifications? *Does not count qualifications normally obtained at school such as GCE, CSE, GCSE, SCE and school certificates.*	Which of the following qualifications do you have? (tick all that apply) □ 'O' Grade, Standard Grade, Intermediate 1, Intermediate 2, GCSE, CSE, Senior certificate or equivalent □ Higher Grade, CSYS, Scottish Group Award at Higher, 'A' Level, AS level, Advanced Senior Certificate or equivalent □ GSVQ/SVQ Level 1 or 2, SCOTVEC/ National Certificate Module, BTEC First Diploma, City and Guilds Craft, RSA Diploma or equivalent □ GSVQ/SVQ Level 3, ONC, OND, SCOTVEC National Diploma, City and Guilds Advanced Craft, RSA Advanced Diploma or equivalent □ HNC, HND, SVQ Level 4 or 5, RSA Higher Diploma or equivalent □ First Degree, Higher Degree □ Professional Qualifications (e.g. teaching, accountancy) □ None of these.

Table D.2: 1991 and 2001 Census Question: Household relationships

1991	2001
What is your relationship to Person 1 (Head or joint head of household)? ☐ Husband or wife ☐ Living together as a couple ☐ Son or daughter ☐ Other relative (specify) ☐ Unrelated	What is the relationship of person 2 to person 1? ☐ Husband or wife ☐ Partner ☐ Son or daughter ☐ Step-child ☐ Brother or sister ☐ Mother or father ☐ Step-mother or step-father ☐ Grandchild ☐ Grandparent ☐ Other related ☐ Unrelated

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