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Exploring the social and spatial inequalities of ill-health in Scotland: A spatial microsimulation approach

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Abstract

The main purpose of this thesis is to explore social and spatial inequalities of ill-health in Scotland using a spatial microsimulation modelling approach. The complex questions of what socio-economic or geographical factors may influence the health of individuals are explored in this PhD, using a variety of statistical methods. Using data from the Scottish Health Survey and the UK Census of Population a Spatial Microsimulation model was designed and constructed to undertake this task. The Spatial Microsimulation Model developed allowed the exploration of simulated health and socio-economic data at small area (micro) level as well as modelling of 'what-if' policy scenarios. The study is focused on Scotland.

The Research begins with a general introduction to what the areas of study will be, with a series of substantive research questions being forwarded for examination. The literature relevant to the field of study is then carefully critiqued and examined to ensure the originality of this research and the gaps which exist in the field of health inequalities research. An examination of the data and methods used as well as the more technical details of Microsimulation modelling are also discussed at chapter length which forms the basis for proceeding with the research questions.

The complex task of building a Spatial Microsimulation Model, the challenges involved and the inner workings of the model are discussed along with methods to assess the accuracy of the model.

The subsequent chapters then focus on the results of the analysis performed. These chapters deal with the research questions posed at the beginning as well as the 'what-if' policy scenarios.

The study then concludes with directions for future research as well as some key points that have been drawn out over the course of the three year PhD project.

Chapter 1

Introduction

"We could all move to East Glasgow, and we'd die at 53"

(Bremner, Bird and Fortune: Silly Money, 2008)

1.1 The story begins...

A baby is born into Scotland with a predisposed set of genes, inherited from their parents. As yet, we do not have a choice about our genetic inheritance, so this part of our lives is predetermined. Some may be happy about their genes, others less so. For the first few years of our life, we grow up, within an environment we have not chosen, at the mercy of those around us. Those people around us will make decisions about our diet, education, clothing, housing and so forth, which will be subtly influencing our health. The people who look after us in our early years are likely to have a profound influence on our subsequent physical and mental health. As the transition from childhood towards adulthood

occurs, this allows us to start making decisions for ourselves, wise or foolish, that will influence our health to varying degrees. The environment which we find ourselves in continues to have subtle influences on our current and future health. As a teenager progresses to adult, behaviours adopted earlier in life may start to have consequences, positive or negative. The level of education we have, if we chose to smoke, our alcohol consumption, diet, the people around us and so on, will have cumulative effects exhibited either now or perhaps later in life. As an adult we may move into employment, unemployment, maybe further study, or one of multiple 'choices' available. This transition period could be one of the most crucial in our lives so far, as we try to 'choose' our environment, housing, diet, behaviour, partner, friends and so on, which will be contributing to health outcomes. The genes we inherited may be influenced by these changes, positively or negatively. The move to middle age signals yet more changes for the majority, perhaps a permanent partner, parenthood, a pet, perhaps not. As we grow yet older, become a pensioner, if fortunate to survive thus far, the accumulation of a lifetime of influences on us, the sum total of our choices we continue making, combined with our genes, will have more overt effects on our health for most. At some point, the story concludes, the exact time of the last word differs for each individual, but was it all random, or is there a pattern to the stories? If you are born in Scotland today, a boy can expect the final chapter of his life to last until age 75, a girl until age 80. This is a typical story, full of choices, twists and turns. But how did we get from beginning to end? What was it that determined our chances of illness and ultimately death? Were we happy along the way? Were we rich or poor compared to our parents and peers? Did where we live make a difference to our health? Did government policies influence our health? Was it our job, or lack of one that made us ill? Through the course of this study these questions and some others, will be addressed.

1.2 A Short Background

The main theme running through this whole research project will be to explore the social and spatial inequalities of ill-health, in Scotland. In order to give a brief context and a justification for undertaking such a large research project a brief overview of the pertinent literature is given. This will highlight the key issues that will be looked at in greater depth in subsequent chapters. So, why study ill-health in Scotland? Is there a need for any more research? What has already been examined and how can this be built upon?

1.2.1 Health Inequalities

Firstly, what is meant when health inequalities are referred to? It is generally accepted that health inequalities are the differences in health status between different population groups. This could mean for example, the differences in morbidity or mortality rates between people from different social economic groups, or with differing levels or qualifications. The more contentious aspect is how these differences arise and what can be done to alleviate such 'gaps' between groups. In other words, are health inequalities caused by people themselves or by the environments in which people live? This is of course a terse and simplistic way of describing a complex series of interactions and issues relating to health, but accurately describes some of the key debates.

Within the United Kingdom (U.K.) context, the study of health inequalities has covered numerous areas and topics. For example in Britain, the differences between socio-economic groups (Black et al., 1980; Acheson, 1998) have been studied as well as gender differences (Rigby and Dorling, 2007; Gjonca et al., 2005; Kruger and Nesse, 2004) and the effect of age on ill-health (Berthoud and Gershuny, 2000). Moreover, research into inequalities by area (Mitchell et al., 2000; Howe, 1970) have also been conducted. In a Scottish context, the media

would appear to focus on the behavioural factors such as cigarettes, alcohol and diet (and therefore obesity). Well-known risk factors such as smoking, which has a well established link with Lung Cancer (see Doll and Hill (1950); Levin et al. (1950); Mills and Porter (1950); Schrek et al. (1950); Wynder and Graham (1950)) could be studied at the small area level in Scotland. Another behavioural factor affecting health is alcohol (Stampfer et al., 1993), which adversely affects individual health when it is abused. There is also evidence that a good diet (Lock et al., 2005) does have positive and protective influences on health and so should be encouraged.

An issue of current debate is the thesis that income inequality may be the cause of inequalities in health and a variety of other social problems (Wilkinson and Pickett, 2007) which could be further examined at the micro-level in Scotland.

Focusing on the geographical aspect, there are known differences between regions and nations (Townsend et al., 1988; Mitchell et al., 2000; Dorling, 1997) within Britain pointing to a 'north-south' divide (Shaw et al., 1999) in health. This is mirrored by mortality inequalities between Scotland and England and Wales (Dorling, 1997), where Scotland fares worse in comparison to its neighbours.

1.2.2 Microsimulation

An important aspect of this research project is the application and refinement of microsimulation modelling techniques. Specifically, to apply microsimulation to a Scottish context for the study of social and spatial inequalities. It is imperative to give an overview and introduction to microsimulation modelling, both to demonstrate the usefulness of this technique as well as to show the potential to apply this technique in a Scottish context for policy analysis. So, what is

microsimulation? Microanalytic simulation or microsimulation "attempts to reproduce or model the demographic, social or economic characteristics of human behaviour" (Clarke, 1996, p.1). Moreover, in terms of microsimulation itself "little of this work to date has had a spatial dimension" (Clarke, 1996, p.1). More recently there have been more applications of spatial microsimulation, for example the national spatial microsimulation model SVERIGE in Sweden (Rephann and Holm, 2004). The paucity is arguably more prevalent in the health aspects of microsimulation. There have been a few examples of work in Great Britain such as SimHealth (Smith et al., 2007), SimObesity (Edwards and Clarke, 2009) as well as work by Ballas et al. (2006c) analysing health inequalities, but no example (at the time of writing) of a Scottish spatial microsimulation model using census and SHS data. Arguably, there is a gap here to apply spatial microsimulation to analysis of health in Scotland. As there are limited sources of geographically detailed microdata there is a need to create these datasets to answer certain research questions which can be done by using static geographical microsimulation techniques (Rossiter et al., 2009). The use of microsimulation can be justified as it is not only a novel method of answering 'what-if' policy questions (see section 1.3) but also makes an original contribution to the existing literature in the field as well as allowing for interrogating the 'new' microdata created for applied policy analysis, answering previously unaddressed research questions on the health of Scotland.

As Merz (1991) states because "microsimulation models are concerned with the behaviour of microunits (such as persons within a family/household/ firm), they are especially well suited to analyse the distributional impacts of policy changes" (p.77) as will be shown. There is a wealth of just this type of analysis worldwide and examples of microsimulation models already in use demonstrate this. An example from the U.K. is the Institute of Fiscal Studies (IFS) analysis

of the changes to various population subgroups as a result of budgets. The TAXBEN model (Giles and McCrae, 1995), shows how these various different groups will be affected by changes to Government fiscal policy, for example, showing the impact of working families' tax credit (Brewer et al., 2007) or the child poverty patterns and how the policies that effect it could be altered (Brewer et al., 2009a). It follows from the above examples that the research of health or of policy impacts in Scotland is a worthwhile context in which to utilise a microsimulation model, as Scotland has a variety of health issues (see chapter 2) as will be discussed in the literature review chapter. The microsimulation model SIMALBA can then be used for applied policy analysis in order to predict the likely effects of changes to government policy (whether positive or negative) for particular population groups or areas to determine which policy is the most suitable overall. This will be explored in much greater depth in the chapter outlining the microsimulation model (see chapter 6). Furthermore, previous examples of research using microsimulation modelling have proven to be reasonably accurate and a valuable 'tool' for policy analysis. The main advantage of microsimulation is that it does not involve the very expensive and time consuming process of collecting data at small areas which is not feasible in the context of this research. The simulated variables that can be created, for example income, are not available elsewhere and this allows gaps in health inequalities research to be addressed. As Boyle et al. (2009) point out "studies that encompass the whole of Britain rarely have sample sizes that allow for Scotland-specific research" (p.386): microsimulation allows us to address this issue. Another advantage is that because detailed microdata does not exist for such small areas, it is useful to see a hypothetical population produced for these areas, especially for policy makers. Moreover, microsimulation is useful in that a 'baseline' can be constructed in the form of a mircodataset, from which the

effects of changes (usually in the form of policy changes) to the population can be quantified or forecast into the future. In other words we can conduct a 'real-world' experiment within a modelling environment without the need to actually conduct a 'real-world' equivalent. The advantages of microsimulation are outlined in brief in Clarke (1996) namely; data linkage, re-aggregation, efficiency of storage and updating or forecasting. So overall, the significant advantages the microsimulation modelling methodology can bring to empirical research with a focus on policy analysis in particular are numerous and justify the use of this technique for the analysis of ill-health in Scotland.

The focus is now shifted onto empirical examples of microsimulation models which have already been developed. There have been several attempts at microsimulation modelling worldwide since the seminal work of Guy Orcutt (see (Orcutt, 1957)), but there is still room to apply this technique to existing areas of research. As will be discussed in a subsequent chapter there are applications of microsimulation worldwide. Some examples include a static microsimulation model for tax-benefit analysis in; Australia (STINMOD), the Netherlands (NEDYMAS; a dynamic cross-sectional model), Belgium (STATION), Canada (SPSD), Spain (GLADHISPANIA), the UK (POLIMOD) and the USA (TRIM). Looking at other microsimulation models which are policy relevant there are; MOSART developed by Statistics Norway (Fredriksen, 1998), the German Sfb3 (Sonderforschungsbereich 3) model, the Australian DYNAMOD model, the SMILE model developed for rural policy analysis in Ireland (Ballas et al., 2006a) as well as The Integrated Analytical Model for Household Simulation (INAHSIM), a microsimulation model for the population of Japan (Inagaki, 2008). This shows the wealth of geographical contexts in which microsimulation has been applied successfully and sets a background onto which the model that will be developed in this project can be benchmarked against.

Moving to a Scottish context, Spatial Microsimulation Models have been built for analysis of numerous policy areas in the UK including; smoking cessation (Tomintz et al., 2008), examining the economic impact of factory closure (Ballas et al., 2006b), income estimation in small areas of Wales (Anderson, 2007a) and England (Anderson, 2007c) as well as for forecasting the demand for water (Williamson et al., 2002). This research project will build on this work by applying Spatial Microsimulation to health and economic areas of policy in Scotland. A model which is of particular relevance is the SimBritain model. It is a dynamic spatial microsimulation model, one of the few attempts to apply spatial dynamic microsimulation specifically in the UK (Ballas et al., 2005a). The SimBritain model showed policy analysis of minimum wage, child and working tax credits as well as winter fuel payments impacts, so provides a useful example of the potential for application in a Scottish context and which will be built on in this study. One of the key points therefore is that microsimulation is an established method in many fields of the social sciences but spatial microsimulation is still relatively 'new' in many areas (Clarke, 1996).

A key feature of the literature is that research (Mitchell et al., 2000; Ballas et al., 2007a) has shown that there is the potential to use microsimulation for 'what-if' policy analysis, as well as for the analysis of health inequalities (Ballas et al., 2006c). As there is no dataset which is available to look at health in Scotland in detail at the small area level, microsimulation can simulate such a dataset from existing data sources and therefore fill a gap in this area. Additionally, by using spatial microsimulation rather than less complex aspatial alternatives, both a microdata set and a microdata set by area can be simulated. This means that not only can the distributional effects of policy be modelled, but also the implications by place simultaneously.

1.3 The Research Questions: What, Who, Where, When, Why?

The substantive research questions which have been formulated are designed to give this project a clear set of objectives, direction and focus. The research questions are outlined below. There are two main aspects to the research project, one of which is mainly descriptive in order to set the scene, following which a more in depth and targeted analysis of policy in Scotland is undertaken.

1. (a) When did the health divergence between Scotland and England and Wales begin?
   (b) and for which individuals?
2. (a) What are the five most prevalent illnesses in Scotland?
   (b) and where are they found?
3. (a) How can microsimulation help paint a picture of social and spatial inequalities in Scotland?
   (b) How do economic policies in Scotland affect social and spatial inequalities in variables that are related to health?
   (c) How do Scottish Government health policies potentially affect different types of individuals?
   (d) How do Scottish Government health policies potentially vary from place to place?
   (e) Are existing policies addressing sufficiently the key population health risk factors?
   (f) What kind of new policies may be needed?

Each research question is to be addressed after careful consideration of the data and methods available as well as the literature (and previous empirical research) which has already been undertaken so as to add to the existing body of evidence on ill-health in Scotland. The idea is to split the answering of the research questions over three chapters of analysis.

1.4 Aims and Objectives

The project is bounded by a series of aims and objectives which frame the research that follows. This gives a clear sense of the direction of travel for the research project and as such will avoid delving into certain areas. In order to address the research questions a series of aims and objectives were formulated. The links can be seen in Table 1.1.

1. An extensive survey and overview of the literature on health inequalities and social and spatial inequalities to provide a theoretical and empirical background.

2. To review and critique the data and methods that could be used for the analysis of ill-health.

3. To review and critique microsimulation techniques and the applications of this approach to assess the potential for microsimulation to be used more extensively for the analysis of health inequalities in Scotland.

4. To explain microsimulation in detail and demonstrate its potential for application for policy analysis in Scotland.

5. To build and develop a spatial microsimulation model of the Scottish population that will be capable of analysing different socio-economic, demographic and health variables at the micro-level at different geographical

levels.

6. To inspect and determine the validity of the microsimulation model, its outputs and potential for policy analysis.

7. To use the spatial microsimulation model for analysis of different policy scenarios at the micro-level in Scotland.

8. To set out an agenda for future research, using the spatial microsimulation framework.

Table 1.1: The aims and objectives

Chapter	Objective	Question
Chapter 2 - Literature Review	1	
Chapter 3 - Data and Methods	2	
Chapter 4 - Spatial Microsimulation		1a, 1b, 2a, 2b
Chapter 5 - The health landscape	3,5	3a, 3b, 3c, 3d, 3e, 3f
Chapter 6 - SIMALBA	4,5,6	3a, 3b, 3c, 3d, 3e, 3f
Chapter 7 - Economic Policy Analysis	7	3a, 3b, 3c, 3d, 3e, 3f
Chapter 8 - Health Policy Analysis	7	3a, 3b, 3c, 3d, 3e, 3f
Chapter 9 - Conclusion	8	

1.5 The Thesis Structure

The thesis is structured into several chapters, each of which addresses a particular issue or objective. A brief outline of each of the subsequent chapters is set out below to guide the reader through the thesis in a logical manner.

Chapter 2 is a literature review that explores the literature which is pertinent to this study a very brief outline of which was explored previously. The general themes that will be covered include health inequalities and the socio-economic and geographical determinants of ill-health. This gives an empirical background to the research showing what work has already been conducted as well as where future research may address shortcomings in the literature. There are major

sections covering the individual level determinants of ill-health; behavioural factors; the environmental and area factors (i.e. place). The chapter concludes by dealing with the various theoretical approaches to health inequalities and the debate over the role of income inequalities.

Chapter 3 is a description and critical appraisal of the various data sources that could be used and the methods that could be applied to the data selected. This chapter delves into some of the more technical aspects of different types of data as well as the pros and cons of each. A similar exercise is conducted for the methods which are selected for use in the analysis chapters that follow.

Microsimulation is discussed from a methodological perspective in chapter 4. This chapter outlines the various approaches to microsimulation and also some of the models which have been constructed worldwide. It discusses some of the approaches taken previously as well as highlighting examples which are particularly relevant to this study. There is also a critical discussion of the advantages and disadvantages of microsimulation.

A descriptive analysis of the Scottish health 'landscape is set out in chapter 5. This sets the context for the more complicated analysis which will follow. Contained in this chapter is an exploration and discussion of historical mortality trends between Scotland and England and Wales which is aimed at addressing research questions previously set out. It also offers some avenues for exploration in future research. This is built upon and supported by a more concurrent analysis of specific illnesses in Scotland, looking at the prevalence of particular illnesses and their spatial location around Scotland. This chapter therefore addresses the first set of research questions.

Chapter 6 explains the process of constructing SIMALBA, the spatial microsimulation model for Scotland. Detailed examples which demonstrate the approach as simply as possible are shown and explained in the text. There are

also some examples of the power of the microsimulation model and its potential usefulness for policy analysis. This is perhaps the most complicated chapter in the thesis in terms of trying to adequately explain how a microsimulation model is constructed. There is also a validation exercise carried out on the microdata created by SIMALBA.

The next two chapters use the SIMALBA model to analyse policy. These two chapters are aimed at addressing the last research question which is heavily focused on 'what-if' policy analysis. Chapter 7 is focused on addressing the economic aspects of government policy, looking at specific policies which may relate to health and which (at the time of writing) are issues of current debate or may be implemented by government. The SIMALBA model is used extensively in this chapter to show the distributional and spatial effects of 'what-if' policy options. The policies which are analysed relate to income and benefits and build on existing work relating to tax and benefit modelling. The additional, original contribution for Scotland is that not only can distributional effects be examined by particular sub-groups of the population, but the spatial impact of these policies can be examined at numerous geographical areas for Scotland down to the Output Area geography if desired.

Building on the economic analysis in the previous chapter, the next chapter is more directly focused on health issues such as smoking, alcohol, mental health and obesity (see chapter 8). The 'new' microsimulated dataset from SIMALBA is again used extensively to model policy scenarios and this data is interrogated so that health issues in Scotland can be illuminated at the small area level. The concluding comments from both these chapters strongly reinforce the point that 'geography matters' and that there is an intrinsic usefulness to spatial microsimulation modelling (over aspatial microsimulation) which adds an original contribution to the body of empirical research in health and quantitative

geography in Scotland.

The conclusions chapter (see chapter 9) sums up the whole research project and highlights key points and future directions for research, setting out a research agenda for further study as well as identifying and discussing the limitations of this study.

Chapter 2

Determinants of Health: Literature Review

"What can be added to the happiness of a man who is in health, out of debt, and has a clear conscience?"

(Adam Smith, 1723-1790)

2.1 Introduction

In this chapter the determinants of health, as discussed in the literature, are examined in depth. The chapter is structured by several key themes; individual and household level determinants, contextual influences, interactions and the theoretical frameworks. In due course, the paucity of studies in certain areas will be highlighted, to show the specific area this study aims to address, advance

and to add to the literature.

By way of introduction to the literature, research on population health has had a long and varied history. In Britain, the work of William Farr (1807-1883) and John Snow (1813-1858), early pioneers in this field, produced relevant research that had a decisive impact on the health of individuals. The disagreements between the two researchers about the causes of cholera, show that research in this field exhibits a history of debate and deliberation, which is still apparent in the more contemporary literature. The journey through the literature progresses from the individual and household determinants of health to the various theoretical approaches, the areas of discussion and debate are made clear.

So, what is health and why study it? Health is defined and measured in two main categories; morbidity and mortality. Morbidity is usually measured as the rate of illness in a specific population, in other words the absence of good health and the presence of a disease of some kind. Mortality is measured as the rate of death of a specific population, premature mortality (or low life expectancy) as an indicator of poor health. Health outcomes refer to measures of illness or death (see Lewis et al. (2009) for example), often used interchangeably in the literature, the measures will be more fully explained subsequently. Moreover, the variation in health between different groups, by various characteristics, for example income, education, employment status, within populations is of interest. This phenomenon is typically referred to as Health Inequalities (or Health Disparities in North America) and is the focus of much Government policy. Therefore, an evidence base is needed to better understand the causes and possible cures so necessary action can be taken, if any.

Studies relating to both morbidity and mortality are used, as the factors that determine both are either the same, or similar (Mackenbach et al., 2002).

So, why study health? Firstly, death affects everyone at some point, so therefore understanding the causes of death are important to eliminate preventable cases. Secondly, illness affects a large number of people at some point in their lives, so understanding the possible causes allows prevention or even cure.

2.2 The individual and household level determinants: who we are and what we do...?

The first section of this chapter deals with the characteristics of the individual and household determinants which are likely to have an effect on health.

2.2.1 Age

The first risk factor we deal with is the most obvious predictor of morbidity and mortality, that is, age. As one ages the probability of illness and death increases, this should be intuitive. This means that methods to measure morbidity and mortality must account for differing age structures in a population to accurately measure mortality, a point returned to subsequently. Evidence of the increasing effect of age on ill-health is found in a report by Berthoud and Gershuny (2000) who show using an index of ill-health, "For men, the average increased from 1.0 in their late teens to 3.7 in their 80s; for women, the corresponding range was from 1.5 to 5.1" (p.170). Furthermore, the "risk of falling ill was low among men and women in their teens, 20s and 30s, but this increased more and more rapidly with age" (Berthoud and Gershuny, 2000, p.183). So not only was there an increase in the index of ill health with increasing age, but it differs by gender, for women the range being greater, which leads to the next determinant, gender.

2.2.2 Sex and gender

The other factor that should be apparent as a determinant of health is the gender of the individual, "popular and scientific literatures report that women live longer than men ... but also report more illness than men" (Wingard, 1984, p.433). As eluded to above, women experience higher morbidity than men (Berthoud and Gershuny, 2000), a high rate of risk and recovery leading to medium term rather than permanent illness. It is known that young males are prone to risk taking behaviour (Kruger and Nesse, 2004), 'fight or flight' male reactions, compared with 'tend-and-befriend' female reactions and that "being male is now the single largest demographic risk factor for early mortality in developed countries" (p.80). Men are also adversely affected by suicide, drug use and road accidents, as reflected in official statistics. Around 76% of male deaths under age 45 are due to motor vehicle accidents, suicide and AIDS, compared to 33% in women, (Phillips, 2005). In relation to mortality, males worldwide have an almost universally lower life expectancy than females. Barford et al. (2006) state, the year 2006 " is the first year in human history when-across almost all the world-women can expect to enjoy a longer life expectancy than men" (p.808). There are also widely known differences between the mortality profiles of males and females, which have been studied using international comparisons, as Rigby and Dorling (2007) state, "for men in their 20's in particular years in the 1980s and 1990s, rates of mortality three times those of women became normal". So the relationship can be summarised as women experience more illness, but live longer on average than men.

2.2.3 Genes

Genetic differences between individuals are far more complex to explain due to the nature of how genes (and alleles) themselves operate. For this reason it is

challenging to either prove (or disprove) that genes could be a causal factor of health inequalities. It is also very contentious to claim someone may be ill due to his or her genetic inheritance, as this offers little opportunity for a solution. The 'selection' arguments, which surround the possible mechanisms at work, are complicated and require many generations for effects to become apparent, so therefore genetics cannot explain shorter-term changes in health outcomes. It is posed that very few diseases (for example cystic fibrosis) are purely hereditary because of the constant interaction between the genes and the environment (Pearce et al., 2004) and that those diseases which are purely hereditary account for a small fraction of the disease burden. A study some time ago in Japan by Marmot and Davey Smith (1989) noted that the "long life expectancy in Japan is unlikely to be due simply to the fact that the Japanese have some intrinsic biological advantage" because this "would not account for the dramatic improvement in life expectancy over the past 20 years" (p.1549). In fact, this is where the controversy arises, geneticists argue epidemiologists fail to account fully for genes and epidemiologists argue geneticists fail to account fully for environment. That is to say, on the one hand there are clear genetic inheritances, but also environmental and social inheritances, for example if your parents lived in poverty, you are likely to do so as well. This is an argument which will be revisited, the nature - nurture debate. The complexity of any individual starting with a given set of genes, but then being exposed to different environments make causality and ultimately a definitive answer difficult to determine.

2.2.4 Marital status

Marriage is shown to have a protective effect on health. The comparison of married and non-married groups in the USA showed that the non-married had an increased relative risk (of mortality) compared to their married peers (John-

son et al., 2000). Moreover, other evidence showed that people who live with a partner had lower morbidity rates compared with solitary persons (Joung et al., 1994). Other studies (Joutsenniemi et al., 2006) which used data from 1971 - 2001 showed that widows, single and divorced men, showed the worst self reported health. Joutsenniemi et al. (2006) argue that "Marital status may directly affect health by means of economic support, psychosocial factors, and health behaviours", in other words there could be a mutually (health) benefiting side to marriage (p.481). So another aspect that must be considered is marital status when exploring health outcomes.

2.2.5 Religion

The religious beliefs an individual hold may also have health effects. Protective mechanisms may operate though social support networks, but this is an area of ongoing research and some controversy. Jarvis and Northcott (1987) report that "religion's effect is probably not due only to social contacts" (p.820) and that "findings reported in this review are often conflicting, even as personal attitudes toward religion are contradictory" (p.822). In a more general sense, Jarvis and Northcott (1987) state that "it is becoming evident that religion has a powerful effect on the way many people live, on the quality of their life, and on the length of time they live to experience that quality" (p.822). In other words, that religion may alter behaviour in health promoting or damaging ways depending on the personal attitudes, which in one sense is more to do with behaviour. Additionally as is has been found that there is likely to be "a positive association between religion and physical and mental health" (Williams and Sternthal, 2007, p.S47). Religion and health appears to be a contentious area, for obvious reasons.

2.2.6 Childhood

Childhood influences on health are often forgotten about, particularly in cross sectional studies, which take no account of anything other than current circumstances. The long term influences of childhood effects can be examined using longitudinal or cohort data. Many of the data sources and approaches are discussed in Braveman and Barclay (2009). Apart from the immediate consequences, the legacy of childhood influences on adult health will be important. Maughan and McCarthy (1997) report how a range of problems in childhood, such as poor parenting, divorce, family violence and alcohol problems, to name a few, are associated with an increased risk of a variety of psychological disorders in adulthood. It should be noted that this is probabilistic, not deterministic, in other words, it is not inevitable that such conditions in childhood result in the named problems in adulthood, it is just more likely to occur. James (2007b), in his book 'They F*** you up', argues that nurture in the first few years of your life is absolutely critical to how you turn out as an adult. Power and Hertzman (1997) argue for the pathways model from childhood social circumstances to later adult health risk, based on evidence from observation and intervention studies. Childhood then has an important legacy effect on health in later life, but which can be altered, to a degree, as the individual ages.

2.2.7 Ethnicity

Ethnic effects in relation to health are supported by a significant body evidence from the literature, as Nazroo (2003) states "a large body of convincing evidence now supports the possibility that ethnic inequalities in health are largely a consequence of socio-economic differentials" (p.282) in the UK and USA. Evidence shows that "minority ethnic groups may have poorer access to health care in the UK compared with the general population" (Davey Smith et al., 2000,

p.403). Ethnicity does not refer to a homogeneous group of people, but it is not unreasonable to assume that certain behaviours; such as diet, smoking and alcohol consumption, are similar within ethnic groups due to cultural reasons. There are two differing meanings of ethnicity. Ethnicity as a structure refers to the inter relationships between health, class and ethnicity, whereas ethnicity as identity refers more to cultural traditions. It has been observed by Karlsen and Nazroo (2000) that "ethnicity as a structure ... is strongly associated with health for ethnic minority people living in Britain" but that "ethnicity as an identity does not appear to influence health" (p.55). That is to say, the cultural traditions are not important in relation to health compared with the position of the individual in a society. There is quite a vigorous debate over how exactly ethnic differences in health have emerged (Krieger, 2005). Is it because of genes or the biological legacy of racial discrimination and deprivation or it is both of these factor combined? - a question still not settled. Overall, ethnic effects in health are linked to SEP as has been shown above. If the evidence is correct, reducing ethnic effects in health should occur by reducing overall socio-economic differences in health, as Nazroo (1998) "we are concerned with (ethnic) inequalities in health because they are a component and consequence of an inequitable capitalist society, and it is this which needs to be addressed" (p.167), that is the most important point to bear in mind. In other words, ethnic inequalities are only a part of the greater inequality in society as a whole.

2.3 Behavioural factors - what we do...?

It should be fairly obvious that a persons' behaviour will also influence their health. After focusing on the individuals biological characteristics, the next section contains an assessment of the evidence on the behavioural determinants of health.

2.3.1 Smoking

The prevalence of smoking is higher among lower Social Classes (Townsend et al., 1994). There is also a well established link with Lung Cancer, after the publication of five studies (Doll and Hill, 1950; Levin et al., 1950; Mills and Porter, 1950; Schrek et al., 1950; Wynder and Graham, 1950), one in Britain and four in the United States, which ensured that more research was initiated into smoking as a cause of ill-health and premature mortality. In the years around 1950, around 80% of men and 40% of women smoked in the U.K. (Peto et al., 2000). The legacy of high rates of smoking can be seen in official statistics, particularly lung cancer. One of the solutions to more recent inequalities created by smoking would be to adjust price, by tax rises, to discourage smoking, as Townsend et al. (1994) suggest this would "reduce the prevalence of smoking in men and women in lower socio-economic groups (those with the highest levels of smoking and the greatest mortality from smoking related diseases) and to reduce cigarette consumption by all women and men aged between 25 and 59" (p.925). The positive side of the story is that "people who stop smoking at 50 or 60 years of age avoid most of their subsequent risk of developing lung cancer, and that those who stop at 30 years of age avoid more than 90% of the risk attributable to tobacco of those who continue to smoke" (Peto et al., 2000, p.328). As eluded to in the section on gender differences, one of the reasons for disparities between the sexes is smoking behaviour. Pampel (2002) states that, "smoking fully explains the recent narrowing of the sex differential" but that for most of the 20th Century, "cigarette smoking explains much of the widening of the sex differential in mortality" (p.96). In other words, male health being adversely affected historically, females more recently due to their later uptake of smoking. A report by Leon et al. (2003) stated that one of the main reasons for the poor performance in terms of life expectancy for Scotland, particularly for

females, was due to smoking. The literature on smoking and health outcomes agrees strongly on the overarching point that smoking is detrimental to health, arguably the most important cause of premature mortality in the developed countries of the world and a major cause of ill-health.

2.3.2 Alcohol

Alcohol, like smoking, can have extremely negative health consequences, but the difference is that for individuals with particular characteristics there are benefits to drinking moderate amounts of alcohol. For example, in a study of Czech men aged 25-64 who had already experienced a non fatal myocardial infarction, a heart attack, (Bobak et al., 2000), the lowest risk was found in "men who drank almost daily or daily" but, there was a suggestion "that the protective effect was lost in men who drank twice a day or more" (p.1379). This is echoed by Stampfer et al. (1993), who observed that "light to moderate drinkers have substantially lower rates of cardiovascular mortality and mortality from all causes than do non-drinkers or heavy drinkers" (p.801). Rimm et al. (1996), report that "The inverse association between moderate alcohol consumption and coronary heart disease is well established" (p.731) and that the effect is due to alcohol, not specific type of beverage, i.e. wine, beer or spirits. The abuse of alcohol, either by binge drinking or alcoholism, has negative effects on health. Alcohol abuse is also linked to Liver Cirrhosis (Iredale, 2003) and other digestive diseases (Corrao et al., 2004). It appears that most research in this area agrees on the central idea that by consuming large amounts of alcohol regularly, an individual will damage their health. The disagreement seems to focus on exactly where the limits of the protective effects of alcohol may be, the protective effect of alcohol being less ambiguous in middle age. Other policy disagreements centre on how to combat problem drinking and the true costs of alcohol misuse (The Scottish

Government, 2008b).

2.3.3 Diet

A poor diet and the consequential lack of nutrition will also have an important influence on the health of an individual over his or her life as Lock et al. (2005) report there is "good evidence that fruit and vegetables protect against cardiovascular diseases and some cancers" (p.100). Research in various countries has concluded that a low consumption of fruit and vegetables was to blame for 3.5%, 2.8% and 2.4% of the burden of disease in the European Union (Pomerleau et al., 2006), Australia (Mathers et al., 1999) and New Zealand (Tobias, 2001), respectively. Also, Verhagen et al. (1995) report that eating cabbage, brussels sprouts and broccoli, results in a reduced cancer risk. In developed countries, a review of 144 studies found a strong inverse relationship between obesity and Social Class (SC) for women, but inconsistent findings for men and children (Sobal and Stunkard, 1989), where historically obesity was more common among the higher SCs. Research has also shown that it is more expensive for those in deprived areas to eat a healthier diet due to the lack of facilities and the higher cost of purchasing suitable food, mainly due to the lack of chain stores (Maronick and Andrews, 1999) and the greater number of fast food outlets in deprived areas (Cummins et al., 2005) in England and Scotland may also be a indication of poor diet. Using the example of Japan, their diet is likely to "play an important part in their health" (Marmot and Davey Smith, 1989) due to the difference in salt intake and the low amounts of fat in their diet compared to a 'western' diet, which is likely to reduce the incidence of colon and breast cancer and also of coronary heart disease. The protective (and damaging) effects of diet on health will be difficult to assess and as yet appears not to have been fully undertaken. It is also worth noting that from a policy perspective,

the strength of representations from the agricultural sector ('food politics') has a bearing on policy due to the large amounts of subsidy involved.

2.3.4 Drug abuse

Drug abuse is clearly associated with all sorts of health problems. A study of intravenous drug users (IVDUs) in Rome found the risk of death was raised tenfold in men and twentyfold in female IVDUs (Perucci et al., 1991). A similar study of Glasgow intravenous drug users found the average age of death to be around 26, overdose being the most likely cause (Frischer et al., 1997). So if one is engaged in drug abuse, particularly intravenous drug use, it is a strong predictor of future illness and premature mortality.

2.3.5 Sexual Behaviour

Sexual behaviour will also have an impact on health, hopefully a positive but, potentially a negative impact. The potential problems could include infection by a sexually transmitted disease (STD), unwanted pregnancy and psychological problems. A study of sexual behaviour in the U.S. in 1998 (Ebrahim et al., 2005) found that "about 20 million adverse health events (7,532 per 100,000 people) and 29,745 deaths (1.3% of US deaths) were attributed to sexual behaviour" (p.38). The same study (Ebrahim et al., 2005) reported a gender difference, that women had a higher health burden attributable to sexual behaviour. In more developed countries, the move from sexual behaviours exclusively for reproduction to a source of normal human interactions, has lead to a situation whereby Viagra is the "world's most popular medicinal drug ever" (Hart and Wellings, 2002, p.899), sexual gratification has become very important indeed. There is a trend with regards to Chlamydia, "rates in 16-19 year olds and 20-24 year olds almost trebled in men and more than doubled in women during 1995 to 2001"

(Tripp and Viner, 2005, p.590), echoed in many other STDs. Teenage Pregnancy is also an important issue to address, the stereotypical consequences of which are a poor mother and child, and absent father syndrome, but is this true? Firstly, with regards to teenage pregnancy it is known that "The United Kingdom has the highest rate in western Europe" (Tripp and Viner, 2005, p.591). However, as Lawlor and Shaw (2002) state there "is no convincing evidence that teenage pregnancy is a public health problem and it is difficult to identify a biologically plausible reason for adverse outcomes of young maternal age", in fact given appropriate support there is no reason why younger mothers (in comparison to mothers in their 30s and 40s) should not experience better health outcomes. It is true that teenage mothers often come from deprived backgrounds themselves (inter alia (Botting et al., 1998)), meaning their children are more likely to experience deprivation. So the relationship with health is far from black and white, particularly with regards to teenage pregnancy where more recently the debate has begun to turn towards the problems associated with delaying motherhood (Stein and Susser, 2000). The ever increasing number of children engaging in sexual intercourse, from 5% of girls under 16 in 1964, to 25% in 1998 (Tripp and Viner, 2005), means that there is the potential for a time bomb of future illness directly related to the rising number of young people who engage in unprotected sex. On a positive note, Wellings and Kane (1999) argue that the majority of teenagers are able to use contraception effectively to prevent pregnancy, as overall fertility trends for teenagers are downwards. So sexual behaviour has an influence on health, the negative aspects are likely to be influenced, particularly teenage pregnancy, by socio-economic and community level factors.

2.3.6 Physical Activity

In addition to the other individual behavioural risk factors, a lack of physical exercise is recognised as detrimental to health, "physical activity is recognised as an important component of a healthy lifestyle, by the population at large as well as by scientists and clinicians" (Hardman, 1999, p.87). Physical exercise is important to the health of middle aged men for example, for those free of Ischaemic Heart Disease (IHD), moderate, or moderately vigorous physical activity was associated with a "significantly decreased risk of heart attack" and of those men with IHD light or moderate exercise was associated with a "slightly diminished risk of heart attack" (Shaper et al., 1991, p.393). What is unhelpful in this case is a 'blame the victim' mentality, for example, if someone is unable to exercise, for example because of the fear of crime, or the poor environment, which will be sufficient to deter people from taking the necessary exercise needed. Government (Department of Health, 2004) guidelines recommend "adults should aim to take 30 minutes of at least moderate activity on at least five days a week ...children and young people ... one hour of moderate intensity physical activity each day and this can be continuous activity or intermittent throughout the day" (p.2). Without delving into numerous technical studies, moderate physical exercise has protective effects for health in terms of reduced risk for a wide range of diseases including depression, diabetes, cancers and heart disease, to name but four. Overall, the literature concurs that moderate amounts of regular exercise have health promoting effects and should be encouraged where possible.

2.4 Socio-economic factors - the position of the individual in society

The socio economic factors that are a determinant of illness and ultimately mortality feature regularly in the literature. The overlap between the different measures of Socio-Economic Position (SEP) is inevitable given that measures of SEP may amalgamate the different component parts in different ways. What is discussed below is an overview of each individual 'measure' before bringing together the evidence to reach a conclusion. What can be seen is that it is difficult to consider socio-economic factors in isolation from each other because they are linked in complex and often subtle ways. There are also links between behavioural factors, such as smoking and SEP for example, which further adds complexity to determining the relationships between SEP and health.

2.4.1 Employment status

Employment status has been shown in numerous studies to be a powerful determinant of health. Why is unemployment so detrimental for health? Or put another way, is employment good for health? Well, arguably the biggest problem is one that was expressed many years ago, (Beveridge, 1944), a person who cannot sell their labour is basically being told that they are of no use. This has consequences on the person, the "psychosocial condition of unemployment appears to have a negative impact" (Shaw et al., 1999, p.84), which leads to adverse health through a number of pathways. The relationship between unemployment and ill-health is well established, as Bartley (1994) comments "it is no longer seriously argued that there is no such relationship" (p.333). The consequences of unemployment operate above pre-existing health problems and Social Class (SC) and will have an immediate effect on personal income, a longer term

effect on income (if remaining unemployed) and motivation in the medium term as well as other consequences. Beveridge (1944) argued that the labour market should be a seller's market, that is, in favour of the worker, for the simple reason that not being able to sell labour has more adverse consequences than not being able to buy labour. Beveridge (1944) argued that in an ideal world there should be more vacancies in the labour market than number of unemployed persons. This makes sense in theoretical terms, but perhaps not in practical terms. Employment is also good for health in the sense that it warrants the respect of others, is good for self esteem and gives structure to the day (Jahoda, 1942). In a study in Finland, Martikainen and Valkonen (1996), found that both Finnish men and women who experienced unemployment "had greater mortality than did employed men and women" (p.912), showing that unemployment is a risk factor for mortality. In a European study of 23 countries (Bambra and Eikemo, 2009) the authors found unemployed people reported higher rates of poor health compared with employed people, but suggested that the relationship may be moderated by differing welfare state regimes in European countries. Bartley et al. (1997) argue that more "equitable social and economic policies may therefore be effective in preventing an accumulation of disadvantage" (p.1194) by providing a safety net and reducing the stress of transition between employment and unemployment. In the Whitehall II study, Ferrie et al. (1995), report that the "anticipation of job change was associated with relative decline in self reported health status that was not accompanied by a relative worsening in the profile of health related behaviours" (p.1269). In other words before even becoming unemployed, there were consequences for health, a similar finding to a subsequent study (Ferrie et al., 1998). Montgomery et al. (1999), reports that unemployment is a risk factor for psychological symptoms of depression which require medical treatment. A study of unemployment and ill-health (Bartley,

1994) found that four mechanisms needed consideration; relative poverty, social isolation and loss of self esteem, behavioural effects and legacy of unemployment on future employment. The effects of poverty due to unemployment stem from the loss of financial security or loss of earnings which in the longer term leads to a run down in resources more generally. Social isolation may result from the loss of social networks gained during employment or the lack of resources the individual now has, loss of self esteem may come from the loss of security and identity in employment. Unemployment leads to potential stress "being unemployed [was a] stronger predictor of psychological ill-health" (Lindstrom, 2005, p.570). There is some evidence of changes in health related behaviour although it is not universally accepted (Bartley, 1994). Overall, there is still some controversy around the precise causation between ill health and unemployment. But as alluded to, the relationship has been established: unemployment is bad for health and employment overall, is good for health.

2.4.2 Education

Education is widely used as a measure of SEP. The more educated one is, the more likely that person is to be employed, with higher income, a higher SEP and so forth (Ross and Wu, 1995; Shaw et al., 1999). The income and education relationship will be explored in the next section. There is also a link between the education of the parents and their children (see the social mobility section), particularly relevant in Britain, as the more affluent members of society can afford to move towards 'better' schools, or pay for private education. Over time these processes lead to polarisation of educational opportunities and achievements. Education is a strong predictor of SEP and health as Muller (2002) states "Lack of high school education may also capture the lifetime effect of adverse social conditions increasing mortality" (p.25) and in addition,

"educational attainment was a more powerful predictor of differences in mortality than income inequality in US states" (p.24). Moreover, this study points out that "less educated people may be concentrated in areas that are more risky to life and health" (p.25). This suggests that income and education are analogous to a degree and that disadvantage may be concentrated in certain areas. In a Scottish study, Davey Smith et al. (1998a) found that the "age at leaving full time education and occupational social class are both strongly related to risk factors and to mortality". Smoking is correlated with an earlier school leaving age, but more strongly correlated with current occupational class. Ross and Wu (1995) reported that there was a well established positive association between education and health based on the strength of the evidence base. Furthermore, they (Ross and Wu, 1995) propose three plausible mechanisms through which health may be altered by education; through work and economic conditions, social-psychological resources or health lifestyle. Dealing with the first strand, more educated people are more likely to be in continuous full time employment, have more fulfilling work and high incomes. Secondly, the social-psychological resources; a higher sense of personal control and social support positively affect health outcomes. Thirdly, by exercising more, drinking moderately and being less likely to smoke their health is positively influenced. Shaw et al. (1999) comment that "education is clearly one of the best means of avoiding unemployment and poverty, although access to post-school education is largely determined by social class rather than ability" (p.25), (social class will be discussed subsequently), avoiding unemployment and poverty has clear health implications as shown previously. As a conclusion, the interrelationships between socio-economic factors are becoming more apparent as we continue the study. As Ross and Wu (1995) remark, education structures work and income.

2.4.3 Income and Income Inequality

Income is essentially a marker of social position according to Marmot (2005) and Wilkinson (2005), which intuitively makes sense: the more income an individual has, the higher their position relative to others. Perhaps a useful thought is that a rich man is one who earns more than his wife's sister's husband. Income and happiness are also linked as shown by Clark and Oswald (2002), discussing the value in income of certain life events such as marriage, divorce or unemployment. It is worth considering that a basic level of income is needed in order to survive, for example the 'dollar a day', but in the developed countries it would appear that 'relative position' becomes important (Marmot, 2005; Wilkinson, 2005), which is discussed fully in the income inequality section below. Marmot (2002) poses that income is related to health in three ways, through the Gross National Product (GNP) of a country, individual income and income inequalities. In a Scottish study, the combination of owner occupation, access to a car, higher self esteem and higher income is a predictor of "better recent mental health, better respiratory function, smaller waist/hip ratio, fewer longstanding illness conditions, fewer symptoms in the previous month, and lower blood pressure" (Macintyre et al., 1998, p.662). From the West of Scotland twenty 07 cohort study, Der et al. (1999) speculate that "measures of wealth (e.g. savings, property ownership or other assets) or of lifetime income or earning capacity might be more powerful predictors of health" (p.276). This will be expanded upon in the poverty and wealth section (see section 2.4.7). They (Der et al., 1999) also conclude that "there is no single relationship between income and health but that the form of the relationship varies according to the aspect of health considered as well as by age and sex" (p.276) meaning that generalisations in this area are potentially problematic, as well as speculation on the underlying mechanisms. It is also important to note, "the widening gap in health has been

preceded by a widening gap in terms of the distribution of income across society" (Shaw et al., 1999, p.85), which links to the income inequality and psychosocial influences on health discussed subsequently. It has also been shown that "Two of the strongest predictors of who gets depressed in a developed nation are being of low income and being a woman" (James, 2008, p.20). On a methodological tangent, Macintyre et al. (1998) report that "current income may not reflect lifetime income or other assets such as savings or earning power; and we cannot assess household expenditure or the distribution of income within households" (p.662). This is an important point to note, one to which we will return when considering poverty and wealth and the lifecourse approach to health. What is evident is that income and health are related.

Turning to the relationship between income inequality and health, it can be observed that it reappears as a major theme in the literature. The first instances of income inequality and health in the literature were discovered by Rodgers (1979) and Wilkinson (1992), who found relationships independently of each other. Within the income inequality literature, there are several plausible ways to interpret the research findings. Lynch et al. (2000) state that there are the individual income, psychosocial environment and the neo-material interpretations, the latter of which the authors seem to strongly favour. The individual income argument is that "health effects at the population are merely sums of individual effects" (Lynch et al., 2000, p.1201), an argument with which I do not completely concur, essentially because it ignores the effects of the area in which an individual lives, shown to have an influence on health. Wilkinson and Pickett (2006) pose that "income inequality is an indicator of the extent of social stratification in a society", based on evidence that there are numerate correlates of income inequality. Further evidence discussed by Wilkinson and Pickett (2007), states that "income inequality is both an indicator and a determinant of

the scale of social stratification in a society" (p.1966). Reviews by Lynch et al. (2004) and Wagstaff and van Doorslaer (2000) found several variations on the income inequality hypothesis. First, the Absolute Income Hypothesis, that the level of income which an individual has is the determining factor. Secondly, the Relative Income Hypothesis and linked to this the Deprivation Hypothesis, that relative position in society in reference to some other 'key' comparison group is important. Thirdly, the Relative Position Hypothesis, that position in the distribution of income, within a society is the key. Finally, the Income Inequality Hypothesis; there is a direct effect on health due to income inequality and the amount of inequality is important in addition to the absolute level of income of an individual. Wagstaff and van Doorslaer (2000) reported that there was no evidence for the Relative Income Hypothesis or Absolute Income Hypothesis and some evidence for the Income Inequality Hypothesis. The correlates of income inequality are numerous (for example, homicide, teenage pregnancy, lack of trust and low social capital) (Wilkinson, 1996). That is to say, there is a clear link between income inequality and health, but better measures of the underlying phenomenon could be found. In a counter argument, Lynch et al. (2000) argue that psychosocial interpretations of income inequality "conflate the structural sources with the subjective consequences of inequality", and "the ambiguous health consequences of tight-knit social networks and greater social cohesion", limit relevance for public health with a "shallow definition of social cohesion or capital" and lastly, "encourages understanding of psychosocial health effects in a vacuum" (p.1202). A strong critique of the arguments, but is this fair? Wilkinson and Pickett (2006) argue that rather than ignoring material factors, psychosocial pathways provide a plausible route through which they can alter health, based on evidence, particularly of the effects of income inequality and on homicide (Daly et al., 2001). Furthermore, what is argued by

Wilkinson and Pickett (2006), quite fairly, is that the mechanism through which income inequality effects health operates at larger areas, not at smaller scales, where the stratification of society is not as evident. Moreover, as Wilkinson and Pickett (2006) state "Taking account of the size of the area and the use of control variables reveals a high degree of consistency in the research findings" (p.1775), meaning that although there is some controversy around the precise mechanisms through which income distribution influences health (Lynch et al., 2000), overall there is a large body of evidence supporting the proposition that income distribution will have some effect on health outcomes particularly at larger scales. The size of area is a key part of controversy as 83% of studies in income inequality support the hypothesis when large areas are considered compared to only 45% when the smallest areas are used (Wilkinson and Pickett, 2006). Moreover, Wilkinson (1996) states that, "among the richer countries it looks as if economic growth and further improvements in living standards have little effect on health" (p.20), supposing that once a country reaches a certain point in terms of national wealth and absolute poverty is essentially eliminated, the relative differences in income seem to matter most. There is still a clear distinction between the rich countries and the poor countries, with Africa exhibiting a much lower life expectancy than Europe for example. In comparison to this, Scotland is far from a poor country. To counter the differences in income, Shaw et al. (1999) strongly argues that the reduction of income inequality, and therefore the elimination of poverty, should be the core policy to 'cure' health inequalities. Boyle et al. (2004) argue that within the developed world, "it is not the wealthiest countries that have the highest life expectancy but those with the smallest spread of incomes" (pg.220). In other words, a reiteration of the argument is that the richer any country becomes after a certain point, makes little difference; it is the distribution of wealth, which matters the most

for health. Wilkinson (2000) states, "greater income inequality tends to be accompanied by more violence, less trust, more hostility and less involvement in community life" (p.20). Wilkinson (2000) also argues that the "pathway from income inequality to health goes from income distribution, through the social environment, to mortality" (p.20). In a study trying to explain the link between mortality and income inequality, Davey Smith (1996) states "increases in income inequality go hand in hand with underinvestment, which will reap poor health outcomes in the future" (p.988). This may well mean that by studying the prevalence of morbidity and mortality in a population, an indicator of a much deeper problem with similar roots can be unearthed. Dorling et al. (2007) argue that "income inequality is associated with higher mortality levels in all Nations worldwide, not just affluent ones, but the effects are more pronounced at different ages" (p.874). What is argued by Dorling et al. (2007) is that another caveat to the income inequality hypothesis is that as well as the area of study being critical to observe a relationship, the relationship has an "age related mechanism that results in higher mortality being experienced in societies where there is greater social competition, all else being equal" (p.874). However, Dorling et al. (2007) do recognise that psychosocial stress is unlikely to be the sole route through which income inequality damages health. When combined, the choice of area and age provide a strong explanation of why the income inequality argument may be stronger or weaker in different studies that consider health and income inequality. Mental illness was also shown to be strongly related to income inequality, a point previously highlighted in the Affluenza section. Kunitz (2007) argues that "inequality of income and wealth has not always been associated with health disparities, even when social differences based upon place and/or culture has been" (p.108), using an example of British Army officers in India who died in greater numbers than lower ranks of the army.

So the argument that income inequality is the cause of inequalities in health is not yet conclusively made, according to Kunitz (2007). So perhaps, currently, income inequality is a reasonably good indicator of health inequalities and of the level of trust, crime, teenage pregnancy and obesity in a society (Wilkinson and Pickett, 2007). In a previous study Wilkinson and Pickett (2006), noted that it was the most egalitarian countries which were the healthiest, suggesting the more equitable the country, the better the average health of everyone. It is of interest that many of the prominent works on income inequality rarely dismiss the opposing view as false, rather, authors emphasise different aspects of the evidence, which in turn leads to different conclusions as to when, where and how income inequality affects health. However, other evidence disputes that the relationship between income inequality and health applies to all developed countries (Ross et al., 2000); only the USA (and arguably the UK) seem to have this relationship. Subramanian and Kawachi (2004) explain that the reason the relationship may not exist in certain countries is because there is a "threshold effect of inequality on poor health" and "the geographical scale at which income inequality is assessed seems to matter" (p.81) additionally, "the evidence implicating income disparities as a threat to public health is still far from complete" (p.89). Deaton (2003) argues that "my conclusion is that there is no direct link to ill health from income inequality per se" (p.115). He (Deaton, 2003) also argues that "For Britain, there appears to be no area study of income inequality and health" (p.145) and that "Inequality may be important, but there is little that suggests it is income inequality" (p.152). Lynch et al. (2004) report that "income inequality is tightly linked to other aspects of social policy, and this may make it difficult to isolate its independent effects on health" (p.2), in other words, it may never be fully explained. Where are the areas of agreement in the income inequality literature? Overall, it seems fair to conclude there is

agreement that a high degree of income inequality is accepted as damaging for health for the population as a whole, not just the poorest. There are also very good reasons, taking into account a large volume of evidence, that a variety of interpretations must be tested when drawing conclusions as to which pathway is the most important. It is also pertinent that the literature on income inequality agrees that it is important how a country shares wealth within the population, but as Pearce and Davey Smith (2003) argue "there is little agreement on the explanations for these patterns or what they mean for social policy" (p.122), which is the critical point. Researchers may agree that income inequality has an effect on health outcomes (ranging from it is the cause to a minor effect), but why this occurs and what to do about it is still vigorously debated. One thing is clear, income inequality is not a panacea.

2.4.4 Social Class

Social Class (SC) is another measure of the SEP of an individual (see Table 2.1). SC differences are used as one indicator of health inequality in the UK, due to 'the gradient' between the SCs for various illnesses and mortality rates. It has been observed since the Black report (Black et al., 1980), that lower SCs (V) exhibit higher premature mortality rates than higher SCs (I) and that this difference has been increasing consistently over time since the 1980s. In a 25 year follow up from the Whitehall study, Van Rossum et al. (2000) found that the "mortality rate was higher in the lower grades compared with the higher grades" (p.180). Furthermore, "even in retired subjects, socioeconomic differences were found for almost all causes of death" (Van Rossum et al., 2000, p.181). We must conclude that SC has a long-term effect for individuals. In a report by Wilkinson (2000), it is explained that, "rather than a simple contrast between high death rates among the poor and lower ones in the rest of society,

the usual pattern is a continuous gradient across the whole of society" (p.5). Roberts and Power (1996) found that children in a low SC were experiencing increasing inequalities (1981-1991) compared to children of a high SC. Men and women in a high SC were roughly 16% more likely to report having 'good' or 'very good' health than those in a low SC (Shaw et al., 1999, p.54). Essentially the relationship is best described as a gradient; worse health associated with low SC, better health is associated with high SC.

Table 2.1: Registrar General's Social Class (based on occupation, 1990)

Class	Occupation	Example
I	Professional	Accountants, engineers
II	Managerial & technical	Proprietors, Managers
III N	Skilled non-manual	Clerks, Cashiers (not retail)
III M	Skilled manual	Drivers of road goods vehicles
IV	Partly skilled	Machine tool operators
V	Unskilled	Building labourers, Cleaners

2.4.5 Socio-Economic Group

Socio-Economic Group (SEG) is a slightly different measure of the SEP than SC. In a very similar fashion to SC differences between SEGs are used as indicators of health inequality. The evidence then is essentially of a similar nature as the classification system is similar but a more recent creation. Evidence on smoking (Townsend et al., 1994), shows that lower SEGs have been slowest to stop smoking and also that they are the least responsive to health publicity, widening the difference between the SEGs over time. Marmot and Shipley (1996) reported that socioeconomic differences in mortality persist beyond retirement age in civil servants (the Whitehall studies) and in magnitude increase with age, so work may play a crucial role in the generation of these differentials. Bartley and Owen (1996) showed that during a twenty year period "those men in

professional and managerial occupations having the highest employment rates and those in semiskilled and unskilled occupations having the lowest" (p.446) in general terms, higher SEGs fared better than lower SEGs. In terms of ill health, Bartley and Owen (1996) also showed that those with limiting long term illness (LLTI) in the lower SEGs generally had higher unemployment rates that those with an LLTI in the higher SEGs. So in many ways SEG is similar to SC. It acts as a kind of marker of position in the social hierarchy; the higher up one is the better one's health is likely to be.

2.4.6 Deprivation

Individual and area deprivation are different concepts as is now explained. Individual deprivation may not be apparent when using aggregated population measures. This is known as the ecological fallacy (see full discussion in Chapter 3, the data and methods). Individual deprivation can potentially remain hidden when using aggregated measures as the aggregate measure is simply the sum of the individuals in an arbitrary area. The mechanism through which deprivation affects individuals could be "that high levels of depression and anxiety, or low self esteem are themselves the outcome of a process in which deprived individuals compare themselves unfavourably with others" (Graham, 2000, p.171). Subsequently, this idea, the psychosocial effects on health, will be more fully discussed. Individual deprivation is likely to have adverse health consequences. Arguably, there is a gap in the literature on the consequences of deprivation on individuals over time. Area deprivation is discussed in a subsequent section, and is the focus of more of the literature.

2.4.7 Poverty and Wealth

Poverty and wealth are also two important components in the overall mechanisms that determine health. As mentioned prior, the relationships between poverty and health as well as wealth and health are linked to other measures of SEP. Plato (c.427 to c.347 B.C.), the ancient Greek philosopher mused that there should exist among the citizens neither extreme poverty or excessive wealth as both produce great evils (Plato, 1965). The type of poverty to which we are referring in this study is relative poverty, in the sense that it excludes people from societal norms, through a lack of income or resources or wealth. Shaw (2007) defines relative poverty when the "resources available to a person, household or area are so far below average levels that they are considered to be excluded from ordinary living patterns, customs and activities" (p.25) On the one hand the poor cannot afford certain resources and have to accept state education and health care. On the other hand, the wealthy can chose to exclude themselves from state education and healthcare and may opt for private provision instead; this problem is most acute in the USA. Shaw et al. (2000), in a study on poverty in Britain, estimated that "almost one quarter of all deaths can be attributed to unfavourable socioeconomic circumstances" (p.152). It has been argued (Baum, 2005) that researchers are "most commonly concerned with poverty and its impact on health" and that, "public health could advance its overall project of improving population health in an equitable manner by studying wealth more directly" (p.542). The study of wealth and health is problematic due to the lack of data on wealth between individuals (Baum, 2005), which hinders measuring its likely effects. Poverty is easier to study in one sense, as data more readily exists. In the context of this study, it is important to point out that relative poverty, rather than absolute poverty, is more prevalent in a Scottish context. Fuel poverty, is also part of the overall problem of poverty, pushed to the fore

recently by rising energy costs.

2.4.8 Child Poverty

A short divergence to highlight child poverty is warranted. Living in poverty, especially in childhood, will have detrimental results in later life. Poverty in the U.K. affects a large number of children and the Government has promised to eradicate child poverty by 2020 (Department for Work and Pensions, 2007). An observational study in Glasgow (Davey Smith et al., 2001b) found that a wide range of adverse socio-economic conditions in childhood did predict adverse health outcomes in later life. Lone motherhood was associated with high psychological morbidity in children (McMunn et al., 2001), more than likely because of the socioeconomic effects, which when controlled for, meant the relationship disappeared. There are other numerous references to childhood in the literature, these are discussed in other sections and highlighted. Again the relationship is fairly straightforward in one sense; child poverty is bad for health and in addition can have lasting consequences.

2.4.9 Housing

There is a dearth of evidence on housing and ill-health, perhaps because it is assumed that there is an obvious link between poor housing and poor health. However, the relationship may be more complex. A report by the Scottish Office concluded that there is a correlation between poor housing and ill-health, but the attempts to prove housing is a cause of illness are often unsuccessful and the literature is characterised by weak or even contradictory evidence. Thomson and Petticrew (2007), reviewing various evidence, point to the idea that the "combination of greater warmth and reduced household expenditure may be a key mechanism through which health effects occur" (p.434). The difficul-

ties associated with the study of housing and health men that "poor housing conditions often exist alongside other forms of deprivation" (Thomson et al., 2001, p.189) meaning that causation is difficult to ascertain. Longitudinal evidence (Dedman et al., 2001) points to the fact that childhood experience of poor housing has adverse consequences in later life (Marsh, 1999), linking back to the child poverty section. In addition, Smith (1990) argues that there is a residual of people left in public housing of which the "quality and condition leave much to be desired" (p.760) after the continued shrinking of the sector. Identifying the homeless is a difficult task due to the nature of the problems. However, examples of studies which have considered homelessness and health report strong relationships between homelessness and ill-health, the risks include a higher risk of death, disease, violence and various infections (Connelly and Crown, 1994). A Scottish study by Walker et al. (2006) found the importance of heating in homes upon health. Overall, poor housing is likely to have a negative impact on health.

2.4.10 Social Mobility

Social mobility has already arisen in a previous section. Essentially social mobility is "the movement (or opportunities for movement) of groups and individuals between different social groups" (Shaw, 2007, p.39), so how does this affect health? First some definitions: there are two widely recognised types of social mobility, intergenerational and intragenerational (the former being children compared to their parents, the latter, within ones' own lifetime). In relation to health, those individuals who move down the social order have adverse health outcomes; those who move up have better health outcomes. Research by Lawlor et al. (2002) showed that "poor socioeconomic position in childhood and in adulthood is associated with insulin resistance, components of the insulin re-

sistance syndrome, and smoking in women" (p.805) in other words, staying in the same (low) position has health implications. Similarly, Davey Smith et al. (1997) reported that their "data show a clear cumulative effect of socioeconomic circumstances acting over a life time" (p.547) strongly urging for a lifecourse approach to the study of health, discussed subsequently. Manor et al. (2003) describe the results of a cohort study (1956 Birth Cohort Study, including England, Wales and Scotland) relating ill health to social mobility finding that those with ill health are likely to move downward (and less likely to move upward), particularly for men and adolescents, (less clear for women). Ultimately, Manor et al. (2003) conclude that the effect of health selection of inequalities is variable, sometimes increasing, sometimes reducing health inequalities. In the west of Scotland cohort study, Hart et al. (1998) report, "we have shown that overall, mortality experience was worse for the stable manual group, best for the stable non manual group and in between these two for the upwardly and downwardly mobile groups" (p.1127). In other words this is linked to the SC gradient and the mobile groups experience differing outcomes depending on where they move, downwardly mobile being a risk factor for adverse health outcomes.

2.4.11 Social Exclusion

Social exclusion is the term, particularly favoured by politicians for the combination of numerous types of problems. The Social Exclusion Unit (set up in 1997) defines social exclusion as what happens when people or an area has a combination of linked problems, such as unemployment, discrimination, poor skills, low incomes, poor housing, high crime and family breakdown, a potentially toxic mixture of 'social ills'. In this regard social exclusion is not new, simply a collection of old problems summarised in one term. A more formal definition is that "an individual is socially excluded if he or she does not par-

ticipate in the key activities of the society in which he or she lives" (Leff, 2009, p.575). The health effects are best described by breaking the problem down into the individual parts of which social exclusion is the sum total. By this it is meant dealing with deprivation, low income, poor housing and so forth separately. Social exclusion, as it is inherently negative, is related to adverse health consequences because the individual problems are all associated with poor health outcomes.

2.4.12 Social Capital

The problem with determining the effect of social capital on health is that social capital itself is rather loosely defined and used to mean many differing, but similar phenomenon. It is posed that "individuals (and their ill health) cannot be understood solely by looking inside their bodies and brains; one must also look inside their communities, their networks, their workplaces, their families and even the trajectories of their life" (Lomas, 1998, p.1182). In other words, there should be a focus on both individuals and the social structure in which they lead their lives. It has been theorised that social capital is a component in the widening (or narrowing) of health inequalities. A typical line of reasoning assumes that income inequality is a major factor affecting health because income inequality reduces social capital through possible psychosocial factors (Pearce and Davey Smith, 2003). Pearce and Davey Smith (2003), using the example of New Zealand (NZ), argued that if social capital (and its psychosocial effects) were direct determinants of health then a worsening of health should have emerged in NZ recently, because of the rise in income inequality, but this is not the case. This means that they (Pearce and Davey Smith, 2003) argue a series of lifecourse influences are the more likely culprits. The evidence on social capital and health appears to be patchy, the strongest support for the

effects of social capital on health are found in the U.S.A., perhaps because of the transient and loosely defined nature of social capital. In summary, it seems fair to conclude, as Pearce and Davey Smith (2003) do, that social capital is likely to be associated with health at a community level. The positives of social capital are that is an easy, almost cost free solution to many of the problems facing society but in reality, the likely policy outcome is that deprived communities will be urged to help themselves instead of addressing the structural causes of poor health. Macinko and Starfield (2001) concluded that the likely role of 'social capital' on the health of a population could be overstated or even misleading in the literature. A different American study (Berkman and Syme, 1979) found that social and community ties helped protect against adverse health consequences. In addition, Berkman and Syme (1979) reported that "social factors may influence host resistance and affect vulnerability to disease in general" (p.203). Depending on definition, it can be argued from a wide body of evidence that social capital and social support in general are good for health.

2.5 The context - Environment, Area and Population Factors

The various possible determinants of health related to the environment in which people live are now discussed in depth. This is necessary as individuals do not live in a vacuum; the area in which they live is likely to contribute to their health and the creation of health inequalities.

2.5.1 Area

Area effects on health are most evident at the extremes of the distribution, for example the 'sink estate' in Glasgow (Easterhouse) compared to the affluent areas of Chelsea and Fulham. Mitchell et al. (2000) conclude "Our evidence suggests that health is a function of characteristics of both individual and area of residence... " (p.78), which is a conclusion, supported a large body of research. This is important in the context of this study as it is important to consider both the composition and context (Curtis and Rees Jones, 1998; Macintyre et al., 2002) of individuals when examining health. As Curtis and Rees Jones (1998) point out area effects are important because this "type of effect would cause people with similar individual attributes to have different health status from one part of the country to another" (p.88). One solution to this problem is multilevel modelling, discussed in a subsequent chapter. In the health inequalities literature, the difference between people and places, (Mitchell et al., 2000) referred to as context and composition effects, are consistently revisited. In a study by Joshi et al. (2000), the importance of composition, "aggregated characteristics of individuals living in an area" and context, "characteristics of the area which are independent of its individual inhabitants" (p.144) are discussed as important factors when considering health outcomes. Davey Smith et al. (1998b) note that "areas with unfavourable social and physical environments are the ones people will, if possible, leave to move to more attractive places", for example the movement of Scots to the South East of the U.K. and the mass population loss in Scotland in the seventies and eighties. It is safe to assume that work and wages are the main driver of movement, particularly among the younger age groups, but also a search for a better physical and social environment, particularly for children, more fully explored in the migration section.

2.5.2 Environment

This leads us to discuss a more 'greener' view of the area in which individuals reside and how this may impact upon health. Greenspace can include; playing fields, rivers, forest, essentially they are open areas with natural vegetation. It has been shown by De Vries et al. (2003) that more greenspace leads to more physical activity, which has positive health benefits (see physical activity section). Similarly, Maas et al. (2006) argue that green space is not to be considered a luxury: it has important stress reducing effects and a positive association with the perceived health of residents. Mitchell and Popham (2008) report that "environments that promote good health might be crucial in the fight to reduce health inequalities" (p.1659). There are also potential negative affects as acknowledged by Groenewegen et al. (2006); the fear of crime in urban parks for example or negative interactions with animals in green space. On balance, it would appear that the positive influence of green space has received little attention to date. Green space could be an important antidote to stress and attention fatigue, as well as helping recovery from illness, helping individuals to exercise more regularly and to promote social cohesion among communities.

2.5.3 Deindustiralisation

The process of de-industrialisation has been well documented (Walsh et al., 2008) with large parts of the 'north' of the U.K. and parts of Scotland (particularly Glasgow) suffering the effects most acutely. The resulting lack of suitable employment opportunities, combined with high rates of unemployment compared to the rest of Great Britain has grown steadily since the 'full employment' peaks in the 1960s, offering a partial explanation of the poor morbidity and ultimately, mortality record of Scotland. The corollary is that this 'managed decline' of parts of Scotland after 1970 has had implications for long term

health outcomes. There is a parallel, in some respects, to the transition of Eastern Europe and Russia, from planned to market economies (Walberg et al., 1998), but with less dramatic consequences in Scotland. In one sense it seems slightly foolish to draw comparisons between Eastern Europe and deprived parts of Scotland, but looking at the evidence suggests it could be a potential source of explanation. For example, (Bobak and Marmot, 1996), describe the Eastern European situation as one where a "lack of control over health may be related to a wider sense of lack of control and mastery, which in turn may be related to the social situation" (p.425). In addition, "Shortages of food and other daily needs, un-fulfilling work, little or no reward for effort at work, low control over lifestyle, and feelings of disadvantage relative to western Europe" and "these psychological factors to poor health, particularly cardiovascular disease" (Bobak and Marmot, 1996). This is not so dissimilar to the picture in seriously deprived parts of Scotland (and the UK). In New Zealand, a study by Blakely et al. (2008) found that during the restructuring of the economy in the early 1980s and 1990s there was a strong suggestion that changing social and economic conditions were linked with disparities between income and mortality changing and it was young adults (25-44) who were adversely affected by these events. This suggests that de-industrialisation (or 'restructuring') has left a lasting legacy in terms of unemployment, illness and life in general in Scotland and other affected areas.

2.5.4 Policy

In Scotland since 1999 it is the Scottish Parliament, not Westminster, (except for reserved matters), who deal with devolved matters. The 1707 Treaty of Union merged the Scottish and English Parliaments, so until 1999 there was no separate Parliament in Scotland. This is an important point, as it sets a political

context for the Scots that may help address inequalities. A devolved government may understand local needs more accurately. Therefore, the importance of policy, both regional and national, could have important long-term consequences for mortality. Current Scottish Government policy focuses on five strategic objectives. The 'healthier' objective aims to help people sustain and improve their health, especially in disadvantaged communities, ensuring better access to health care (The Scottish Government, 2008c).

2.5.5 Health Policy

Health policy will have a role to play in that the provision of medical care is approached in a diverse manner. A short historical divergence is warranted at this point in order to explain where the status quo (in the U.K.) originated. In the period immediately after the Second World War a number of important changes occurred in the U.K. in relation to policy. After the Beveridge Report (Beveridge, 1942) there was a step change in health policy (as well as Government policy in general) with the advent of the National Health Service (NHS) in 1948, now taken for granted. This was part of the creation of the welfare state, providing health, education, employment and social security benefits to the population of the UK. In essence the Government can have a huge influence on the health of its citizens, positive or negative.

What follows is a discussion of some of the key policy documents in relation to Scottish health as well as those which focus on areas such as health inequalities and form the basis of policy in Scotland. The new Scottish parliament gave the option of creating a more bespoke and geographically relevant policy context for Scotland as well as to create differences from policy in the rest of the UK which could make a difference to the health of the Scottish population. A white paper entitled "Towards a Healthier Scotland, set out the basis for

tackling health inequalities in Scotland. A report on the same area (Scottish Executive, 2003) outlined the key 'risk factors as tobacco, alcohol, low fruit and vegetable intake, physical activity levels and obesity in Scotland. In terms of policy related to smoking, Scotland introduced several measures such as a ban on tobacco displays and sales from vending machines as well as the ban of smoking in public places (which also became UK wide). Policy focused more on alcohol consumption has also been featured in debates more recently, with research into a minimum price per unit for alcohol (Purshouse et al., 2009) which has formed part of the foundations of policy in this areas. Additionally, research estimated the costs of alcohol abuse at around £2.25 billion each year (The Scottish Government, 2008a) meaning that there is an economic benefit to improving health outcomes in this area. Mental well being is also an issue covered by health policy (The Scottish Government, 2009), with clear defined actions outlined in a report entitled "Towards a Mentally Flourishing Scotland: Policy and Action Plan 2009-2011". The area of mental well-being is therefore on the health policy agenda in Scotland, particularly in terms of suicide prevention in the "Choose Life strategy aimed at suicide prevention. The area of obesity has been addressed in a document outlining a road map on preventing obesity and overweight in Scotland (see The Scottish Government (2010). This recognised the problems of high levels of Scottish obesity within Europe and pointed to the economic costs of obesity in Scotland as well as having the benefit of a healthier population contributing to economic growth. The costs in terms of obesity have been estimated at £457 million. Therefore, policy responses yield not only a health, but an economic benefit. The main policy responses centre on reducing energy consumption in some way as well as increasing energy expenditure. This gives an overview of the health policy landscape in Scotland as well as focusing on particular areas of importance such as smoking, mental well-being, obesity

and alcohol consumption.

2.5.6 Economic Policy

As alluded to in the section on de-industrialisation, the economic policy which a Government pursues can have real and lasting consequences for life in general and health specifically. This is important as it affects the levels of employment, unemployment benefits, the income distribution and education and training. The emergence of 'hidden unemployment', particularly in de-industrialised regions (Beatty and Fothergill, 2005), means that many have moved into permanent sickness or incapacity benefit and been removed from the labour market in these areas. A regional policy which stimulates demand in areas most adversely affected is likely to improve the level of employment, income and ultimately health in these areas.

2.5.7 Migration

The role of migration is another important aspect of this puzzle, particularly in a UK context. Migration is likely to have been misunderstood or underused as a vital component of health research as O'Reilly and Stevenson (2003) argue. An aspect of migration that is thought to be particularly important for health is selective migration. Davey Smith et al. (1998b) state, "where population has shrunk, the average mortality is high compared with places in which the population has grown" (p.1439). Moreover, Norman et al. (2005) state "areas with poor socio-economic conditions are likely to be selectively losing healthy migrants who will tend to be attracted to economically favourable, less deprived locations" (p.2768). Furthermore, Boyle et al. (2004) states, "migration tends to be selective both in terms of socio-economic and health characteristics" (p.77) "selective migration may well be an influential factor in the apparent widening

gap in health inequalities" (p.77). The conclusion is that the worst areas (in terms of deprivation) are losing the healthier proportion of their population and gaining the least healthy from other areas. A significant negative correlation between population change and change in standardised mortality ratio during the early 1970s to early 1990s of -0.37 ($p<0.001$), which suggests that population change and mortality are linked and that as population declines (or increases) mortality rates increase (or decrease) (Davey Smith et al., 1998b, 2001a). Over the past few decades, "changes in the housing market have had the effect of spatially filtering people with the result that wealth and location are now somewhat more closely related" (Dorling et al., 2000, p.194). Through these mechanisms, health outcomes have become much more spatially polarized as time has passed leading to changes in the distribution of health (and education). This was not always the case. In the later part of the 19th century the opposite was true, as infectious diseases were the main killers and this was concentrated in rapidly urbanising (wealthier) areas (Kunitz, 2007). Therefore, we should conclude that the relationship is specific to time and place. It is also pertinent that resources are usually allocated, in many areas, based on population. Therefore, population decline has an additional negative effect of losing a share of resources. One possible solution to this problem is to allocate resources to the most deprived areas, or those with the most need. Other research (Brimblecombe et al., 1999), shows "the majority of migration is also between local areas rather than between regions" and somewhat uniquely, "migration appears to explain all of the geographical variation at sample of anonymised records district level within Britain" (p.986). In a Northern Irish study, O'Reilly and Stevenson (2003) report that there was a "net population drift from more disadvantaged to more affluent area and that those households and individuals who moved tended to be the more affluent residents of the areas they left" (p.1459). In agreement with

earlier evidence, they report that "through a process of selective migration, the socio-economic landscape has become more polarised" (O'Reilly and Stevenson, 2003, p.1459). Additionally, Boyle et al. (2002) conclude "we have shown that migrants tend to be healthier than non-migrants" (p.29) and that in general "ill individuals are relatively immobile" (p.30). On the strength of the evidence there is a process of selective migration at work which could plausibly have led to increasing inequalities in health.

2.5.8 Area Deprivation

Area deprivation has similar effects to individual level deprivation. Large concentrated pockets of deprivation in Scotland partially explain excess mortality (McCarron et al., 1994; Sridharan et al., 2007; McLoone and Boddy, 1994). In terms of morbidity the effect is similar, that is, rising morbidity rates with rising levels of deprivation as is explained below. A study focused on Avon and Somerset (Eachus et al., 1996) reports, "the association found in this study between deprivation and broad categories of morbidity is undeniable" (p.292), basically that deprivation is strongly linked with numerous common diseases. A smaller scale study found a "positive correlation at electoral ward level between the prevalence of all of the conditions examined in the self reported morbidity survey in small areas ... and Jarman scores in those areas" (Payne et al., 1993, p.165); the Jarman score being a measure of deprivation. A regular feature of the literature is the 'Scottish effect', a term widely associated with deprivation, but the effect is simply a description that deprivation (as measured by the Carstairs-Morris index) is unable to explain the differences in mortality between constituent parts of the UK. The Townsend deprivation index is a well known and widely used measure of deprivation (more will be discussed in the methods section), particularly in the UK. Carstairs (1995) argues that the link between

deprived areas and adverse health has been clearly demonstrated by numerous studies on the topic. Wilkinson and Pickett (2007) argue that "numerous social problems are associated with relative deprivation - from ill health to poorer educational performance" (p.1972). In summary, area deprivation is bad for health.

2.5.9 Transport

Transport may not seem an obvious candidate to be related to health, however, car ownership is related to measures of health (Macintyre et al., 1998, 2001; Davey Smith et al., 1990) as it is a crude measure of SEP. Transport deprivation can have clear problems, such as being unable to access green space and its associated benefits (Mitchell and Popham, 2008) through to causing pollution or accidents on one's doorstep (McCarthy, 2006) or a lack of suitable public transport. As discussed previously the link to physical activity is important as transport, particularly if one walks or cycles, is beneficial to health, but detrimental if one uses the sedentary alternative continuously. It is noted (McCarthy, 2006) that in urban areas "air pollution is now mainly due to road traffic" (p.137). It is also established that children and old people are most at risk from road injuries as pedestrians, where young and middle age persons are more at risk as drivers or passengers. It is also reported (Jarvis et al., 1995) that deaths of children from lower SCs are over four times higher than those from the highest SC. So the relationship between health and transport would appear to be mostly negative, except for the health benefits of walking and cycling and ironically through access to green space.

2.5.10 Inverse Care Law

Access to healthcare services is also differential across space. Tudor Hart (1971), in his polemic, forwarded the argument that good medical care varies inversely with the need for medical care in the population. This is because doctors in less affluent areas have longer patient lists, are less well qualified, have less hospital support and are likely to inherit more ineffective consultation traditions when compared to healthier areas. The inverse care law is the operation of the invisible hand (the market), so where there is more reliance on private health care the differences between healthy and unhealthy areas are more apparent. It is hard to argue against the pros of universal healthcare coverage (UK), compared to negatives of selective healthcare coverage (USA). More recently, Watt (2002) has argued that "as affluent groups accrue the public-health benefits of effective clinical interventions, the perverse effect of evidence-based medicine will be to increase inequalities in health" (p.253). Furthermore, Watt (2002) argues that "we need policies that will make a difference and resources to ensure that good medical care is provided where it is most needed" (p.254). The inverse care law is likely to play a role in Scotland, due to the prevalence of deprivation in certain areas as discussed previously. This could usefully extend to a general inverse 'needs' law whereby as a population declines, resources and revenue decline and so a dangerous downward spiral begins, for example during de-industrialisation. The inverse housing law is also an aspect of this puzzle, discussed subsequently.

2.5.11 Inverse Housing Law

The inverse housing law is similar to the notion of the inverse care law; the need varies inversely with the requirement for housing. Poor housing quality, which is likely to be linked to poor environment or area, will also have an influence on the health of an individual and the accumulation of risk over a lifetime. It should

be obvious that poor housing combined with a lack of heating, insulation, basic amenities and so on, will lead to a reduced quality of life and have an impact on health outcomes. The use of housing as an indicator of wealth is important as the value of the house itself is a proxy for household income (and wealth) and therefore linked to SEP, which helps us understand why so many factors are interlinked and have a similar effect on health outcomes. Part of the solution is to improve the quality of social housing, so the difference between the housing sectors is less marked. In many respects, overcrowding, poor housing and lack of basic amenities are all sub categories of the measurement of deprivation. Moreover, if poor housing is associated with poor health outcomes, then it is likely deprivation will be also, as the phenomenon will be interlinked. Several studies have examined the inverse housing law, notably Blane et al. (2000) and Mitchell et al. (2002). In a study relating to the health effects of poor quality housing, Blane et al. (2000) note that "there is an inverse housing law in Britain and, on the balance of probabilities, it both damages respiratory health and contributes to social and regional inequalities in health" (p.748). In addition, Mitchell et al. (2002) found that their results "appear to confirm a genuine influence of area of residence on health" (p.837). This is of special interest in a Scottish context as Blane et al. (2000) state "areas of Britain that experience a poor climate are also characterised by poor quality housing, including Scotland" (p.746). So this is of particular relevance to this study.

2.5.12 Crime and Violence

The frequency (or even the perception) of crime and violence in an area is likely to lead to consequences for individual and population health. It has been observed that in more unequal societies there is more violence (Wilkinson, 2005). It is worth noting that according to research by Leyland (2006) there is a 'knife

culture' among some groups in Scotland, such that "homicide rates in Scotland have increased considerably over the past 20 years, particularly amongst young men, with the increase largely attributable to homicides involving knives" (Leyland, 2006, p.146). There are also spatial patterns, "rates in Glasgow (14.01 per 100 000) were nearly three times those in Scotland as a whole (5.38)" (Leyland, 2006, p.146). As crime is now accepted as a relatively normal part of everyday life in developed societies (Pantazis, 2006) does it follow a random or a stratified pattern? Arguably both, depending on the type of crime in question. The highest risk of burglary was for unemployed, social renting and low income households. On the other hand, vehicle related theft is more likely for high income individuals, but both poor and rich alike face the same risk for total violence (Pantazis, 2006). Another finding by Wilkinson and Pickett (2007) was that "there are ten-fold differences in homicide rates between more and less equal countries" (p.1976). This issue is explored further in the income inequality and psychosocial sections. In conclusion, violence, the threat of violence and crime more generally is most likely to result in poor health outcomes for the population in the area effected whether victims or not.

2.6 A Broader Perspective

The aim of the next section is to point to the picture more broadly, highlighting the international perspective, looking for generalizations, specific regional factors and specific countries which are similar to Scotland in some way. In other words, geography matters; the choice of areal unit (country, region, local authority) can influence the results. This problem (the modifiable areal unit problem, MAUP) will be returned to in the methods section (see chapter 3). The variety of studies in the literature at numerous different scales, enable generalisations to be made and general patterns to be illuminated and explained.

2.6.1 Worldwide Studies

Health inequalities are not just a UK phenomenon. The literature includes many European and the more developed countries as well as some of the Eastern European countries as discussed prior. A text by Boyle et al. (2004) documents and tries to explain health inequalities in the developed world, noting that "all developed countries display marked geographical variations in the health of their populations" (p.3) and in addition the gaps "have not lessened despite overall improvements in health and longevity". In the USA the health inequalities literature normally uses the term health disparities and focuses on racial differences as social class is not collected in the same way as in the UK. Worldwide studies on income inequality (Dorling et al., 2007) and health outcomes (Rigby and Dorling, 2007; Barford et al., 2006) use worldwide data in their analysis. The Reversal of Fortunes (Ezzati et al., 2008) traces the shifts in life expectancy in the USA by counties. It concludes that "between 1983 and 1999, male and female life expectancies had statistically significant decline in 11 and 180 counties, respectively" (p.560) showing that the 'gap' between the best and worst areas was widening, but also going backwards for some of the poorest counties in the US. The reasons given for increased mortality among females, was primarily due to smoking and to obesity, but relative poverty played a large role. The poor health performance of Scottish women is not unique in the developed world. On a different note, numerous studies of health in the USA (Ezzati et al., 2008; McDonough et al., 1997; Ebrahim et al., 2005; Kawachi et al., 1997), the USA and Canada (Daly et al., 2001), Japan (Marmot and Davey Smith, 1989), Australia (Mathers et al., 1999) and New Zealand (Tobias, 2001; Blakely et al., 2008) documenting health inequalities, discussed in some of the previous sections, which are a selection of the evidence that this is a problem in numerous developed countries.

2.6.2 European Studies

A study comparing the self-assessed health in ten (Finland, Sweden, Norway, Denmark, England, Netherlands, West Germany, Austria, Italy and Spain) European countries found a remarkable persistence in the nature of socioeconomic inequalities in self-assessed health (Kunst et al., 2005). Moreover, in these countries, "socioeconomic inequalities in self-assessed health showed a high degree of stability" (Kunst et al., 2005, p.303) and the relationships between income and health (lower income, worse health) and education and health (lower education, worse health) held, generally speaking, for all of the countries examined. In Eastern Europe Marmot and Bobak (2000) illuminated the decline in life expectancy and cited income inequality as an important part of the puzzle, and this may work because "autonomy may be an important factor related to inequalities in health among and within countries" (p.1182), proved using correlation coefficients. A regional study in Russia (Walberg et al., 1998) found that income differences again were very important in the decline of health. Other studies such as the edited text by Mackenbach and Bakker (2002) examine situations between European countries as well as within them.

2.6.3 UK Studies

Within the UK there have been numerous different types of studies exploring different aspects of health inequalities. One of the key geographical patterns is the widening gap (Shaw et al., 1999), the 'north-south' divide, the gap between the more economically prosperous, wealthier 'south' of Britain and the relatively poorer and less dynamic 'north' of Britain. In essence, the argument is that there are significant differences (gaps) between the 'north' and the 'south' which proliferate into all areas of life, for example employment, housing, health and so on. The precursor to a significant proportion of research in this

area was the Black Report (Black et al., 1980) that found that there were differences in morbidity and mortality that disproportionately affected lower SCs and which were allowed to fester and continue growing almost unchecked. In the Independent Inquiry into Inequalities in Health Report, (Acheson, 1998), states "inequalities in health exist, whether measured in terms of mortality, life expectancy or health status; whether categorised by socio-economic measures or by ethnic group or gender" which is uncompromising in stating that there is an urgent and growing problem that needs to be addressed. Other studies research includes a simulation of what would happen if Britain were more equal (Mitchell et al., 2000) and the wealth of other studies using data from England and Wales, Scotland and Northern Ireland (O'Reilly and Stevenson, 2003). So a wide range of evidence has been assessed and discussed. The breadth of the evidence base shows the importance of health inequalities, but there are still numerous gaps in the literature, particularly studies exploring Scotland as a separate entity in comparison to its neighbours. There is also room to utilise the longitudinal and numerous survey datasets much more to explore the role of a lifecourse approach to health inequalities.

2.7 A Theoretical Perspective

Making sense of the wide variety of underlying theories is difficult given the range of topics covered up to this point. However, there have been numerous references to the theoretical underpinnings already. It is inevitable that underlying the vast body of evidence is the author's theoretical approach to the subject. This section aims to highlight the important theoretical concepts in the health inequalities literature. As will be shown, "the fundamental tension is between theories that seek causes of social inequalities in health in innate versus imposed, or individual versus societal, characteristics" (Krieger, 2001, p.668). There are four models, or

schools of thought for explaining health differences according to Bartley (2004) namely; Lifecourse, Materialist (and neo-materialist) models, Psycho-social and Behavioural and Cultural. Each model is assessed in turn.

2.7.1 Lifecourse

Lifecourse approaches to health are an overarching approach to epidemiology. Davey Smith (2003) states "a simple model of lifecourse influences is that the accumulation of risk occurs, such that an adverse exposure early in life has an additive effect with later life adverse influences to increase disease risk" (p.xviii), in other words, events throughout the whole life of an individual (Davey Smith et al., 1997) have an influence on health as one ages. For example, it is noted, "social position across the lifecourse relates to health outcomes" (Davey Smith et al., 1997, p.xxxii) so that lower social position results in lower average health outcome. This means that one must consider the whole life of an individual to fully realise all the influences, which can influence health. As shown previously the literature (for example see Davey Smith et al. (1997)) to fully understand the aeitology of disease one needs to consider the full lifecourse of an individual as roots of current disease may be found in previous roles, areas, childhood and so forth. The lifecourse approach includes a "study of long-term effects on chronic disease risk of physical and social exposures during gestation, childhood, adolescence, young adulthood and later adult life". Additionally, it "includes studies of the biological, behavioural and psychosocial pathways that operate across an individual's life course, as well as across generations, to influence the development of chronic diseases" (Ben-Shlomo and Kuh, 2002, p.285). The critical period (Ben-Shlomo and Kuh, 2002, p.286) is an exposure acting during a specific period which has lasting or lifelong effects on the structure or function of organs, tissues and body systems which are not modified in any dramatic way

by later experience. Evidence also states that "factors that raise disease risk or promote good health may accumulate gradually over the lifecourse (Ben-Shlomo and Kuh, 2002, p.287). The lifecourse approach is a more holistic approach to the study of health, trying to gain as full an understanding of health as is possible, based on the past experiences and risks accumulated by individuals over their entire lives.

2.7.2 Material

The neo-materialist explanation is less about individuals and more about the experience of whole societies. There is a distinction, according to Bartley (2004) between the materialist and neo-materialist explanation of health inequality; the former is about "the relationship of income and what it can buy, to the health of individuals" the latter, "on the relationship of public provision such as school and transport to health of everyone in a country" (p.101). The neo-material explanation is that health inequalities are the result of the "differential accumulation of exposures and experiences that have their sources in the material world" and that health is effected through "a combination of negative exposures and lack of resources held by individuals, along with systematic underinvestment across a wide range of human, physical, health and social infrastructure" (Lynch et al., 2000, p.1202). The neo-material argument then is the easiest to grasp in one sense, as it relates to mostly tangible objects in the material world; it is easy to observe a 'poor' or 'rich' area. The materialist explanation was used by the authors of the Black Report (Black et al., 1980) who identified material factors such as car ownership and housing for example. The problem with using income is that income cannot have a direct health effect - it is more about what income buys that is important (Bartley, 2004). For example, more income may reduce exposure to hazards (pollution, poor housing, poor nutrition), or more

income could exclude individuals from physical risk.

2.7.3 Psychosocial- it's all in your head!

The psychosocial literature on health is strongly influenced by Wilkinson (Wilkinson, 1992, 1996, 2000, 2005) and also by Marmot (Marmot, 2005) who argue that rank, or position, in the social hierarchy are determinants of health. Oliver James (James, 2007b,a, 2008) has a similar vein of thought behind several of his books, arguing particularly in 'Affluenza' (James, 2007a) that the rise of this new disease, Affluenza, is linked to placing too high a value on various goals (money, fame and possessions) which ultimately lead to emotional distress. The psychosocial model is most focused on the psychological influences on individuals, for example stress, status, 'control' at work. The essence of this model is that "the brain is a crucial organ in generating the social gradient in health" (Marmot, 2005, p.20) over and above other factors. The 'risk' factors in this theoretical model include social support (or lack of it), control, autonomy, effort and reward balance and the balance between work life and home life (Bartley, 2004). This theoretical model was forwarded because of the inability of the behavioural and the material 'risk' factors to fully account for health differences. The most direct way in which the psychosocial model may work is by influencing the feelings of individuals by the social inequality which will lead to changes in their body chemistry (Bartley, 2004). In an evolutionary psychology perspective this means the 'fight or flight' (or 'tend and befriend') reactions to danger, threats in modern terms, stress (Wilkinson, 2000). This stress, prolonged over a long period of time may account for the health differences of different social groups. Those at the lowest end of the scale will exhibit higher blood pressure, higher blood fat levels, higher fibrogen levels (causing blood clots and increased heart disease risk) or increased cortisol levels (which increases the levels of fat

in the body), all leading to adverse health outcomes (Wilkinson, 2000).

2.7.4 Status Syndrome

There are also factors, which influence health outcomes through psychosocial mechanisms as alluded to previously. Marmot (2005) in his book 'Status Syndrome', states his hypothesis as, "where you stand in the social hierarchy on the social ladder - is intimately related to your chances of getting ill and your length of life" (p.1). This is a very neat summation of the very complex problem. What Marmot (2005) is arguing is that there has been a move, with economic growth in developed countries, from absolute income being the main predictor of poor health towards more psycho-social factors affecting a persons' health. Marmot (2005) also argues that "sustained, chronic and long-term stress is linked to low control over life circumstances" (p.109), which in turn, is linked to the resources a person has access to take control of the situation in the first instance. For example, a well educated, financially secure, confident person will be able to take control (rather than be controlled by events), compared to a poorly educated, insecure, financially struggling family. The psychosocial factors are demonstrated in everyday life as shame, disrespect, status and appearance. A study of prisoners found that one of the main reasons for violence was a perceived disrespect towards the perpetrator. A study in the USA (McDonough et al., 1997) found that downward mobility associated with a loss of income resulted in being unable "to retain ongoing consumption patterns and the psychological distress caused by lifestyle changes may compromise individuals' health" (p.1481). The mental 'shock' and adjustment may cause stress, affecting an individuals' health. A similar psychosocial mechanism is described by Wilkinson (2005) explaining why unequal societies may be more violent. He states "Where income differences are greater, then more people at the bottom are deprived of

the money, jobs, housing, cars and all the things that serve as markers of status and command respect" (p.151) which leads to an acute sensitivity of the individual being seen as inferior and becoming locked in a fight for pride and self respect with others. This is fittingly illuminated in an autobiography of a young black American explaining why violence is likely to have occurred in poor neighbourhoods and subsequently in prison (McCall, 1994). In terms of the effects that underlie some of this theory, Wilkinson (2000) argues that the flight or fight response is a central idea of the constant anxiety effect and that "what affects health is the individual experience of chronic stress arising from social anxiety" (p.59). This means that lower social ranking leads to a premature ageing of sorts whereby the individuals body is experiencing higher stress throughout their whole life. In more biological terms "higher fibrinogen levels are also more common in junior office staff, as if their subordinate positions put them at risk of physical attack from their superiors" (Wilkinson, 2000, p.48), which translates into a clear effect on health due to the hierarchical nature of societies. Fibrinogen is responsible for clotting the blood, for example, after being attacked. So what is becoming clear is that the position in society is central, and that the bigger the 'spread' of incomes (or of the different social groups) the more likely poor health (and violence) will be the end result for a significant minority of the population.

2.7.5 'Affluenza'

Affluenza, was a term coined by Oliver James (James, 2007a) who states that, "the Affluenza Virus is a set of values which increase our vulnerability to emotional distress" (p.vii). Furthermore, "it entails placing a high value on acquiring money and possessions, looking good in the eyes of others and wanting to be famous" (James, 2007a), which can lead to multiple negative consequences for

society. Somewhat interestingly, part of the puzzle is that "much to the consternation of social scientists, on average, regular churchgoers suffer less depression and unhappiness than unbelievers" (James, 2007a, p.20), perhaps because regardless of the religion, socioeconomic group, ethnicity and so on, the religion is the antithesis of the Affluenza virus. The situation in Britain is that almost "a quarter of Britons suffer emotional distress, such as depression and anxiety, and another quarter are on the verge thereof": a huge burden (and potential burden) of psychiatric morbidity. This is evident from a study by Andrews et al. (2005) who argued that "perhaps depression in the Western world will affect half the population during their lifetime, and have incidence peaks in the young and the very old" (p.496) and that it was the second biggest cause of the disease burden in the developed world. So this new virus helps to explain what could plausibly be causing such adverse health outcomes concurrently.

2.7.6 Control

Control is another risk factor recognised in the psychosocial model. A study in Russia (Bobak et al., 1998) found that "self-rated health and physical functioning were strongly associated with ... perceived control over life" (p.275), showing the importance of control as a risk factor. Marmot et al. (1997) showed that the largest contributor to the gradient in Coronary Heart Disease (CHD) in the Whitehall studies (of civil servants) was from low control at work. The findings of Marmot et al. (1997) add to evidence that "psychosocial factors are important in the aetiology of CHD" (p.239); in other words, to fully understand the causes of CHD (and illness more generally), a variety of psychosocial factors must be explored. On a similar note, the link between "low control and low socioeconomic status are separable" (Marmot et al., 1997, p.236); in other words, low control has an independent effect on health. A similar study of both East-

ern and Western European countries uncovered several notable findings. Firstly, "the importance of people's life control for their self-perceived health is shown to be very similar among the European countries, both west and east" (Carlson, 1998, p.1364). Secondly, that "an unsatisfactory economic situation is most clearly related to a worse self-perceived health" (Carlson, 1998, p.1364). This could have implications in Scotland, and during periods of recession for example. Interestingly, it is also noted that "people with less 'life control' tend to perceive their health as worse" (Carlson, 1998, p.1360). Overall, Carlson (1998) states that "Both life control and economic satisfaction were significantly stronger predictors of self-perceived health in Western Europe" (p.1364), than in Eastern Europe. So from the evidence, the effect of control is another important aspect of the health inequalities problem. Perhaps the most understandable example of psychosocial factors is that the death of one partner raises the risk of the other partner dying shortly afterwards. Another clue (Marmot and Bobak, 2000) is that "the difference in mortality between married and unmarried people" (p.1127) most plausibly because of direct psychosocial pathways affecting unhealthy behaviours, especially for men, less so for women. This sums up many of the methodological problems of capturing the psychosocial influences on health as they are not easily identifiable nor measurable, but clearly do have an impact on health outcomes.

2.7.7 Behavioural

Another theoretical model is the behavioural (or 'cultural') model, used to try to explain health inequalities. An example used previously (Townsend et al., 1994) shows that smoking is more common in the lower socio-economic groups, one of many such 'riskier' behaviours (for example a poor diet and excess alcohol consumption), that are generally more prevalent in lower SCs. As Bartley (2004)

explains, there is an assumption underlying some of the vast body of research in health inequalities that people in a low SEP with low control (over employment, income, status) are less endowed with particular characteristics (intelligence or resilience) which enable them to behave in a 'healthier' way or to succeed in general. The implication of this assumption is very controversial; an 'underclass' exists who either lack the intelligence or self discipline to know how to be healthy and that those in higher SCs are there because they are 'gifted', intelligent and self disciplined, or have some other kind of special ability. It has also been theorised that behaviours of particular 'cultures' may become habitual, by this it is meant a tendency to eat healthier food, exercise more, not smoke, drink moderately and so forth. The behavioural model then offers useful concepts on how the mechanisms that create health inequalities may operate, but the lack of concrete evidence exposing and documenting this is a weakness.

2.7.8 Alternative Theories

A slightly different approach is taken by Kunitz (2007) in his book entitled 'The Health of Populations'. He explains that there are two types of understanding in relation to health, to which he refers to as hedgehogs and foxes. This refers to the difference between someone who bases understanding on a central theory or a single central vision (hedgehogs) and those who understand many different, perhaps unrelated and contradictory themes (foxes). Kunitz (2007) argues that "there are exceptions to every generalization" and "rather than ignore them they must be embraced" (p.vii). This means that either the exceptions can be integrated into existing theory or, the existing theory must be modified or abandoned. This theme runs through the text and addresses many issues of health inequalities critically. There is also an interesting debate between the role of the institution and the individual influencing health outcomes. More-

over, there is the debate, known as the standard of living debate, on which two sides, the optimists and the pessimists pose opposing views on the advantages and disadvantages of a rising standard of living. The optimist will argue that rising standards of living are better for everyone, regardless of inequalities. On the other hand, the pessimists argue that the relative differences between individuals are important. Other research on 'the hidden assumptions' of health inequalities poses that "the assumption is that minimizing inequality trumps maximizing health" (Klein, 2000, p.570) and argues that research on health inequalities should not be used as a "battering ram for wider social reforms or, indeed, as an argument for changing the very nature of society" (p.570). Actually, this is probably fair comment given the suggestions for policy makers of some of the research reviewed, which tend to call for these type of measures. This brings us back to the underlying tension, those who argue that there is social causation going on, i.e. that 'structures' cause health inequalities, in the extreme case, capitalism is the cause. On the selection side, there is a sort of genetic argument that the unhealthy are selected into unemployment, unmarried and other undesirable states: the extreme view of which is that natural selection means the fittest should survive. Therefore, a wide range of theoretical approaches must be taken into consideration when explaining and researching the causes of health inequalities. Without a broad overview of all the main theoretical models and view on health inequalities it is difficult, if not impossible to ascertain why the author may have arrived at their conclusion.

2.8 Conclusion

This chapter has covered the vast amount of literature on the socio-economic and geographical determinants of ill-health and was designed to give a background to the analysis that will follow, both in terms of the data and methods

that will be selected and the substantive analysis chapters that follow. What can be deduced from the literature is that there are individual level determinants of health (micro-level) such as smoking or alcohol consumption as well as population level determinants of health (macro-level) such as income inequality or area deprivation which are important. So analysis of health must consider mechanisms that may operate at both extremes of the spectrum. The literature also points to which data and which specific socio-economic, geographical or demographic variables are important when studying ill-health. This chapter has focused heavily on completing an extensive survey and overview of the literature on health inequalities and social and spatial inequalities to provide a theoretical and empirical background, which was the first research objective of this thesis.

Chapter 3

Data and Methods: the raw ingredients of research

"Lies, damn lies and statistics"

(Mark Twain)

3.1 Introduction

This chapter discusses the wide range of data and methods which were considered for this research project. It sets out a description of each data or method and where appropriate details the pros and cons of the usage of a particular dataset of method. The various different types and sources of data for this research project are dealt with to begin with. This is followed by a similar exercise for the methods that could be used. The conclusions section at the end of this chapter will summarise and suggest the most appropriate data and methods to

address the research questions given the discussion that now follows.

3.2 Data Introduction

The first part of this chapter outlines the various sources of the data used and some technical details on each of the data sources. What data can be used to answer the research questions? Well, the research question determines what data will be required in order to be most useful in providing an answer. The research questions (see section 1.3, in Chapter 1) each require a slightly different approach. Firstly, the datasets that could be potentially useful in addressing each research question are discussed. Building on this section, the methods that could then be applied to answering the research questions given the data available are discussed in the next half of the chapter. The pros and cons of each type of data source (and subsequently each type of method) are also explored in detail. Those data sources most likely to be of use to this research project are also highlighted.

3.2.1 Cross Sectional Data

This section deals with cross-sectional data. Cross sectional data is data that has been collected at a particular point in time. The fact that it is collected at a point in time means that it provides a 'snapshot' of the population from which the data is derived. Each sub section deals with the potential sources of cross-sectional data that can be used to address the previously mentioned research questions. Cross sectional data is particularly useful for assessing metrics at a point in time such as the prevalence of an illness. This can be extended to monitor the trends between several points in time by using repeated cross sectional measurements. The disadvantage of cross sectional data is that because it is a 'snapshot' the temporality of relationships cannot be established, for example

did unemployment precede ill-health or vice versa. So causality is difficult to apportion with this type of data and this exercise is usually best avoided as the results are probably going to be misleading rather than informative and objective on such a question. There is also bias associated with this type of data as those who do not respond or are missed may be systematically different from those who do respond, for example respondents in a survey. On balance, cross sectional data usually provide a wealth of information which can be used for many aspects of public health research. Some of the potential cross sectional datasets considered in this thesis are now explored and discussed with relation to their potential application to this research.

Human Mortality Database: Vital Statistics

A principal source of data for comparisons between England and Wales with Scotland in terms of mortality, is the Human Mortality Database (HMD) datasets. This is essentially a collection of demographic data on mortality. The data derived from the HMD contains data for population and number of deaths, by sex and by single year of age, for the period 1925-2005, for England and Wales and Scotland. This type of historical data (back to 1925) allows longer term trends in mortality to be explored, potentially uncovering social and spatial inequalities in mortality. The data is available on line (see `http://www.mortality.org/`) and the HMD has a full methods protocol available (see Wilmoth et al. (2007)), detailing how the data has been constructed.

The United Kingdom Census of Population

One of the main sources of data should be the UK Census of Population for several key reasons which are outlined after a brief overview of the data source. The census has been conducted since 1801, when the population of Scotland was just 1.6 million, it had reached 5.1 million in 2001. Pragmatically, the

United Kingdom Census of population has easily accessible data for the years 1971, 1981, 1991 and 2001 (see `http://www.census.ac.uk/`) and provides close to universal coverage of the population of the UK. There are of course several problems with census data despite its strengths. As Martin et al. (2002) report "differences between censuses may be divided into four categories, namely; geography, variables, environment and access mechanisms" (p.83). The issues with geography relate to the fact that boundaries change over time and this creates issues in terms of comparability of areas post boundary changes. The variables included in the census, derived from the questions, may also change form such that the interpretation is not consistent over time. In addition, the body of questions may be added to or depleted such that variables appear or disappear at each census. The environment issue relates more to the societal and political attitudes present in a particular area. For example, with respect to income questions, for some this is an intrusion, for others it is not. Another problem is the way in which the data can be accessed, which has changed over time from paper to electronic. The main reason for using the census data would be the close to universal coverage of the population on a wide variety of socio-economic and demographic data for the UK. The main issue with census data, which relates back to the determinants of health discussed in chapter 2, is that there are both micro and macro level influences on health. So for example, the census does not provide the researcher with individual level data on ill-health for the whole population that would be useful in determining who, not just where and perhaps even why ill health affects some and not others. Another limitation of this dataset is that the data is constructed into predefined cross-tabulations which cannot be altered. The literature review discussed many of the key variables which determine health outcome, but if a cross tabulation between ill-health and a variable of interest is not available or cannot be con-

structed due to confidentiality, this problem cannot be addressed. This would suggest the need for an alternative approach, such as microsimulation for example. An additional problem is that if a variable is not recorded in the census, such as alcohol consumption, there is no way in which to explore this but to use an alternative datasource, or to combine the census with other datasources using microsimulation for example. The census is therefore a very useful building block for a spatial microsimulation model.

The Sample of Anonymised Records The Sample of Anonymised Records (SARs) are census based samples of individual records. The SARs are therefore a subset of the census. The 1991 individual SAR is a 2% sample. The 2001 individual SAR is a 3% sample of all census records. There are also household SARs and Small Area Microdata available. The SARs contain many of the standard census variables but for individuals instead of in an aggregate format. In this respect it is useful for overcoming the ecological fallacy, a problem related to conflating individual with area influences. The SARs data will have similar pros and cons to the census as it is a subset, but is slightly different in that it is a sample of a series of individual records rather than a 'complete' record of the population.

The Scottish Health Survey: SHS

The Scottish Health Survey (SHS) began in 1995 and currently has data available for 1995, 1998 and 2003. It will be running continuously from 2008-11. The SHS uses a clustered stratified multi-stage sample design. This survey design creates some issues in terms of larger standard errors than a simple random sample of the population. The first stage of the survey was to select the Primary Sampling Units (PSU) which were postcode sectors in this instance. Secondly, addresses within each PSU were selected. Subsequently, some PSUs were over

sampled because of low response rates. PSUs were ordered by Carstairs index (a measure of deprivation) and then a specific number were chosen in each health region. For a full description of the SHS methodology see (SHS). The primary aim of the study was to gain knowledge about the health of the population of Scotland which is what it will be used for in this context. It is cross sectional rather than longitudinal as fresh samples of addresses throughout Scotland are taken every survey. There is information in the SHS on physical activity, eating habits, smoking and drinking, blood pressure, obesity, respiratory symptoms and lung function tests, bloods, cardiovascular disease and its risk factors, general health, use of health services, prescribed medicines and dental health, psychosocial well-being, accidents as well as other standard measures. This data source provides a wealth of information from which to assess many aspects of health in Scotland and could potentially be compared to the England and Wales Health Survey and the Northern Ireland Health and Well-being Survey if this was a research question to be addressed. This dataset could be used to understand the first research question for example, which deals with the issue of illness in Scotland and its spatial location. It could also be used as a building block for a spatial microsimulation model as it contains a wealth of health variables and socio-economic and demographic information.

It has been noted by Leon et al. (2003) that using existing individual-level survey data, that are comparable for nationally representative samples of the Scottish population and other parts of the UK (with the primary aim of elucidating differences between Scotland and other areas of the UK) would be a worthwhile exercise.

Vital Statistics

Vital statistics, or Vital event statistics, are concerned primarily with the measurement of births and deaths. It is the death data which can potentially be

linked to lifetime health most closely as it could be used as a proxy for lifetime health as well as for the calculation of Life Expectancy measures. This data is collected within Scotland by the General Registrar Office for Scotland (GROS). It is straightforward to understand as it is simply counts of each event, usually broken down by age and sex. This kind of data would be very useful for exploring differences between groups of people between Scotland and other Countries as a Cross-National comparison, or comparing areas within Scotland, or comparing different groups of people by a particular socio-economic classification.

3.2.2 Longitudinal Data

This section deals with longitudinal data. Longitudinal data is fundamentally different from cross sectional data as it follows individuals over time rather than observing those individuals at a specific point in time. Longitudinal data allows the temporal relationship between exposure and outcome to be established, if such a relationship exists. Therefore any study which wished to determine whether or not there was a link between a particular factor and ill-health would benefit from longitudinal data. There are several disadvantages to longitudinal data, primarily the cost of collection, but also concerns about confidentially of the data when used for research. A further issue is known as attrition whereby individuals drop out of the data who may (or may not) be systematically different from those left in the study, which would introduce bias. Moreover, because individuals are followed over time, there is a lag between a study commencing and data being available to analyse.

The British Household Panel Survey

A further source of data could be the British Household Panel Survey (BHPS) which began in 1991 and runs annually. The British Household Panel Survey

(BHPS), since 1991 has tracked a representative sample of individuals over time, within households. The advantage of this data source is that it can be used for UK wide research as well as Scottish specific research. The disadvantage is that the sample size for Scotland is small (around 3,000 to 4,000), whereas the Scottish Health Survey has a larger sample and provides better information on individual health. For an overview of the layout and the pros and cons, these are discussed in a working paper by (Lambert, 2006) which provides in depth technical coverage which is not useful or necessary in this context for selecting appropriate datasets..

The British Birth Cohort Studies

Birth cohort studies, of which there are several, could potentially be useful in the Scottish context. There are the 1946, 1958, 1970 and 2000 British cohort studies, given various names at the time of their creation. Each study focused on different topics and therefore has a selection of different variables available to analyse. The strength of cohort studies is the following through time aspect which allows us to compare different types of individuals (perhaps based on socio-economic indicators) over time. In addition we can compare different cohorts, for example at the same at (but in different years) to see how life has changed over time for different groups of people. Each observation point is usually referred to as a 'sweep' with each of the cohort studies. This type of data requires a specific methodological approach, dealt with in the methods section.

1946 Birth Cohort

The National Survey of Health and Development (NSHD) began when all the births in England, Scotland and Wales that occurred in one week in March 1946 were included in this cohort study. This group of people (cohort) were then re-

peatedly observed over time to see how their lives progressed. This studies major strengths are that it has a "national and representative sample...repeated measures...extensive information, throughout life...high quality data" (Wadsworth et al., 2006, p.53). It has also been running for many years now so provides a wealth of data over time on lifecourse change. More critically, definition of poverty may have changed over time for example, so comparability of data through time may be problematic. Access to the data is also more complex compared with census data for instance.

1958 Birth Cohort

The National Child Development Study (NCDS) follows the lives of all those born in one particular week in 1958 over time using quantitative information. There have been 7 sweeps (plus the original data in 1958, sweep 0) in 1965, 1969, 1974, 1981, 1991, 1999-2000 and 2004. A full cohort profile also exists with Power and Elliott (2006) setting out the various measurements and variables collected at each stage. The strengths of this study include "the large study sample, extensive data coverage, eight ages studied, use of objective measures, and standardized tests or scales" (Power and Elliott, 2006, p.39). The cons include the comparability of measures over time.

1970 Birth Cohort

The 1970 British Cohort Study (BCS70) began in 1970, sampling all births in a specific week and then the individuals followed up with repeated observations on a variety of measures, these individuals over time to the present. To date there have been 8 collections of data (1970, 1975, 1980, 1986, 1996, 2000, 2004, 2008) with similar variables collected at each time point. This provides a wealth of relevant information with which to explore health over the lifecourse of a subset of Scottish people since 1970. The main disadvantage is that these individuals

are age 38 (in 2008) so necessarily, only up to this point in the lifecourse can be explored. Like the other British cohort studies there is a fuller description in the cohort profile Elliott and Shepherd (2006). For brevity a full list of variables and methodology is omitted. This data source is a possibility but will only be able to uncover health influences up to age 40 or thereabouts at this point in time, thereby missing a significant proportion of Scottish population.

2000 Birth Cohort

Millenium Cohort Study (MCS) was instituted in the year 2000 as the name suggests. To date there have been four sweeps (Hansen, 2010): in 2001-2 (MCS1); 2004-5 (MCS2); 2006 (MCS3); and 2008 (MCS4); as well as a future sweep planned for 2012 (MCS5). This is a UK wide study, including births in Northern Ireland. The main problems are similar to the BCS70, in terms of limited time coverage, such that the children are only 11 (in 2011). As this study is relatively new in longitudinal terms not a lot can be explored in terms of lifecourse events, only childhood influences. However, this is a major strength of the MCS as exploring early influences on health with the wealth of information that has been collected so far is possible. It is not desirable to use this study due to the time consuming nature of data analysis combined with the problem that this study will only shed light on children up to 11 in Scotland, so omitting the whole adult population.

The Scottish Longitudinal Study

The Scottish Longitudinal Study (SLS) is one of the primary sources of longitudinal data for Scotland. The Scottish Longitudinal Study (SLS) currently has data from the individuals census data with vital events, migration and National Health Service (NHS) data. This type of data includes longitudinal studies for England and Wales, and Northern Ireland with records for individuals, so cross

national comparisons would be possible. It is described in detail by Boyle et al. (2009) in a cohort profile. It is designed to be a "nationally representative 5.5% sample of the Scottish population" (Boyle et al., 2009, p.386). Its strengths are that "relatively rare health events can be studied" as well as "subpopulations" or "contextual effects" (p.390) which can also be studied. The main weaknesses are that there is little information between the key census collections (every ten years) and the information is restricted, so requires specific access arrangements (Boyle et al., 2009). However, it is still a very useful dataset for analysing Scottish health, although only two points in time are present in the dataset at present.

3.2.3 Panel Data

Panel data is data which contains observations on multiple variables observed over multiple time periods for the same set of individuals. A further distinction commonly made is between balanced and unbalanced datasets. Balanced panel datasets refer to where values for each respondent are observed for each wave of the panel. Unbalanced panel datasets occur where there is not full information for every individual for every wave. This may be because of sample attrition, or in the case of international panel datasets, because some countries began conducting a panel at a later stage than other countries.

British Household Panel Study

This has been discussed in detail in a previous section. It is an example of a panel survey.

Table 3.1: Datasets

Dataset	Year	Description	Geography
Census of Population	1971,1981,1991,2001	Socio-Economic (SE) information on UK population	OA
Sample of Anonymised Records (SARs)	1991, 2001	Individual level census data	SARs areas
British Household Panel Survey (BHPS)	1991 to present	SE variables for households	LA
Scottish Longitudinal Study (SLS)	1991 to present	A collection of SE data on individuals	LA
1946 Birth Cohort Study (BCS46)	1946 to present	SE data observations for a cohort	SSR
1958 British Cohort Study(NCDS)	1958 to present	SE data observations for a cohort	SSR
1970 British Cohort Study (BCS70)	1970 to present	SE data observations for a cohort	SSR
Millennium Cohort Study (MCS)	2000 to present	SE data observations for a cohort	Region
Scottish Health Survey (SHS)	1995,1998,2003	Survey of the Health, with SE data	HB

lower level data is available under special licence Output Area (OA) Local Authority (LA) Standard Statistical Region (SSR) Health Board (HB)

3.2.4 Data Conclusion

What can be seen from the preceding sections is that there is a wealth of possible data that could be used, but not all the data sources discussed above are appropriate to address the research questions posed previously. Due to the bounded nature of a research project it is not desirable to discuss every possible source of data within the UK and Scotland, rather it is those with a particular health focus, or which contain important socio-economic or demographic data which are most useful to address the proposed research questions. The methods are now discussed as they relate directly to the data available

3.3 Methods Introduction

In this half of the chapter, the methods that could be used to provide answers to the research questions posed are explained and evaluated. Each method will be explained in turn, with examples of application where necessary, to demonstrate the usefulness of the particular method. Furthermore, each method will be justified with reference to research questions, relevant literature and the data to be used. The approach taken by the project will be quantitative due to the nature of the research questions to be answered (see Chapter 1.3). The proposed research will draw on a variety of standard statistical methods including; correlation, regression (linear, multilevel and logistic) and microsimulation. Additionally, more complex or less well known methods are also explored in this section. Other methods that could be used but have been rejected are Structural Equation Modelling (SEM), Survival Modelling and Agent Based Modelling (ABM) as they are unsuitable for answering the research questions or unnecessarily complex compared to the aforementioned methods. For example, SEM is a method which is similar to multiple regression. The advantage over

multiple regression is that it allows interpretation when multicollinearity occurs and that it is mainly useful for confirming models, but this adds unnecessary complexity. Survival modelling is another branch of the methods used, however it is more appropriate to a different type of data and research question, such as how long will an individual survive after diagnosis of cancer. ABM usually needs individual level data, so requires microsimulation (in this research context) to model a whole system, for example the modelling of disease epidemics (Huang et al., 2004). Therefore, it is not desirable or necessary to use a method which will add little, if anything, to the research at considerable time cost.

The proposed methods will be chosen based on a careful and critical review of the literature. The data available will, to a large extent, determine the methods used. It is important to note that cohort studies require different methods compared to cross-sectional studies. Longitudinal data, e.g. the Scottish Longitudinal Study (SLS), can be crucial to establish causality (Menard, 1991), as the temporality of relationships between variables can be ascertained (e.g. does unemployment precede ill-health?) which is not possible with cross-sectional data. Longitudinal data does suffer from problems associated with bias, especially as those lost (attrition) over time may be systematically different from those remaining, although there are methods (weighting) to adjust for this problem. Cross sectional data, e.g. the census, can be used to measure prevalence or association between variables. This issue has been discussed in more depth in a previous section. The next step is to move onto explaining the possible research methods and assessing their suitability for use in this context.

3.3.1 Epidemiological Measures

Epidemiological methods have been developed to help measure the spread and burden of disease, so naturally lend themselves to the study and research of

population health. Briefly, some of the methods are described. When used correctly, these methods provide a comprehensive toolbox for measuring disease. The methods described below could be used as they are the benchmark for quantifying disease in epidemiology.

Incidence

Incidence is a measure of the number of new cases of a specified disease during a time period and there are three main methods for calculation of incidence which are now explored.

Cumulative Incidence (Risk) Cumulative incidence (or risk) is one of three measures of incidence. It is measured by dividing the number of new cases of a disease during a specific period by the total number of disease free people at the start of the period (Bailey et al., 2005), which is a proportion. This measure can be constructed using the equation (see equation 3.1), but it is also a dimensionless measure.

$$\frac{Number\ of\ new\ cases\ of\ disease\ in\ a\ specific\ period}{Total\ number\ of\ people\ disease-free\ at\ start\ of\ period} \tag{3.1}$$

Odds Ratio The odds ratio is one of the most common measures of disease. It is ascertained by dividing the number of new cases of a disease in a specific period by the number of disease free people at the end of the period (Bailey et al., 2005). Like cumulative incidence, the odds ratio is a dimensionless measure. A simple example of how to calculate the odds ratio is shown in Table 3.2. To calculate the odds ratio, (a*d / c*b), is the odds of illness when deprived compared to non-deprived. The interpretation of which is that if the odds ratio is greater than one, there is a greater odds of having a limiting long term illness in the deprived compared to the non-deprived and vice versa.

Table 3.2: Odds Ratio

Deprivation	Illness: Yes	Illness:No	Totals
Exposed	a	b	a + b
Unexposed	c	d	c + d
Totals	a + c	b + d	a + b + c+ d

*
To calculate the odds ratio: (a * d) / (c * b)
The odds of illness if deprived, compared to non-deprived

Incidence Rate The incidence rate is slightly more complicated to calculate, as it involves the person-time at risk, the exact amount of time each individual is observed for (Bailey et al., 2005). The incidence rate is obtained by dividing the number of new cases in a given time period by the total person-time at risk during that period. The result is expressed in person-time, e.g. 3 cases per 100 person-years. This method is not suitable in this context as it requires a specific type of data and research question.

Prevalence

Prevalence is the frequency of existing disease in the population. There are two measures of prevalence. Prevalence can be defined in terms of either point or period prevalence. This is a useful measure in this context as it allows quantification of the burden of disease in a population provided the data exists with which to calculate prevalence.

Point Prevalence Point prevalence is calculated by dividing the number of cases of a disease at a point in time by the total number of people a defined population at the same point in time (Unwin et al., 1997), resulting in a proportion. Point prevalence is defined as the "frequency of existing cases (i.e. of a disease) in a defined population at a particular point in time". The equation below (see

equation 3.2), shows how to calculate point prevalence per 1000 people. This could be used with cross sectional data such as the census or the SHS.

$$\frac{Cases\ of\ disease\ at\ a\ specific\ time}{Total\ number\ of\ people\ in\ population\ at\ a\ specific\ time} * 1000 \tag{3.2}$$

Period Prevalence Period prevalence is essentially the same as point prevalence, but over a period of time. Therefore, it is similar to point prevalence and calculated by dividing the number of cases of a disease during a period in time, by the total number of people a defined population at the same point in time (Unwin et al., 1997). More formally, period prevalence is the frequency of existing cases in a defined population "over a given period of time" (Bailey et al., 2005, p.19).

3.3.2 Correlation Coefficients

A correlation coefficient is a measure of the linear association between two variables (ranging from -1 to 1), -1 indicating a perfectly negative linear relationship, 1 indicating a perfectly positive relationship. The strength of the association between the two variables is indicated by the magnitude of the correlation coefficient, for example closer to -1 or 1 indicates a strong association, closer to 0 indicates a weaker association. This is a useful for summarising the strength of relationships between variables, but it cannot prove causality (Field, 2005). This technique has been used extensively, for example to show that income inequality and mental health and strongly positively correlated and income inequality and educational outcome are strongly negatively correlated (Wilkinson and Pickett, 2007).

3.3.3 Morbidity Measures

Aside from simple rates of illness and age standardised rates, Standard Morbidity Ratios, self assessed (reported) health and the General Health Questionnaire (GHQ) can all be used to measure illness.

Standard Morbidity Ratio

Standard Morbidity Ratios allow the researcher to compare the morbidity of a reference population (e.g. the national average) and the component parts of the national average (e.g. ward areas). The morbidity ratio controls for the confounding effect of age between different areas which is a major advantage of its use. It is very similar to the Standardised Mortality Ratio which is explored subsequently.

General Health Questionnaire (GHQ)

The General Health Questionnaire is used as a measure of mental health and well-being. The respondent will answer a series of questions which in turn leads to a score, which corresponds to various states of health. The score is usually on a scale from 0 to 12 (or to 28 or 36) and can then be grouped into three categories. A score of 0 indicates good psychological well-being or crudely speaking, 'happy'. Scores between 1 and 3 indicate a moderate psychological well being and finally scores of 4 or more can be considered a measure of poor psychological health. It has been shown GHQ is remarkably robust measure of mental well being (Goldberg et al., 1997), even internationally. GHQ has also been shown to be associated with deprivation or even the inverse care law as (Stirling et al., 2001) report "GPs working in areas of high socio-economic deprivation are faced with a higher prevalence of psychologically distressed patients" (p.460). So the GHQ score is a very important health measure and should be used if possible.

Self Assessed (Reported) Health

Self assessed health is recorded in the decennial census in the UK and various other surveys. Essentially, a question is asked of the respondent, who categorises their health, usually on a scale from Very Good, Good, Fair, Poor, Very Poor or some other similar system. It is also usual to find a similar question asking the respondent to indicate whether or not they have a limiting long term illness to which the respondent will answer yes, no or don't know. It is useful to assess the burden of disease, but may suffer from problems due to the subjective nature of the answer.

3.3.4 Mortality Measures

Life Expectancy

To calculate Life Expectancy (LE) two series of data are needed; population and the number of deaths (usually by single year of age and sex). LE is calculated using a life table derived from the population and deaths data and a hypothetical population (usually 100,000) with several specific calculations performed to calculate the LE. This may be different for each year and usually is reported as a 3 year average to avoid instability of estimates due to epidemics and so forth. There are several different methods for calculating LE which are not discussed here. For brevity the mechanics of the life expectancy calculation have also been omitted. The important point is that LE is a one number summary which can be used as a proxy for population health.

Standard Mortality Ratio

Calculation of a standardised mortality ratio (SMR) results in a one number statistic, where 100 is equal to the reference, 200 is two times and 50 is half the reference respectively. The mortality ratio, like the morbidity ratio, essentially

controls for the confounding effect of age between different areas which is the main reason for its use. The reference population chosen will therefore influence the resulting statistic. Choosing the reference population is usually a case of selecting a national population to compare to groups or areas within that population. The SMR is again a one number summary of the health of a particular group or area which is its main strength.

Lexis Diagrams

To visualise and analyse mortality (or morbidity) data a Lexis diagram, named after Wilhelm Lexis (Lexis, 1875), can be used. The Lexis diagram (or map) is one of the most useful technical devices of demography (Alho and Spencer, 2005, p.17). To interpret a Lexis diagram a few details need to be explained. The horizontal axis refers to time and the vertical axis refers to age group. The result is a series of coloured cells consisting of years (columns) multiplied by age groups (rows). Lexis maps are shaded contour maps that represent an array of demographic data over three dimensions (Gjonca et al., 2005, p.11). Each cell of the Lexis diagram represents a mortality ratio, which is the colour coded according to magnitude. The simplicity of the Lexis diagram is that in a single diagram a wealth of data is conveyed through coloured cells. Moreover, the reader can identify age, period and cohort effects. In the most simplistic terms possible, age effects are apparent as horizontal lines of the same colour, cohort effects are identifiable as diagonally upwardly sloping lines of similar colour and period effects are shown as vertical columns of a similar colour. The colour of each cell in the Lexis diagram is representative of the ratio of number deaths in X, over the number of deaths in Y, men and women are represented in separate diagrams. Therefore, a rate ratio of one would signify that the ratio is the same in X and Y. A rate ratio which is greater than one would signify a greater number of deaths in X than Y. Conversely, a rate ratio less than one would

signify a greater number of deaths in Y than X. The rate ratio is calculated by dividing the Age Specific Death Rates (ASDR) in X by Y, for men and women separately. The ASDR is the number of deaths by single year of age, divided by the population at risk for the same single year of age. Essentially, the ASDR is simply the mortality rate for a particular age group (Unwin et al., 1997, p.42). The other Lexis diagram that can be drawn is the sex ratio of mortality, the male rate ratio divided by the female rate ratio. The raw data has been smoothed using the geometric mean of the two preceding cells, the original cell and the two subsequent cells. This smooths the Lexis diagram that is drawn (Rigby and Dorling, 2007). The usefulness and simplicity that is inherent in the Lexis diagram justifies its use as a comparative tool.

3.3.5 Regression

Regression methods are a broad topic and contain methods which range in complexity from reasonably straightforward to technically complex. The regression methods used also depend to an extent on the type of data available or, the type of data that has been selected. Regression methods encompass a variety of different 'flavours' to essentially describe as simply as possible, a summary of relationships between variables, based on their particular characteristics and context.

Ordinary Least Squares (OLS)

Ordinary least squares (OLS) regression (or linear regression) is one of many tools which can be used to analyse, determine and predict relationships between variables (Lewis-Beck, 1980). The assumptions (shown in the list below) of regression either multiple or univariate, are similar and are usually assessed using regression diagnostics. The assumptions underpinning regression (see Lewis-

Beck (1980) p.26) mean that only data which fits these assumptions can be used in the process. Rigorous checks of linear regression assumptions are crucial as the assumptions are a key weakness if violated.

1. The model is linear in coefficients
2. The error term has zero population mean
3. Independent variables are not correlated with error term
4. The errors are statistically independent from one another
5. Error term has a constant variance (i.e. no heteroskedasticity)
6. The independent variables are not a perfect linear function of each other
7. Error term is normally distributed (optional)

Each independent variable should have a linear relationship with the dependant variable, which can be checked using the partial plots. The residuals must also be checked. The normality of the residuals can be checked using a Q-Q plot, looking for a diagonal line or alternatively with a histogram, looking for a normal distribution. Otherwise, a scatterplot can be used as a check of the standardised residuals looking for no systematic pattern that would indicate heteroskedasticity. Heteroskedasticity is linked to the assumption of the error term having a constant variance or non-linearity violations. In multiple regression, multicollinearity is detected using a correlation matrix, (values higher than 0.7 indicate potential problems), Tolerance (1- R^2) and Variance Inflation Factor (VIF), values lower than 0.1 or over 10 respectively, which indicate violations of any assumptions. Outliers can be detected using the standardised residuals values, (greater than three is a problem) or values of Cooks Distance. Greater than one indicate undue influence on the model. The Durbin Watson (DW) statistic reports if autocorrelation is present in the model. Values of DW between 1 and

3, (close to 2) are desirable. Rigorous checks of linear regression assumptions are crucial as the assumptions are a key weakness if violated. To evaluate the model, the R^2 value is reported, indicating how much variance of the dependent variable the independent variables explain. The adjusted R^2 value gives a better reflection of the true population value. The F-Statistic tests the overall significance of the model. For each independent variable its significance and coefficient can be reported and discussed to help assess various hypothesis. The beta values and semi partial correlation coefficients squared, indicate how much unique contribution each independent variable adds to R^2. In addition, small sample sizes also cause problems with generalisability (Tabachnick and Fidell, 2007). As a rule of thumb $N > 50+8m$ is the minimum (Tabachnick and Fidell, 2007),where m is the number of independent variables and N is the sample size.

Overall, regression is a very useful tool for quantifying relationships, so will be important to address the proposed research questions. It can be used to quantify and predict relationships between socio-economic variables and various health measures, for example seeing if socio-economic variables from the SHS influence the level of consumption of alcohol of individuals in Scotland.

Logistic Regression

Logistic Regression is used when the outcome (dependent) variable is categorical (Field, 2005) usually 0, 1 where 0 would be absence of disease, 1 would be the presence of a disease and one wishes to estimate the probability of an individual being either 0 or 1. Logistic regression "allows for the prediction of group membership when predictors are continuous, discrete or a combination of the two" (Tabachnick and Fidell, 2007, p.24). This is especially appropriate for the analysis of health as most variables measured, which relate to health, are categorical, (for example if the individual has an limiting long term illness or not). The use of logistic regression is necessary in these types of cases. Logistic

regression is similar to linear regression in the sense that it allows the modelling of relationships between a dependant variable and one or more independent (predictor) variables. This would allow the testing of questions such as "what are the main socio-economic factors relating to ill-health" for example.

It is also important to point out that independent variables can be continuous (e.g. income) or categorical (e.g. social class). The outcome of the modelling can be assessed using regression diagnostics (similar to linear regression). The way in which the estimated logistic regression coefficients are expressed is in exponentiated form as odds ratios. The overall fit of the model is assessed using log-likelihood. The significance of the variables is determined by the Wald statistic (and its significance)

Ordinal Logistic Regression Ordinal Logistic regression is used whenever the dependent variable is not binary (0 or 1) but is ordered in some way, for example 0,1,2 or a similar ranking (Kleinbaum and Klein, 2002). It is useful just to highlight this more advanced type of logistic regression, but due to its complexity and range of assumptions which must be met, it is technically and practically difficult to apply. This makes ordinal logistic regression an unlikely candidate method to use as questions can be answered in many instances by using less complicated methods which are easier to explain, interpret and understand.

Multilevel Modelling

Multilevel modelling (Goldstein, 1987, 2003) is a technique used for data which has a hierarchy, for example individuals (level 1) within households (level 2). The variance between households (level 2 variance) and between individuals (level 1 variance) can then be explored simultaneously quantifying the percentage variation in both allows us to understand the relationships (by level)

accurately. This structure can also be used to analyse longitudinal data for each individual (level 2), measured repeatedly (level 1), to assess the between individual changes (level 2) and within individual changes (level 1) over time (Singer and Willett, 2003). This method is especially useful for modelling area effects (Gould and Jones, 1996; Subramanian et al., 2005), which is especially relevant to the geographical determinants of ill-health. The negative aspects of this approach are the complexity involved in both analysis and interpretation. However, multilevel modelling is the most appropriate method for hierarchically structured data and so will be used. Multilevel modelling is particularly important for data which has a hierarchy, such as different geographical scales or repeated measurements over time. As Diez-Roux (1998) reports, processes of disease causation extend across levels and are likely to involve the interaction of individual-level and macro level variables (p.221) adding further evidence to the argument that both composition and context, as discussed in the literature review (chapter 2), are important in health outcomes. For this reason it is useful to use multilevel modelling techniques to fully explore and either concur with or refute this type of hypothesis. On balance, multilevel modelling suits a specific type of dataset such as hierarchical or longitudinal for example, and therefore a specific type of research question.

3.3.6 Spatial Analysis

Mapping

Simple descriptive mapping has been used as a tool to visually detect patterns in spatial data for some time. A useful historical example is Jon Snow's cholera map (see Figure 3.1) which visually plotted the specific locations of a cholera outbreak to determine the source of an outbreak. A more applied way of conducting such analysis is to map the locations of diseases in Scotland, to

Figure 3.1: John Snow's Cholera Map

determine if certain patterns can be seen in a similar manner. This is of course a descriptive method, so will only hint at possible causes or influential factors.

Moran Statistic

The Moran statistic, as explained in (Cliff and Ord, 1981), is a measure of spatial autocorrelation which produces one number that can be interpreted based on predetermined criteria. If the statistic is positive this indicates positive spatial autocorrelation and conversely if the statistic is negative it indicates negative spatial autocorrelation. However, like previous measures, sources of bias can be introduced through the choice of spatial weights, as this choice could be described as subjective. The Moran statistics main strength is that it summarises complex spatial patterns into a one number summary statistic.

3.3.7 Microsimulation

Microsimulation will be a key part of this body of research as it is most suitable for directly addressing the research question on 'what-if' policy analysis. This means that it is is discussed at length subsequently (see chapter 4). Briefly, microsimulation is a technique used to create (simulate) output data by combining, or merging various datasets to 'populate' and therefore create a 'new' synthetic population. This means that 'new' data is created which is as close as possible to the real population. Once the data has been simulated it is possible to analyse and interpret it in a variety of ways or to undertake further dynamic microsimulation modelling. Microanalytic simulation or microsimulation "attempts to reproduce or model the demographic, social or economic characteristics of human behaviour" (Clarke, 1996, p.1). Previous research (Mitchell et al., 2000; Ballas et al., 2007a) has shown that there is the potential to utilise this technique for 'what-if' policy analysis, as well as for the analysis of health inequalities (Ballas et al., 2006c), which are major strengths and supporting factors for choosing this method to build and explore a microsimulation model (MSM). Some of the technical detail surrounding microsimulation, and its various 'flavours', are discussed in chapter 4 as well as the empirical applications of this microsimulation modelling. On balance, the main issue with microsimulation is the validation of results and determining the reliability of results. Furthermore, microsimulation is a time consuming and complex method so implementing this methodology is challenging (Clarke, 1996; Orcutt, 1957). The main advantages centre on the 'new' data created at the microlevel which can be used for in-depth policy analysis. The advantages of microsimulation also include data linkage, re-aggregation, efficiency of storage and updating or forecasting (Clarke, 1996). So, for example, more than two datasets can be combined (data linkage); different geographies can be re-aggregated from the microdata

and there is also the potential to forecast policy scenarios into the future. This would be especially relevant and useful for answering the research questions in relation to policy.

3.3.8 Methods Conclusion

There are a wide range of methods that could be applied to potentially answer the research questions. It is imperative that methods are weighed up in terms of pros and cons before being selected to answer a particular research question. It may well be the case that certain methods are not perfect but are the best compromise given the data that is available. So in many ways methods will depend on access to data as well as the type of data that is available.

3.4 Data and Methods Conclusion

What has been demonstrated in this chapter is that to address the research questions appropriately a wide variety of data and methods must be brought to bear on the problems. The main method will be microsimulation which will make use of the SHS and census data to model the population of Scotland at small area level. Moreover, descriptive mapping, Lexis diagrams and regression analysis will also be used on the same two data sources. These decisions have been made after careful consideration of the data and methods discussed above. The census was chosen as it is the most comprehensive source of data available for Scotland. The SHS has been chosen as it contains detailed high quality health, socio-economic and demographic data which is crucial to address the research aim, objectives and research questions. Other data sources, for example the SLS and the cohort studies, were disregarded due to the significant restrictions on usage (SLS) and pragmatically due to the more complex methods required to analyse this type of data. Moreover, the cohort and longitudinal

data offers little advantage over cross-sectional data in addressing the research questions posed. In order to address the research question on the divergence between Scotland and England and Wales, the Lexis diagram method was chosen as this allows a complex set of mortality data to be explored over a long period of time and also to simultaneously examine the question of who is experiencing different patterns from the overall trend. An important aspect of addressing the question relating to prevalence will be to calculate the prevalence for diseases in Scotland. The most appropriate dataset for this is the SHS as it contains detailed information on specific illnesses. In terms of answering the research question on the location of illnesses, descriptive mapping will be used as it is the most appropriate and pragmatic choice. As part of the process of selecting constraints for a microsimulation model regression will be used to help assess the suitability and order of constraints. Microsimulation is also chosen due to its significant potential to address 'what-if' policy related research questions as well as the fact that there does not appear to have been any spatial microsimulation models built using SHS and census data to examine social and spatial inequalities in terms of health within Scotland.

So in summary, Lexis diagrams, regression modelling, descriptive mapping and spatial microsimulation will be the main methods used. The data sources will be mortality data for Scotland, England and Wales, the census and the SHS.

Chapter 4

Spatial Microsimulation: An introduction

4.1 Microanalytic Simulation: A (Very) Brief Introduction

As discussed in the data and methods chapter previously, microanalytic simulation or microsimulation "attempts to reproduce or model the demographic, social or economic characteristics of human behaviour" (Clarke, 1996, p.1). Additionally, research using microsimualtion has demonstrated the potential for 'what-if' policy analysis (Mitchell et al., 2000; Ballas et al., 2007a), as well as for the analysis of health inequalities (Ballas et al., 2006c). Some of the technical detail surrounding microsimulation and its various 'flavours' are now discussed in this chapter. Moreover, the empirical applications of this microsimulation modelling are also highlighted and discussed.

4.2 Spatial Microsimulation: An Introduction

Spatial microsimulation is a technique used to create simulated output data by combining or merging various datasets to 'populate' and therefore to create a 'new' synthetic population with an inbuilt geography. This means that the 'new' synthetic data is created which is as close as possible to the real population for a given set of geographical areas. Once the data has been simulated it is possible to analyse and interpret it. For instance, the microsimulated or synthetic data can be used in Geographical Information Systems (GIS) to draw maps of the 'new' variables created or as a starting point for further dynamic microsimulation modelling. The technique can be summarised as an 'upscaling' of data, for example, taking data from a survey (e.g. SHS), in order to match a series of constraint tables from a different source, e.g. the census output area totals for Scotland. The result is that the unknown census variables can be 'filled in' from the variables which exist in the survey data. This can be achieved using spatial (or geographical) microsimulation by iteratively merging census and survey data to create the data that will 'populate' areas (as opposed to creating just a 'national' population which would ignore the geographical element of the data, which would be aspatial microsimulation). This technique works by finding individuals in the survey who closely match the census constraints and then cloning these individuals so that there are enough to create a whole population for each small area. Furthermore, dynamic spatial microsimulation, which "involves forecasting key socio-economic variables into the future based on either current trends or on the consequences of different policy scenarios" (Ballas et al., 2006c, p.66), is a technique which has been used for applied policy analysis, but introduces a further level of complexity compared to static spatial microsimulation models. Moreover, in terms of microsimulation itself "little of this work to date has had a spatial dimension" (Clarke, 1996, p.1).

There are very few sources of geographically detailed microdata sets, so there is a need to create these datasets using static geographical microsimulation techniques (Rossiter et al., 2009, p.15). Microsimulation can be justified as it is not only a novel method of answering 'what-if' policy questions (see chapter 1.3), but also makes an original contribution to the existing literature in the field as well as allowing for interrogating the 'new' data created for applied policy analysis, answering previously unaddressed research questions on the health of Scotland.

4.3 Microsimulation Methodologies: Creating Microdata

The various methods of creating the microdata from the methodology can include "balancing factor methods in spatial interaction models .. linear programming models, discrete choice models to iterative proportional fitting (IPF) procedures" (Clarke, 1996, p.2). This shows that there are a variety of methods which can be used to produce the microdata as well as alluding to the level of complexity of possible modelling strategies. Other methodologies also include Simulated Annealing (SA), Combinatorial Optimisation (CO) and other reweighting approaches. CO is a method which can "attempt to reduce the error, relative to the constraints, to acceptable levels" (Voas and Williamson, 2000, p.354) of the output data. The method itself is "a stochastic process; the initial position is selected at random, as is every candidate household subsequently" (Voas and Williamson, 2000, p.354). The basic principle is "to select a combination of households ... that reproduces, in so far as is possible, the characteristics of a chosen" area (Voas and Williamson, 2000, p.350) so that estimates are as close to the real world situation as possible. The SA tech-

nique (Rosen and Harmonosky, 2005) is an optimisation method that attempts to introduce random (stochastic) components into a system. An SA procedure "would select a combination of ... households that would have ... characteristics as close as possible to the actual data" (Ballas et al., 2007b, p.2488). The overall aim of simulated annealing is "to minimise the total absolute error" (Ballas et al., 2007b, p.2488) of the data. SA is a form of CO, but also can be used for reweighting records in a survey for example. SA also involves a stochastic or a random number element.

Deterministic reweighting as a spatial microsimulation methodology is explained by Ballas et al. (2005c, 2007a). What this entails is "the reweighting of an existing microdata sample (which is only available at coarse levels of geography), so that it would fit small area population statistics tables" (Ballas et al., 2005c) such that the result is a 'new' microdata sample for each small area. As Anderson (2007b) simply explains the "weights represent the 'existence' of the corresponding household in the corresponding area" in other words "how many of that household type exist in that area" (p.11). This means that the original survey weights are recalculated to form a series of new weights that match a series of alternative constraints from a different source.

4.4 Microsimulation: The Flavours

This section aims to define some key types of MSMs to give the reader an idea of the differences between alternative approaches and the varying levels of complexity of each of the different microsimulation methodologies. It also alludes to the possible applications of each type of model which will differ slightly due to the type of model output. Describing the different approaches may also better illuminate which is the most appropriate to address the research questions.

- Static Microsimulation - This is the most basic type of MSM. In essence what happens is that "in static microsimulation, certain behavioural relations and institutional conditions of a microdata base of a certain time period are systematically varied" (Merz, 1991, p.79). In other words, a mirco-dataset is created and from this the policy analysis is performed for a given point in time. An example of this type of model is the TAXBEN (Giles and McCrae, 1995) model. This type of analysis (tax and benefit modelling) is particularly useful for 'macro' or national level policy impacts, showing the potential impacts by particular subgroups of the population but doesn't take account of spatial impacts.

- Static Spatial Microsimulation - a more advanced version of a static MSM with geography taken into account. This means that the spatial patterning of the model inputs and outputs are taken into consideration. In designing the model, provision is made for different areas to contain different numbers and types of individuals rather than a single 'national' population. The main difference is that unlike a Static MSM, the Spatial MSM is estimated several times for each area separately. So, it is an extension of the Static MSM in that the 'national' populations become the small area populations. In practice several separate MSMs are formed. This of course adds to the complexity of the model as it requires re-running an algorithm multiple times for each geography to be estimated. Static spatial microsimulation has been effectively used for some time, for example the work of Williamson et al. (2002) used this approach to forecast demand for water. Other examples include the Simulation Model for the Irish Local Economy (SMILE) which is a static spatial model (Ballas et al., 2006a) as well as the SimCrime (Kongmuang et al., 2006) model, showing that there is room for application in areas outside economics.

- Dynamic Microsimulation - a model is considered dynamic primarily when ageing is added to the model. As Merz (1991) states "in principle, the main difference between a dynamic microsimulation model and a static one is the ageing procedure" (p.81). So, the model is allowed to change over time, meaning that forecasts of present and future scenarios can be made. A static MSM, such as the two previous types, only allow for one point in time to be modelled, whereas a dynamic model will also allow the effects impacts of changes in policy over time to be modelled. The Dynamic Simulation of Income Model (DYNASIM) was one of the first models to begin the process of building a framework for this type of model (Orcutt et al., 1976). A further example of this type of model is CORSIM (Caldwell, 1997), which is discussed in greater detail in a later section. This type of model would be particularly useful for policies which change over the lifecourse; pensions analysis for example. Other dynamic models are discussed further in later sections of this chapter.

- Dynamic Spatial Microsimulation - is a dynamic MSM but with both a dynamic and a geographic element. In other words, this 'flavour' is a more complex version of both the static spatial and dynamic microsimulation models. Not only will the model change over time, but also across space. The task is to "create geographically referenced microdata and project them forward through time by simulating demographic processes" (Ballas et al., 2005b, p.158). The SimBritain model (Ballas et al., 2005a) is an example of a dynamic spatial microsimulation model. Another example of a national dynamic spatial microsimulation model is the SVERIGE model (Rephann and Holm, 2004) designed for analysis in Sweden. This type of model requires considerable resources in terms of model development and computing power. Most models of this type begin life as a more

simple static MSM which is then further developed into a dynamic MSM. On the other hand, the power of the dynamic MSM to predict changes into the future, or over time is a major feature of this type of model which may justify the considerable resource and time inputs. Dynamic spatial MSMs are therefore extensions of both static spatial and dynamic microsimulation models which brings advantages in terms of forecasting geographically but also negatives with respect to the resource intensive nature of building such a model and the complexity involved in doing so.

4.5 Issues: the good, the bad and the ugly

4.5.1 The main issues

The main issues surrounding microsimulation centre on the validation of results and their reliability as well as the time consuming nature and complexity of the methodology. Most of the technical detail surrounding MSMs would appear to be hidden in obscure technical documentation as noted by Williamson (2007). This means that understanding and implementing this methodology is a challenge. The other downside to the translucent nature of this field is that determining whether or not a model is reliable is a challenge.

Validation

One of the main issues with MSM methodologies is that it is a challenge to assess the reliability of the results objectively. This is because the main reason for using MSM is that the data does not exist elsewhere. This is a 'catch 22' whereby the validation of results from a model cannot be judged against other actual data as it does not exist as this is one of the main reasons for conducting microsimulation in the first instance. A MSM can be internally validated.

This can be done by comparing the simulated outputs of the constraints to the appropriate input constraints, which should approximately match and by comparing the last fitted constraint to its input equivalent which should fit perfectly (Anderson, 2007b). The procedure involves summing the output data from the 'micro' up to the 'macro' level, that is to say the level the constraints were input into the model and comparing the two series of data. For example, assuming the model is based on Output Areas (OA), whereas the constraint data is at Health Board (HB) level, this means one would aggregate the simulated data from OA to HB level and compare this to the constraints data (at HB level). This will give an indication of the fit of the constraint variables and would draw attention to caveats or anomalies in any model. The likely outcome should be a reasonable fit on average with a small number of outliers. The issue is dealt with by Ballas et al. (2005c) with a discussion on the importance of validating the small area comparisons pointing out that data estimated at coarser geography "is significantly better than the respective fit at the small area level" (p.87). Another caveat, discussed in Voas and Williamson (2001), is whether or not the validation should be more concerned with accurately predicting proportions or absolute values. Voas and Williamson (2001) conclude that "TAE or SAE .. offer a quick means of evaluating successive samples" (p.196). Note that the TAE, is the Total Absolute Error, which "sums the discrepancies" (p.190), in other words, gives a crude indication of how far the values are from the observed. This can be adjusted to calculate the Standardized Absolute Error (SAE) whereby the SAE = TAE / N, where N is the total expected count for the table (Voas and Williamson, 2001). This gives an overview of the main issues to consider when undertaking microsimulation model validation.

Choosing Constraints

A constraint is a variable which is present in all the input datasets to help with the prediction of a previously unknown variable within realistic bounds. Constraints ensure that the aggregations of the 'new' data totals match the appropriate constraint totals. The constraints must be common to both datasets, available at the appropriate level (e.g. individual) and a reasonably good predictor of the indicator at micro level and chosen geographical scale (Anderson, 2007b). In selecting constraints for the model it should be acknowledged that there is a degree of subjectivity and compromise. A detailed approach to the selection of constraints is set out by Anderson (2007b), detailing some important considerations when choosing model constraints. The constraints chosen can then be used for a MSM in each small area such that the outputs should closely match the corresponding constraint input totals. Anderson (2007b) also notes that the variables should be fitted from least important to most important (in terms of prediction) as the last variable "will necessarily be fitted perfectly" (p.12). There is some debate in the literature over the appropriate method of choosing constraints. The two main approaches are outlined in Chin and Harding (2006), using bivariate regression and Anderson (2007b), using nested multivariate regression. Anderson (2007b) states that it is important to "consider the candidate variables in a multivariate context" which should account for variables that become redundant and measures the 'pure' effects, whereas Chin and Harding (2006) opt to use a simpler approach, ranking variables in order of the R-squared values in bivariate regression. Additionally, one can make use of the literature to see which variables are 'good' candidate constraints from previous MSMs in a similar situation.

General Modelling Issues

Building a MSM is a complex task. Due to the time and resource intensive nature of the process choosing the appropriate platform (e.g. Windows, Linux, etc) and programming language can make a difference to computing time. As a general principle the idea of reproducible research (Koenker and Zeileis, 2009) is important as it requires self documenting reproducible code to be produced as a matter of course. This can then be re-run or debugged as becomes necessary. As building a MSM is a complex task, it is inevitable that considerable time and effort will be expended if the model is built 'from scratch' rather than purchased from a commercial company. Conventional software packages such as Microsoft Excel are not suitable for MSM in the main as they do not feature the correct functionality and processing power compared to the alternatives. A programming language such as Java, C++ or R may be more useful, as would Statistical packages such as SPSS, SAS or STATA which have the ability to run syntax. Previous models have been developed using a variety of the above mentioned software and programming languages. There is of course not a single 'right' approach, but rather it could be argue that there are a range of approaches to bear in mind and consider. Another aspect of building a model which requires thought, is the debate over the number of iterations, which to a large extent seems to depend on the data sources being used and the spatial scale. On the one hand, Ballas et al. (2005c) suggested 5 to 10 iterations, whereas Anderson (2007b) suggested 20 iterations. Two general points to bear in mind are that the outputs must remain stable and should of course be as accurate as possible. It could be argued that the stability of the outputs would negate the need for more iterations after a certain point.

4.5.2 Advantages of Microsimulation: the good

Some of the various advantages of microsimulation are now discussed in more detail. The applied aspect of a MSM is that it provides a very useful micro-dataset for policy analysis. As Merz (1991) states, because "microsimulation models are concerned with the behaviour of microunits (such as persons within a family/household/ firm), they are especially well suited to analyze the distributional impacts of policy changes" (p.77) as will be shown. There is a wealth of this type of analysis worldwide and examples of MSMs already in use demonstrate this. An example from the United Kingdom (U.K.) is the Institute of Fiscal Studies (IFS) analysis of the changes in the budgets, the TAXBEN model (Giles and McCrae, 1995), showing how various different groups will be affected by changes to Government fiscal policy. For example, showing the impact of working families' tax credit (Brewer et al., 2007) or child poverty patterns and the policies that effect it could be altered (Brewer et al., 2009a). It follows from the above examples that the research of health in Scotland is a worthwhile context in which to utilise a MSM, as Scotland has a variety of health issues (see chapter 2) as have been discussed in the literature review chapter. The MSM could then be used for applied policy analysis in order to predict the likely effects of changes to Government policy (whether positive or negative) for particular population groups or areas to determine which policy is the most suitable overall. This will be explored in much greater depth in the chapter outlining the microsimulation model (see chapter 6). Furthermore, previous examples of research using MSM have proven to be reasonably accurate and a valuable 'tool' for policy analysis. The main advantage of microsimulation is that it does not involve the very expensive and time consuming process of collecting data at small areas which is not feasible in the context of this research. The simulated variables for example, income or wealth, are not available elsewhere and this

allows gaps in health inequalities research to be addressed as Boyle et al. (2009) point out "studies that encompass the whole of Britain rarely have sample sizes that allow for Scotland-specific research" (p.386); microsimulation allows us to address this issue. Another advantage is that because published data does not exist for such small areas, it is useful to see a hypothetical population produced for these areas, especially for policy makers. Why simulation is useful is that a 'baseline' can be constructed in the form of a mircodataset, from which the effects of changes (usually in the form of policy changes) to the population can be quantified. In other words we can conduct a 'real-world' experiment within a modelling environment without the need to actually conduct a 'real-world' equivalent. The advantages of microsimulation are outlined in brief in Clarke (1996) namely; data linkage, re-aggregation, efficiency of storage and updating or forecasting. The data linkage issue relates to joining together multiple data sets, providing a breadth of coverage, in other words not being limited to just merging two datasets, but potentially merging together several relevant datasets to bring a wealth of data to bear on the model. The re-aggregation is an advantage as one can re-aggregate the microdata produced to any geographical scale. For example, once the micro data has been created it can be re-aggregated up to any other nested geographical area if required. Efficiency of storage is mainly a technical point, when compared with other types of models. The ability to update and forecast future changes is perhaps the most important point, as this relates especially to policy analysis. So, overall, the significant advantages the microsimulation modelling methodology can bring to empirical research with a focus on policy analysis in particular are numerous and justify the use of this technique.

4.5.3 Disadvantages of Microsimulation: the bad and the ugly

As alluded to, the main disadvantage is one which cannot be avoided but must be acknowledged, the reliability of the microsimulation outputs. There are several possible solutions to this particular issue as discussed previously. What becomes clear is that there are measures, or metrics, to quantify the 'fit' of the model, but the fact still remains that if accurate data existed to compare MSM outputs against there would be no need for microsimulation in the first instance. As Rossiter et al. (2009) point out, perhaps the most elusive aspect remains the concept of error. Even static spatial MSMs, those which model patterns or behaviours across space at only one point in time, will not produce exact matches when tested against independent data (Rossiter et al., 2009, p.16). However, on balance, a series of 'tools' exist with which to check the validity of model outputs. A potential disadvantage of microsimulation is the complex nature of the process and the computing power required (Clarke, 1996; Orcutt, 1957). Moreover, another disadvantage is that this is not 'real' data, it is estimated and as such is subject to bias. Microsimulation is also unsuitable for prediction of variables affected substantially by external and localised factors Ballas et al. (2005c). A drawback to producing, or for that matter updating microdata using random numbers, is that "different solutions for different sets of numbers random numbers" (Clarke, 1996, p.5), which may not be the desired outcome in certain situations. This could be a potential issue for those who rely on a single 'right' answer rather than a range of possibilities. The solution to this particular problem is to use a deterministic reweighting algorithm for example, which produces the same answer for each 'run' of the model, rather than a stochastic (random number) approach. Another issue with microsimulation, alluded when discussing constraints, is that the constraints are assumed to be good predictors

of the variable one wishes to predict at regional level and the national level. This may not always be the case, as the ecological fallacy would warn. In conclusion, the main issues to be aware of are the selection of constraints, measurement of error and the choice of reweighting method. All of which have possible outcomes, but with differing solutions for the final simulation results and the policy analysis that would follow.

4.6 Microsimulation Modelling Applications

In this section an overview of the variety of applications of microsimulation is given as well as some of the MSMs that have been developed are discussed in brief. A disclaimer should be made at this point, in that this is in no way a comprehensive list of models, rather a selection of the breadth of applications. A further source of information on modelling application is available online (see http://www.microsimulation.org/IMA/Population-based.htm). The selection of models in this chapter is designed to give a breadth of coverage of applications without listing every application. This is a pragmatic choice given that discussing every application may involve repetition of key issues or underlying principles. There are a variety of fields in which microsimulation has been applied. There is a need to discuss the very earliest models (such as DYNASIM) or the first of a 'type' of model (such as SVERIGE), to give an idea of what has been successful in microsimulation modelling. The series of models towards the end of this chapter are selectively highlighted as they are UK specific spatial microsimulation models with direct relevant to the research presented in this body of work.

The earliest models developed in the 1960s were rather limited in scope due to the relatively poor computing power in that era. The earliest models originate following the seminal work of Guy Orcutt (Orcutt, 1957), who proposed

a 'new type of socio-economic system'. Some early examples included static MSMs such as the Reforms in Income Maintenance (RIM) model, which was "developed to evaluate alternative welfare reform plans" (Michel and Lewis, 1990, p.109). This model evolved into the Transfer Income Model (TRIM) used "extensively for analysis of public welfare programs and the federal and state income tax systems" (Michel and Lewis, 1990, p.109). Applications of static and dynamic microsimulation for analysis of Government tax and welfare policy have a long history and therefore have been subject to considerable testing and refinement over the intervening period to the present. Spatial MSMs have been built for the analysis of numerous economic and social challenges in the UK including; smoking cessation (Tomintz et al., 2008), the economic impact of factory closure (Ballas et al., 2006b), income estimation in small areas of Wales (Anderson, 2007a) and England (Anderson, 2007c) and forecasting water demand (Williamson et al., 2002). In an international context, static microsimulation models for tax-benefit analysis exist in; Australia (STINMOD), the Netherlands (NEDYMAS; a dynamic cross-sectional model), Belgium (STATION), Canada (SPSD/M), Spain (GLADHISPANIA), the UK (POLIMOD) and the USA (TRIM) for example. Other models applicable to policy research include; MOSART developed by Statistics Norway (Fredriksen, 1998), the German Sfb3 (Sonderforschungsbereich 3) model which was the first major application of dynamic microsimulation in Europe, the Australian DYNAMOD model, the SMILE model developed for rural policy analysis in Ireland (Ballas et al., 2006a) as well as The Integrated Analytical Model for Household Simulation (INAHSIM), a microsimulation model for the population of Japan (Inagaki, 2008). This shows the wealth of geographical contexts in which microsimulation has been applied.

In the next section, some models in the field of microsimulation are discussed

in brief. Additionally, models which are relevant to the research that will be conducted are highlighted. The aim is to give an overview of the type of models which exist as well as strengths and weaknesses of each MSM.

4.6.1 DYNASIM

This model is referred to in the literature as the first dynamic MSM (Caldwell and Keister, 1996) and has been used as the basis for many more developments in microsimulation modelling. The Dynamic Simulation of Income Model (DYNASIM) was aimed at addressing a key type of question, if "policy makers are considering ... one spending policy as compared to some other spending policy, they should know what the consequences of ... policies under consideration are likely to be" (Orcutt et al., 1976, p.1). The model took around seven years to develop, showing the time and effort expended at the outset required to give consideration to individuals or households (micro units) rather than averages or aggregates (macro units) in a modelling context. The main issue would therefore appear to be the considerable resource required to build such a model. On the other hand, as this has been referred to as the first dynamic MSM, this is a reasonable explanation for the time taken to build a framework for any future analysis.

4.6.2 CORSIM

The CORSIM model is another key model in the field of microsimulation, a development that arguably made a series of crucial improvements to the DYNASIM model. This is because the model itself (Caldwell, 1997) has been the starting point for many of the models that exist today, such as those in Sweden and Canada, via the sharing of the machine code used to create the microdata. It is not explicitly a spatial MSM; rather it generates a synthetic longitudi-

nal dataset of families and persons, so is therefore a dynamic MSM. The main criticism is that there is no spatial element to the model which could provide additional useful information for policy analysis.

4.6.3 SVERIGE

Microsimulation has been used in Sweden to build a dynamic spatial MSM called SVERIGE (System for Visualizing Economic and Regional Influences Governing the Environment) which has then been the foundation for other analysis (Rephann and Holm, 2004). The type of analysis that has been performed includes the assessment of economic-demographic effects of immigration in Sweden (Rephann and Holm, 2004). It was the first national level spatial model of its kind, examining the spatial consequences of policy in Sweden. The model itself is based on Swedish households and generates events for individuals based on household and regional socio-economic variables which determine the probabilities in the model of moving from one state to another state, for example into marriage. The model is separated into 'modules', like many other dynamic models, which contain a series of specific functions, (for example a mortality module determines who is terminated from the model). The main feature of the model itself is that it has built upon previous models by adding a spatial element to the dynamic MSM. This makes the SVERIGE model a worthwhile example of the type of analysis that could be conducted in Scotland and demostrates clearly the usefulness of the technique.

4.6.4 DYNACAN

This dynamic MSM is another 'child' of CORSIM, which as previously mentioned was developed from DYNASIM. Among its uses the DYNACAN model is an attempt to assess the possible impacts of changes to the pension plan

on the population of Canada. It is an open dynamic longitudinal MSM, as it allows additions to the population through births and immigration over time. The model starts its analyses with a database that is representative of the Canadian population in 1971 and then extends this base population over time modelling a variety of characteristics. With such a complex model it has been noted that errors may propagate in such a way as to make the cause not readily apparent to the modeller. The model is primarily used within the Government of Canada. Many of the advantages and disadvantages of DYNACAN reflect those of CORSIM.

4.6.5 MOSART

MOSART is a model developed by Statistics Norway and is a "dynamic microsimulation model with a cross-section of the Norwegian population and a comprehensive set of characteristics" (Fredriksen, 1998, p.13). The purpose of MOSART is to make projections of population, education, labour supply and public pension benefits for the Norwegian population. The MOSART model begins with a "1 per cent random sample of the population of Norway in 1989 ... 40000 persons with actual information on marriage, birth histories, educational level and activities, pension status and pension entitlements" (Fredriksen, 1998, p.43). This shows the range of microdata which already exists, providing a solid foundation for the model to be developed from. The model was developed to help assess the impacts of an ageing population on the expenditure on public pensions, among other things. It has been reported that by using historical data the model performs reasonably well and that its underlying assumptions turn out to be correct. The model was first developed in 1988 (Fredriksen, 1998) and completed in 1991, which shows the length of time such complex dynamic models take to develop, a significant disadvantage. As the model has been de-

signed with sensitive data it is not widely available for use, mainly confined to Norwegian Government applications. On a positive note, the accuracy of the model and its usefulness have been demonstrated.

4.6.6 DYNAMOD

This dynamic MSM was developed at the National Centre for Social and Economic Modelling (NATSEM) in Australia. The model can be used to estimate "personal income taxation, household assets and superannuation" (Kelly and King, 2001, p.13) for example. It has been an attempt to produce an in-depth view of Australias population up to the year 2050 (Kelly and King, 2001) which is a considerable forecasting time frame. A drawback as noted by Kelly and King (2001) is that there is a "slower pace of acceptance for dynamic modelling ... given the greater complexity" (p.20) when compared to static MSMs. However, Kelly and King (2001) do note that "outcomes have plausibility, flexibility and transparency and they align with either real or user-defined outcomes" (p.21) which is a useful property of the model. Overall, the usefulness of the model is demonstrated post alignment to realistic values, however acceptance does appear to be an issue in this (Australian) context for some end users and the potential target audience.

4.6.7 STINMOD

This static MSM (again developed at NATSEM) has been used to create a synthetic income distribution. A description of the model itself can be found in Brown and Harding (2002). The purpose of this model was to develop a user friendly model which required no programming or mainframe computer to run. Its main use however, is to provide estimates of the immediate distributional impact of a proposed policy change (Brown and Harding, 2002) and to determine

the 'winners' and 'losers' under such scenarios. It provides the user with a system which simulates the payment of personal income taxes as well as the receipt of social security cash transfer (Brown and Harding, 2002) on Australian families. As Brown and Harding (2002) helpfully point out, microsimulation models are limited by their design, their assumptions and algorithms as well as data requirements, including STINMOD and its associated modules. On balance, the impact of policy analysis is again stressed as a major advantage.

4.6.8 NEDYMAS

This MSM was developed in the Netherlands to simulate social security benefits and contributions into the future. It is a dynamic cross-sectional MSM. The main strength of this model is that it can simulate the lifetime effects of changes to social security schemes in Holland. Nelissen (1993) notes that "from the simulation results it is clear that the model is able to reconstruct the long-term socioeconomic development at the macro level satisfactorily" and therefore the model is able to "simulate the social security benefits very well" (p.263). The model then appears to offer a 'tool' with which to analyse the Dutch social security policies which works well and has been validated against real data with success.

4.6.9 SMILE

The SMILE (Simulation Model for the Irish Local Economy) is both a static and dynamic spatial MSM which has been designed to address the possible impacts of policy change (Hynes et al., 2009) and of economic development on the rural areas of Ireland (Ballas et al., 2006a). The main thrust of the model is a core which simulates the components of population change (mortality, migration, fertility) at the small area level which can be projected forward over time. It

uses data from the UK Census of Population Small Area Population Statistics (SAPS) in Ireland. The static model creates a population at District Electoral Division level and assigns attributes to individuals which becomes the base population. This is then aged by adjusting the individuals fertility, mortality and migration characteristics (Ballas et al., 2005b). The errors in the model are calculated to be reasonable averaging between 2 and 3 percent at the county level. The SMILE model produced a useful set of disaggregated spatial data for Ireland which could potentially be used for much more policy and spatial analysis. The model has also been used to estimate visitor numbers (among other variables) for an outdoor recreation site (Cullinan et al., 2011). Another use for the model was to examine the emissions of methane gases from Irish farms with microsimulated data created using a simulated annealing methodology and combining data from the Irish Census of Agriculture and a National Farm Survey. This again shows the power of microsimulation, which can be applied to a variety of settings as well as the potential to expand a static model to different fields or to forecast future policy scenarios.

4.6.10 SimCrime

The SimCrime model was developed using the British Crime Survey and census data to create synthetic microdata for output areas in Leeds. This static spatial MSM used a simulated annealing method, which has previously been discussed, to create the synthetic data. This model was developed using the Java programming language to implement combinatorial optimisation using a simulated annealing based reweighting algorithm. The model itself allowed the production of new cross-classifications (Kongmuang et al., 2006) which would be unavailable from census data. The applied aspect of this model is that is now allows various aspects of crime, such as victimisation or propensity to commit

crimes, to be explored at small area level. The main disadvantage of this model is reported (Kongmuang et al., 2006) as the computationally intensive nature of the simulated annealing method itself. However, the results appear to be policy relevant and could be used for many other analysis.

4.6.11 Leeds and Bradford: Smoking Model

A relevant example to the UK is a MSM that estimates the smoking rates in the Leeds and Bradford areas using a static deterministic reweighting approach. The model uses the General Household Survey (GHS) and census data (Tomintz et al., 2008) to try and simulate the smoking rates for small areas using a four constraint model. The spatial static MSM has then been used in an applied context to try and determine the optimal location for a series of stop smoking centres within the study area. Overall, the model is a simpler, but no less policy relevant analysis which produces invaluable information to support decision makers at a regional level.

4.6.12 SimHealth

The SimHealth model is arguably the most comparable analysis relevant to this research context. It is similar to the smoking model described above as it covers the Leeds and Bradford areas. The data used is the census and the Health Survey for England data. The model predicts the prevalence of diabetes at small area levels (Smith et al., 2007). The model was validated using an unconstrained variable (i.e. a variable not used as a modelling constraint) which is a novel way of testing the error of the model. The core of the model was based on the SimBritain model (see section 4.6.13) which is explained elsewhere. The "deterministic method used to create the synthetic populations is a proportional fitting technique" (Smith et al., 2007) which creates the same data each time the

model is run. The model again provides a previously unknown set of variables at the small area level.

4.6.13 SimBritain

This dynamic spatial MSM has been developed using UK Census and British Household Panel Survey (BHPS) data. This is one of the few attempts to apply spatial dynamic microsimulation specifically in the UK. The SimBritain model used a deterministic reweighting approach to create microdata, which essentially adjusts the existing survey weights to fit census totals for each of the desired geographical areas. The SimBritain model is used for "what-would-have-happened-if scenarios for the period 1991-2001" as well as to "project the population microdata-set in different ways for each year up to 2021 under these future oriented what-if policy scenarios" (Ballas et al., 2005a, p.32) which could give policy makers an indication of the impacts of policy changes in the UK. The type of policy analysis that has been undertaken with this model includes minimum wage, child and working tax credits as well as winter fuel payments impacts. This model provides a useful template of what could be possible to undertake in a Scottish context. The considerable time and resource which went into building this model could not feasibly be harnessed in this research study. The results from this model show that the error is again low and provides further strengthening evidence for the use of microsimulation methodologies in a UK context.

4.7 Conclusions

Microsimulation is an established method in many fields of the social sciences, whereas spatial microsimulation is still relatively underused (Clarke, 1996) in many respects but the literature and empirical research (as discussed above)

has shown the potential for this method to be applied in a Scottish context. However, there does appear to be many useful situations which use MSM for policy analysis, a major strength of this approach. On the other hand, the disadvantages of validation issues must be taken into consideration. In a Scottish context there is a lack of any model which uses the SHS data and furthermore there is a dearth of any health related microsimulation within Scotland. Models such as SimBritain do contain a Scottish element however. At present there would not appear to be a Scotland specific spatial MSM which addresses health specifically. The suitability of microsimulation for analysis of tax-benefit changes is supported by a large body of literature and empirical research as has been shown in this chapter particularly. There is also a body of work to support the use of spatial microsimulation in applied policy analysis in a variety of fields and contexts. The more recent models include dynamic spatial MSMs which are complex due to the variability of time and space simultaneously, so may not be the most appropriate given the time constraints of this project. So as mentioned in the DYNASIM section, the model took seven years to develop. Given this scenario, using a dynamic microsimulation approach is arguably not the right choice given the time and resource constraints even though computing power has increased. It is preferable therefore to opt for static models. Moreover, as the research questions, aims and objectives have clear spatial elements, the use of spatial microsimulation, although complex, would be a very suitable and appropriate choice for addressing these type of questions. So, given the arguments set out above, the most appropriate 'flavour' of microsimulation would be static spatial microsimulation. Future research could also incorporate a dynamic element. The use of deterministic reweighting seems to be an appropriate 'flavour' of MSM for policy practitioners as it allows the same results to be produced consistently (Ballas et al., 2005c). The use of random (stochastic) components

in a model may well confuse the issues if the outputs are marginally different after each iteration. It is therefore appropriate that spatial microsimulation should be used as a method to determine the impact of policy changes on the population of Scotland at small areas given the research questions posed at the outset. This overview has shown the potential for spatial microsimulation analysis of the health of Scotland as there is a hiatus of this type of application thus far in the literature. Models in similar contexts worldwide have illuminated why microsimulation in all its 'flavours' is worthwhile as an empirical research method as well as the specific additional usefulness of spatial microsimulation, particularly for policy analysis.

Chapter 5

The health landscape: past and present

"Be careful about reading health books. You may die of a misprint"

Mark Twain (1835 - 1910)

5.1 Introduction

This chapter is about setting the scene in terms of the health of the Scottish nation. The main thrust of this chapter is a macro level analysis of health before exploring a micro level aspect in the policy analysis chapters. It is spilt into two separate, but closely linked halves. To do this an analysis of historical trends in health and mortality (as a proxy for lifetime health) is forwarded and discussed,

then a more current (2003) state of Scottish health is explored, illuminating the burden of disease and its location. The mortality aspect of the health divide is explored first as it is likely this would illuminate when and where differences emerged within Great Britain (GB). This is done by comparing the mortality of Scotland with England and Wales, often described as the 'sick man' of Europe in terms of health, but the question remains, was this always so? Moreover, a descriptive analysis of illnesses in Scotland more recently is forwarded to give a broad description of the types of illnesses that affect the Scottish. Descriptions of the most prevalent illnesses and their spatial distribution are also explored. In other words, which illnesses are most common and in which areas of Scotland? This gives an overview of the focus of this chapter.

5.2 Data and methods: In brief

The data used has been derived from the Human Mortality Database (HMD) as discussed in chapter 3. Mortality data is used as it has been shown to be a good proxy of health and vice versa (Idler and Benyamini, 1997). The data derived from the HMD contains the death rates for England and Wales and Scotland by single year of age and sex respectively for the time period 1925 to 2005. The HMD has a full methods protocol available (see Wilmoth et al. (2007)), detailing how the data has been constructed which is not discussed here for brevity. The sample in 2005 includes: 2,456,109 Scottish men; 2,638,691 Scottish women; 26,096,092 English and Welsh men; 27,142,483 English and Welsh women; a total sample size of 58,333,375 people.

The Lexis diagram, or map, is "one of the most useful technical devices of demography" (Alho and Spencer, 2005, p.17). To interpret the diagram a few details need to be explained. On the Lexis diagrams, the horizontal axis represents the years from 1925 to 2005. The vertical axis represents age group,

from age 0 to age 90 or greater. There are coloured cells consisting of years (columns) by age groups (rows). Lexis maps are "shaded contour maps that represent an array of demographic data over three dimensions" (Gjonca et al., 2005, p.11). Each cell of the Lexis diagram represents a number; for example, an ASDR or a mortality rate ratio which is then colour coded according to magnitude and shown on the scale. The rate ratio is calculated by dividing the Age Specific Death Rates (ASDR) in Scotland by England and Wales, for men and women separately. The ASDR is the number of deaths by single year of age, divided by the population at risk for the same single year of age. Essentially, the ASDR is "simply the mortality rate for a particular age group" (Unwin et al., 1997, p.42). The use of Lexis diagrams enables us to easily identify possible age, period and cohort effects. In the most simplistic terms possible, age effects are apparent as horizontal lines of the same colour, cohort effects are identifiable as diagonally upwardly sloping lines of similar colour and period effects are shown as vertical columns of a similar colour.

Applying this method required suitable data and software. The data transformation and analysis was undertaken using the statistical software R (R Development Core Team, 2010). The data collected and created allows the construction of graphs of age-specific mortality rate graphs (see Figure 5.1) as well as the construction of Lexis diagrams (Lexis, 1875) of mortality rate ratios or ASDRs, which were drawn using Lexis map software (Andreev, 2002) by adopting a similar approach to a more general study of mortality in relation to sex in the affluent world (Rigby and Dorling, 2007).

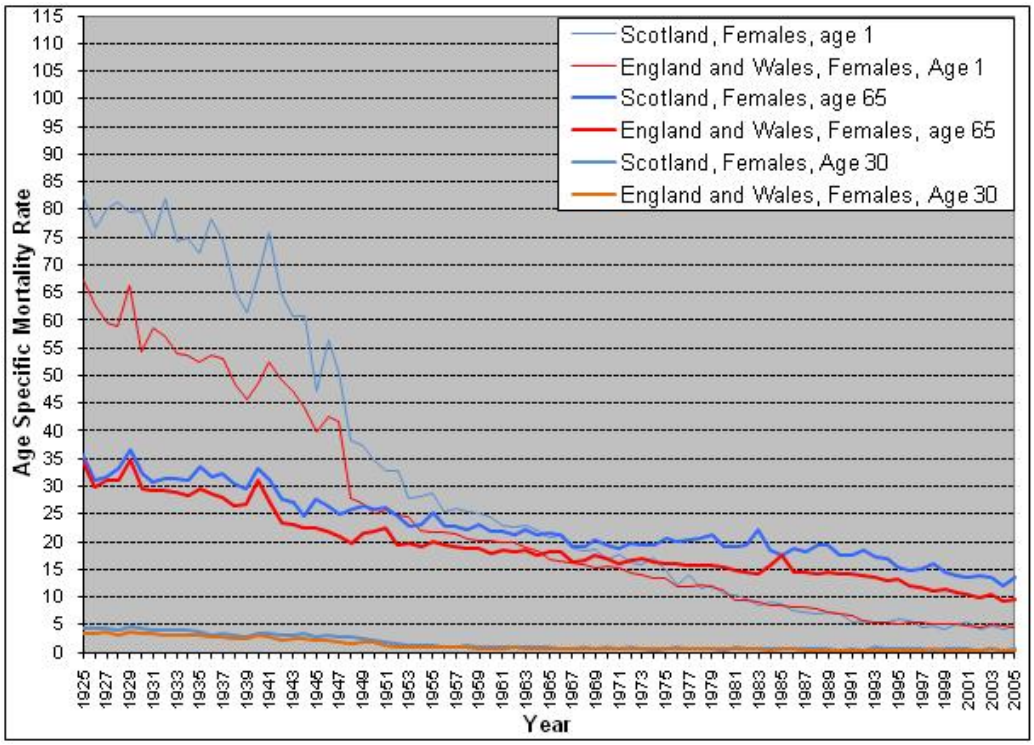
Also utilised in this chapter is the descriptive mapping technique outlined in the methods chapter (see chapter 3). The descriptive mapping is undertaken using Scottish Health Survey (SHS) data which is weighted to refelect the Scottish population. This can also be used to calculate prevalences of specific illnesses

and therefore answer questions on which is the most prevalent.

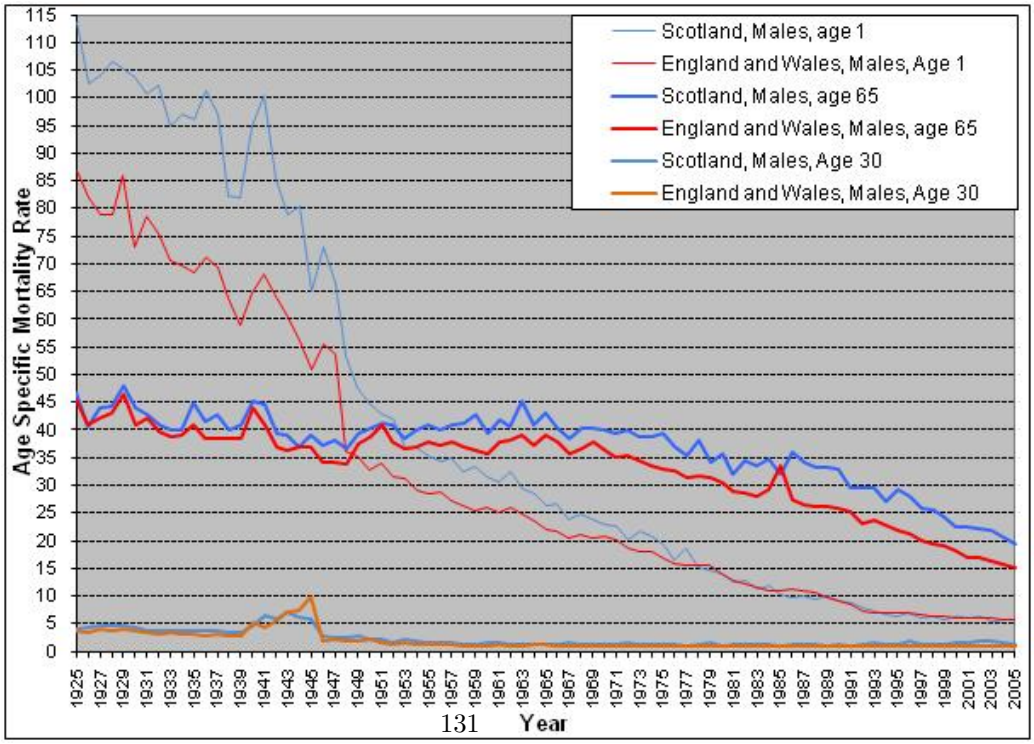
In summary the Lexis diagram will be used on historical mortality data and the SHS 2003 will be analysed using a descriptive mapping technique.

5.3 The historical health context

Without reiterating much of what has been discussed in the literature review (in chapter 2), it is necessary to give some context for the analysis that follows. There have been numerous studies of Health Inequalities in Britain examining gender differences,(Rigby and Dorling, 2007; Gjonca et al., 2005; Kruger and Nesse, 2004) differences between socio-economic groups (Black et al., 1980; Acheson, 1998) and differences between areas at different geographical scale (Mitchell et al., 2000; Howe, 1970). Several of these studies highlight the differences between regions and nations (Townsend et al., 1988; Mitchell et al., 2000; Dorling, 1997) within Britain and suggest the existence of a North-South divide in health, (Shaw et al., 1999) that reflects a wider social and economic divide, a divide which has been widening. The analysis presented in this chapter explores the mortality aspect of this divide through a comparison of historical trends in mortality between Scotland and England and Wales. The historical pattern of mortality in Britain has been researched and mapped in detail and it has been pointed out that "between 1950 and 1985 the standard mortality rate for Scotland, relative to England and Wales as 100, never fell below 111 or rose above 112" (Dorling, 1997, p.27). In this study we build upon this previous body of work by investigating and visualising historical trends in male and female mortality in Scotland and comparing this to England and Wales.

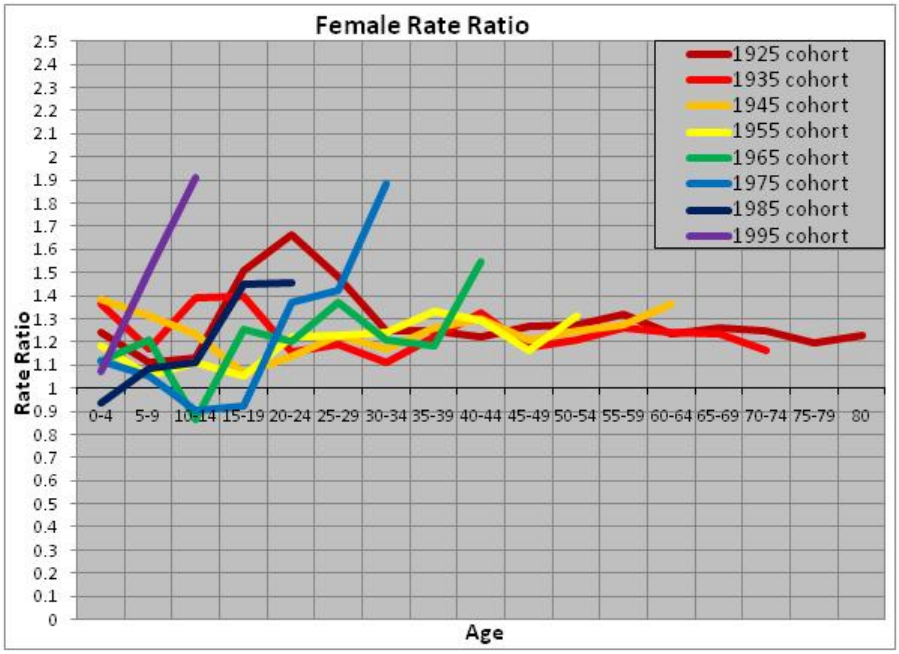


(a) 1a Mortality,Females, Specific age groups

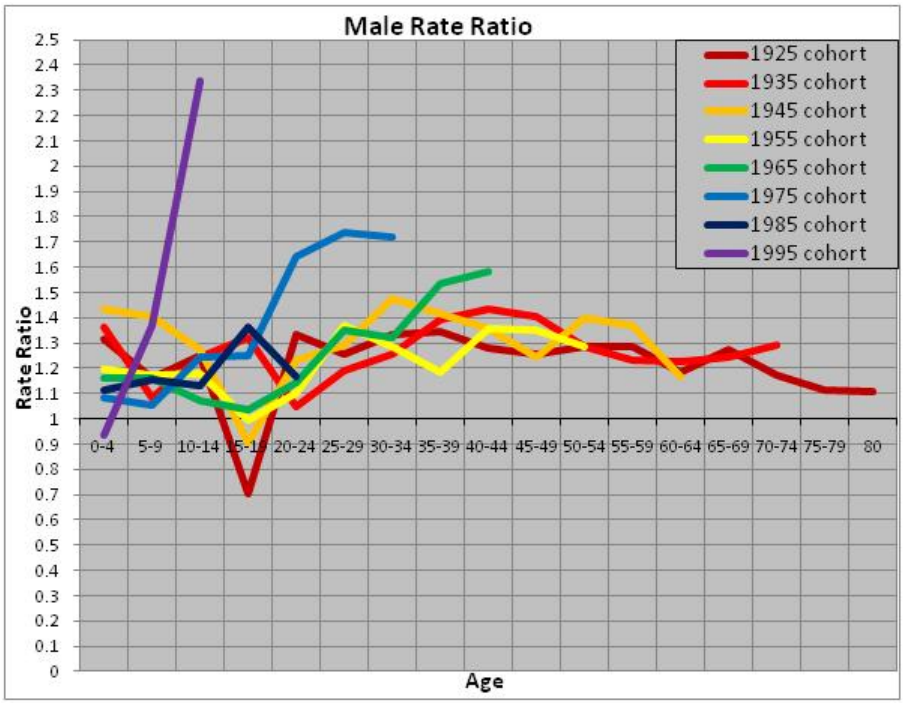


(b) 1b Mortality,Males, Specific age groups

Figure 5.1: Age Specific Death Rates

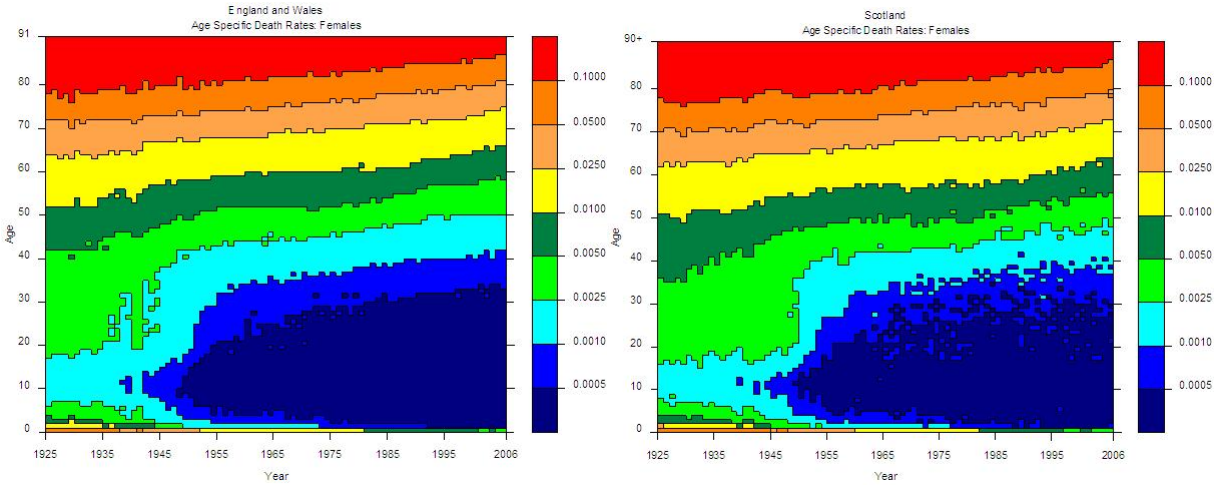


(a) Cohorts, Females, 1925-1995



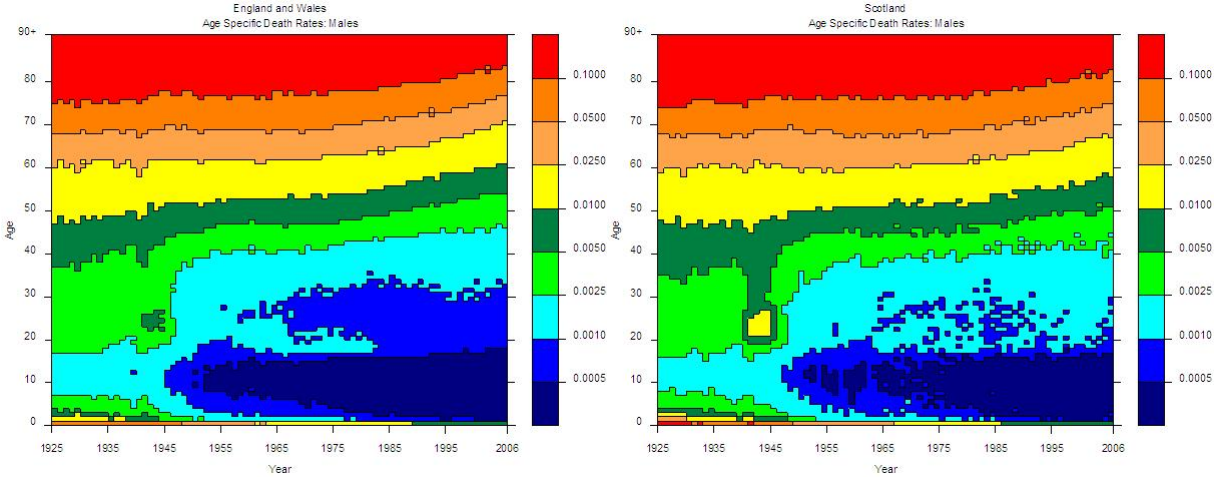
(b) Cohorts, Males, 1925-1995

Figure 5.2: Rate Ratios



(a) Age Specific Death Rates in England & Wales (Females)

(b) Age Specific Death Rates in Scotland (Females)



(c) Age Specific Death Rates in England & Wales (Males)

(d) Age Specific Death Rates in Scotland (Males)

Figure 5.3: Age Specific Death Rates

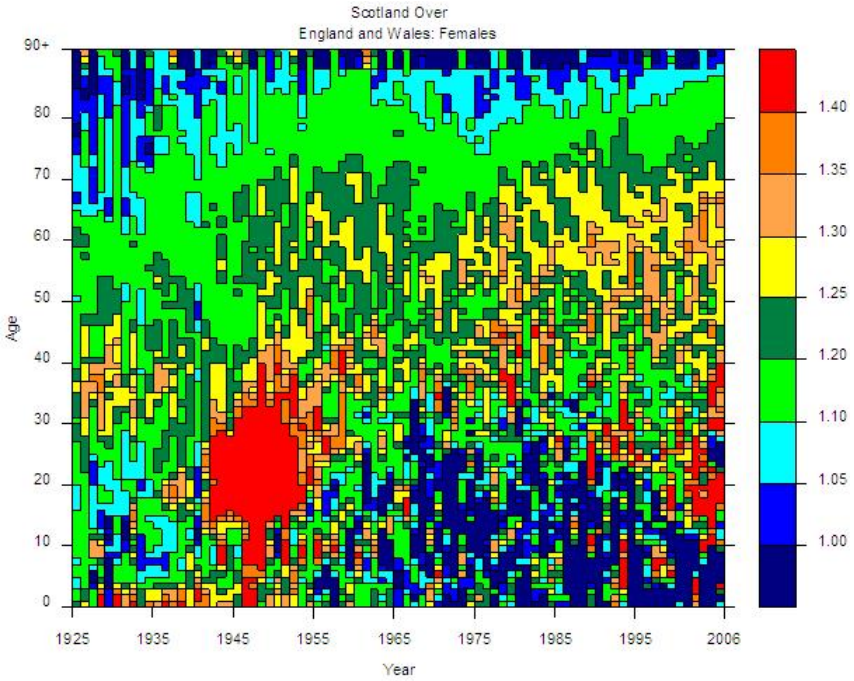


Figure 5.4: Rate Ratio: Scotland over England & Wales, Females, 1925-2005

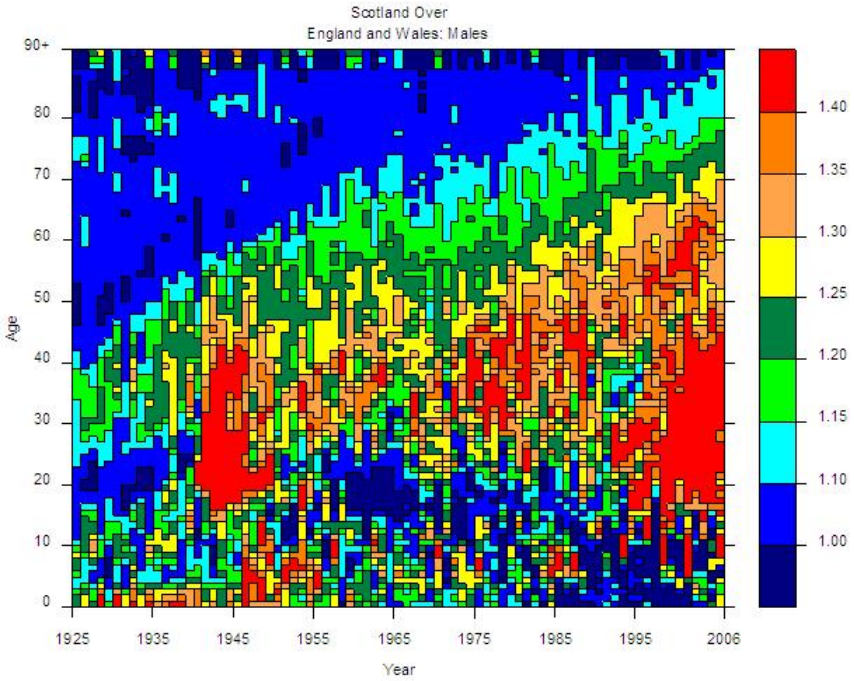
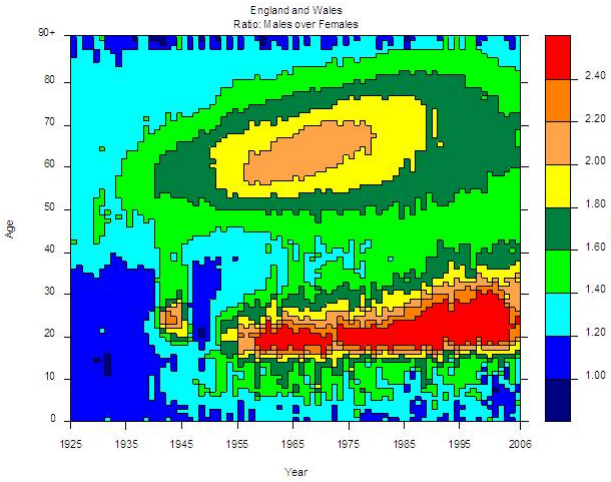
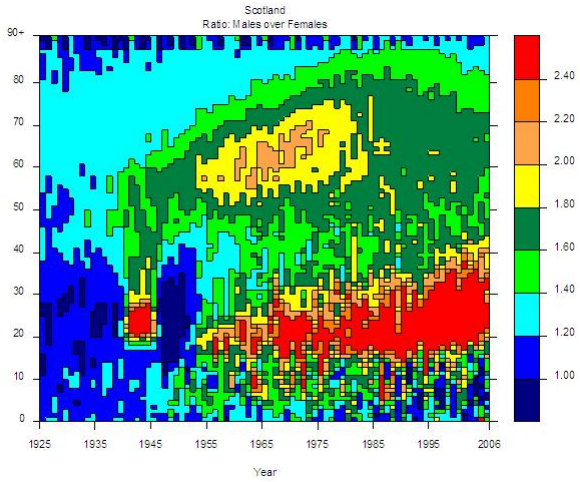


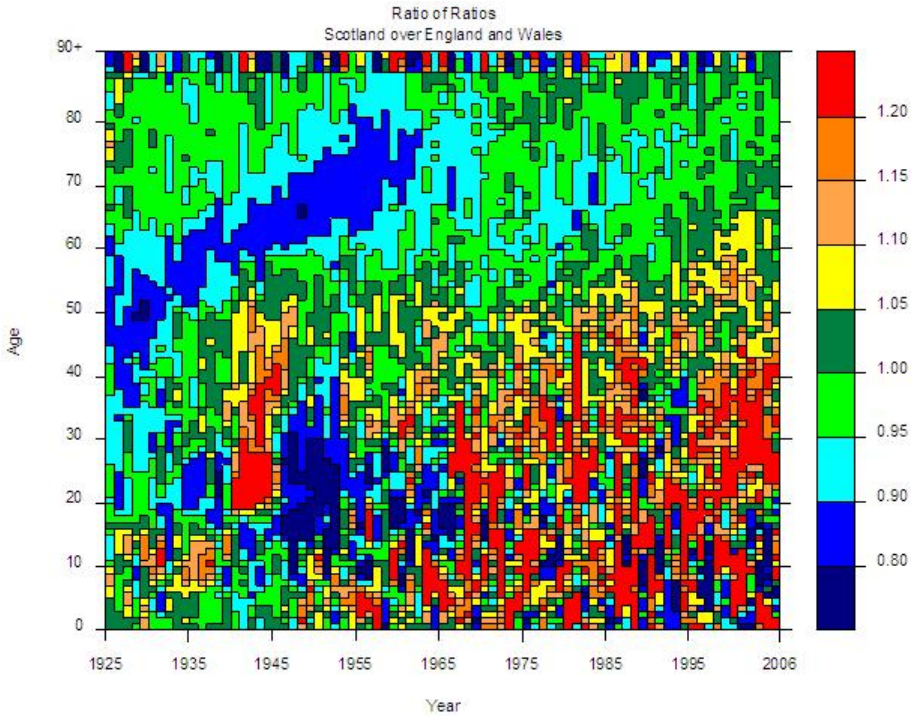
Figure 5.5: Rate Ratio: Scotland over England & Wales, Males, 1925-2005



(a) Ratio of Males over Females in England & Wales



(b) Ratio of Males over Females in Scotland



(c) Ratio of Ratios (Ratio of Males in Scotland/Females in Scotland)/ (Ratio of Males in England & Wales/Females in England & Wales

Figure 5.6: Ratio of Ratios

5.4 Historical mortality results

This section begins the process of examining and describing the Lexis diagrams and graphs produced, commenting on important features of the results. The most notable point is that almost universally, Scotland performs worse than England and Wales, (figures 1a and 1b, see Figure 5.1), for the entire study period. We also can see the differences between males and females, most readily in the 1 year old and 65 year old age groups where men have higher ASDR compared with women, especially prior to 1950 for 1 year olds (it is interesting to note that the National Health System was introduced in 1948). Age effects are apparent in the declining mortality of those males aged 1 year old Figure 5.1) in Scotland, the most dramatic falls in the early period 1925 to 1950, less dramatically for England and Wales. Females aged one also exhibit a similar but less dramatic pattern (Figure 5.1). Since 1985 the Age Specific Death Rate (ASDR) for 1 year olds in Scotland appears to have stabilised, matching the rate in England and Wales. In addition, there is a slow steady decline in the ASDR of the over 65 year old males and females for both Scotland and England and Wales. However, the decline for England and Wales has been faster than for Scotland. Looking at the data for individuals aged 30 there is a rather less striking, but still an observable, downward trend in mortality since 1925, with the exception of the period during World War Two for men.

Cohort effects can also be observed. It is apparent that almost without exception, Scotland's population has been at more risk of premature deaths than England and Wales and this situation has worsened with the passage of time. This is clear from the two graphs in Figure 5.2, as the lines are almost exclusively above the horizontal axis drawn at 1, indicating equity between countries. The rate ratios of those female cohorts born in 1965, 1975, 1985 and 1995 (Figure 5.2), are increasing. A similar trend is observed for male cohorts

born in 1965, 1975 and 1995. The rate ratio for males is stable after age 20, for the cohorts born 1925, 1935, 1945 and 1955, although male mortality is consistently higher in Scotland (see Figure 5.2) compared with England and Wales. After 1955 the rate ratio drifts slowly upwards to the high levels in the most recent cohorts where the rate ratios begin to exceed the 1.5 (50% increased mortality) threshold. This suggests that the roots of the increasing disparities in mortality may well be found in the period 1955 to 1965, with increasing inequalities in mortality becoming a trend. For those cohorts of persons born in 1925, 1935, 1945 and 1955, a pattern of lower volatility in the rate ratio, averaging around 1.2 to 1.3, for the age groups over 30 years old can be observed

The simplicity of the four Lexis diagrams in Figure 5.3 is the clear impact of age on mortality, almost universal increases with age. The exception being the second world war (1939-45) for Scottish males. The general upward trend can be linked to increasing life expectancy for all groups over the study period 1925 to 2005. The Lexis diagrams here are essentially an extension and improvement on the graphs in Figure 5.1. It is interesting to note the gradual decline of death rates of young females (aged between 16 and early 30s) after the second world war in both England and Wales and Scotland (see Figure 5.3), and the respective decrease in infant mortality rates for both males and females (see the four Lexis diagrams in Figure 5.3). These patterns may be explained by the decline of deaths in child births. Looking at the mortality rates for males (the bottom two panels in Figure 5.3), it is interesting to note the increase of death rates for males in their 20s between the second world war years of 1939-1945. It is also interesting to note the fall in young male mortality rates (aged between 20 and early 30s) after 1955 for both England and Wales and Scotland. This could be explained by the increased numbers of young fathers and the associated higher likelihood of lifestyle behavioural change towards less risk taking.

Looking at the England and Wales versus Scotland rate ratios, one of the most striking patterns of both the female (Figure 5.4) and male diagrams (Figure 5.5), is the concentration of the darkest blue, the rate ratios less than 1, in the under 20 year old in the period post-1950. The transition that occurs around age 17, particularly for men, with rate ratios rising to over 1, signalling a worsening of fortunes, is clear.

It is also interesting to examine the Lexis diagrams of the male over female mortality ratios in both England and Wales and Scotland (top two panels in Figure 5.6) as well as the 'ratio of ratios' (bottom Lexis diagram, Figure 5.6). As can be seen in the top two Lexis diagrams in Figure 5.6 there is a second world war period effect resulting in a considerably higher mortality rate for males than females and especially those in their 20s. However, it is worth noting that the gender inequality is much higher and wider in Scotland (Figure 5.6). It is also worth noting that there is a cohort effect affecting females aged between 50-70 years old between 1955-1985, which can be explained by the increased prevalence of smoking in by women earlier in the century. It is also interesting to note that the mortality rate for males in their 20s is higher than females from about 1955 onwards. This trend may be explained by child birth becoming safer and therefore resulting in fewer female deaths. In addition, it can be argued that the continuation of these trends into the 1970s and 1980s could be explained by de-industrialisation processes and rises in unemployment which may have affected males more than females.

5.5 Discussion of historical health context

The rising rate ratios of successive cohorts from 1925 to the present is most apparent for males, less so for females. For men born in 1875 in Scotland, a similar mortality experience to the England and Wales is evident. Scottish men born

in 1885 start to experience a slight worsening in the relative position, followed by those born in 1895, experiencing increasing disparities. This deterioration continues to the end of the study period, when the rate ratio has increased to its highest levels if we exclude World War Two. There is also a large concentration of red in Figure 5.5 indicating a rate ratio greater than 1.4, which can be observed as a triangle shaped block of colour, in the period 1995 to 2005 for males, started with those aged 16 years ageing to around 40 years. This sits in stark contrast to the concentration of low rate ratios in the early 1960s for men aged approximately 15 to 20 years old. What is perhaps most striking for men in this series of comparisons, is that Scottish males up to around 16 years old do relatively well compared to their English and Welsh counterparts in the period following 1990. It is the sudden reversal of fortunes once males reach age 16 to 18 that is noteworthy.

Turning the focus to female mortality, the most notable concentration of higher rate ratios is in the period 1942-53, for females aged 15 to 30. Those Scottish females aged up to 25 years old appear to have done better in comparison to England and Wales post 1960 to the late nineties. In a similar fashion to men, the rate ratio for women seems to increase with age once females reach age 30. There is a strong triangle of poor performance, starting with women aged 45 in 1970 as they age, to those aged 45 to 75 years old in 2005. The gradual slide from equality with England and Wales to elevated mortality in Scotland can be seen by looking at men aged 45. Starting at the bottom of the distribution in 1925 (rate ratio 1) and reaching the top of the distribution by the end of the period (rate ratio 1.35), shows that working age males mortality prospects have been gradually declining over time. This means that for every 100 men dying in England and Wales aged 45 in 2005; the equivalent is 135 men aged 45 dying in Scotland. This compares with equal numbers in both England

and Wales and Scotland in 1925.

It can be argued that the elevated rates for men in Scotland since 1970 to the present indicate that divergence began around this period of time. The economic decline in Scotland, notably Glasgow, but also the social recession in the same time period has had a lasting effect as the aftershock of de-industrialisation. A key factor relating to the high ratio for men is the selective migration of young skilled people, (also likely to be the healthiest) out of Scotland (Norman et al., 2005). This would have the effect of worsening the Scottish position relative to England and Wales, as shown in the results. Another key factor is the deterioration in the labour market through mass de-industrialisation in Scotland since the 1970s alluded to previously. This may also be true for Scottish women, whose mortality performance worsens noticeably after age 25 in the most recent years of the study. The role of migration is an important aspect of this puzzle. Areas with poor socio-economic circumstances are liable to be selectively losing the healthier migrants, who tend to be pulled to economically favourable, less deprived places (Norman et al., 2005). This process leads to a situation where the most deprived areas lose the healthier proportion of their population and gain less healthy persons from other areas. Selective migration processes over in the recent past, has lead to polarisation in the housing market, spatially filtering people, resulting in wealth and location becoming more closely related (Graham, 2000, p.194). We also know that Scotland (and especially Glasgow) in the periods 1974-1988 and 1995-2002, experienced net out migration, which appears to have had longer term consequences for Scotland, bearing in mind that resources are usually allocated based partly on population size (Pollock, 1999).

It is also well known that young males are prone to risk taking behaviour, 'fight or flight male reactions compared with "tend-and-befriend" female reac-

tions and that "being male is now the single largest demographic risk factor for early mortality in developed countries (Kruger and Nesse, 2004, p.80). Men are also adversely affected by suicide, drug use and road accidents, as reflected in official statistics.

It can be argued that part of the growing mortality inequalities may be due to the rising number of young men who commit suicide (Boyle et al., 2005; Christie, 2001) combined with the knife culture, "homicide rates in Scotland have increased considerably over the past 20 years, particularly amongst young men, with the increase largely attributable to homicides involving knives (Leyland, 2006, p.146). Further explanations for excess mortality are the large concentrated pockets of deprivation in Scotland (McCarron et al., 1994; Sridharan et al., 2007; McLoone and Boddy, 1994). The inverse care law may also play a role in Scotland (Tudor Hart, 1971; Watt, 2002), extended to a general inverse needs law whereby as a population declines, resources and revenue decline and so a dangerous downward spiral begins. It should also be noted that there is a growing literature on income inequalities (Davey Smith, 1996; Wilkinson and Pickett, 2006), which shows a relationship between income inequality and health outcomes. This must also be part of the explanation, especially considering the rise in income inequality since the 1980s in Britain (Jenkins, 1996). The polarisation of the housing, labour and education markets resulting in a dichotomy between 'work rich and 'work poor households, is also a possible reason for mortality differentials. The effect of psycho-social influences on health (James, 2007a; Marmot, 2005) is also well documented. A lack of suitable employment opportunities combined high rates of unemployment compared to the rest of Great Britain which have not been sufficiently addressed and have grown steadily since the full employment peaks in the 1960s, may also be a large part of the explanation (Martikainen and Valkonen, 1996; Morris et al., 1994). The

corollary is that this managed decline of parts of Scotland after 1970 may have had implications for mortality long term.

It would appear that something dramatic happened to the Scottish population in the early 1970s. The growing inequality of mortality in Great Britain has affected young Scottish men after 1995 most severely. The divergence in mortality between England and Wales, and Scotland is notable in successive male cohorts and to a lesser extent in women. Smoking gun, perhaps not, but not just smoking!

5.6 A Recent Health Context: Morbidity

This section turns the focus onto the more recent health landscape. The more recent data on Scottish health shows that the most prevalent illness in Scotland is the category which includes Arthritis, rheumatism and fibrositis, based on weighted data (see Table 5.1) from the Scottish Health Survey (SHS) 2003. Arthritis, rheumatism and fibrositis has a prevalence of 53.73 per 1000 of population in Scotland. This is also shown graphically using a weighted barplot (see Figure 5.7), which shows in ascending order the most prevalent diseases (per 100 of population) in Scotland with Arthritis the tallest bar on the extreme right of the bar chart. Note that the bars placed on top of each green bar represent 95% confidence intervals as this is weighted data rather than a whole population sample. The second most prevalent illness is asthma (39 per 1000 of population), followed closely by problems which affect the back (34 per 1000). This is followed in fourth place by problems which affect the bones, joints or muscles (31 per 1000). The fifth most prevalent illness in Scotland based on the weighted SHS 2003 data, is hypertension or high blood pressure with a prevalence 25 per 1000 of population. As alluded to, this can also be seen in the barplot (Figure 5.7) which graphically displays all the illness categories, ranked

by prevalence from least to greatest (left to right) in Scotland. Comparing the Scottish experience to England (which is shown in Figure 5.8), it is remarkably similar. The same five illnesses appear at the top of the distribution in both England and in Scotland. The only caveat is that Asthma is most prevalent in the data for England, and then Arthritis whereas in Scotland this pattern is reversed. Moving onto answering the research question fully as outlined in section 1.3, pertaining to the prevalence of illnesses in Scotland. The five most prevalent illnesses are identified in the Prevalence of Illnesses table (see Table 5.1). The five most prevalent illnesses, based on weighted data are; Arthritis, rheumatism and fibrositis; Asthma; Back problems or slipped disc or spine or neck injuries; Other problems of bones, joints and muscles and Hypertension or high blood pressure. This list is ordered from the greatest to least prevalent diseases.

	Prevalence (per 1000)
Arthritis/rheumatism/fibrositis	53.73
Asthma	39.06
Back problems/slipped disc/spine/neck	34.21
Other problems of bones/joints/muscles	30.83
Hypertension/high blood pressure/blood pressure	25.22

Table 5.1: Five most Prevalent Illnesses in the SHS

Addressing a separate part of the research question covering the areas where the most prevalent illnesses are found, these results are shown in both maps and tables. The geographical Health Board (HB) identifier can be used to add a spatial dimension to the health landscape. As discussed in the methods section, the five most prevalent illnesses can be mapped (by HB) in quintile groups (i.e. 15/5, 3 Health Boards in each class). The 'top 5' illnesses by HB are also shown in Table 5.2 so that the figures can be seen clearly. From Table 5.2, the main results are that Lanarkshire has the highest prevalence

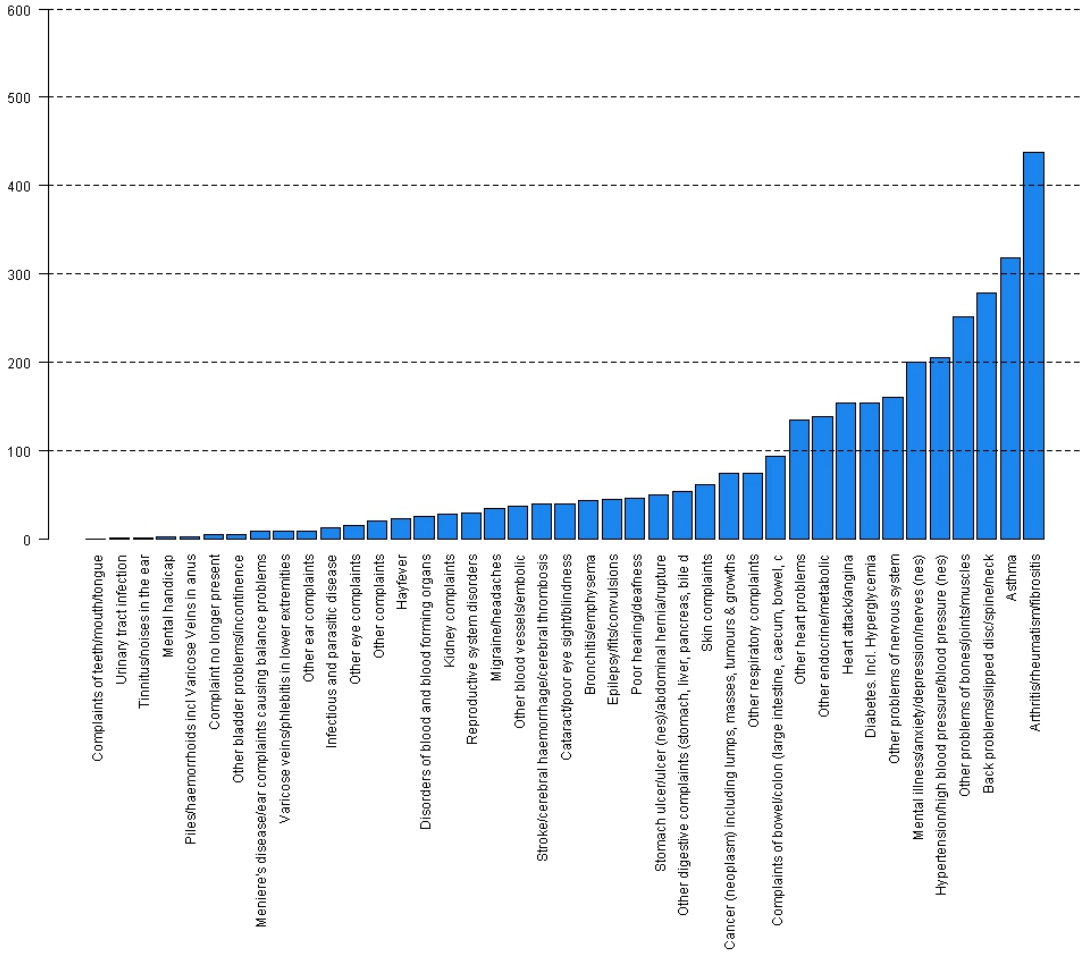


Figure 5.7: Counts of Weighted Illness, SHS 2003, Scotland

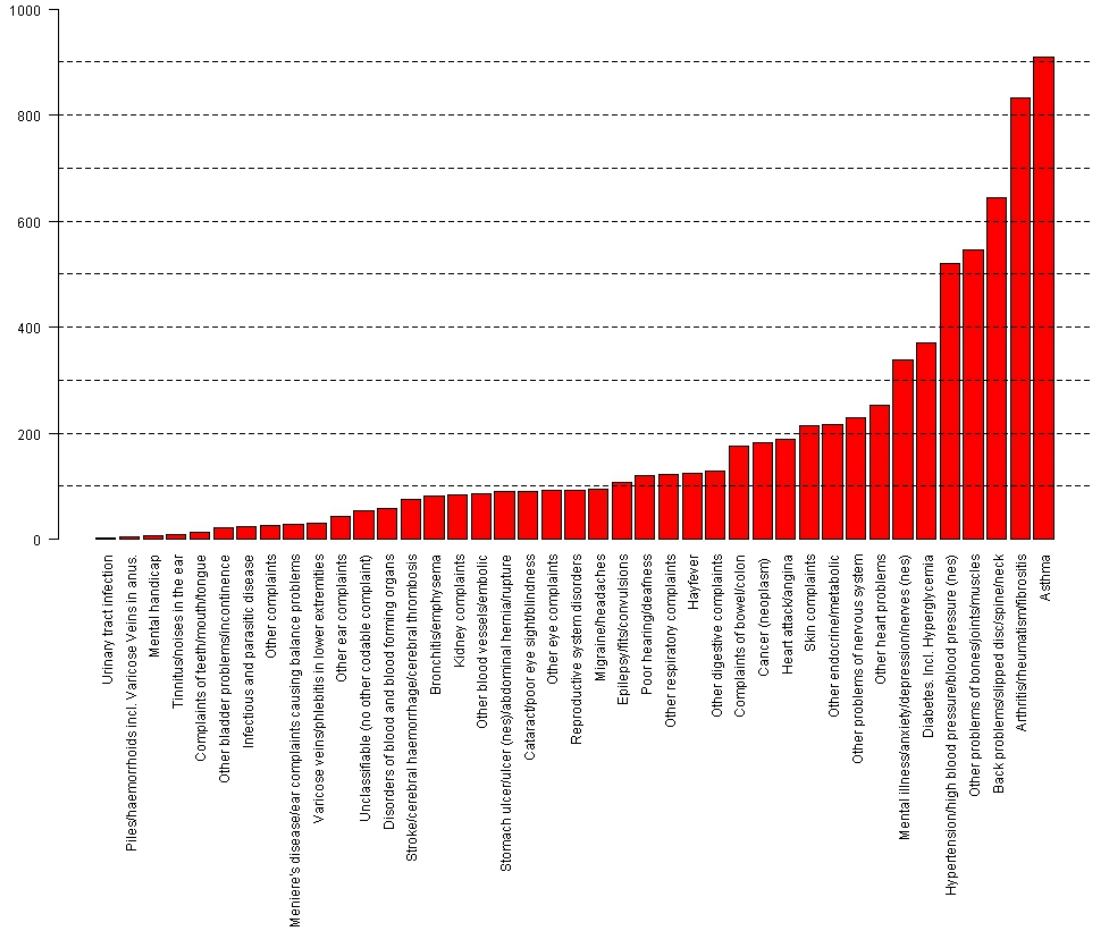


Figure 5.8: Counts of Weighted Illness, HSE 2003, England

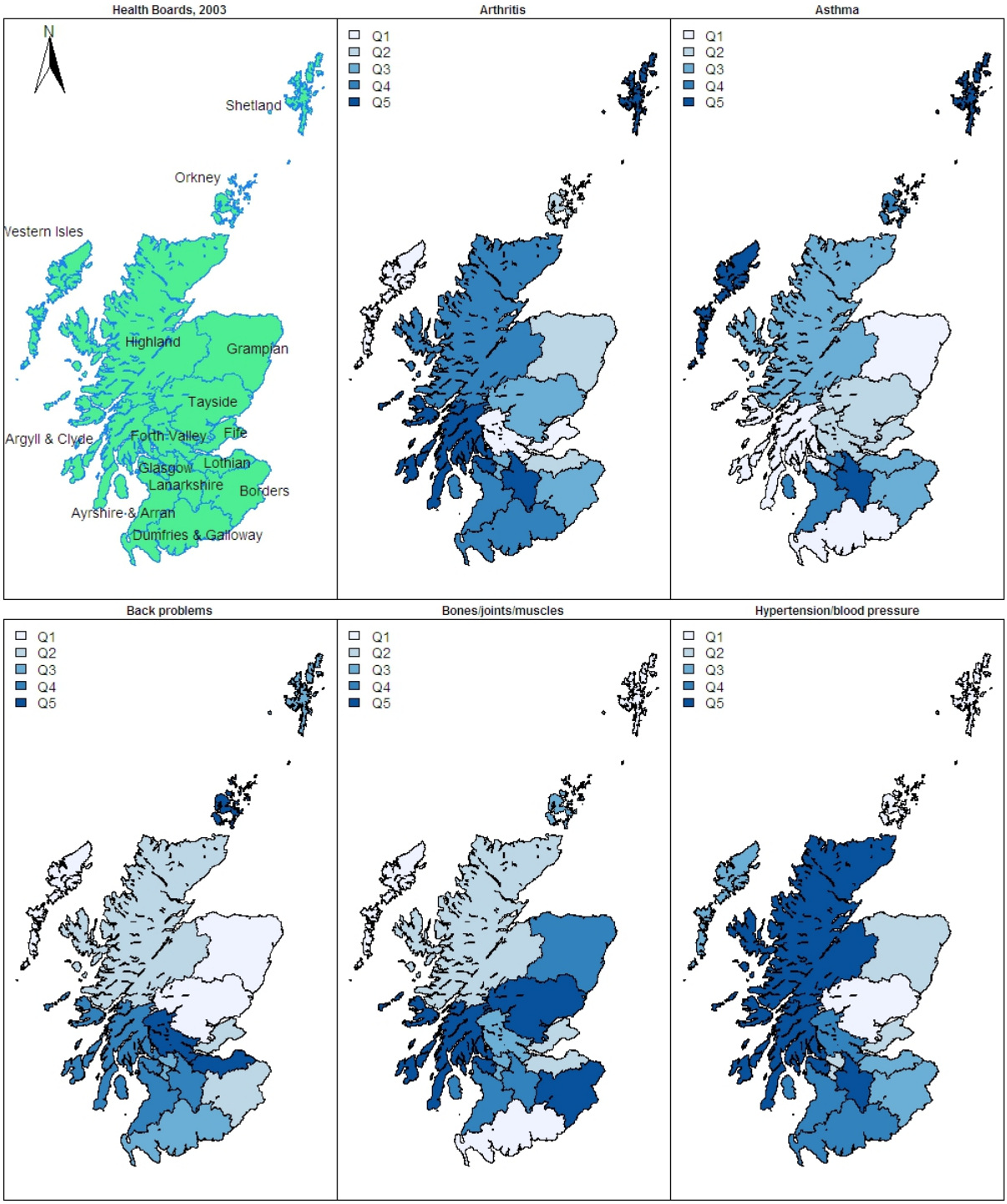


Figure 5.9: Five most prevalent illnesses, Quintiles, SHS 2003 (Q1:Low)

	Arthritis	Asthma	Back	Bones	Hypertension
Ayrshire & Arran	62.00	46.50	39.50	32.90	29.20
Borders	52.00	42.90	27.10	38.80	24.20
Argyll & Clyde	66.00	16.40	35.00	36.60	34.70
Fife	36.50	37.50	26.80	26.60	20.50
Greater Glasgow	53.90	47.10	33.80	30.40	21.20
Highland	62.40	39.50	30.30	28.50	35.20
Lanarkshire	75.00	47.30	39.30	32.60	30.50
Grampian	37.50	31.20	25.20	34.20	20.50
Orkney	42.50	47.00	78.70	28.60	0.00
Lothian	50.00	41.50	40.00	26.00	24.40
Tayside	57.50	35.10	26.30	35.90	19.40
Forth Valley	33.70	37.50	44.00	30.20	29.30
Western Isles	25.70	76.10	22.60	15.00	24.70
Dumfries & Galloway	61.70	25.00	31.50	16.80	26.70
Shetland	67.20	78.90	34.70	25.10	0.00

Table 5.2: Prevalences by Health Board

of Arthritis/rheumatism/fibrositis (75 per 1000), which is driving the illness figures, compared with the Western Isles (25.7 per 1000) which is significantly lower than Lanarkshire. Shetland has the highest prevalence of Asthma (78.9 per 1000) compared with Argyl and Clyde, which has the lowest prevalence of Asthma (16.4 per 1000), which seems counter intuitive. Orkney has the highest prevalence of Back problems/slipped disc/spine/neck conditions (78.7 per 1000) compared with Western Isles which has the lowest prevalence of this condition (22.6 per 1000). Additionally, it is also shown that Borders HB has the greatest prevalence of bones/joints/muscles conditions (38.8 per 1000) which is in contrast to the Western Isles HB (15 per 1000). Shetland and Orkney have the lowest Hypertension prevalence (0 per 1000) and Highlands has the highest prevalence of Hypertension/high blood pressure/blood pressure (35.2 per 1000), although the small sample sizes in the islands may well be affecting this result. The Western Isles has the lowest prevalence of three conditions; Arthritis, Back and Bone problems. This gives an overview of both the spatial location of

illnesses by HB and the spatial concentrations of each disease. The issue which raises concern is how often the islands feature in the top (or bottom) or the ranked illnesses, suggesting small (or unstable) samples in these areas.

What could be argued is that the diseases are most likely to occur in older age groups, showing that the burden of disease is weighed more towards the older age groups. So it could be expected a prior that those HBs with the oldest populations are most likely to feature heavily near the top of the illness table.

5.7 A Recent Health Context: Mortality

This section gives an overview of the current geographical variation of mortality in Scotland. This mortality 'profile was created using data for 2010 for a measure known as the Standard Mortality Ratio (SMR) which was discussed in the data and methods chapter (see chapter 3). The map (see Figure 5.10) and the table (see Table 5.3) complement each other by showing the raw figures and their spatial patterning for Scotland. As discussed in the data and methods chapter, an SMR of 100 is equal to a reference population, in this case the Scottish national average mortality, so an SMR over 100 is worse than, less than 100 better than the Scottish average. The geographical unit used in the map and table is the council area of which there are 32 in Scotland. From Table 5.3, the distribution of SMRs ranges from the lowest in Perth and Kinross (SMR of 80) to the highest in Glasgow City (SMR of 123).

From the map in Figure 5.10 what can be detected visually is the higher SMRs (in red) in the central belt of Scotland. This contiguous area of high SMRs stretches from Inverclyde through Renfrewshire, Glasgow City, North Lanarkshire across to West Lothian from west to east. This clustering of high SMRs is interesting given the concentration of areas, suggesting that geography is an important aspect of understanding patterns of variation in Scottish mor-

Council Area	SMR
Aberdeen City	98
Aberdeenshire	89
Angus	95
Argyll and Bute	96
Clackmannanshire	97
Dumfries and Galloway	96
Dundee City	104
East Ayrshire	101
East Dunbartonshire	81
East Lothian	92
East Renfrewshire	85
City of Edinburgh	90
Eilean Siar	103
Falkirk	100
Fife	93
Glasgow City	123
Highland	96
Inverclyde	121
Midlothian	98
Moray	94
North Ayrshire	100
North Lanarkshire	118
Orkney Islands	91
Perth and Kinross	80
Renfrewshire	112
Scottish Borders	94
Shetland Islands	102
South Ayrshire	100
South Lanarkshire	102
Stirling	91
West Dunbartonshire	116
West Lothian	103

Table 5.3: Standard Mortality Ratios by Council Areas, 2010

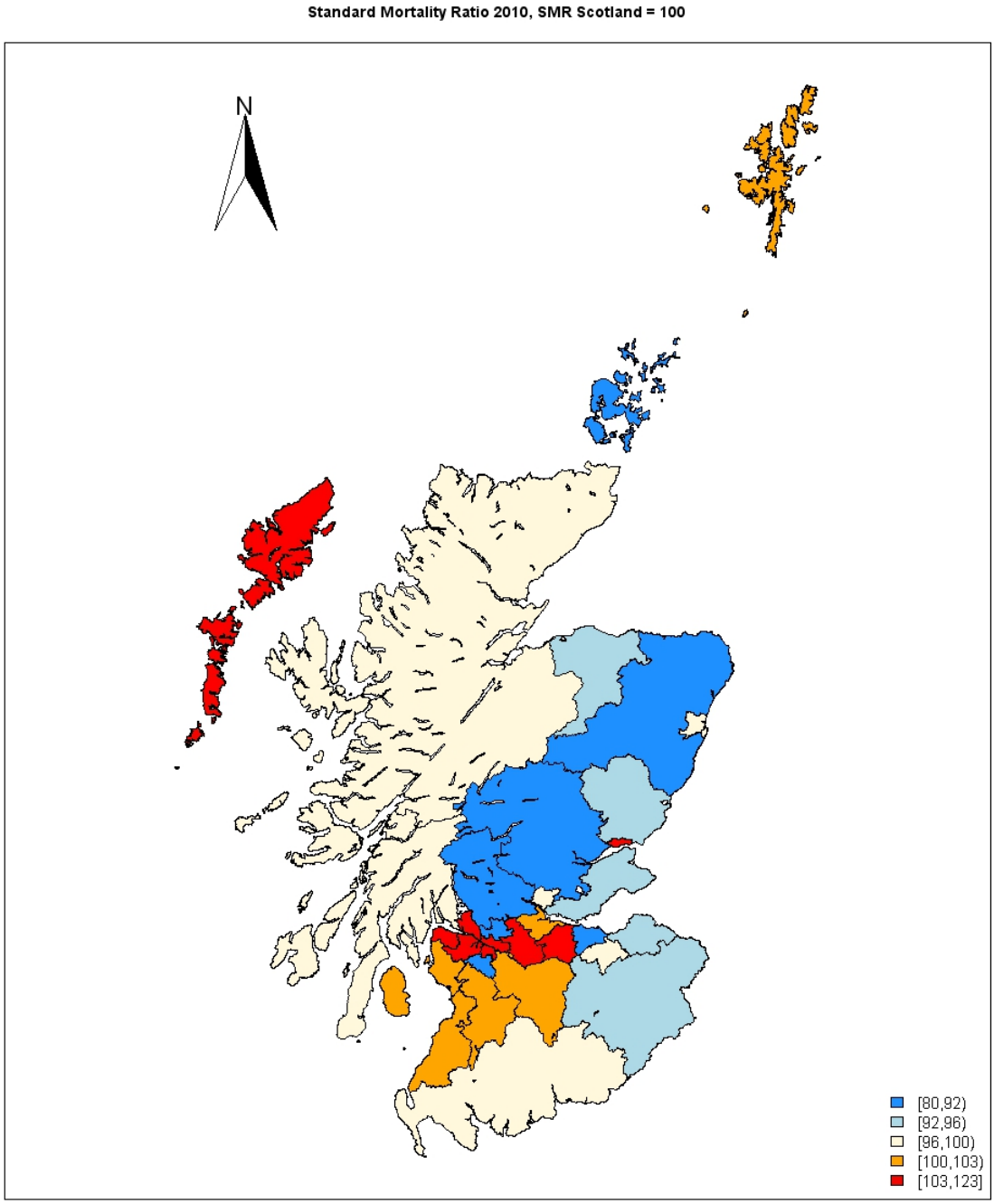


Figure 5.10: Standard Mortality Ratio, Scottish Council Areas, 2010

tality. The other two areas of high SMRs are Dundee and Eilean Siar (Western Isles). At the lower ends of the distribution are the areas on the outskirts of Glasgow, East Renfrewshire to the south and East Dunbartonshire to the north of Glasgow. There is also a large contiguous area of council areas extending from north of Glasgow (East Dunbartonshire) through Stirling, Perth and Kinross into Aberdeenshire, moving from the Glasgow northwards. This pattern of low SMR is in direct contrast to the high SMR pattern in the central belt. The analysis presented here in Table 5.3 and in the map in Figure 5.10, gives an overview of the geographical variation in mortality in Scotland. The analysis also sets the scene for comparisons to morbidity and historical mortality patterns in Scotland.

5.8 Conclusions

In conclusion the results from both parts of this chapter are drawn together and overarching conclusions made. Firstly, what the analysis of mortality data shows is the importance of both age and sex effects as well as how some effects are temporal and can change over time. The differing mortality of people of a particular age is apparent, and it is obvious that as people age their chances of death increase. The interesting point is that young men experience over twice the mortality of corresponding women starting in the early sixties, effecting young males most acutely (ages approximately 16 to 25).

It would appear that something dramatic happened to the Scottish population in the early 1970s. More recently the pattern of specific illnesses within Scotland is less clear. The growing inequality of mortality in Great Britain has affected young Scottish men after 1995 most severely. The divergence in mortality between England and Wales, and Scotland is notable in successive male cohorts and to a lesser extent in women. Smoking gun, perhaps not, but not

just smoking!

Secondly, the results of the most current analysis are rather nuanced as can be seen from the five maps in Figure 5.9. In addition, it is likely that the small sample sizes in the Islands, especially Shetland and Orkney, may be influencing results. It is clear that Ayrshire and Arran as well as Lanarkshire are consistently in the bottom third for all illnesses. Moreover, Fife is consistently in the lowest third of the distribution for all illnesses. This addresses the research question (see chapter 1.3) as the five most prevalent illnesses have been identified and their locations have been explored. Perhaps what is surprising is that given the level of focus on certain diseases, the most prevalent diseases in Scotland are rather different and perhaps little can be done to prevent many of the 'top 5' diseases in Scotland.

As set out at the very beginning of this chapter, the analysis contained in this chapter was designed to provide a 'macro' level view on health in Scotland. This sets the scene for what will follow with respect to more detailed analysis of policy at the 'micro' level in Scotland. Moreover, this chapter has addressed the research question relating to the health divergence between Scotland and England and Wales and for whom as well as exploring the prevalence of illnesses in Scotland and their location.

Overall, it could be argued that the effect of both age and sex on mortality and morbidity have been demonstrated in the analysis presented in this chapter.

Chapter 6

A Scottish Spatial Microsimulation Model: SIMALBA

6.1 Introduction

This chapter provides a description of the microsimulation models which have been developed in order to answer what-if policy questions in a Scottish context. The models developed and described here are known as static spatial microsimulation models. The various types have been discussed in a previous chapter (see chapter 4). Moreover, the particular microsimulation 'tuning' method used is deterministic reweighting, which will be described in greater detail subsequently and was briefly outlined in the microsimulation methodology chapter (see chapter 4). The model itself has been named SIMALBA, because it is a spatial microsimulation model (SIM) of Scotland, which is also known as Alba

in Scottish Gaelic. The spatial microsimulation model will be referred to as SIMALBA from this point forward. SIMALBA has been created using a combination of Scottish Health Survey (SHS) data from 2003 and census data for Scotland from 2001 for Output Areas (OA). The purpose of SIMALBA is to model 'what-if' analysis of policy scenarios or policy options, outlined in the research questions (chapter 1.3) at sub-national geographies. This allows the existing policies to be examined as well as setting out possible future policies which could be formulated. Microsimulation modelling is a complex and a time consuming task as was outlined in the chapter on microsimulation methodology (see Chapter 4). Considerable effort in terms of time, but also with respect to computer power, are required to build spatial microsimulation models. The time and resource effort is mainly expended on programming a model structure and then the subsequent debugging of that code to fine tune the model.

The structure of the chapter is as follows; firstly a brief description of terms and definitions is given in section 6.2, followed by an explanation of a stylistic microsimulation model in section 6.3. A section detailing the setup of microsimulation models is given in section 6.4 including; what data is used, how geography can be added, an overview of deterministic reweighting as well as an example from an early prototype model with actual data from the original sources to give an insight into the construction of the synthetic data set. This part of the chapter also involves some discussion of the data sources used as well as the constraint tables chosen and the adjustments made prior to running the spatial microsimulation algorithm. A next step is to evaluate the model and possible diagnostics are forwarded to achieve this task in section 6.5. Also in this section are sample model outputs, which are described and explained in terms of what it is and how this can then be used. A possible policy application is also outlined briefly to give an indication of the potential of SIMALBA for 'what-if'

analysis. By way of conclusion in section 6.6, pros and cons of this modelling approach are discussed, as well as any caveats and directions for future research are also described.

6.2 Definitions and Terminology

Setting out definitions and explaining terminology is useful in order to properly grasp how microsimulation modelling works. The definitions and key terminology will be explored and explained as simply as possible to give the reader a clear insight into the 'engine' of the microsimulation models. Firstly we must construct this 'engine' with various components. Once this 'engine' has been built, the spatial microsimulation model can then be used as a vehicle with which to model possible policy scenarios ('what-if' analysis). The data sources for the model have previously been explained: the SHS and the census in this context. By conducting microsimulation modelling it is possible to add value to the original SHS survey dataset. The 'value added' portion of the analysis is to 'upscale' the SHS data to match a series of census totals (constraints) which is key. In doing so, new variables can be added to the census at the individual level, by small area geography for the whole of Scotland. When referring to constraints, it means the specific series of data from the dataset which is being used to determine the aggregate totals for the model: i.e. for example, the totals for males and females or social class and so on, by area. The data to be 'upscaled' will ultimately converge using these constraint totals. For the SIMALBA model the constraints are based on the census data to which the SHS is 'upscaled' to match. The constraints themselves must be chosen based on which are available in both data sets and are the 'best' predictors of the key variable to be microsimulated (e.g. Income). Choosing the 'best' set of constraints is discussed in a subsequent section. With the help of a numerical

example (in a later section) the key ideas of microsimulation should become apparent.

6.3 A Simple Spatial Microsimulation Model

The microsimulation 'engine' needs to be built from a series of data inputs, which have been described in more detail in a section in the Data and Methods chapter (3). The data inputs, in this case the SHS and the census, are the basic building blocks from which the model is constructed. The data inputs are sorted into a series of potential constraints. As is explained more fully in a subsequent section, the constraints are essentially the best set of predictors of a variable to be microsimulated and which occur in all the data inputs. The goal of microsimulation is to estimate this 'new' variable which can then be used in the 'what-if' analysis further down the line. The 'new' variable is created by reweighting the survey data (SHS) to match the constraint totals of the census data. So the survey is 'upscaled' to be locally representative. The reweighting procedure used is deterministic in that it will produce the same result every run as opposed to a stochastic (random) procedure which may not produce exactly the same set of outputs. The reweighting procedure is carried out for a specific number of times (iterations), after which the (re)weights will converge to a more or less consistent number for every individual in the survey. The number of iterations is somewhat subjectively chosen by the modeller, but between 5 and 20 has been suggested (Ballas et al., 2007a) as discussed in chapter 4. This series of weights can then be used to create a 'new' microdata set which matches the census totals for a particular set of geographical areas, for example electoral wards. The (re)weights are crucial to calculate before the 'what-if' analysis can commence. The 'new' variable can then be added to the census at each geographical area simulated to determine the results of various scenarios

by area, and if required for different groups of people within each area. Once this stage has been reached the challenge is then to begin to model the possible policy scenarios. The results can then be analysed and examined. This process is described more formally in a subsequent section of this chapter. So, to recap, the model is built from two data sources, the SHS and the census. Constraints are picked which are common to both datasets and then ranked according to their association with the variable one wishes to predict. The survey is then reweighted iteratively until convergence of the (re)weights is achieved. Following this the simulated microdata can be used for 'what-if' analysis.

6.4 Model Setup: the model toolbox

The model setup is a crucial part of the future 'what-if' analysis. In the following sections the data used, the constraints and their selection as well as the deterministic reweighting procedure are discussed. The section finishes with a worked example from a simplified prototype Health Board spatial microsimulation model.

6.4.1 Data

The data used in the simple model is outlined in Table 6.1. The way in which a MSM is built requires data from at least two sources, but more can be used if necessary. As previously discussed, data will be derived from the SHS 2003 and UK Census (Scotland only) 2001. For a fuller description the datasets are discussed in the data and methods chapter (see chapter 3). These two datasets were chosen as they contain the most suitable information with which to build a microsimulation model which will address the research questions as well as giving insights into health outcomes for small area geographies within Scotland. The UK Census provides a close to complete coverage of the population of Scot-

land, but misses variables which will be simulated from the SHS which provides significantly more health information than the census. The microsimulation constraints for the Health Board Model are shown in Table 6.1. Age and Sex can be adjusted to fit 5 year distributions of age. The Illness data (UV022) only contains counts for all persons, so it must be 'scaled down' to 16-74 or we can use the alternative census Table (CS021) which is all persons 16-74 and this can be broken down further by Sex. Similarly for Tenure, the count contains persons in households rather than all persons, so it needs to be 'scaled up' to match the census totals for those aged 16-74. The NSSEC table is limited to those aged 16-74 and is only available for this age range. The data will come from the same two sources for all the microsimulation models developed, no matter which spatial scale is simulated. By simulating data at the same spatial scale for input and output, one can compare the output of the model (at HB level) to the input of the SHS and CENSUS (at HB level), to see the magnitude of the errors in a comparable manner. This also allows the modeller to determine which variables are being predicted most accurately.

Table 6.1: Input Data: UK Census of Population

Variable	Table	Description
Age	CS02	Age by Sex and Marital Status: All
Sex	CS02	Age by Sex and Marital Status: All
Nssec	UV31	NS-SeC: Ages 16 to 74
LongIll	UV22	Limiting Long-Term Illness: All
Tenure	CS17	Tenure and Age by Health and LLTI: HH
Qualifications	KS13	Qualifications and Students: Ages 16 to 74
Marital Status	CS02	Age by Sex and Marital Status: All
Economic Activity	CS28	Sex and Age by EA: Ages 16 to 74

6.4.2 Constraints

The spatial microsimulation models used the constraints that are outlined in Table 6.1. The selection of constraints is influenced also by the literature review (see chapter 2). In other words, the literature review discussed the importance of age (Berthoud and Gershuny, 2000) and sex (Rigby and Dorling, 2007) in relation to health. In addition, the importance of NSSEC (Bartley and Owen, 1996), housing (Marsh, 1999) and martial status (Johnson et al., 2000) are important in determining health outcomes. Furthermore, economic activity (and more specifically unemployment) has negative consequences on health (Shaw et al., 1999). Qualifications are important also, so better qualified persons have a lower risk of ill-health (Muller, 2002). Then there is the role that income (Marmot, 2005) and income inequality (Wilkinson and Pickett, 2006) play in affecting health as well as being interlinked will many of the variables discussed above.

The literature allowed the most important variables to be highlighted and this is more formally assessed by regression modelling. Therefore, the selection of constraints depends on both the literature to guide the variables which are likely a priori to be important as well as the results of more formal statistical analysis. Selection of appropriate constraints for the microsimulation model is important, as without a clear idea of the likely determinants of the variable being estimated the results are likely to be unreliable. The preferable method for selecting constraints is to use a formal statistical analysis to select the 'best predictors' of the variable that is to be microsimulated (Smith et al., 2009), so that it can be assessed objectively as opposed to subjectively (or using solely the literature on microsimulation which are other options). The selection of constraints would ideally differ for each key variable the microsimulation model is attempting to simulate, due to the fact that income, for example, may not be

influenced by the same variables as smoking (Tomintz et al., 2008) or alcohol consumption, as discussed in the literature review (chapter 2). However, there does not seem to be much difference in the determinants of socio-economic variables such as these, or in the simulated outputs from the model. The other issue to consider is the formulation of the constraints into appropriate categories. This has previously been noted by Smith et al. (2009) who state that "categorisation or configuration of these constraints is also important to consider" (p.1255). So, for example, NSSEC can be split into 3 or 8 categories of occupations. A key point in the construction process of the model is that the constraints should be ordered from the least to the most important predictor of the variable in question. This is noted by Smith et al. (2009) who note that the "order in which constraints are reweighted influences the accuracy" (p.1256), so this must be taken into account. The variables were selected using a technique which order the variables using the adjusted R^2 values from OLS regression models of candidate variables. The process begins with a simple age and sex adjusted model as it is desirable that age and sex be included in the microsimulation model at the very least. The order of the constraints as determined by this technique is shown in Table 6.2. The constraints are then ordered and can then be used in the microsimulation process. This also determines which of the candidate variables is not important. Once the constraints and their order have been decided upon the process of simulation can begin.

6.4.3 Geography

As mentioned previously, a suite of models for different Scottish geographies can be developed. The HB model and the Output Area (OA) model are the primary focus as the HB model can be used to validate outputs and the OA model can be used as the basis for aggregation up to other Scottish geographies

Table 6.2: Constraints Order: Adjusted R^2 Values

	+NSSEC	+OWN	+MARITAL	+ECONACT	+QUAL	+ILL
Initial models	0.247	-	-	-	-	-
	-	0.353	-	-	-	-
	-	-	0.415	-	-	-
	-	-	-	0.457	-	-
	-	-	-	-	0.469	-
Final model	-	-	-	-	-	0.471

if desired. One of the issues in constructing the spatial microsimulation models was whether or not to stratify the SHS sample by HB, prior to microsimulation by HB, the most fine-grained geography available. The results produced by the models varied depending on which approach was used. Using a sample stratified by HB produced less accurate results. The most plausible explanation is that if there are small samples in some health boards to begin with and then cross tabulations of multiple variables are made, the chance of an individual filling every cell in the cross tabulations is reduced. For example, assuming that there are 9 Nssec categories, 6 age categories and 2 for sex, i.e. 108 possible cells to be populated, the larger the sample, the more likely every cell is to be populated. Conversely, a smaller sample makes this process more unstable and increases the likelihood of unreliable results due to either missing 'types' of individuals or very small numbers of a 'type' of individual which in turn will make results unstable: (note, that by 'type' it is meant the particular socio-economic and demographic make up of an individual in the sample based on the constraints chosen). The inherent danger is that "an acceptable solution might not be achievable if an appropriate mix of households is not available in the sample being 'weighted' " (Rees et al., 2002, p.239), so it was decided to use the whole of Scotland as the sample, rather than each HB separately. The trade-off being that intra-Scotland geography is compromised so that persons from Glasgow

could 'populate' Shetland and so forth.

There are two main geographical units used in this project, the Output Area and the Health Board. In Scotland there are 42,604 OAs, where the minimum size is 20 resident households as well as 50 resident people. From the OA geography it is possible to aggregate up to the other geographical scales for census data as it is one of the basic building blocks of geography for Scotland. There is a mean population of 119, minimum of 50 and a maximum of 2,357 persons in OAs The Health Board populations are shown in Table 6.3. This shows that the population varies from over 850,000 people in Greater Glasgow, to under 20,000 people in Orkney. There is also wide variation in the land areas covered by each of the HBs, with some covering much larger areas than others.

Table 6.3: Health Board Populations

Health Board	Population 2001
Argyll and Clyde	420,491
Ayrshire and Arran	368,149
Borders	106,764
Dumfries	147,765
Fife	349,429
Forth Valley	279,480
Grampian	525,936
Greater Glasgow	867,150
Highland	208,914
Lanarkshire	552,819
Lothian	778,367
Orkney	19,245
Shetland	21,988
Tayside	389,012
Western Isles	26,502

6.4.4 Deterministic Reweighting

Deterministic Reweighting has been forwarded as a microsimulation method by Ballas et al. (2005a), who used the method to simulate the local impact

of national policies in Britain. As Ballas et al. (2005a) note the essence of deterministic reweighting is that, "it does not use random number generators at any stage (hence the term deterministic), and it therefore produces the same results with each run" (p.18). The process is also employed and described by Ballas (2004) using the same reweighting technique on British Household Panel Survey (BHPS) data to simulate trends in poverty and income inequality. The deterministic reweighting technique was also adopted by Tomintz et al. (2008), who used it to estimate the individual smoking rates and what the implications would be for the location of stop smoking services in Leeds. The model, and research presented here, builds on this existing research and further applies and refines the deterministic reweighting technique for spatial microsimulation.

Once the constraints have been set-up for both the SHS and census data the process of deterministic reweighting can begin, which creates the new weights and the spatial microsimulation model. As Tomintz et al. (2008) explain, "deterministic microsimulation modelling ... is a kind of cloning exercise where individuals .. are selected to populate each ...[area]... if they match the socio-economic conditions used as constraints (p.344). In general terms this takes the form shown in the equation subsequently whereby the Newweight (NW) for individual i, is calculated by multiplying the weight (W) for individual i by element ij of the census table divided by element ij of the SHS table (Ballas et al., 2007a), such that the general form of the equation is then

NWi = Wi * CENij / SHSij

The weight (W) in this case is set to 1, rather than the survey weight. There have been experiments with different weights (not shown here) such as using the survey weights for example, however setting the weight to 1 yields the most stable results. Sensitivity analysis of iterations with a starting weight of 1 for each individual in the SHS, compared with the SHS survey weight, were

also trialled with negligible difference in the outputs, but marginally in favour of the former approach.

A simple two constraint example of microsimulation, based on the work of (Ballas et al., 2007a) and demonstrating the reweighting technique simply is now outlined. The Tables (6.4,6.5, 6.6, 6.7) show the process at work for the simple two constraint example. What has been done is that the original survey weights seen in Table 6.4 have been adjusted to new (re)weighted survey weights that now form the microsimulated microdata set (see Table 6.7). Using the formula the first new weight is calculated by multiplying the weight (Wi), which is 1, by the old owners (CENij) of whom there are 3 (i.e. Table 6.5 row 2, column 1), divided by the corresponding number (SHSij) which is 2 (i.e. Table 6.6 row 2, column 1). So in summary that is 1 * 3/2 = 1.5, which is the new weight shown in Table 6.7. This process is completed iteratively until a suitable level of convergence is reached.

Table 6.4: A Simplified Microdataset (SHS)

Serial Number	Tenure	Age	Survey Weight
001	Own	Old	1
002	Own	Old	1
003	Own	Young	1
004	Rent	Old	1
005	Rent	Young	1

Table 6.5: Census Cross Tabulation for Output Area

Age	Own	Rent
Young	3	5
Old	3	1

Table 6.6: Microdata (SHS) Cross Tabulation

Age	Own	Rent
Young	1	1
Old	2	1

Table 6.7: A Simplified Microdataset (SHS)

Serial Number	Tenure	Age	Survey Weight	Re-Weight
001	Own	Old	1	1 * 3 / 2 = 1.5
002	Own	Old	1	1 * 3 / 2 = 1.5
003	Own	Young	1	1 * 3 / 1 = 3.0
004	Rent	Old	1	1 * 1 / 1 = 1.0
005	Rent	Young	1	1 * 5 / 1 = 5.0

6.4.5 A Worked Example: Prototype Model

After discussing a simple example of reweighting, this section shows the work flow of an early prototype model with numerical examples. As a short aside, this modelling procedure uses the principle of reproducible research (see Koenker and Zeileis (2009)) which should mean that the results are replicable. The model was designed using the Statistical Software R (R Development Core Team, 2010) as the modelling language and for producing outputs from the microdata. Firstly, the census and SHS data are loaded into the R software along with a set of lookup tables to allow geographical identifiers to be added. R provides a variety of statistical and graphical techniques with the ability to be extended utilising a variety of add-on packages for various tasks (e.g. GIS). For this reason it is possible to conduct all the programming and data manipulation and analysis as well as GIS within the R software. The strength of R is that because all the modelling, calculations and analysis are within one program there is less room for human error when transferring between software programmes. In addition, as it is a code driven object orientated language, re-running models or analysis

Table 6.8: SHS Data

Area	Males	Females	Males (%)	Females(%)
Highland	469	535	47	53
Grampian	487	557	47	53
Tayside	278	354	44	56
Fife	349	394	47	53
Lothian	704	859	45	55
Borders	199	232	46	54
Forth Valley	267	306	47	53
Argyll and Clyde	284	362	44	56
Greater Glasgow	822	994	45	55
Lanarkshire	464	595	44	56
Ayrshire and Arran	451	490	48	52
Dumfries and G'way	337	387	47	53
Orkney	47	45	51	49
Shetland	47	45	51	49
Western Isles	61	51	54	46

Table 6.9: Census Data

Area	Males	Females	Males (%)	Females(%)
Highland	75510	77174	49	51
Grampian	195598	194920	50	50
Tayside	138545	146442	49	51
Fife	123549	131164	49	51
Lothian	281135	300581	48	52
Borders	37610	39528	49	51
Forth Valley	99655	105895	48	52
Argyll and Clyde	149972	159300	48	52
Greater Glasgow	304477	336770	47	53
Lanarkshire	196594	211935	48	52
Ayrshire and Arran	129193	139582	48	52
Dumfries and G'way	52333	55058	49	51
Orkney	6971	6941	50	50
Shetland	8100	7598	52	48
Western Isles	9704	9245	51	49

is made much easier than a more familiar 'point and click' approach. R is also open source, so therefore there is no cost involved with usage.

Once the data has been loaded it is manipulated into a set of constraints at

Table 6.10: Adjusted Tenure

Tenure	OWN	RENT	ALL HOUSEHOLDS
Greater Glasgow	518882	333623	852505
Adjusted Tenure	OWN	RENT	AGE 16-74
Greater Glasgow	390298.6	250948.4	641247

the HB geography. This creates matrices that will be used for the reweighting process (weight * census / survey). The two Tables (Tables 6.8 and 6.9) show the sample sizes in each HB area for the SHS and the UK Census respectively. This shows the differences between the input data from both the sources, as well as the sex constraint totals from the census (Table 6.9) which will be the 'target' of the microsimulation model. The process of creating matrices is repeated for every constraint used. In the prototype model there are four constraints; age, sex, illness and NSSEC. In the final spatial microsimulation model there are eight constraints; qualifications, economic activity, marital status and tenure are added to the constraints listed above.

Following this the next step is to adjust the tables for each constraint so they all conform to the same total for each area. What this means is that some tables sum to all persons, others to those aged 16-74 or all persons in households. this creates a problem in the form of three different totals for example which means the model will not be able to converge on a single solution. In order to overcome this problem a 'reference' table must be chosen to act as a 'true' total. It is important to point out that setting which table will be the 'reference' is somewhat subjective as the 'true' population may not be known. The age table has been chosen as the reference table as it is likely to be correlated with other key determinants (e.g. health, income) and is also likely to be correct as the vast majority of people should accurately recall their age. The totals of all the constraint tables do not match, due to the definitional differences between

all persons, those aged 16-74 years and all households. Age and sex match as we have chosen to restrict sex to those aged 16-74. Age and illness match for **all** persons (867,150), so this needs to be apportioned back to those aged 16-74 (641,247) total. Tenure is based on persons in **households** (852,505) so is slightly different to all persons and so needs to be apportioned to those aged 16-74 total. Nssec has already been restricted to 16-74, so no change is needed. The Table (see Table 6.10) shows the before' and 'after calculations for tenure, the old all households total (852,505) now matching the 16-74 (641,247) target. Once tenure, illness and NSSEC have been adjusted, the data can then be edited by changing zero values to 0.0000000001 in order to negate the problem of division by zero and remove missing values from the SHS after restriction of this dataset to those aged 16-74.

Once this preliminary set-up is complete, the next step is the reweighting process. A simple example was described previously, so as to better illustrate how this process works in practice, a full worked example will be shown of a prototype HB model. To start the iterations we first create a series of dataframes which will hold the new figures (after each iteration). The purpose of these dataframes is to allow the tables to be 'updated' after each constraint has been calculated, (the reason for this will become more apparent subsequently). A further container for the output are the new weights for the SHS, which are used to update the data in the constraint dataframes. The reweighted SHS is the goal of microsimulation as it can then be used to form new synthetic microdata which can be used for 'what-if' analysis. The reweighted SHS can then also be used to add value to the census by joining in variables, such as income, which were previously unavailable. To start the iterative reweighting we first set the starting weight to one. The first constraint is sex, so to reweight we divide each element in this constraint in the census, by the matching el-

ement in the SHS. For example in the Highland HB, the number of males is 75,510 (census) and 469 (SHS). The reweighting formula; newweight = (weight * census) / Survey, is then used ((1 * 75,510) / 469 = 161.0021) to update the weight (for each HB separately) in the SHS and to calculate that element in the microdata by summing the weights (for that HB) of all males (37,513.5). The next constraint is illness so we follow a similar approach this time using the updated data rather than the original SHS. So the calculation for those with a illness is; (weight * 28,118.576) / 29,186.988, where the weight now is the weight calculated previously for males and females, so for a male in the Highland HB, the weight is 161.0021. Therefore the newweight would be 155.1085 ((161 * 28,119) / 29,187). Moving to the next constraint, NSSEC, suppose the person was a male, ill, NSSEC=1, then the calculation would be (151.1085 * 8,237) / 8,969.278, so the newweight becomes 142.4450. The final constraint then is age, which will fit perfectly to the original census table at the potential expense of all other constraints. So the person is male, ill, NSSEC=1 and aged 41. The reweighting will be the weight from the previous calculation i.e. 142.4450, multiplied by 32,018 / 29,533.392, which is 154.4287. The number (154.4287) represents the number of 'clones' of this individual in the synthetic microdata created. This completes 1 iteration. This process is then followed for n iterations (where n is chosen by the model designer). The numbers (rounded) are shown in Table 6.11, where CEN.x is the interim simulated dataset and weight is the (re)weight for the SHS. This microsimulated data can then be used for static spatial microsimulation. Note that it is possible to check the accuracy of this microsimulation method against **known** totals, as the microsimulated data can be checked against the SHS totals. A sample of the type of synthetic data output is shown in Table 6.12 for several variables.

Table 6.11: Where do the numbers come from

Variable	Census	SHS	CEN1	CEN2	CEN3	CEN4	Weight	Note: figures rounded
Sex=M	75510	469	37513	69771	74219	72001	161.0	1 * 75510 / 469
Ill=Y	28119	354	29187	28119	27070	29402	155.1	161 * 28119 / 29187
Nssec=1	8237	41	5290	8969	8237	9887	142.4	151 * 8237 / 8969
Age=41	32018	137	18215	37119	29533	32018	154.4	142 * 32018 / 29533

Table 6.12: Synthetic Microdata

Health Board	Age 35 to 44	Males	Nssec1	LongIll
Highland	32018	77220.19	8105.58	27481.71
Grampian	82117	198065	30565.06	58374.38
Tayside	57361	141221.5	16898.07	53307.17
Fife	52687	125692.1	15081.22	48546.39
Lothian	121364	286268	55872.34	90276.3
Borders	16535	38843.63	4490.297	13369.33
Forth Valley	42798	101738.8	13136.5	38896.44
Argyll and Clyde	66398	152092.9	18512.99	61364.06
Greater Glasgow	135220	307933.1	43655.04	136386.7
Lanarkshire	87266	199283.4	21119.94	83721.91
Ayrshire and Arran	55365	131853.3	13523.41	56084.99
Dumfries and Galloway	21817	53561.9	4211.409	22324.99
Orkney	2887	7176.455	570.3529	2388.707
Shetland	3300	8159.399	699.999	2345.635
Western Isles	3731	9704	824	3883.179

6.5 Model Evaluation: assessing the error

This part of the chapter deals with the accuracy of the microsimulation results. In the chapter detailing the microsimulation methodology (see chapter 4) the more technical details of how a thorough evaluation (or validation) could be achieved are explained in greater depth. The focus of this section is on the practical application of diagnostic checks for the assessment of quality with examples where appropriate. Perhaps one of the most crucial aspects of the model development is to ensure that the output is reliable. This is acknowledged

to be a challenging area of microsimulation modelling (Voas and Williamson, 2001). This is necessary for a number of reasons. Firstly, the likelihood of human error, due to the large body of complex code, is reasonably high, so a series of checks for this are a prerequisite. As previously discussed, models can always be internally validated because of how the model is designed. This can be done by comparing the simulated outputs to the (input) constraint variables. The basic diagnostics involve re-aggregating the output data from the 'micro' to the 'macro' level. This practically involves re-aggregating OA data up to HB level and comparing the input and output data. After showing in detail how a simpler prototype model would work, it is now the final 8 constraint model that is examined in greater detail at both HB and OA geographies. Additionally as Clarke and Holm (1987) report an "important test of any model is its predictive power" (p.152) which is intuitive, as if the model doesn't predict accurately it is essentially void. There is also the possibility of externally validating the model by comparing the results of a simulated variable against a proxy dataset. A further possibility is to test an 'unconstrained' census variable against the original UK Census data.

In order to assess the quality of the output against some standard, a 5% and a 10% error margin as an indication of potential error are included on the diagnostic plots. The basic diagnostic involves comparing the input and the output variables at HB geography using a 45° line. The approach has previously been used to determine the magnitude of errors in spatial microsimulation models (Ballas et al., 2007a; Tomintz et al., 2008). The comparison is a scatter plot of the input and output variables on the horizontal and vertical axes respectively. Those points which fall on the 45° line (which should be the case for the last fitted constraint) match exactly, so the closer to the 45° line the better the fit of the data. The diagnostics plots are therefore an attempt to show the accuracy

of the microsimulation results. For each of the 8 constraints used in the final model a diagnostic plot has been prepared. As previously explained the last fitted constraint will fit perfectly (NSSEC), so all points on this plot should lie on the 45° line. The other important point is that the dotted lines represent 5% and 10% deviation from the 45° line, which gives a rough indication of the fit of the constraints.

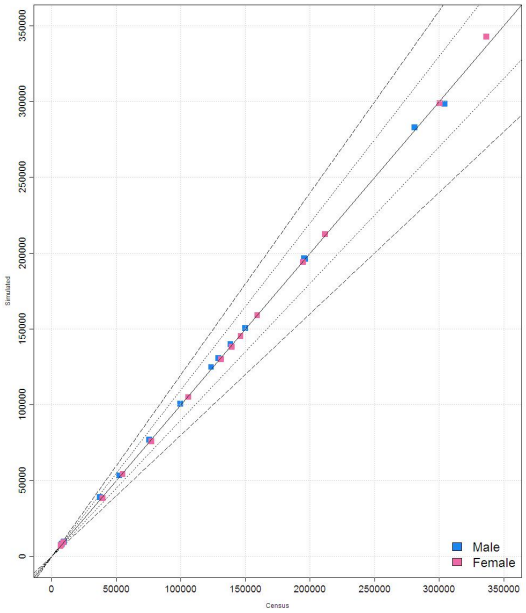
6.5.1 Health Board Diagnostics

Firstly, looking at the simulation of male and female (Figure 6.1(a)), the results appear to be accurate and all lie within the 5% line of error. This could be considered surprising as this is the first constraint to be fitted, so should perform least well. However, given that the constraint only has two categories (i.e. male and female), this may explain the result. The next plot 6.1(b) is rather less accurate than the first. Several points, most notably in the oldest (65-74) and youngest (16-24) age groups fall outside of the 10% error margin line that has been set up as a guide. Overall, it could be argued that there does appear to be a reasonable fit for the points. The third constraint that was estimated was the presence or absence of a long-standing illness. Similar to males and females, there appears to be a very good fit of this simulated variable against the UK Census input data. All points appear to lie inside the 5% margin of error in Figure 6.1(c). Qualifications constraint performs reasonably well, and it should be expected to be more accurate than the previous three constraints as it is fitted afterwards. There does seem to be a pattern emerging in that the more categories a constraint has, the worse the accuracy of the simulation results. Overall, Figure 6.1(d) shows that no points fall outside the 10% error margin. The economic activity diagnostic 6.1(e) shows a more systematic trend than the others in that there is an overestimation of the numbers of retired com-

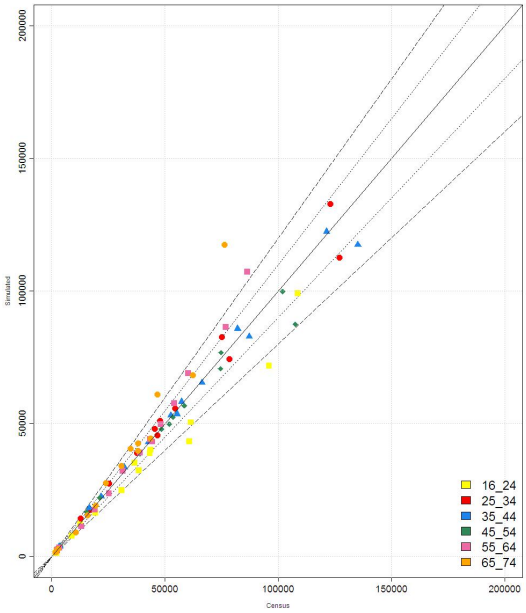
bined with what is an underestimation of both the employed and economically inactive numbers to balance out this effect. However, the employed numbers look accurate (within 5%), it is only a few of the retired and unemployed simulations that fall outside the 10% mark. The marital constraint also appears to be performing well 6.1(f), within 5% error for every simulated point. The tenure constraint is similar in that the points 6.1(g) also all fall inside the 5% mark. The NSSEC constraint is of course fitted perfectly 6.1(h) as expected. So the model is producing the results that are expected from theory and which in the majority of cases demonstrates that an accurate dataset has been simulated.

6.5.2 Output Area Diagnostics

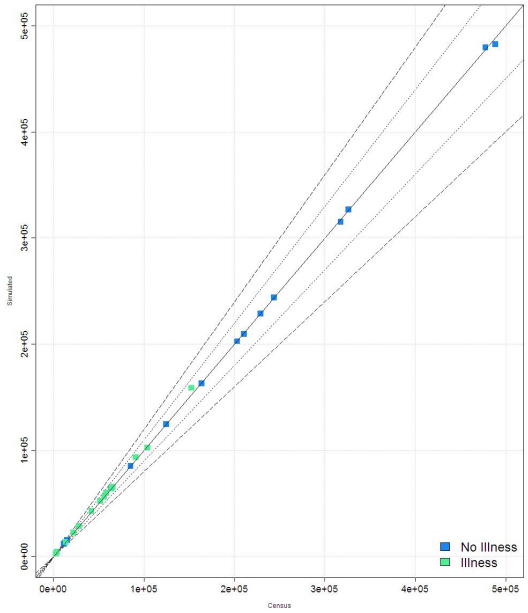
The same evaluation of model fit can be performed at output area level. The sex constraint (see Figure 6.1(i)) shows that almost all points lie inside the 10% lines of error, with a few outliers. The age constraint is rather more variable in performance (Figure 6.1(j)) with many more outliers, though it is expected to fit less well given it is estimated early and has six categories. The long-standing illness constraint (Figure 6.1(k)) shows a reasonable fit. The qualifications constraint in Figure 6.1(l), shows the systematic overestimation of high qualifications, whereas the other categories fall within the error margins. Economic activity diagnostics (Figure 6.1(m)) also show a reasonable fit, perhaps the retired are overestimated again (as seen in the HB model) which would be linked to the overestimation of particular age groups also. The marital constraint also appears to be performing well (Figure 6.1(n)), almost universally inside the 10% error lines. The tenure constraint is similar to the marital constraint as the points in Figure 6.1(o) are almost all within the 10% error lines. As with the HB model, the NSSEC constraint is fitted perfectly (see Figure 6.1(p)) as expected. The OA model results appear to be reasonably robust, as there are



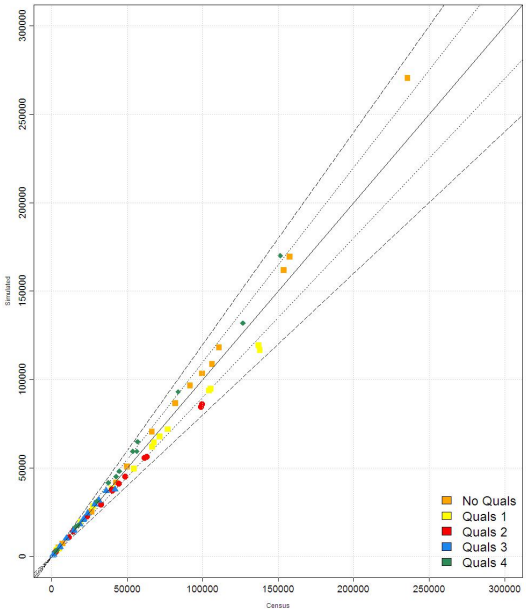
(a) Sex Diagnostics: Health Boards



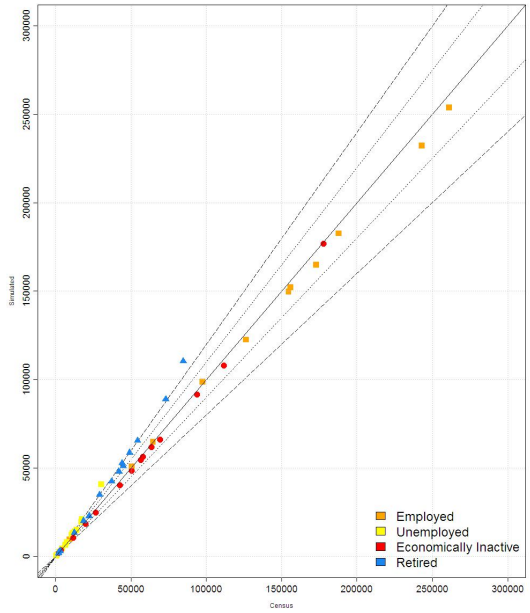
(b) Age Diagnostics: Health Boards



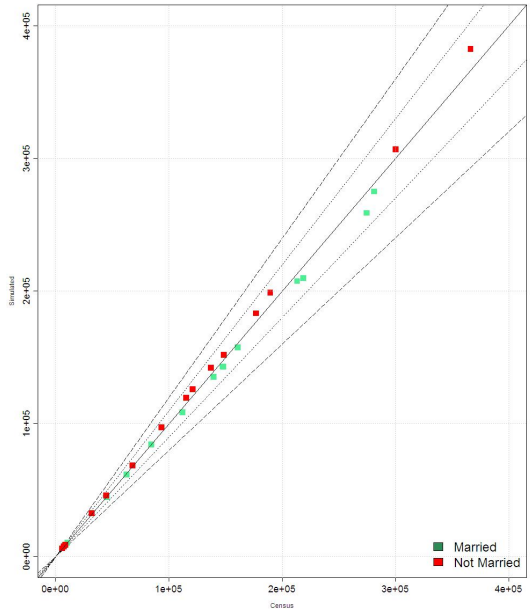
(c) Illness Diagnostics: Health Boards



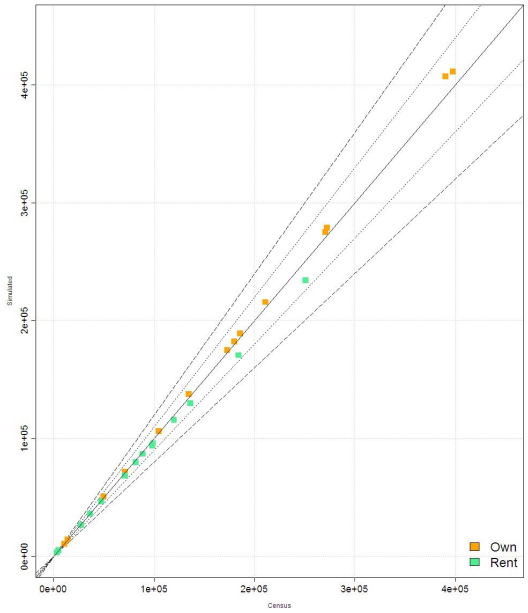
(d) Qualifications Diagnostics: Health Boards



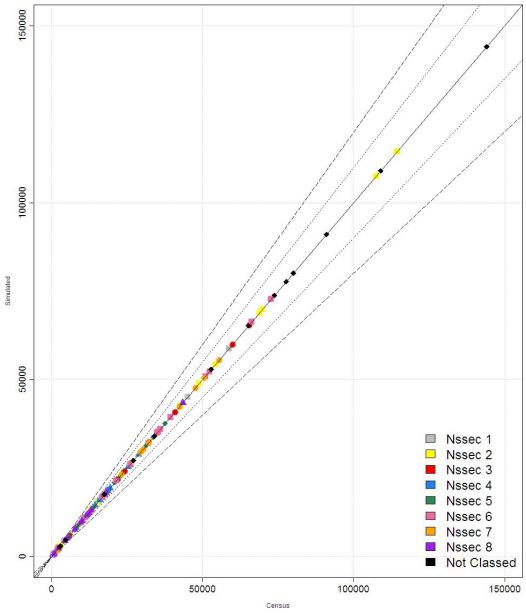
(e) Economic Activity Diagnostics: Health Boards



(f) Marital Diagnostics: Health Boards



(g) Tenure Diagnostics: Health Boards



(h) Nssec Diagnostics: Health Boards

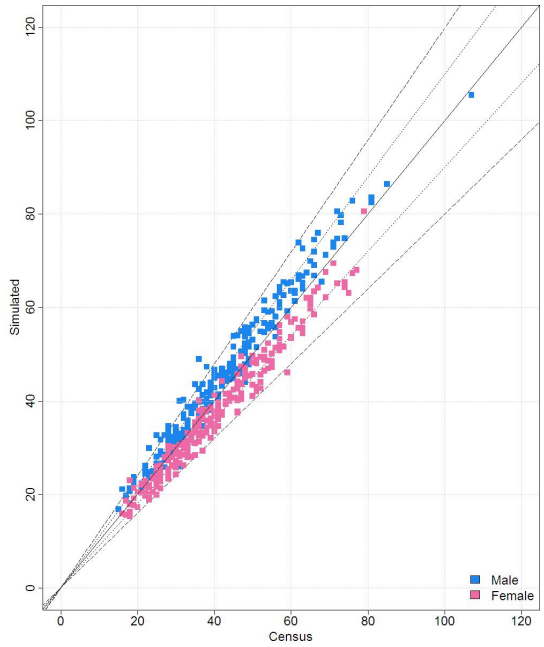
very few extreme outliers among the data even given the smaller numbers at the OA geography compared to the HB level.

6.5.3 Unconstrained Variable

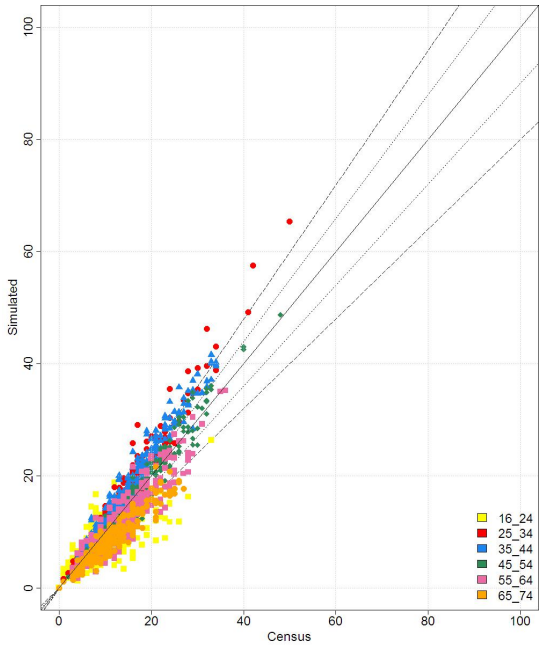
The other validation test that can be applied to a microsimulation model is to use the 45° line on an unconstrained variable. An unconstrained variable is one which has not been included as a constraint in the model, but is still present in both datasets. In this instance the ethnicity variable has been used as it meets this criteria. The variable has been recoded into binary format so that there are white ethnicities and non-white ethnicities. The Figure (see 6.1) shows the results of the validation for all the OAs in the Western Isles HB area of Scotland. The small numbers of those output areas with non-white ethnicity (all under 15% of total population) make it difficult to determine the accuracy of this group, there are no outliers falling outside the 10% deviation lines. The white ethnic groups appear to have been estimated accurately, to within 10% of the actual value from the UK Census data, with the majority inside the 5% deviation lines. What can be deduced from this figure, is the accuracy of the microsimulation results for variables other than income which can be microsimulated using SIMALBA.

6.5.4 Model Output Validation: Income

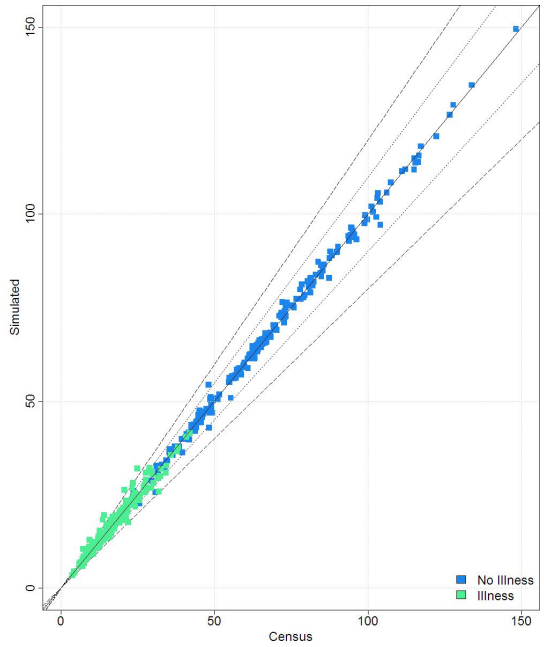
A further check of the microsimulated data can be made by comparing the input data from the SHS to the microsimulated equivalent. Note, that this is still not comparing actual data, rather it is using the survey data as a proxy to check the deviation from a 'known' total. What this section shows is the microsimulated income data from SIMALBA at the HB geography. A table has been constructed showing the percentage differences between the simulated data and the survey



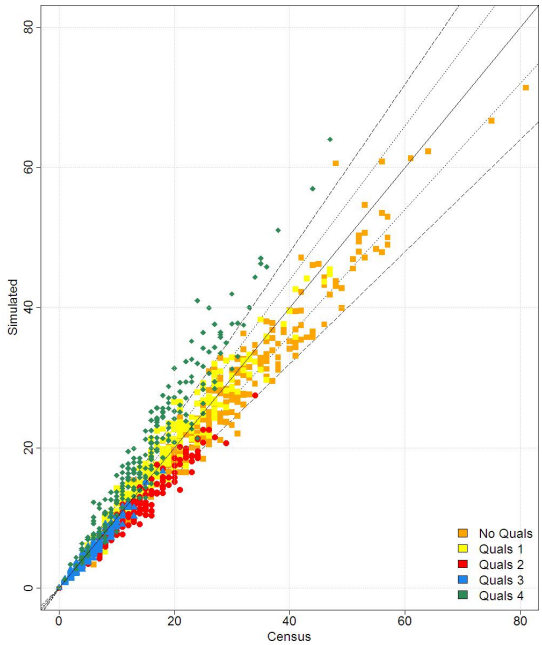
(i) Sex Diagnostics: Output Area Model



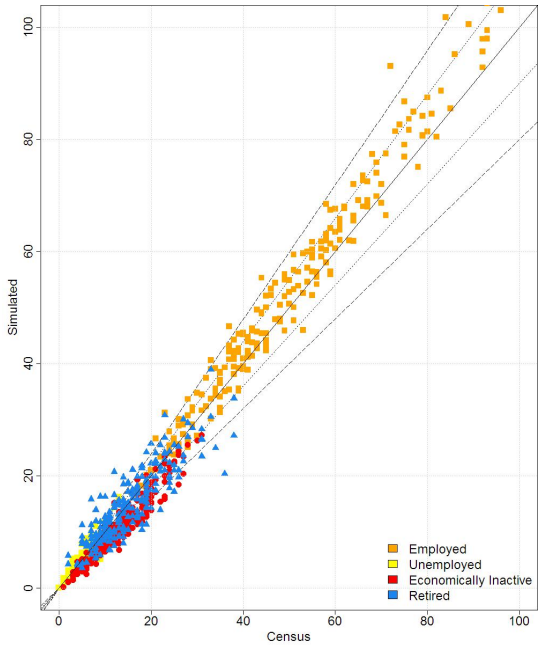
(j) Age Diagnostics: Output Area Model



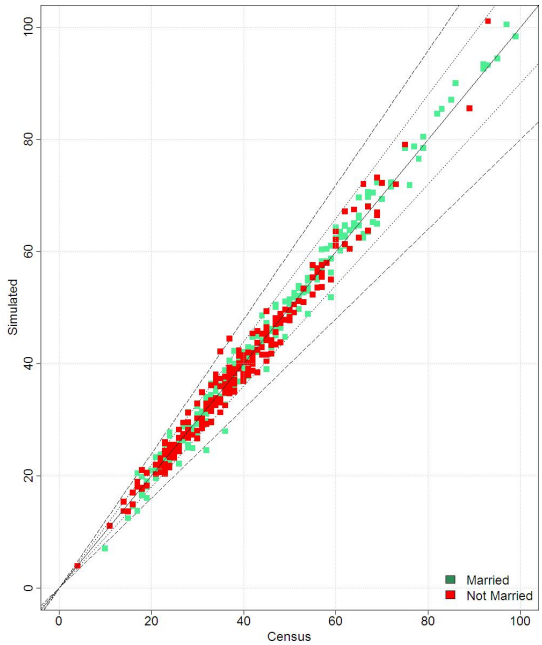
(k) Illness Diagnostics: Output Area Model



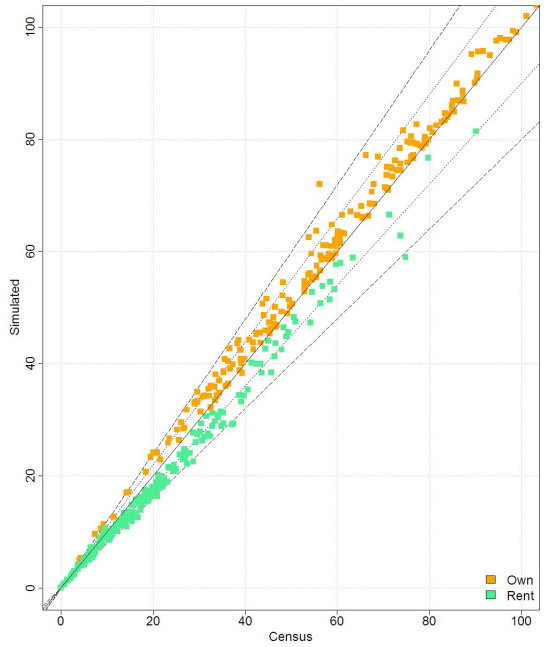
(l) Qualifications Diagnostics: Output Area Model



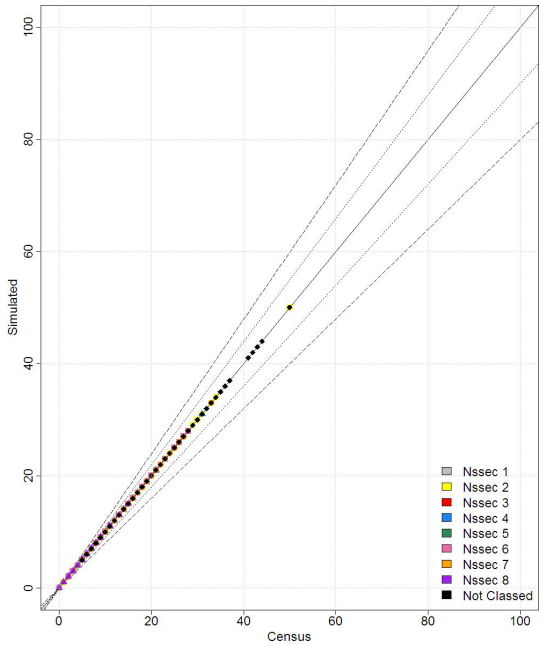
(m) Economic Activity Diagnostics: Output Area Model



(n) Marital Diagnostics: Output Area Model



(o) Tenure Diagnostics: Output Area Model



(p) Nssec Diagnostics: Output Area Model

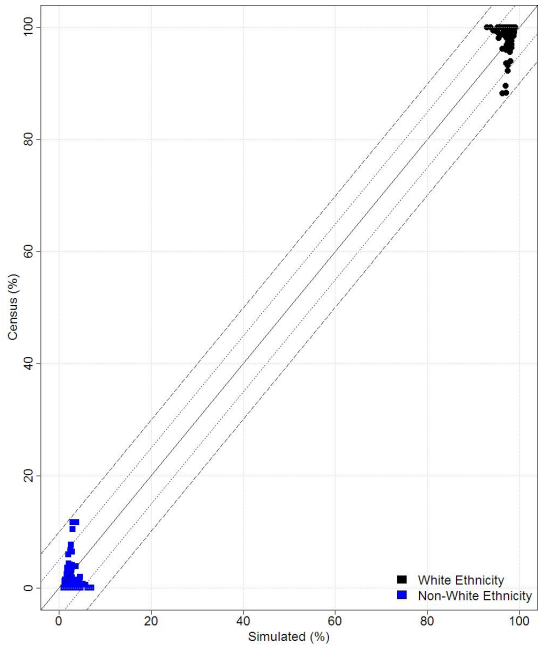


Figure 6.1: Validation using Ethnicity

weighted data, showing that the differences vary by Health Board (HB) from an almost identical 0.5% in the middle category of £13,000 to £36,400 in Grampian HB, to a more concerning 31% difference in the £13,000 to £36,400 category in the Borders HB (see Table 6.13). This gives an idea of the type of data that can be microsimulated and which can then be reformatted into any number of categories. The microsimulated data contains the original 31 income categories, but for practical reasons the data is aggregated into three categories to aid with comparison between the two data sources. What can be seen from Table 6.13 is that some HBs seem to predict income which is much closer to the SHS figures than others, but overall the majority are reasonably accurate to within +/- 10% of the SHS numbers. It could be argued that SIMALBA produces accurate income figures for HB areas within Scotland in the majority of cases, using the SHS data as a proxy for comparison.

Table 6.13: Simulated Income vs SHS Income: percentage (%) differences

	<=£13,000	£13,000 - £36,400	£36,400+	Total
Highland	2.26	-4.30	2.04	0.00
Grampian	-6.88	-0.48	7.36	0.00
Tayside	4.08	-6.65	2.57	0.00
Fife	8.05	-14.07	6.01	0.00
Lothian	4.15	-12.44	8.29	0.00
Borders	15.36	-31.15	15.79	0.00
Forth Valley	-22.99	14.82	8.18	0.00
Argyll & Clyde	0.60	0.49	-1.10	0.00
Greater Glasgow	10.09	-3.84	-6.25	0.00
Lanarkshire	6.89	-9.50	2.61	0.00
Ayrshire & Arran	13.69	-19.08	5.40	0.00
Dumfries & Galloway	7.64	-11.86	4.22	0.00
Orkney	11.54	-13.23	1.69	0.00
Shetland	12.63	-6.35	-6.28	0.00
Western Isles	6.05	-0.98	-5.07	0.00

Microsimulation Output: New Possibilities

The other advantage of microsimulation that has been discussed in a previous chapter on methodology (chapter 4) and in previous sections of this chapter is that microsimulation 'creates' new data which gives added value to existing datasets by combining them (see Table 6.14). The table shows just some of the possible 'new' variables that have been simulated using SIMALBA. A simple example of how this can be done is shown in Table 6.15. What has been done is to construct data which could explore health status and income simultaneously. Previously, ill-health (Table 6.15, column 5) or low income (Table 6.15, column 7) could be explored, whereas with microsimulation, the proportion of persons with ill-health and low income simultaneously (Table 6.15, column 1) can be examined. This provides an original and new dataset with which to begin policy analysis in later chapters.

Table 6.14: Microsimulation Output: SIMALBA Variables

Variable	Description
Age	Continuous variable of individual age
Sex	Individual Sex (Male or Female)
Income	31 Categories of individual income
Housing Benefit	Does the individual claim housing benefit?
Child Benefit	Does the individual claim child benefit?
Tenure	Tenure of individual housing (e.g. Rented)
NSSEC	Socio-Economic Classifications
Marital Status	Marital Status of individual (e.g. Married)
Qualifications	Level of Qualifications; None, Level 1 to 4.
Ill Health	Has an Illness (Yes or No)
Smoking	Smoking category (e.g. ex smoker)
Obesity	Measure of Body Mass Index
Alcohol Consumption	Drinking by recommended limits by Sex
GHQ 12 Score	Mental well being measure.
Note:	any variables from the SHS can be simulated

6.5.5 A Simple 'What-if' Scenario

In this short section an example of the power of SIMALBA is presented. Detailed here is a 'what-if' policy simulation showing those who would be liable to pay the 50% tax rate if introduced in the UK. This is shown in map format (see Figure 6.2). What this shows is the percentage of people in each HB who would be liable for a 50% rate of income tax if it were introduced in the same time period as the model. What can be seen is the concentration of those people in the southern areas of Scotland (and around Aberdeen) with the Islands having the lowest proportions of people with a simulated income over £150,000. Without validation of this data, this pattern does make sense as it could be argued that it is expected Edinburgh and Aberdeen in particular are likely to have employment opportunities that command salaries at that level, whereas in Orkney, Shetland and the Western Isles that is less likely. It is the 'real world' applications such as this simple example, that make microsimulation modelling

Table 6.15: Microsimulation Output: New Possibilities (%)

Health Board	Ill <=£28,600	No Ill <=£28,600	Ill £28,600+	No Ill £28,600+	Ill	NoIll	<=£28,600	£28,600+
Highland	29	40	9	23	39	61	69	31
Grampian	31	35	9	25	36	64	66	34
Tayside	29	36	12	23	40	60	65	35
Fife	25	36	11	28	35	65	61	39
Lothian	24	28	12	36	36	64	52	48
Borders	32	36	7	26	40	60	68	32
Forth Valley	28	33	11	28	39	61	61	39
Argyll & Clyde	41	32	12	14	54	46	74	26
Greater Glasgow	37	35	9	19	45	55	71	29
Lanarkshire	38	28	12	22	50	50	66	34
Ayrshire & Arran	35	36	9	20	44	56	71	29
Dumfries & Galloway	28	40	11	21	39	61	68	32
Orkney	28	43	9	20	33	67	72	28
Shetland	26	35	9	30	36	64	61	39
Western Isles	35	35	7	23	41	59	70	30

a powerful tool for applied policy analysis. In future chapters on Economic Policy (chapter 7) and Health Policy (chapter 8) more examples of the policies currently implemented and future 'what-if' scenarios are examined in greater detail and depth. From this simple example it is clear that there is a spatial dimension to the application of national policies; the pattern is most definitely not uniform across Scotland. This is the strength of spatial microsimulation modelling. It highlights spatial differences across Scotland and allows these differences to be explored and potentially to be explained.

6.5.6 The Socio-Economic Geography of Edinburgh and Glasgow

In this section of the chapter, the socio-economic geography of Lothian with a focus on Edinburgh city is explored using census data. Additionally, a closer inspection of Glasgow city (in the Greater Glasgow HB) is explored and discussed. This allows a 'picture' of different 'types' of areas within Edinburgh and Glasgow to be built up aiding future policy analysis that will follow in the economic and health policy chapters (see chapters 7 and 8) by highlighting the areas of each city which it would be expected would exhibit low income for example. This exploratory spatial analysis is therefore useful in giving a general benchmark with which model outputs can be compared against in an efficient manner.

To help the reader with orientation, the maps in Figure 6.3 show the OAs (top panel) and a more conventional version (bottom panel). This shows both the OA boundaries and also the road network of Edinburgh with suburbs and areas labelled.

Moving onto describing the socio-economic landscape of Scotland, more specifically within Edinburgh and Glasgow. The focus is on the predictors

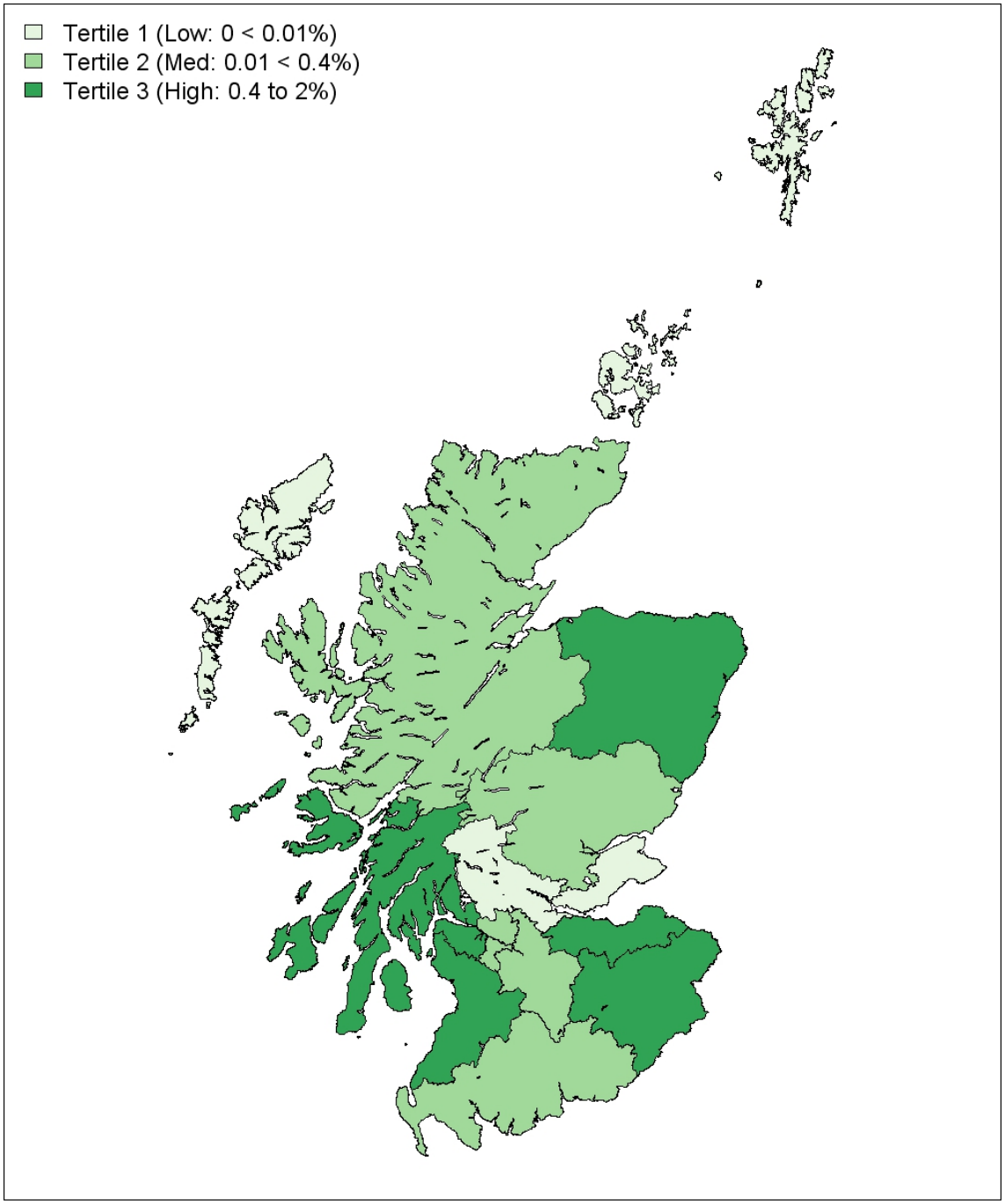


Figure 6.2: Percentage Earning over £150,000 Tertiles

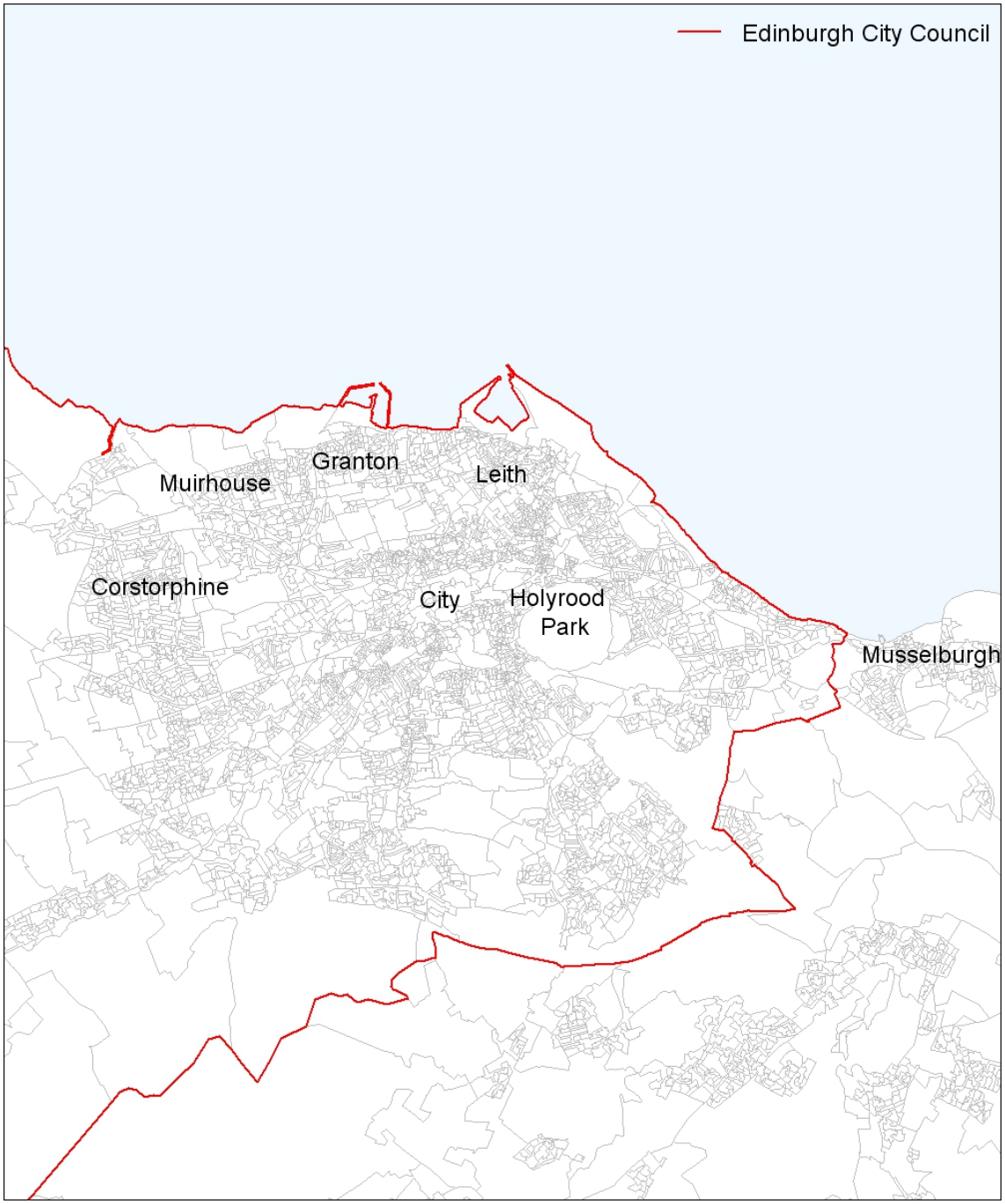


Figure 6.3: Map of Outputs Areas, Edinburgh City, Selected Areas

of income, in other words the constraints of the SIMALBA model (shown in Table 6.2) that are now mapped. The distribution which is mapped is based on the proportions of each variable in each OA divided into five classes (quintiles) within either Lothian or Greater Glasgow HB which is then colour coded either lighter (Q1) representing lower proportions or darker (Q5) for higher percentages of a variable for a given area. So for example, Q5, the top quintile is the top 20% of OAs in terms of the proportion of individuals in that area with a particular socio-economic characteristic.

Looking at the Nssec constraint, i.e. using higher managers and professional occupations (Nssec 1 and 2), this is mapped as a proportion of the population in each OA. Owner occupiers are also mapped in the same way, as is the proportion of married persons. Looking at those with higher level jobs, the pattern (see Figure 6.4, top left) shows the concentration of these areas in the inner north of Edinburgh around the 'old town' and to the south, with a notable absence of areas to the western fringe and clustered to the northern tip of Edinburgh, particularly around Muirhouse. It is interesting to note the pattern of owner occupation in Edinburgh. There is an obvious gap in the middle of Edinburgh (Figure 6.4, top right), with generally speaking increasing rates in areas towards the edges of the city. Those who are married (Figure 6.4, bottom left), are also absent from the centre of Edinburgh, rather more concentrated on the suburbs which is a spatial pattern similar to owner occupation.

Looking at factors which are detrimental to income, ill health, no qualifications, and unemployment rates are mapped. The unemployed persons are concentrated in area around (see Figure 6.5, top left) Leith to the north, but elsewhere the pattern is difficult to determine. The people with no qualifications (see Figure 6.5, top right) are noticeably absent from the centre of Edinburgh. There is clustering on the outer edges of the city, particularly the western fringes.

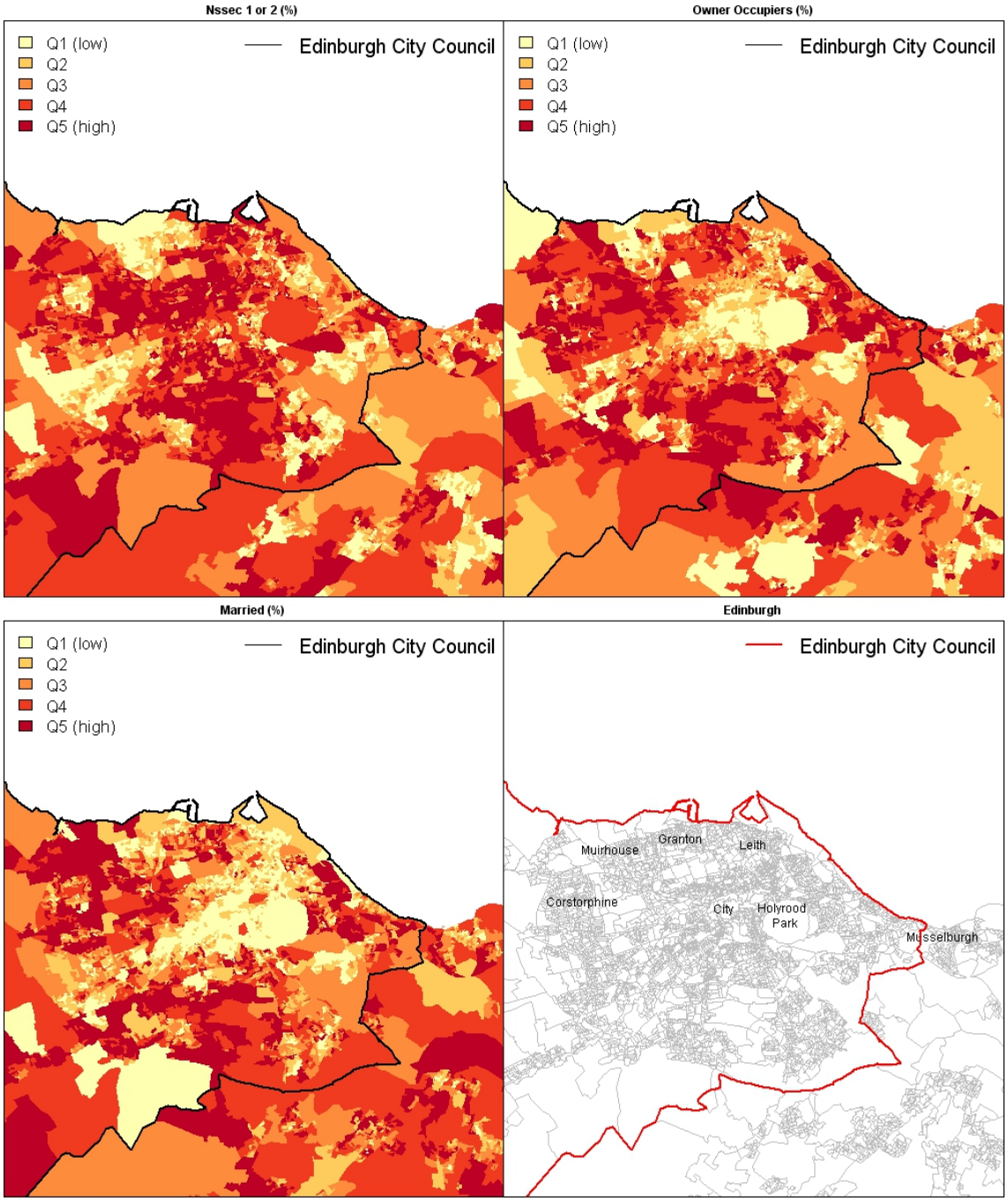


Figure 6.4: Map of Constraints, Edinburgh City

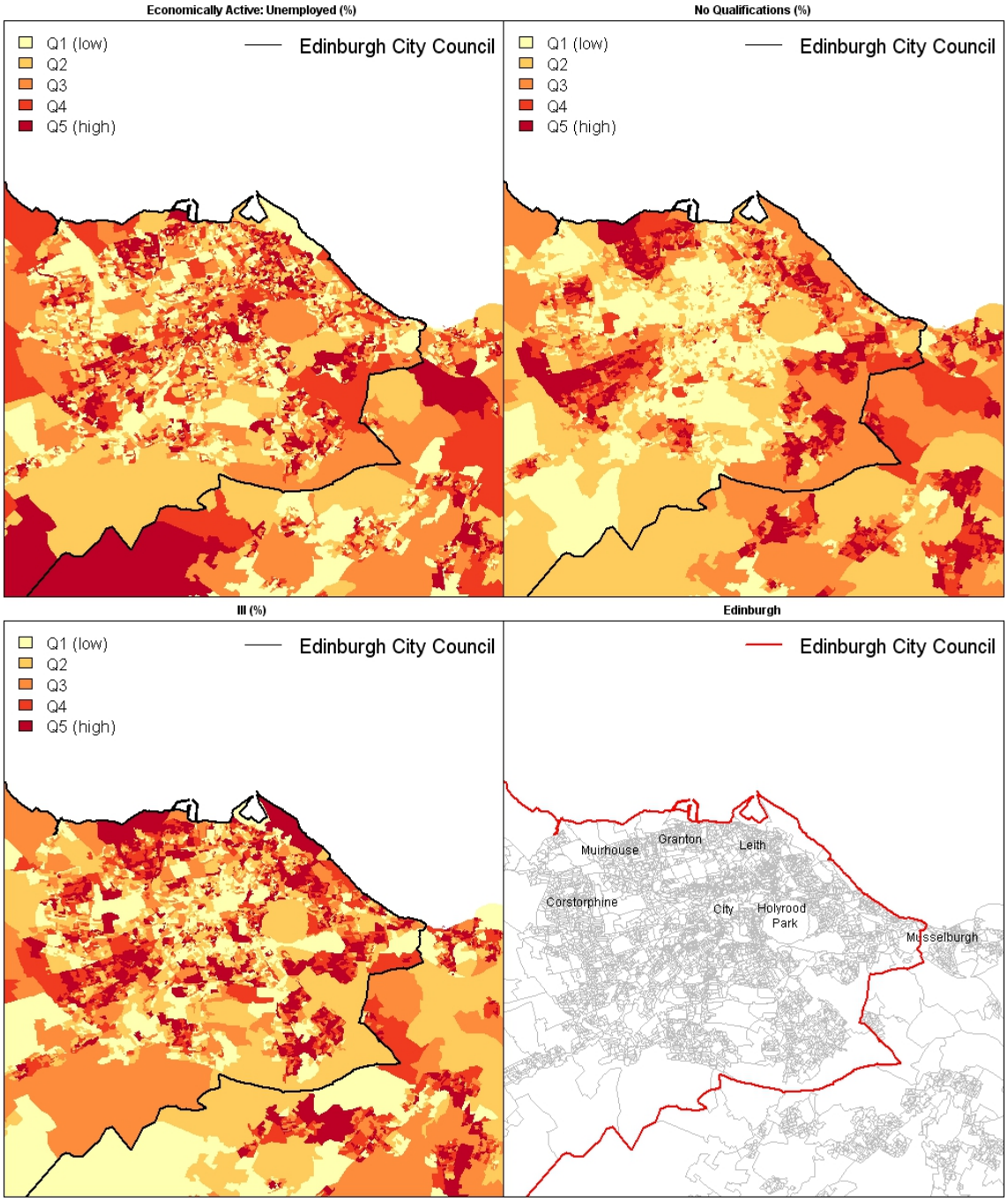


Figure 6.5: Map of Constraints, Edinburgh City

This may be biased by age however, as the older generation are less likely to have qualifications for a variety of reasons, such as compulsory schooling being introduced for younger cohorts of Scottish people. The interesting variable is the proportion of people in each OA with ill-health (see Figure 6.5, bottom left) as this is one of the key issues this research is aiming to explore in greater depth. Overall the pattern of illness shows a more random pattern, with clusters to the north and pockets dotted around elsewhere. From the literature review chapter, age is a key determinant of this variable. So mapping illness as a proportion of each OA is likely to illuminate and reflect the underlying age profile as well as the burden of disease in each OA.

The three maps in Figure 6.6 compliment those in previous figures but shown for Glasgow rather than Edinburgh. Similarly to the approach taken with the Edinburgh data, the maps in Figure 6.6 show the OAs in the top panel and conventional version map in the bottom panel. This gives the map reader a better idea of which OAs are larger or smaller and the layout of the Glasgow city area.

The map of professionals (NSSEC 1 and 2) which is the top right panel of Figure 6.7, shows the areas with highest proportions of these individuals are located in the west end, flowing out towards Bearsden (to the north west). A similar linear tract exists stretching southwards from the river Clyde outside the city council boundary to the south.

The map displaying the owner occupiers (top right panel in Figure 6.7), shows a more distance decay type relationship with (generally speaking) increasing rates of owner occupation as the distance increases from the city centre. Again there are noticeable clusters around Bearsden and to the south of Glasgow.

The proportion of individuals in each OA who are married in Glasgow (bot-

Figure 6.6: Map of Outputs Areas, Glasgow City, Selected Areas

tom left, Figure 6.7) follows a similar pattern to owner occupation. However, there is a distinct gap in the very centre of Glasgow and a noticeable proportion in the top quintile (Q5) immediately outside the city council boundary.

The map of unemployment in the top left panel of Figure 6.8 shows areas around Drumchapel (north west edge of Glasgow city council), Easterhouse (east end) and Castlemilk (south eastern edge of Glasgow) featuring heavily in the areas with the highest proportions of unemployment (Q4 and Q5). Other areas mainly in the east end feature prominently with areas to the west end notably in the lowest (Q1 and Q2) quintiles. The map of no qualifications (top right panel in Figure 6.8) shows a more clustered version of unemployment with much larger contiguous areas of polar extremes of the distribution in the west end (Q1) compared to the east end (Q5) for example. With respect to the pattern of illness (bottom left panel in Figure 6.8) the pattern is somewhere between the clustered map of qualifications and the less clustered unemployment map. The pattern overall is similar for all three maps, although it could be argued that there are varying degrees of clustering (or polarisation) between the extremes (Q1 and Q5) of the distribution in the 'types' of areas in Glasgow.

The other point of note when using spatial data such as this is the problem of the ecological fallacy and the modifiable areal unit problem (MAUP) (Openshaw, 1984; Unwin, 1996). This means that when figures for an area are reported this may not mean that every individual in that area experiences the same. So, the average experience may not accurately reflect the heterogeneity within that area. So for example, "analysis of the same data can give very different results if they are aggregated to different modifiable areas" (Boyle et al., 2004, p.267). The strength of the spatial microsimulation approach over both aspatial and other methods is that these types of problems can be addressed and better understood if desired.

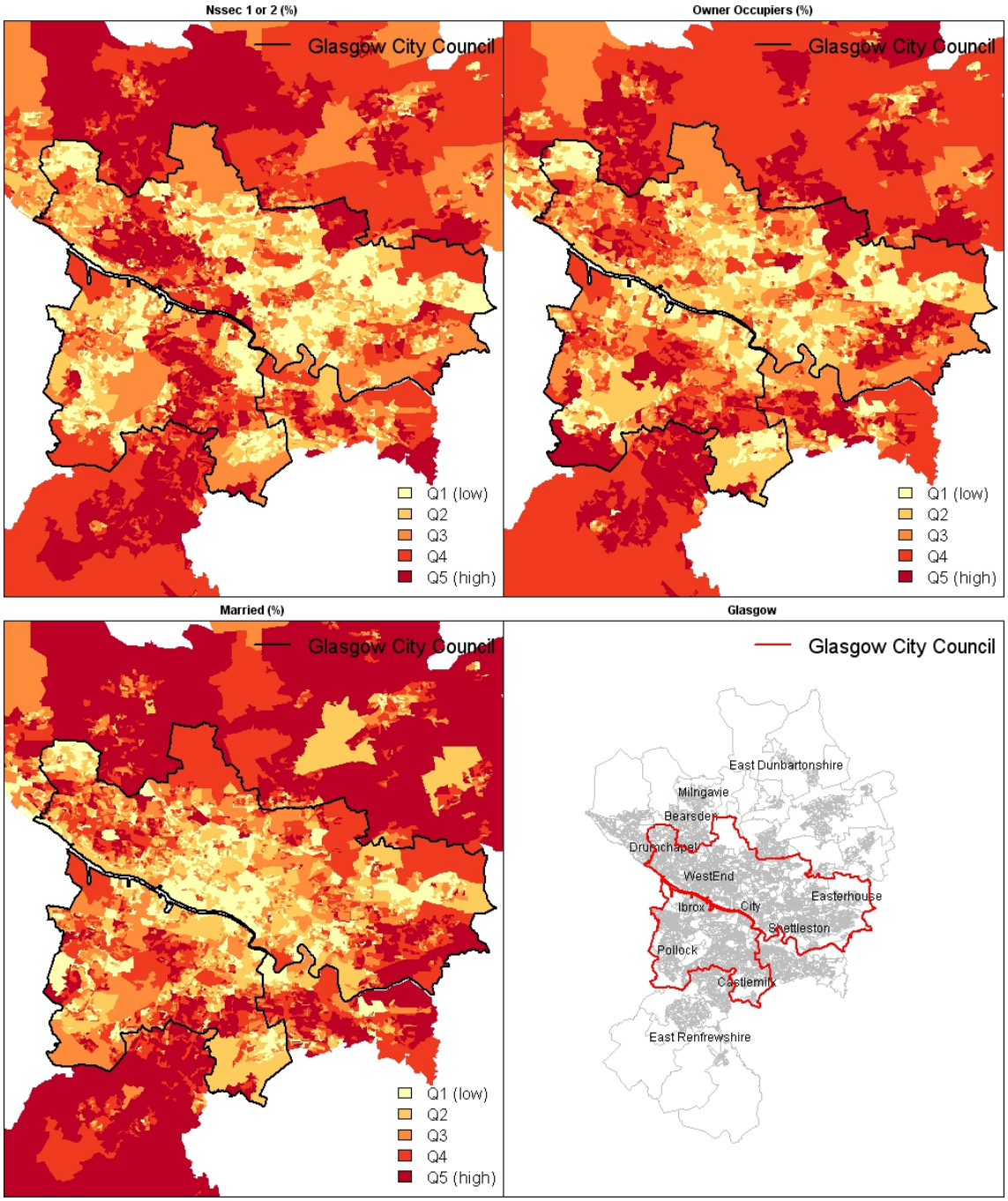


Figure 6.7: Map of Constraints, Glasgow

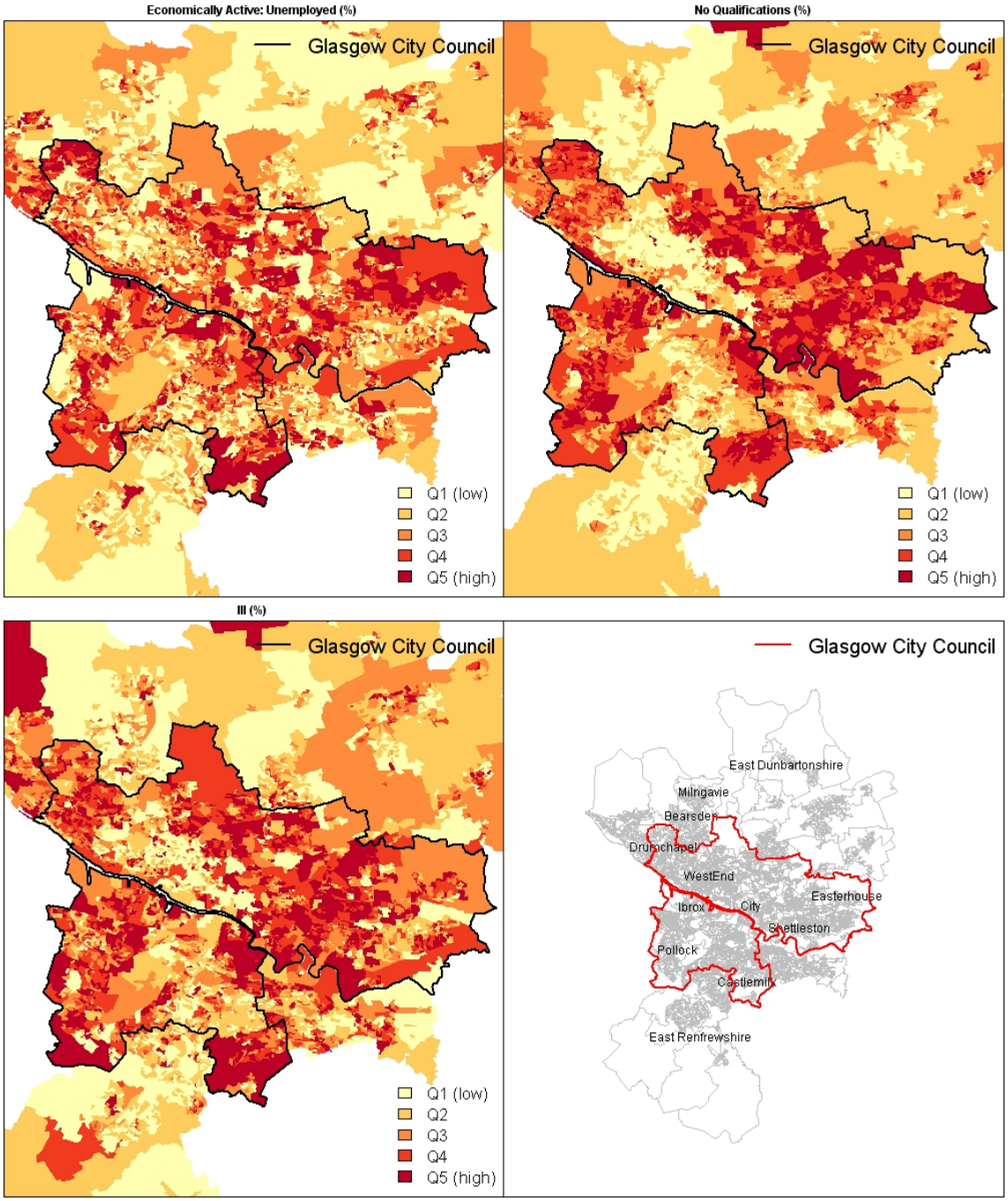


Figure 6.8: Map of Constraints, Glasgow

Overall, the spatial pattern of the constraints has been shown, which provides a series of references with which to set the microsimulated data in a context within Edinburgh. There are general trends towards Holyrood Park and the area immediately to the south-east of this area toward the edge of Edinburgh appearing 'poorer' in terms of the constraints, as well as to the north around Leith, and also parts of the western fringes of the city of Edinburgh. This gives an indication of the spatial 'suspect' areas for 'poor' performance in terms of income and welfare as well as health.

6.6 Conclusions

To conclude, the model constructed has the potential to be used for 'what-if' policy analysis subject to the following caveats. The model outputs assume that the constraints used are accurate predictors of the variable(s) simulated as discussed previously in the constraints section. The data created is ultimately an estimate, so therefore caution must be exercised when using this dataset in any further analysis and it is important to take note of this. On the upside, the model has created a dataset which previously did not exist. The estimation of income, in particular, is very useful for policy analysis. Moreover, data on mental well-being (i.e. GHQ score), smoking and alcohol consumption as well as a wealth of other health information contained in the SHS, has previously not been available at such a small scale (i.e. output areas). The techniques used above to evaluate the performance of the model, show that the results are reasonably accurate.

The most useful aspect of the deterministic reweighting method is that we can use an accounting framework to check for errors in the data as everything should add up to a known total. This feature is reassuring to the modeller as it allows a basic check to be made on the accuracy of the microsimulation

method and model outputs. Another point of debate is whether to use a simple tabulation of each constraint or whether to use a 2 or even a 3 way table as a constraint for the model. It is unclear under what circumstances each is most appropriate and this could be the focus of future research. A connected issue is that it would appear to be the case that the more categories the constraint has, the worse the fit of the constraint, something which should be taken into account. This issue could also be the subject of future methodological research. It is of course resource intensive to begin to untangle such complex interactions on the model and is perhaps beyond the scope of this study.

Other issues centre around the number of iterations to be used as there is no 'gold standard' in the literature rather only rules of thumb on this point. In general terms, the more iterations the better, that being the case, the weights will converge; "estimates have converged typically after a dozen or fewer iterations" (Ballas et al., 2007a, p.50) so there the suggestion was to use around 10 iterations. The SIMALBA model used 50 iterations in the HB model. A model for income deprivation in England developed by Anderson (2007c) noted that "20 iterations were sufficient to achieve a stable indicator value" (p.12). So the modeller has to make a decision on the stability of the indicator. The issue is to achieve the balance between accuracy and computing time required as more iterations will require more computing power, but not necessarily a directly proportional increase in accuracy after a certain point.

The number of constraints to use in the model must to some extent be weighed against sample sizes available to begin with otherwise the risk is run of overconstraining the model (Smith et al., 2009). Of course it should be obvious that more constraints means more computing and time resource needed, so this also needs taken into consideration when constructing a microsimulation model.

Overall, the model would appear to be a very useful tool to fill a hiatus of

data for small areas in Scotland. The analysis that could be conducted from this original dataset would be policy relevant. The SHS has not been used in microsimulation, so this is an original application of this dataset. The next step will be to use the 'new' microsimulated dataset for the analysis of economic and health policy in Scotland. This will have the advantage of providing a previously unavailable 'toolbox' for policy analysis. In this sense the dataset created is an original contribution to the study of health in a Scottish context.

Chapter 7

Economic Policy Analysis

"In this world nothing can be said to be certain, except death and taxes"

Benjamin Franklin (1706-1790)

7.1 Introduction

The main purpose of this chapter is to present a series of economic and geographical analyses of government policy with the use of the spatial microsimulation model SIMALBA. The analyses contained within this chapter includes analysis of current policy as well as possible future options for policy makers where appropriate.

It may not immediately be obvious as to why economic policies may alter or affect health outcomes. The literature review (chapter 2) looked in depth at the issue of income inequality and how this is linked to health (Wilkinson

and Pickett, 2006, 2007) so that more unequal societies experience worse outcomes in health or life expectancy. As a consequence, policy changes which directly relate to income, such as benefits or income tax could potentially alter income inequality and thus alter health in the long term. Other areas such as housing are also affected by economic policies and can have important health consequences (Mitchell et al., 2002). Also, in the literature review, issues such as child poverty and poverty in general (Shaw, 2007) as well as deprivation can potentially be affected through economic policy changes as so may have links to health outcomes. This gives an insight into the reasoning behind the decision to explore economic policies, as there are often consequences for health either positive or negative.

It is necessary to outline the current situation of government in the UK in order to provide some context for the analysis of economic and of health policies that will follow in the next chapter. First, there is a multi-level governance system at work in the UK, with regional (Welsh, Scottish and Northern Irish) parliaments responsible for devolved matters, although all three do not operate in the same manner or have the same powers, but there are large areas of similarity. For example, the devolved administrations do not have any control over defence or international relations but over health and education policy areas (Cairney, 2006). Second, there is an unusual situation at present at the national (UK) level, with a coalition government in place. This came about as "no one party secured an overall majority of seats" meaning that this was the "first time ever in modern British politics that a coalition between two whole parties was formed afresh immediately after a general election" (Curtice, 2010, p.623). At the most recent general election in 2010, the Conservative party won 307 seats of a possible 650, but needed 326 to be able to form a majority government. In order to form a government a coalition was formed with the Liberal Democrat

party (57 seats) to pass the threshold needed to form a government and remove the previous Labour government from power (1997-2010).

The focus now shifts specifically to Scotland. How has Scotland fared in electoral terms in the recent period? Within the Scottish Parliament the 1999 election, saw 56 of the 129 seats won by the Scottish Labour party; in 2003, 50 seats were won by Labour; in 2007, the Scottish National Party (SNP) won 47 seats and formed a minority government (a party would normally need 65 seats to gain a majority). This happened in the most recent election on May 5th 2011, when the SNP won 69 seats.

The budget from which many of the polices are taken was presented on the 22nd June 2010 (see Budget 2010 for the full document). Note that economic policy is still driven primarily by the UK (i.e. Westminster) government, although the Scottish government does have some tax varying powers as a devolved region with a legislative assembly. The tax varying powers extend to adjusting the basic rate of income tax by three pence in the pound if desired. This is known as the 'tartan tax' and as noted by Mair and McAteer (1997) it has "a 3% tax varying power" (p.1) which could be considered a small, but potentially significant margin for deviation from the rest of the UK. There are several important policy changes likely to occur due to the coalition government budget, particularly with respect to personal taxation and entitlement to welfare. In the section on policies, the policy changes which will be modelled in the 'what-if' analysis are explained and explored in greater depth.

The main thrust of the 'what-if' analysis of economic policy areas will be on changes to the income tax rates in Scotland and to examine the spatial effects of the distributional changes if any exist. Additionally, the changes to welfare entitlement will also be modelled and explored with a view to determining whether or not there is a spatial pattern and the likely consequences of a change in pol-

icy. A set of relevant and current options, (for example those that have been set out by the UK coalition government in the austerity drive) can be seen in the programme for government (HM Government, 2010). It is possible that some of these polices can be modelled and the effects on the population of Scotland at various geographical areas can be examined using SIMALBA. The policies are explained in greater detail subsequently.

So to reiterate, the aim of this chapter is to try and model the possible effects of policy changes particularly in areas such as income tax and welfare for Scotland at sub national geographies for one point in time using the SIMALBA microsimulation model.

7.2 The Economic Policies

This section aims to give a brief overview of the policies that are potentially going to be implemented assuming that political parties use manifestos as a template while in government. Prior to the British general election political parties published a series of manifestos filled with a set of promises in the event that the party concerned are elected to serve in Government. It is these manifestos from the Labour Party, the Liberal Democrats, the Conservative party and for Scotland, the Scottish National Party (see The Labour Party (2010), Liberal Democrat Party (2010), The Conservative Party (2010), Scottish National Party (2010) respectively) that contain the likely alterations to existing policy or the new policies which could be introduced during a period of government by the respective political party. One of the policies which may be relevant to the study of health inequalities is the proposal to increase the threshold of income tax to £10,000, meaning that the first £10,000 of earned income is not taxed. In other words the tax rate on earnings up to £10,400 would be 0%. However, there will still be deductions, for example national insurance. The idea behind

this policy proposal suggested by the Liberal Democrat Party in their manifesto was arguably that it would provide an incentive to 'make work pay' over and above the level of state benefits an individual or family would be receiving. This would thereby remove perverse incentives giving rational individuals few options but to remain on benefits, as their absolute income was potentially lower or the equal when in employment. Additionally, the effective marginal rates of tax for some individuals moving from benefits to employment are high. Governments in the United States, Canada, UK and New Zealand have resorted to measures such as in work benefits; for example tax credits "in an attempt to alleviate poverty without creating adverse incentives for participation" (Brewer et al., 2009b, p.F1). Another report notes the problem of working a minimum wage job that, "compared to an income at 40 hours of work, a couple on Jobseeker's Allowance will only be £29.06 better off" (Kay, 2010, p.7). This kind of scenario is known as the 'poverty trap' (in the UK) (Kay, 2010).

At the other end of the income scale the planned rise in the tax rate on those earning over £150,000 will help to address income inequality to some extent, particularly if the goal is to redistribute this wealth towards the 'poorest' in Scotland (or the UK). As discussed in the literature review chapter (see chapter 2) income inequality is an important determinant of health. Therefore, policies which could reduce or increase inequality may well affect the health of that nation. Other policies, mainly from the Conservative party manifesto (which are likely to be implemented from the Budget 2010), suggest removing the child benefit payments for those earning over a certain limit as well as placing a cap on the level of Housing Benefit by number of bedrooms.

It is an original contribution to policy debates to model these policy scenarios outlined above using the spatial microsimulation model for Scotland SIMALBA, (chapter 6 has a more complete description of the model). This is the strength

of spatial microsimulation. The impact of policy can be seen on different 'types' of individuals as well as on different areas in Scotland and the results discussed 'before' and 'after' a policy is introduced.

7.3 Income Tax

In order to examine changes on personal income tax rates, data on personal income is essential. This has been simulated using the spatial MSM SIMALBA (as explained in detail in chapter 6) using a spatial deterministic reweighting algorithm. It is this microsimulated dataset which can be manipulated and moulded to address both current policy and potential future policy changes which directly relate to income. In this section of the chapter it is economic policy analysis which relates to changes to the income tax rates that are explored. The two main changes that will be examined are the increase in the tax free threshold on earned income, which will be raised to £10,000. The other income tax change, is the 50 pence tax rate for every pound earned over £150,000, which was an increase on the tax rate of 40% and was introduced by a previous Labour government. For each of the policies a brief description of the background is given, followed by the analysis. The analysis includes tables and maps, showing the spatial distributions and the impacts of the policies on Scotland at sub-national levels.

7.3.1 Raising The Income Tax Threshold

There has been some discussion about the advantages and disadvantages of raising the income tax threshold for individuals in the UK as well as more general taxation issues which have been outlined by several different bodies with varying viewpoints (see for example Bassett et al. (2010)). In general, the consensus is that by raising the tax threshold it will provide an incentive

whereby employment will be preferable to living on benefits as the first £10,000 of income earned will be received by the individual directly. It could be argued that this removes the perverse incentives whereby an individual is in a more financially secure position in choosing not to be in employment and continue to support him or herself using the welfare entitlements provided to them by the state. The current rules stipulate that the personal allowance is £6,475 for 2009-11 and will rise to £7,475 by 2011-12 (see HMRC). As discussed previously there is a compromise in the microsimulated dataset in that there is only categorical data for microsimulated income. Therefore, the policy analysis presents a case for assessing people currently in the income categories up to £7,800 compared with those who are in the income categories up to £10,400 to show the effect of the policy if the income tax threshold was raised to the £10,400 level from £7,800. It therefore must be noted that it is a compromise that the cut-off point has been chosen as £10,400 due to the categorical nature of the estimated income distribution from SIMBALBA. What this section aims to explore is where the individuals live who will 'gain' most from the increase in the income tax threshold to a hypothetical position of £10,400.

The SIMALBA model has simulated which HBs have the highest proportions of population that fall into the income categories up to £10,400 as well as those in the up to £7,800 category. What can be done with the SIMALBA model is to show who would potentially move from paying tax currently to a situation whereby there would be no tax for those earning under £10,400. This is also shown in Table 7.1 which shows that Argyll and Clyde has the highest proportion of people who would gain from an increase in the tax threshold (15%). However, The Western Isles would see almost no difference under this policy scenario (0.01%). The spatial patterning of 'winners' is different across Scotland, with some HBs gaining a greater proportion of population who would pay no tax,

whilst others experience an almost negligible difference. This provides a useful insight into the location of those individuals likely to be affected by such a policy change. The situation is also demonstrated in Figure 7.1 which is a series of maps showing the two different income categories (£10,400 and £7,800) with the 'gainers' under an increase in the tax threshold in the bottom right panel (i.e. the difference between the two income categories). This is the column on the extreme right of Table 7.1, labelled "differences". For example Lanarkshire would have a decrease from 18% to 8% of individuals paying income tax on earnings, a decrease of 10% of people paying any tax. This would mean that an extra 10% of the HBs population would now be exempt from paying income tax under this scenario. It could be argued that it is this policy that will address the 'poverty trap' to some extent by altering the disincentive to take up employment due to the high marginal rates of income tax in such circumstances and potential loss of benefits.

Health Board	£10,400 (%)	£7,800 (%)	Differences (%)
Highland	17.23	8.05	9.18
Grampian	15.68	13.29	2.39
Tayside	17.99	12.86	5.13
Fife	13.85	6.94	6.91
Lothian	10.73	5.55	5.18
Borders	12.67	9.14	3.53
Forth Valley	40.13	37.11	3.02
Argyll & Clyde	24.67	9.63	15.04
Greater Glasgow	23.53	15.70	7.83
Lanarkshire	18.19	8.18	10.01
Ayrshire & Arran	14.12	10.53	3.58
Dumfries & Galloway	13.19	5.46	7.74
Orkney	10.89	5.34	5.55
Shetland	15.98	7.36	8.62
Western Isles	9.52	9.51	0.01

Table 7.1: Microsimulated income scenario

The situation can also be explored at a smaller scale using the SIMALBA

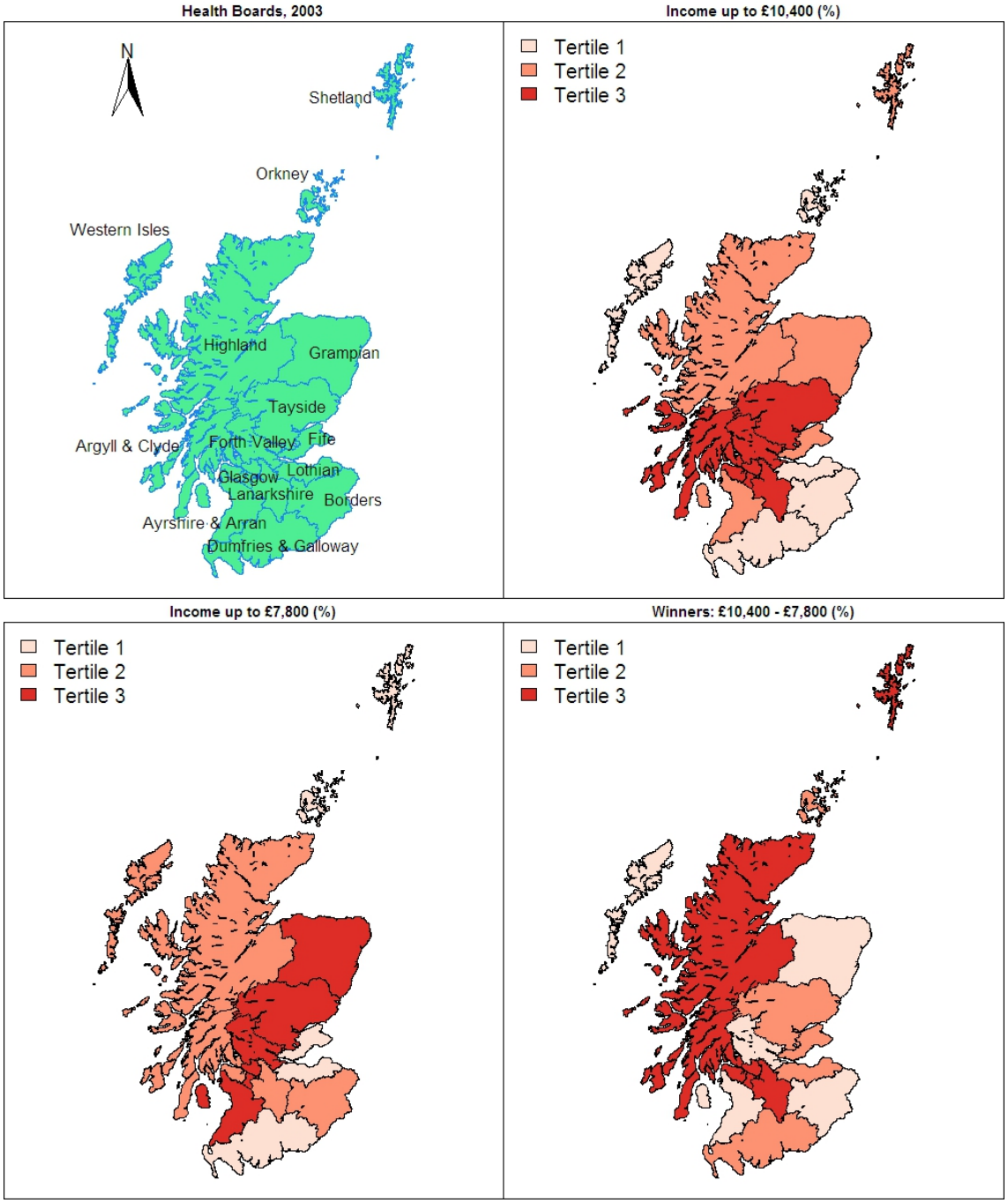


Figure 7.1: Policy Scenario: Raising The Income Tax Threshold, Health Boards (T1:Low)

algorithms with OA geography level data. This model will be referred to as the SIMLOTHIAN model. Using the SIMLOTHIAN model, the figures show the situation in the Lothian HB (Figure 7.2) and in Edinburgh City OAs within Lothain HB (Figure 7.3) and those who will benefit most from the changes. This mirrors the HB analysis but at a smaller spatial scale. The darkest colour represents the highest proportions (the areas with proportions in the highest fifth of the distribution) of low income earners that is up to £10,400 in each OA. The lightest colour represents the lowest income earners as a proportion of total population in that OA. The Lothian HB area exhibits a general trend of those areas with the highest proportion of low income earners being located in OAs around Edinburgh (in the middle of the HB) or around urban areas. At the other end of the distribution, the areas with the lowest proportion of low earners are generally speaking located in the more rural areas of the HB, for example in the east, near North Berwick and to the south west of Lothian HB also. As this map is based on area (rather than a cartogram which is based on population) it is helpful to 'zoom in' on Edinburgh City. What can be seen within Edinburgh is a slight clustering effect, particularly around Muirhouse and Leith (to the north) where there is a concentration of low income persons. There is also some clustering of (Q5) areas to the western edges of the map. The power of a simple map is that we can see where it is likely that individuals who will benefit most will reside and target particular policies or resources to those areas if desired.

Next, Glasgow is examined using the SIMGLASGOW model. Those earning up to £10,400 are shown in Figure 7.4. There does appear to be a clustering of areas, but it is a rather sporadic pattern, not particularly concentrated in any one area of Glasgow other than the east end. This would appear to be demonstrating the curious pattern of poverty in Glasgow which exists in both the

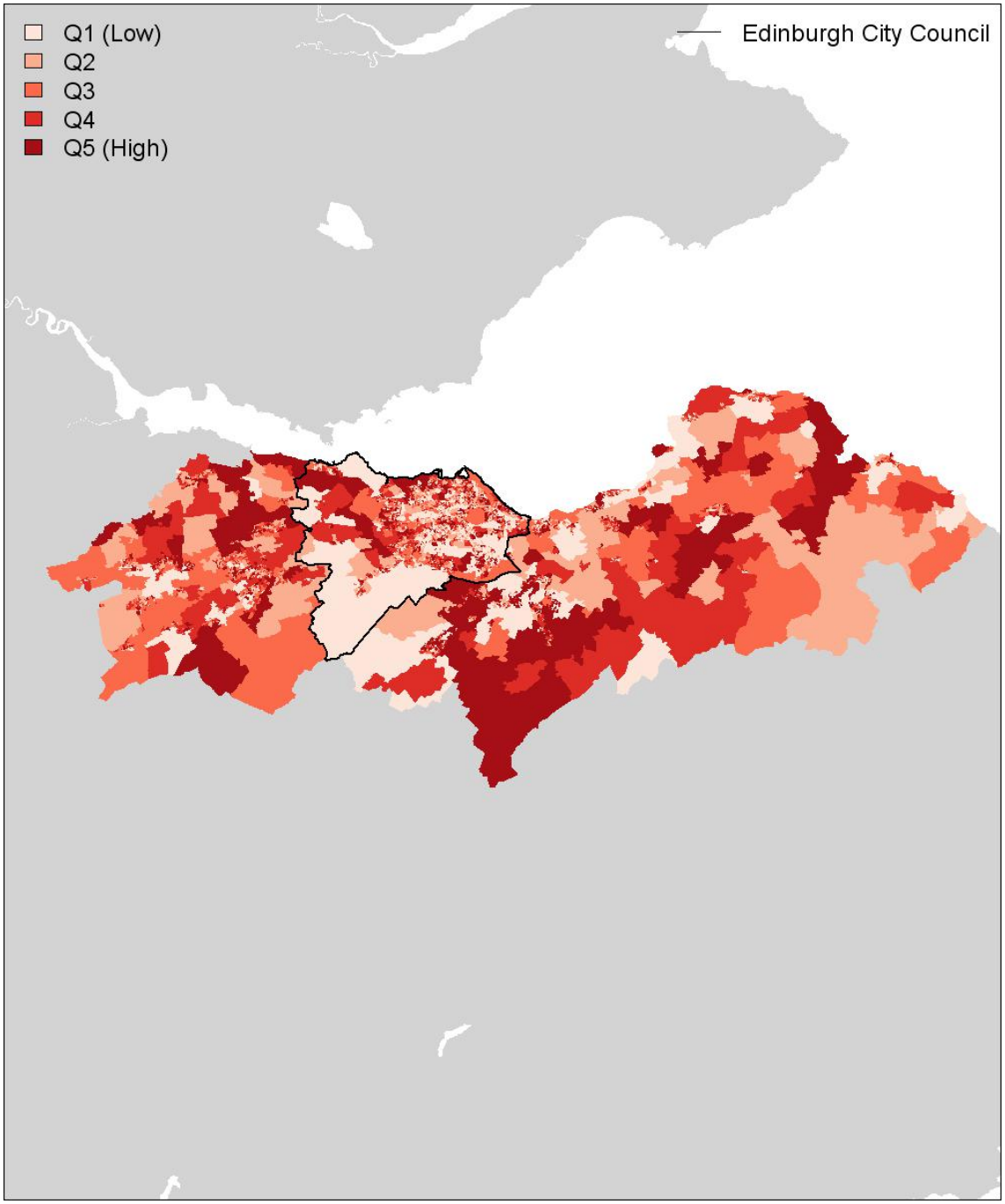


Figure 7.2: Percentage Earning up to £10,400 Lothian OAs: Quintiles

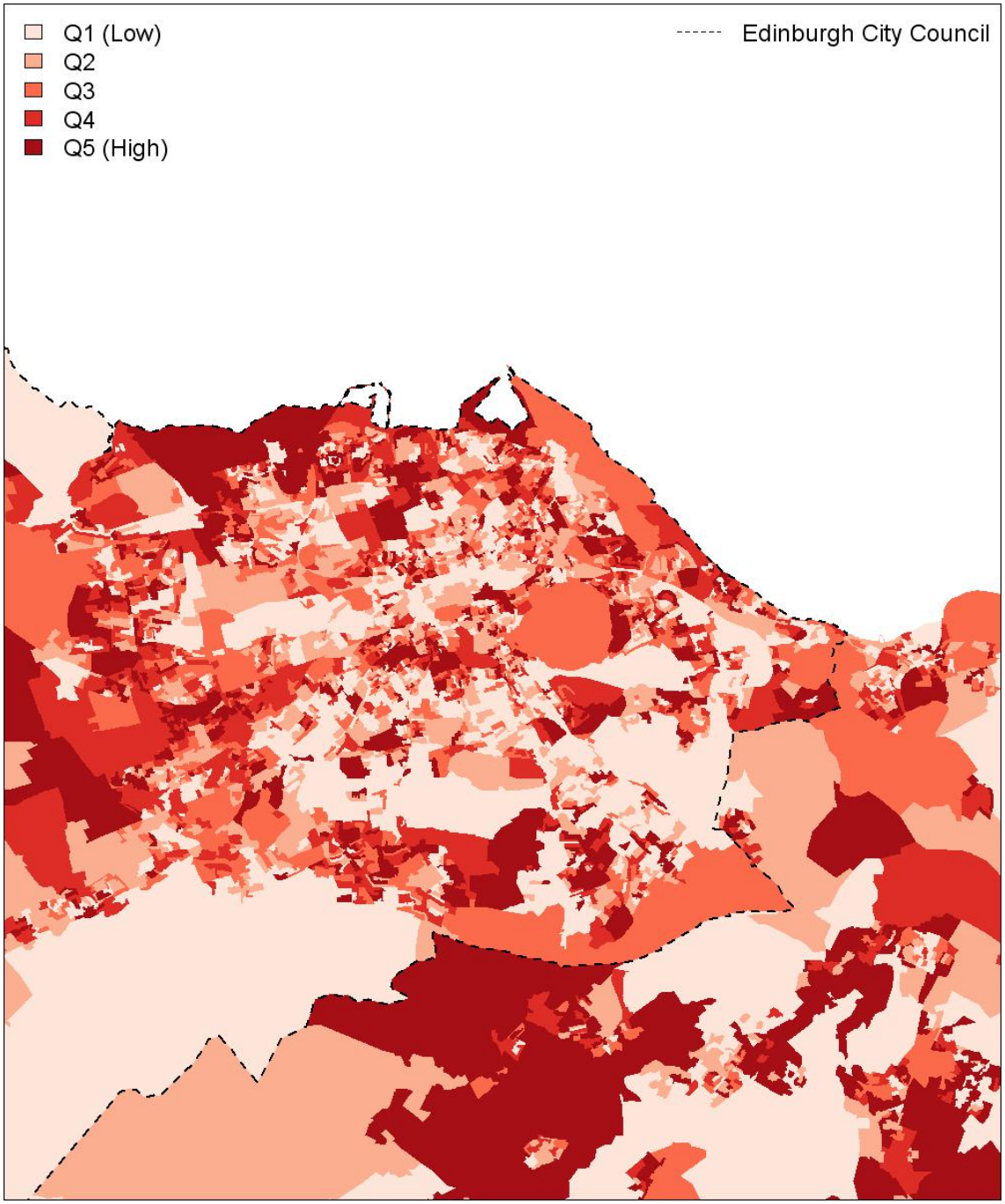


Figure 7.3: Percentage Earning up to £10,400 Edinburgh OAs: Quintiles

more 'traditional' deprived inner city as well as more deprived estates around the edges of Glasgow. The distribution of areas has been split into quantiles, so Q5 represents the areas with the highest proportions of low earners. These 'types' of areas look concentrated in the inner city areas of Glasgow along the river Clyde extending towards Clydebank on the northern edges of Glasgow (Partick, Govan, Parkhead, Gorbels for example). In addition, areas just outside the city council boundary to the north in East Dunbartonshire feature in the lowest quantile, but are more rural in nature. The areas with the lowest proportions of low earners (Q1) are most visually noticeable congregating in the east of Glasgow.

What can then be modelled is the change in threshold up to the £10,400 from the current level which is assumed here to be £7,800. The 'day after' changes are shown for Edinburgh in a map (see Figure 7.5). The biggest gains are coloured the darkest (over 15% of the population gains - Q5), whereas the least effect is seen in those areas which are coloured lightest (Q1), so the gradient of colour gets progressively darker as more people are hypothetically 'lifted' into a position whereby they are completely free from personal income tax in this policy scenario. It is not practical in this context to show a table of the various gains at OA level as there are too many areas (6637 OAs). The HB level geography is more useful at this point showing the average effect across all OAs in a particular HB (see Figure 7.1). The areas out of the central area of Edinburgh, that is to the north and south, appear to gain the most from a policy scenario such as this. There is little change in the areas in the vicinity of the city centre overall, with a detectable 'hollow' in the centre, (perhaps except around Holyrood Park and the immediately surrounding areas).

Looking at this policy scenario for Glasgow, the areas with the greatest number of 'winners' from the increase in tax threshold are modelled and shown

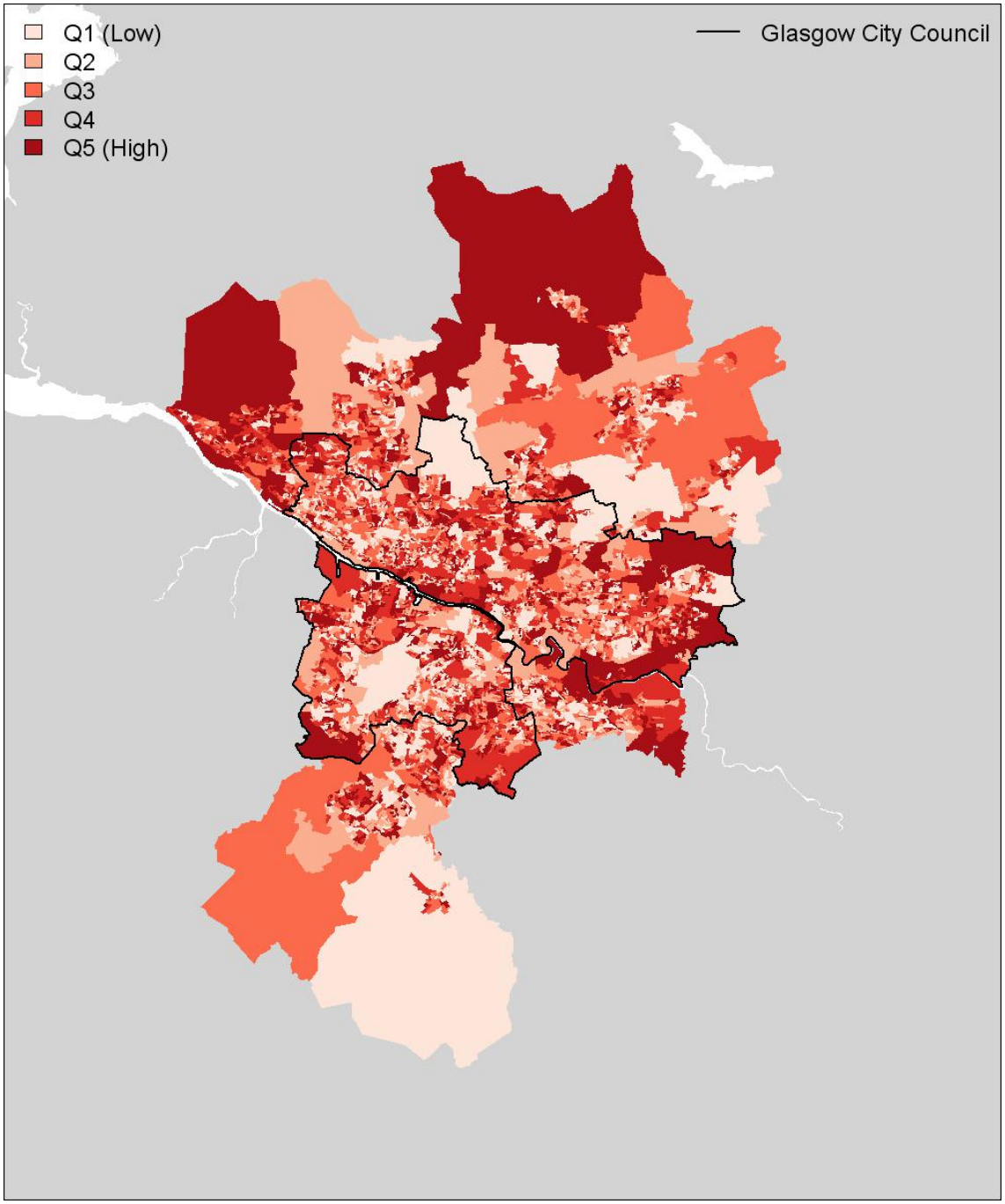


Figure 7.4: Percentage Earning up to £10,400 Glasgow OAs: Quintiles

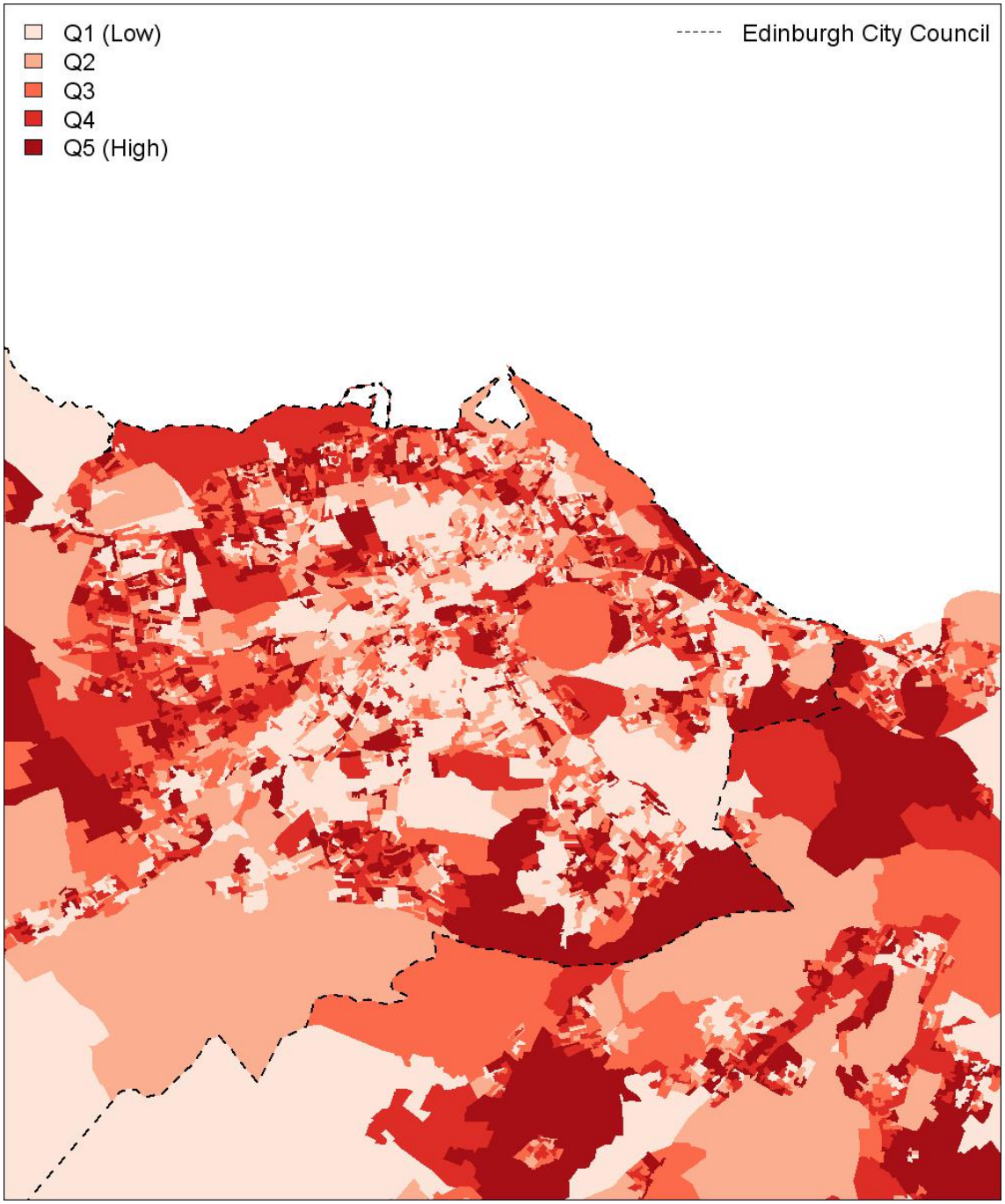


Figure 7.5: Increase of personal income tax threshold to £10,400 Edinburgh OAs: Winners (%)

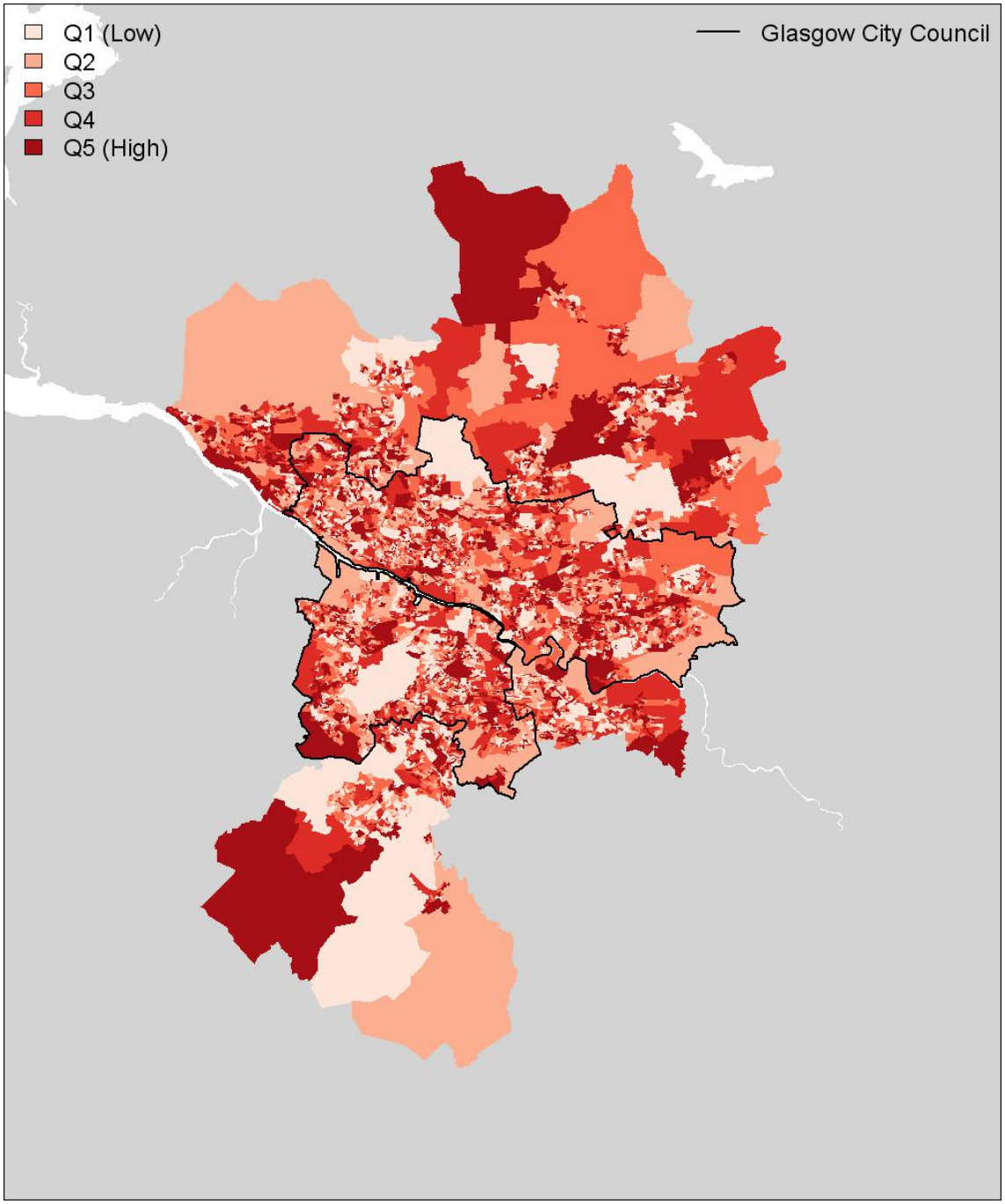


Figure 7.6: Increase of personal income tax threshold to £10,400 Glasgow OAs: Winners (%)

in Figure 7.6. There is an absence of 'winners' to the north and west (Q1) in the lightest shades, as well as a similar hiatus to the south of the Glasgow area inside the city council boundary. The pattern is mainly determined by the presence of high numbers of people in a particular area on low incomes and appears to be sporadic overall, which may well be a desired outcome so that no one area benefits disproportionally. There is a slight problem in that visually the larger rural areas are skewing the perception so that it appears to be benefiting the areas outside Glasgow most, when on closer inspection the areas around Clydebank and Drumchapel appear to benefit more (in terms of population).

7.3.2 The 50 Pence Tax Rate

The introduction of a tax rate of 50% on personal income in the UK is discussed in detail (previously shown briefly in the model chapter 6). SIMALBA allows the spatial distribution of people who will be affected by this change to be mapped at either HB (see Table 7.2) or OA geography (or any other spatial scale between the two extremes). First, the percentage of people who earn over £150,000 must be calculated in each HB or for each OA. This can then be mapped shown in figures 7.7, 7.8, 7.9 and 7.10. What each map represents is the percentage of people in each HB (or in every OA) that would be liable for a 50% rate of income tax if it were to be introduced in Scotland.

The pattern is that southern areas of Scotland (and around Aberdeen) have the highest proportions of individuals with incomes over £150,000. At the other end of the spectrum, the Islands (Western,Shetland, Orkney HBs) have no individuals with a simulated income over £150,000. Note that this may be due to small sample sizes in the SHS. This data is shown in Table 7.2 and in Figure 7.7, with the proportions of individuals in each category reported. Note

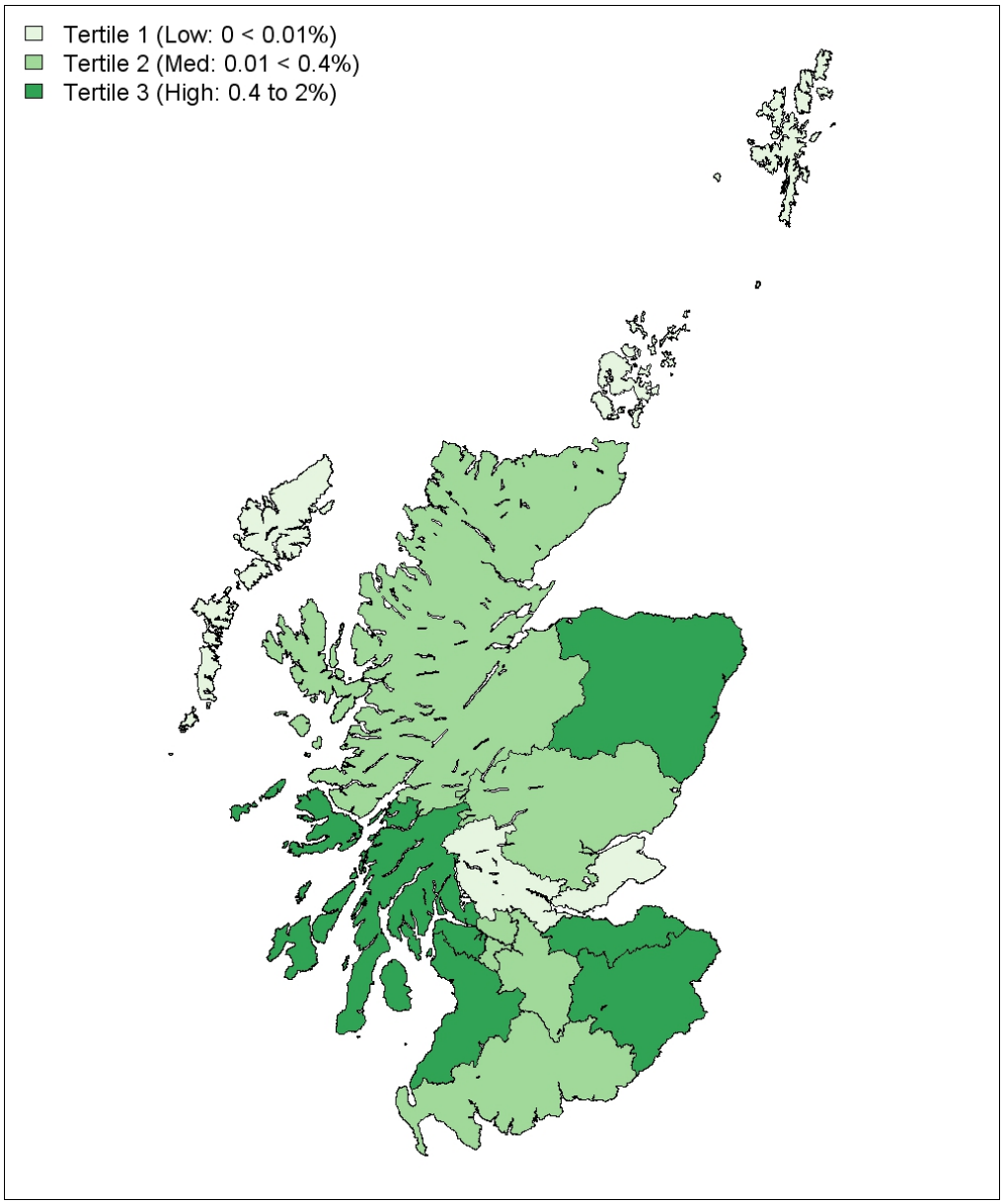


Figure 7.7: Percentage Earning over £150,000, Health Boards: Tertiles

Health Board	£150,000(%)	non-£150,000(%)
Highland	0.08	99.92
Grampian	0.41	99.59
Tayside	0.13	99.87
Fife	0.00	100.00
Lothian	1.87	98.13
Borders	1.17	98.83
Forth Valley	0.00	100.00
Argyll & Clyde	0.63	99.37
Greater Glasgow	0.34	99.66
Lanarkshire	0.08	99.92
Ayrshire & Arran	0.46	99.54
Dumfries & Galloway	0.34	99.66
Orkney	0.00	100.00
Shetland	0.00	100.00
Western Isles	0.00	100.00

Table 7.2: Microsimulated Income: proportion (%) of individuals £150,000

that because of the problem of zero counts the HB map has been split into tertiles (thirds). So, Western Isles, Shetland, Orkney, Fife and Forth Valley have a microsimulated value of zero. It is the Lothian HB (approximately 2%) which has the highest proportion of individuals who could be affected by the increase in tax rate on earnings over £150,000. Overall, the pattern can be summarised with the statement that no HB has over 2% of individuals earning over £150,000. So this change may only have a very small impact in terms of proportion of population in Scotland compared to the £10,400 threshold. However, there may be a noticeable increase in terms of the absolute amount of tax collected.

It is also possible to explore data using SIMLOTHIAN to see the pattern within the Lothian Health Board. SIMLOTHIAN is a subset of the SIMALBA model in the sense that it is the same algorithm but for Output Areas rather than Health Board. It therefore includes every OA within the Lothian HB with the full complement of microsimulated variables. Figure 7.8 shows the

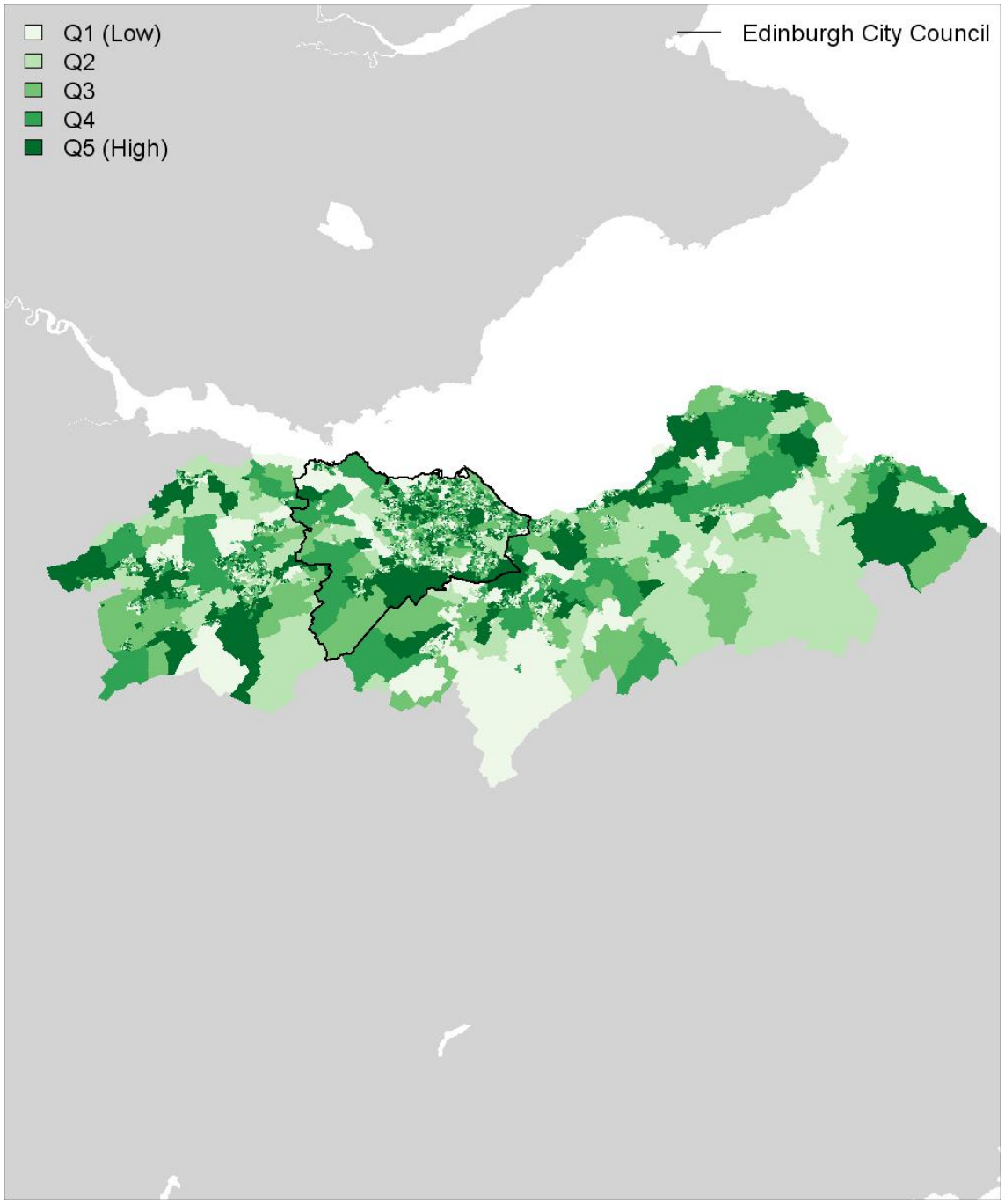


Figure 7.8: Percentage Earning over £150,000, Lothian OAs: Quintiles

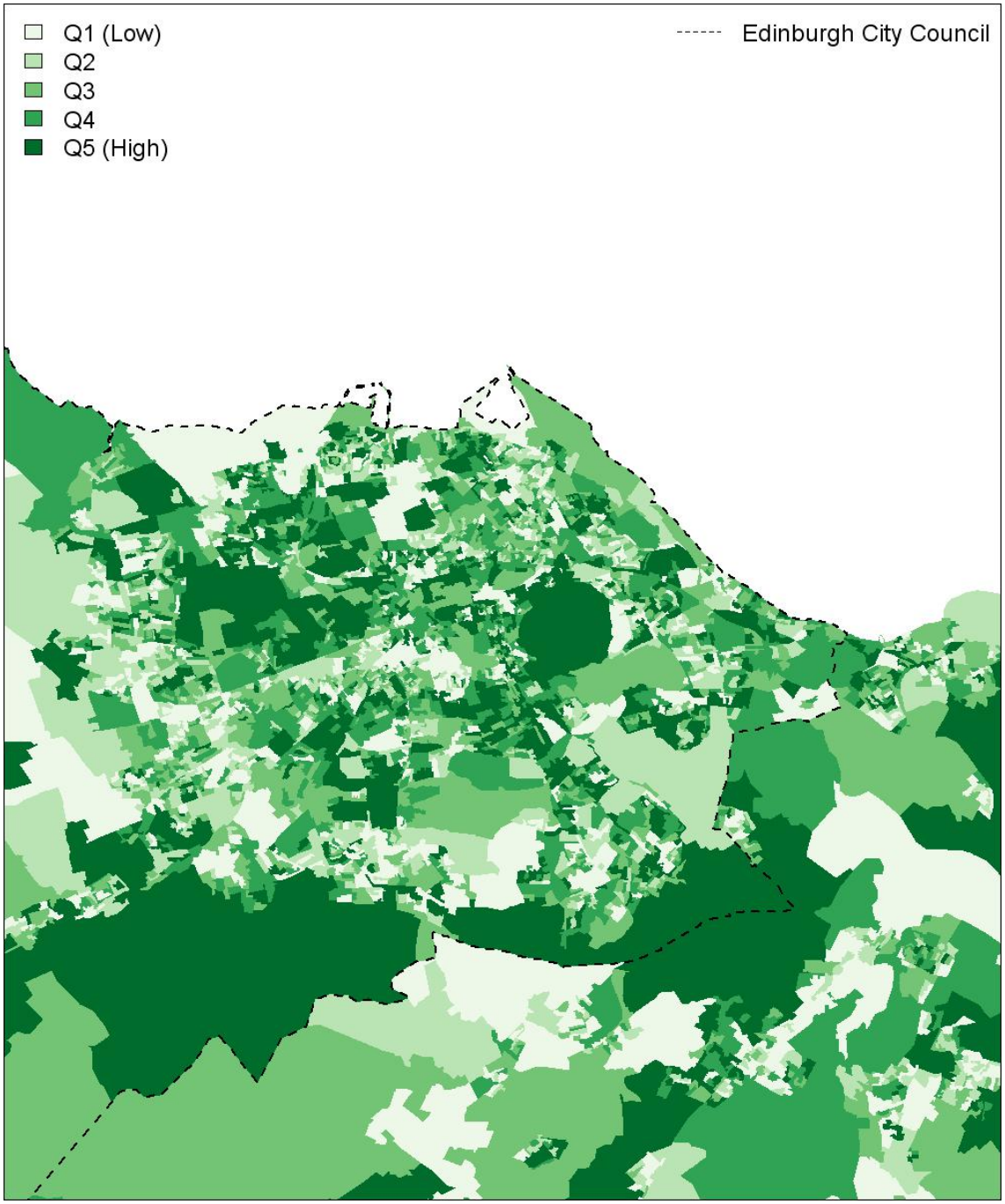


Figure 7.9: Percentage Earning over £150,000, Edinburgh OAs: Quintiles

Lothian OA model outputs and Figure 7.9 shows a version of the same model, but focused on Edinburgh City. What can be deduced from Figure 7.8, is that the pattern would appear to be fairly random, such that those parts of Lothian where the microsimulated data has estimated the highest concentrations of those earning £150,000 and therefore will be liable for a new 50 pence tax rate on those earnings is not immediately obvious other than to highlight it is mainly the polar opposite of the figure showing those earning up to £10,400. There are smaller clusters to the south of Edinburgh and the eastern side of Lothian HB also has some concentrations, but overall a clear pattern is difficult to deduce. This may be due to the small proportions in each area.

Looking within Edinburgh the main concentration of these individuals is around the southern edges of the city. There is also a clustering effect of the highest proportions of areas with those earning £150,000 or more around the financial and central western districts of Edinburgh and Holyrood Park. There are also notable gaps, with areas in the lowest quintile mainly to the north of Edinburgh. The spatial pattern then is not particularly easy to categorise for this particular microsimulated data. It is the areas in the darkest shade of the colour that will be affected by an increase in the tax rate on individuals earning over £150,000 most severely. Looking back to the socio-economic geography of Edinburgh in chapter 6, the pattern of high earners is similar to the figure showing the areas with high proportions of NSSEC 1 and 2 type jobs, in other words professionals and managers.

In the figure showing the very highest income earners for Glasgow (see Figure 7.10), the most noticeable feature is the larger OAs, which can be assumed to be more rural in nature that dominate the top of the distribution of OAs (Q5). On closer examination there are lower numbers of high earner areas towards the central areas of Glasgow, as well as more generally speaking, to the eastern

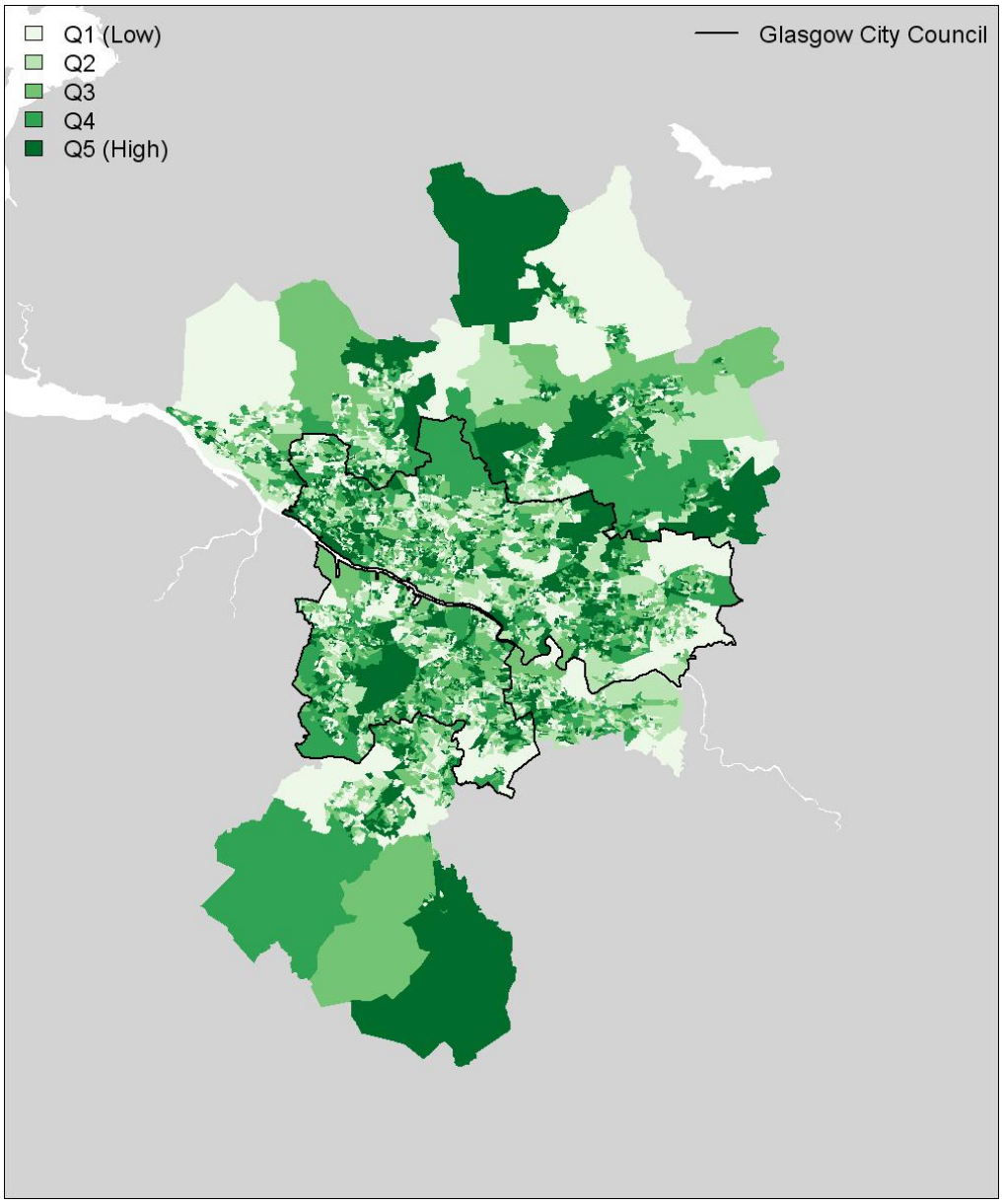


Figure 7.10: Percentage Earning over £150,000, Glasgow OAs: Quintiles

side of Glasgow. Of note are the areas with the highest proportions of people earning £150,000 or more clustering just outside the edges of the city boundary. There are also visually detectable gaps in Bridgeton towards Shettleston and Easterhouse as well as to the south in the areas around Castlemilk. The areas in the west end towards Bearsden and Milngavie feature most areas in the higher quantiles. Generally speaking, the prominence of areas along the Clyde and in the east end in the lower quintiles is to be expected, although the pattern is by no means simple to interpret.

7.4 Welfare Changes

In this section some possible changes to welfare entitlements are modelled and discussed using the microsimulated data from SIMALBA. The focus of this section is on the potential changes to housing benefit and to child benefit. Additionally, the current situation is also modelled where possible to show the 'before' and 'after' results. Both will be explored in more detail in the subsections that follow. The welfare changes section builds on the previous income tax analysis and provides data on 'types' of individuals and policy scenarios. The previous analysis on income tax is used as a template for the analysis of policy on welfare, with analyses involving welfare changes described here. The results are of particular relevance for policy debates surrounding issues of who will bear the burden of the cuts most acutely including which areas (and which people) the cuts will effect most directly.

7.4.1 Housing Benefit

The aim of housing benefit is to provide those on low income or in receipt of welfare with a way in which to pay their full housing costs. For example, rent is the most obvious cost. It is therefore a means tested benefit. In practice, this can

be beneficial to both the tenant receiving this benefit, but also to those private landlords who will potentially gain financially from providing accommodation.

The rules surrounding the eligibility for housing benefit are complex as when eligibility is established there are varying rates that can be paid as well as for different reasons (Child Poverty Action Group, 2003). Briefly, there are several key criteria. Income must be low (which is defined as below a certain threshold) and savings and capital must also be below a certain limit (usually under £16,000). You are not normally eligible for housing benefit if a full time student or from abroad. The individual (or their partner) must be liable for rent and occupy the property in question as home. The amount that can then be claimed will depend on individual circumstances, for example if a person is receiving job seekers allowance or other benefits.

The current coalition government has proposed a maximum level of housing benefit of differing levels depending on the size of the property. The most likely levels (per week) are around £250 for a one-bedroom property, £290 for a two-bedroom property, £340 for a three-bedroom property rising to £400 for a four-bedroom property at the highest level. This could cause an issue for individuals (or families) that are currently receiving a level of housing benefit which is higher than the new levels to be implemented. The cost difference would have to be made up somehow. This is set against the context of the local housing allowance, which sets rates by geographical area for different parts of the UK. As housing benefit entitlement is complex to model given the dataset, the most efficient and pragmatic approach is to determine the spatial location of housing benefit claimants (and therefore individuals) who will be affected and in which areas. This allows the areas where the likely impacts are greatest to be identified as well as which 'types' of individuals. The assumption underlying this policy analysis is that changes will be felt greatest where there are the

greatest number of claimants.

If, housing benefit caps such as those above are introduced, those who currently rent property at a rate over and above this threshold will have to make up the difference from their own income or else choose to relocate to a property which is within the threshold for the size of property if this change affects that individual or a particular family. SIMALBA can be used to show likely places where those individuals currently receiving housing benefit reside and therefore those most likely to be directly affected by any change to this particular benefit. In order to assess this policy SIMALBA has simply modelled whether or not an individual receives housing benefit. This is a compromise in the dataset as ideally the exact amount is more appropriate but it is not possible to model this with the data available in SIMALBA. On the other hand the model allows at least a 'ballpark' idea of those people and places who could experience the changes in this policy. It is important to issue a health warning with a variable such as receipt of housing benefit. In this type of scenario where external factors have a large influence on the variable the microsimulation model is less robust.

The discussion now focuses on to the figures produced and the analysis conducted. Table 7.3 shows the percentages of each HB which are receiving any housing benefit and are therefore vulnerable to changes in the level of payments. The Greater Glasgow and Ayrshire and Arran HBs with approximately 6% and 5% of the population receiving housing benefit are therefore most at risk in terms of any reduction in this payment. On the other hand Orkney and the Western Isles will essentially be immune from any effects according to the SIMALBA results. This information has also been displayed in the maps in Figure 7.11, to show the spatial pattern at the HB geography. In a similar manner to the previous analyses, SIMLOTHIAN has also been used to provide the 'picture' at a smaller spatial scale. The map in Figure 7.11 shows the results

from the SIMALBA model. The spatial heterogeneity is again clear. However, for housing benefit the differences are within approximately 5% for every HB in Scotland. So the differences between areas are very small in comparison to some of the other variables and within the 5% error margins set previously for accuracy.

Health Board	No Housing Benefit(%)	Housing Benefit(%)
Highland	96.22	3.78
Grampian	99.22	0.78
Tayside	98.08	1.92
Fife	97.27	2.73
Lothian	97.40	2.60
Borders	94.63	5.37
Forth Valley	98.75	1.25
Argyll & Clyde	96.07	3.93
Greater Glasgow	93.77	6.23
Lanarkshire	96.96	3.04
Ayrshire & Arran	94.72	5.28
Dumfries & Galloway	97.01	2.99
Orkney	100.00	0.00
Shetland	95.87	4.13
Western Isles	99.99	0.01

Table 7.3: Microsimulated housing benefit

If the OA model is used, (looking at Figure 7.12 showing Lothian HB as a whole), the distribution of housing benefit claimants is more clustered than perhaps income, particularly those areas in the bottom quintile (Q1). There is less of a rural/urban split with this variable and it would appear to be more clustered than income. The map (Figure 7.13) is again a close up view of Edinburgh. At this level, the expectation is that the location of housing benefit would be determined to an extent by the location of either local authority rented housing locations, or potentially of suitable private sector housing rental alternatives. The model simulates large numbers of housing benefit claimants in the central area of Edinburgh in the areas surrounding Holyrood Park. There is also

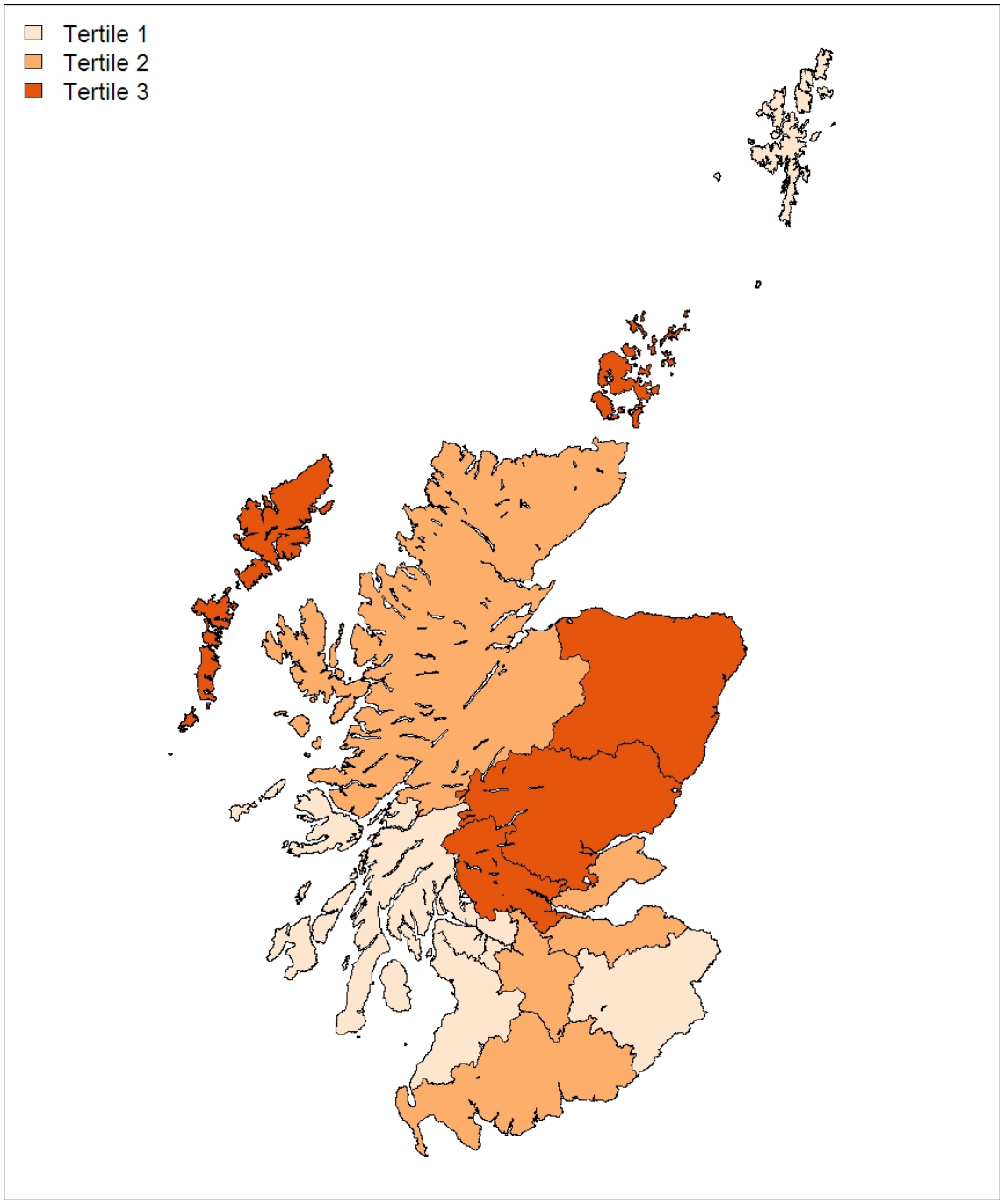


Figure 7.11: Housing Benefit Recipients (%), Health Boards: Tertiles (T1:Low)

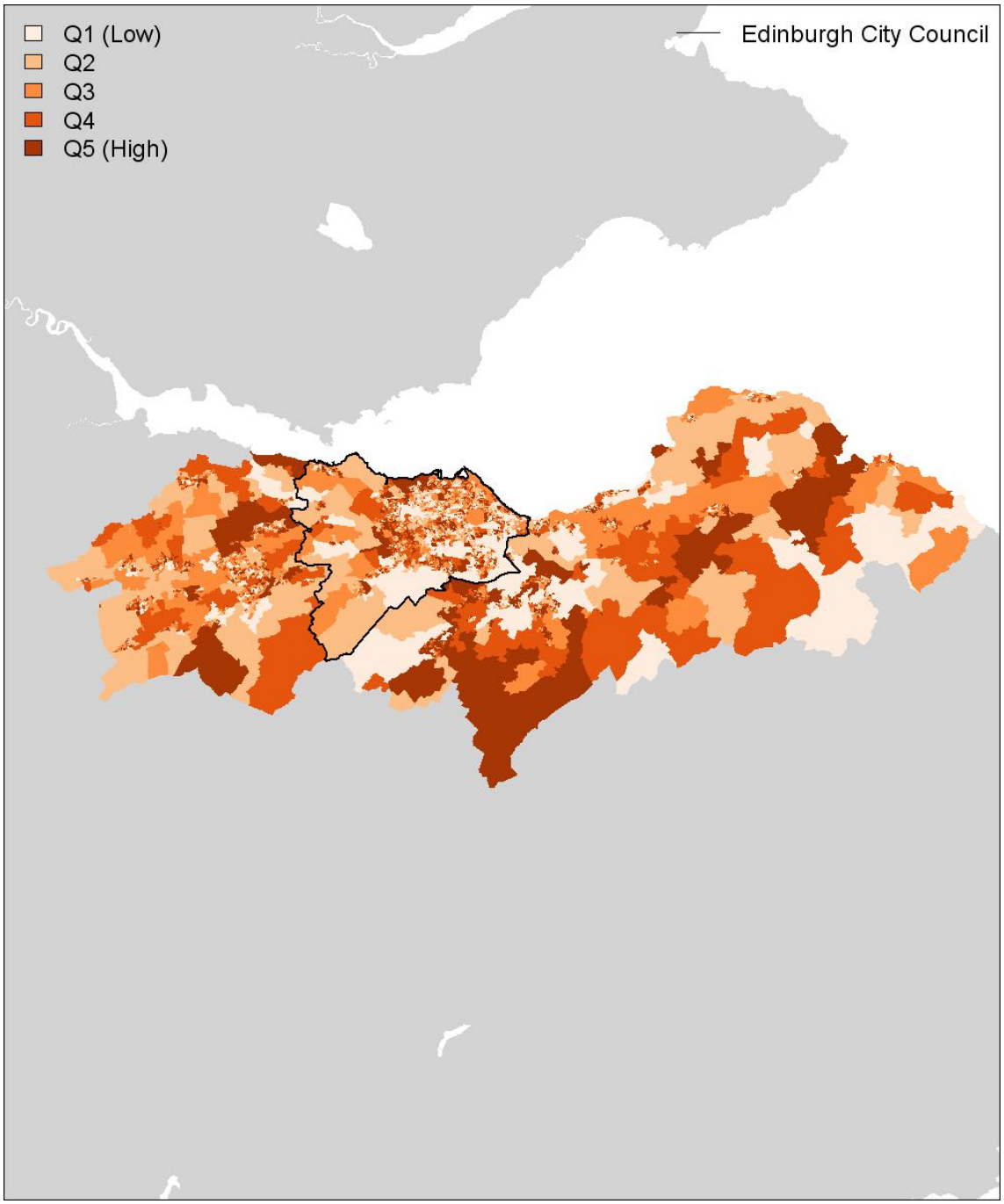


Figure 7.12: Housing Benefit Recipients (%), Lothian OAs: Quintiles

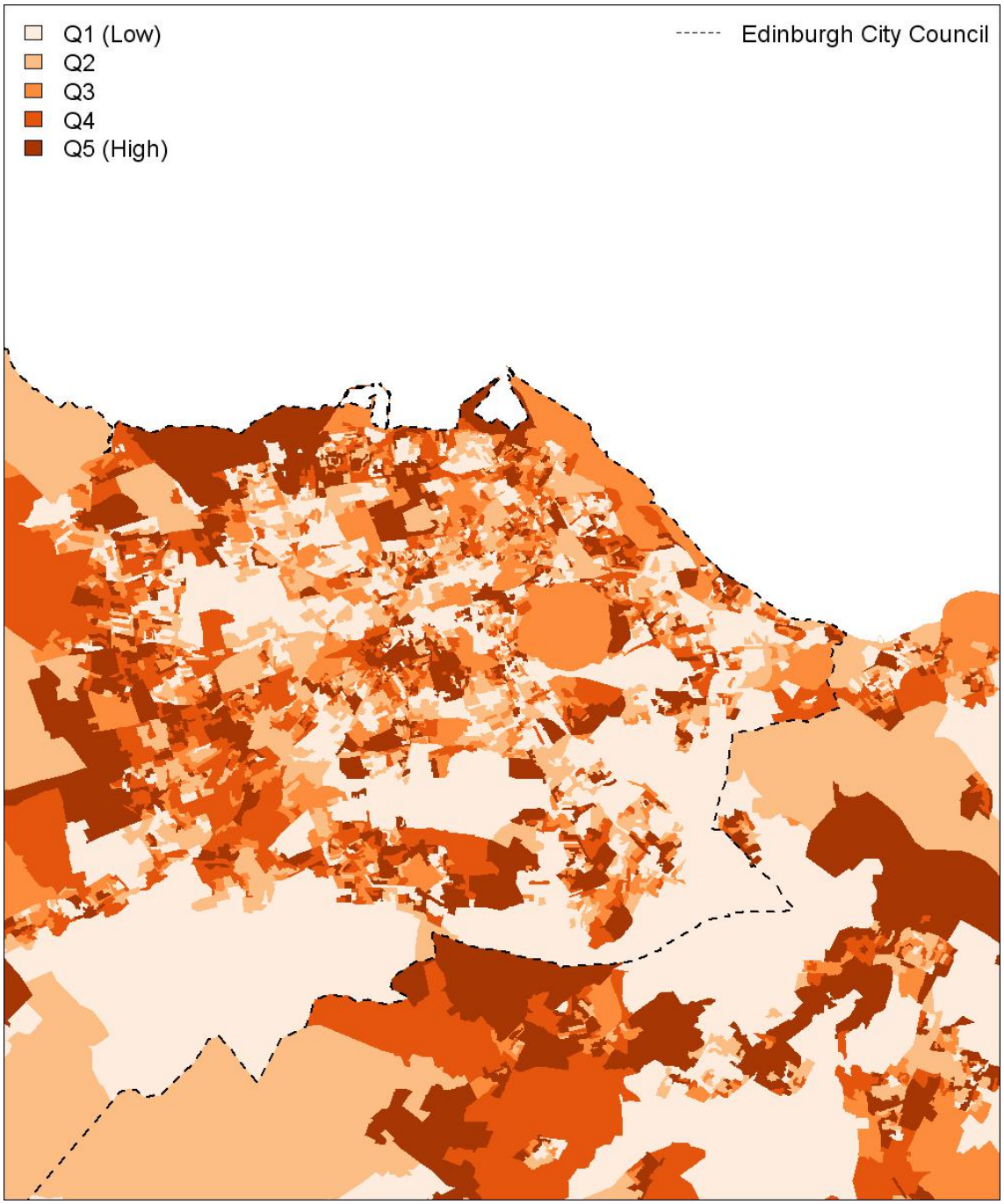


Figure 7.13: Housing Benefit Recipients (%), Edinburgh OAs: Quintiles

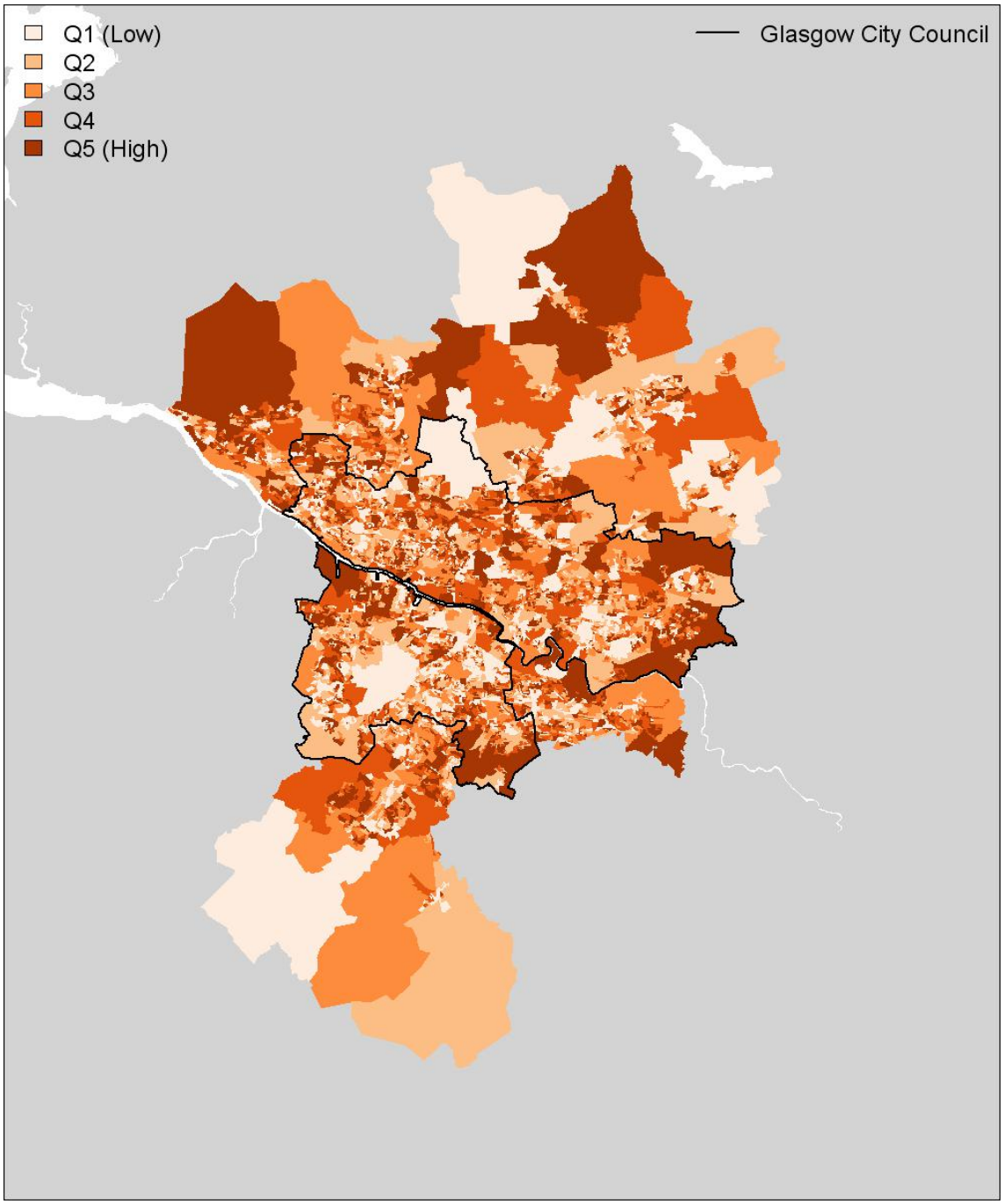


Figure 7.14: Housing Benefit Recipients (%),Glasgow OAs: Quintiles

a series of large clusters on the outer edges of Edinburgh. Additionally, there is a clustering to the north around Leith, Granton and Muirhouse. An interesting future research question (which is beyond the scope of this study), would be to determine the accuracy of microsimulated housing benefit against the actual housing benefit (official) if this data could be obtained without breaching confidentiality.

Housing benefit claimants in the Greater Glasgow area are modelled in Figure 7.14. The pattern shows the smaller OAs, towards Glasgow city being more prominent in the areas with the highest proportion of OAs receiving housing benefit. This is mirrored, to an extent, by areas of low income. It could be argued that the larger housing estates of Glasgow; Easterhouse, Castlemilk, Drumchapel and Pollok, are likely to contain the areas with the highest proportion of benefit claimants, so it is expected that these areas would be in the top half of the distribution if the model is reasonably accurate. Furthermore, the more 'traditional deprived inner city areas in the east end would be expected to feature. This would appear to be the case, as areas near Easterhouse, Castlemilk and to a lesser extent Drumchapel, Govan and Ibrox do stand out in the highest fifth (Q5) of areas with housing benefit claimants. There are some rural areas in the highest quintile (Q5) which visually skews the map.

7.4.2 Child Benefit

This section presents the analysis conducted using SIMALBA to microsimulate child benefit across Scotland. As a result of being able to generate microdata for small areas in Scotland which has previously not been modelled in this way, a number of policy scenarios can potentially be modelled. Eligibility for child benefit is reasonably straightforward. The benefit is paid "to people who are responsible for a child" (Child Poverty Action Group, 2003, p.1:232). There is

of course a slight anomaly in that the amount paid differs for the eldest child, who receives a higher amount of child benefit than subsequent children. A child is defined in the entitlement criteria as someone who is "under 16" or "16 or over but under 19 who is receiving full-time non-advanced education (Child Poverty Action Group, 2003, p.1:233). where full-time education is for more than 12 hours a week. So it becomes obvious that even a simple universal benefit like child benefit which appears straightforward can be complex to administer and also as a consequence to model using microsimulation. The rates of child benefit (per week) in April 2003 were £16.05 for the eldest child, £10.75 for subsequent children and £17.55 for lone parents (instead of eldest child rate).

The microsimulated data allows a cross tabulation to be made of those who are receiving child benefit as a source of income, but also earning over £41,600. This means that if government policy were to switch so that it was a means tested benefit (as opposed to a universal benefit) which would be withdrawn for higher rate taxpayers, SIMALBA can map the spatial consequences of such a decision. This builds on the previous section which merely maps one variable, by combining it with a further variable and allowing cross tabulations. This data is novel in the sense that the census does not contain such information, either on income or child benefit, therefore neither simultaneously either. Looking at the maps (see Figure 7.15) and also in Table 7.4, there is a clustering of HBs in the south of Scotland which have the highest microsimulated levels of child benefit. Therefore it is these areas which are liable to feel the largest effect of any change in the definitions from a universal benefit to a means tested benefit. The two panels in the bottom half of Figure 7.15 showing 'Keepers' and 'Losers' are a mirror image of each other. Therefore, those who keep the benefit and those who potentially lose the benefit will sum to the total microsimulated child benefit receivers for each area. Those in the 'Keeper' category are therefore

defined as in receipt of child benefit as a source of income as well as earning up to the £41,600 level. So this group would meet the means tested criteria. Those in the 'Loser' category can then be defined as reviving child benefit as a source of income while simultaneously earning over £41,600 and by default would no longer meet the new criteria for receiving this benefit. It is the HBs in the south of Scotland; such as Borders, Dumfries and Galloway, Ayrshire and Arran, Argyll and Clyde and the Western Isles (67%, 42%, 56%, 21% and 40% respectively) who stand to lose the highest proportions of individuals with child benefit as a source of income. However, looking back at the previous analyses on income, there has to be both high income (places like Lothian and Fife) and receipt of child benefit for this to be a potential loss. Therefore, Lothian, Fife, Forth Valley as well as the Highland and Shetland HBs will lose the most (47%, 43%, 31%, 35% and 56% respectively) in this respect according to SIMALBA as there are larger proportions of high earners combined with child benefit as a source of income. This demonstrates the potential of creating 'new' data which can be used for policy analysis. The situation is not at all obvious in a policy scenario where there are interactions between two variables such as this. So, microsimulation modelling is a novel and useful technique for such analysis as has been demonstrated here.

What effect would a policy such as this have at the OA level geography? For this SIMLOTHIAN is employed to show patterns within Lothian HB as well as within Edinburgh city itself. There is a slightly clustered pattern to the distribution of child benefit as a source of income across Lothian HB (see Figure 7.16). To the south of Edinburgh as well as other parts of rural fringes feature in the top fifth of areas with individuals claiming child benefit. There are also pockets to the north-eastern extremes and southern of Lothian HB. In terms of a policy change which would affect higher rate tax payers, there is clustering of

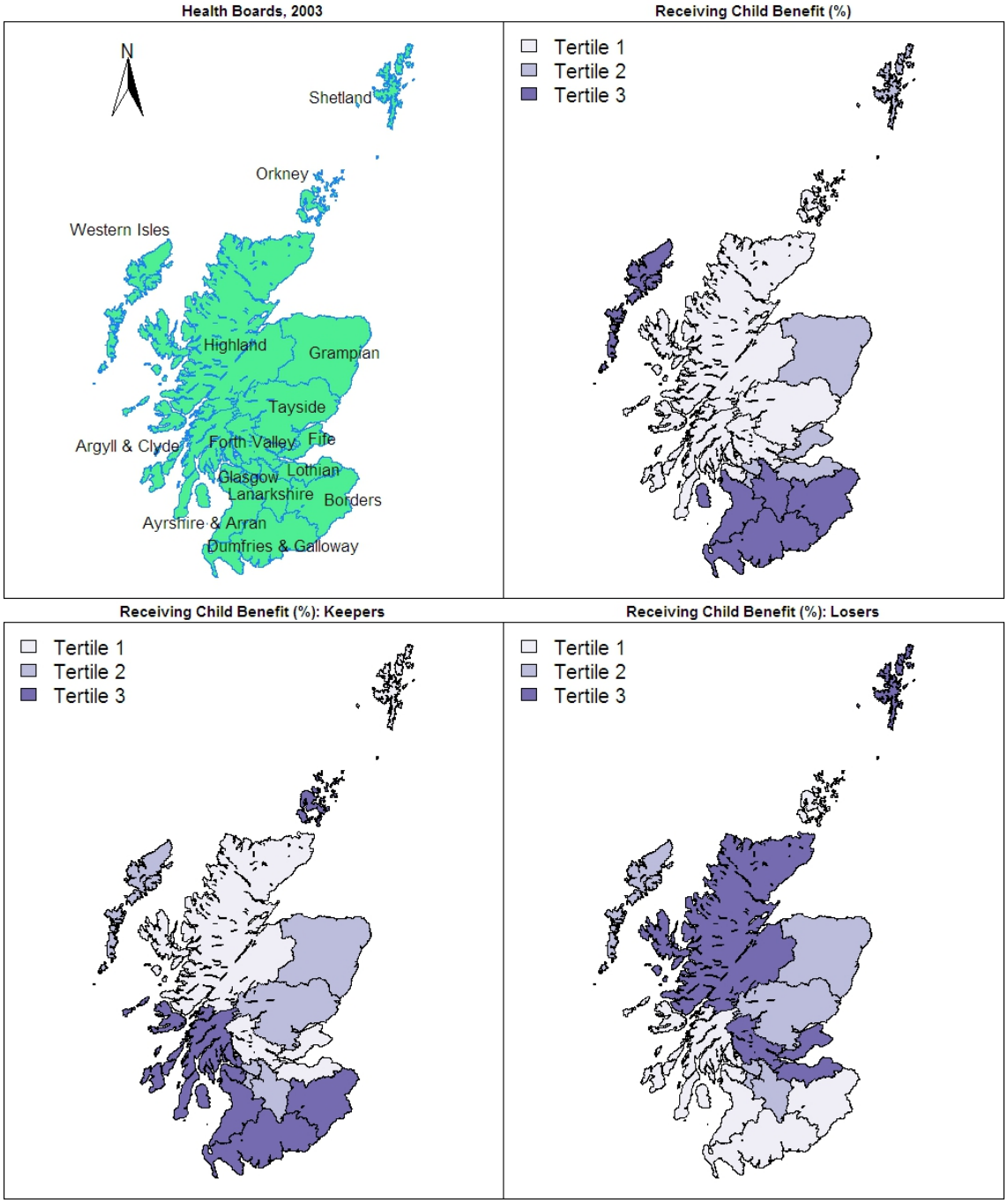


Figure 7.15: Child Benefit, Health Boards: Tertiles (T1:Low)

Health Board	Child Benefit (%)	Keepers (%)	Losers (%)
Highland	23.35	65.03	34.97
Grampian	34.54	84.60	15.40
Tayside	20.74	86.13	13.87
Fife	29.21	57.40	42.60
Lothian	26.17	52.79	47.21
Borders	66.67	96.62	3.38
Forth Valley	18.56	69.46	30.54
Argyll & Clyde	21.06	88.21	11.79
Greater Glasgow	36.92	83.46	16.54
Lanarkshire	37.65	84.39	15.61
Ayrshire & Arran	56.34	90.49	9.51
Dumfries & Galloway	41.88	91.94	8.06
Orkney	16.47	89.02	10.98
Shetland	35.03	44.07	55.93
Western Isles	40.13	72.74	27.26

Table 7.4: Microsimulated child benefit

people who could be adversely effected by a potential change in policy in the more rural parts of Lothian HB. Conversely, there is almost no effect on the areas which are in the lowest quintiles of 'Keepers' as this is a mirror image of the 'Losers' map.

If Edinburgh, shown in Figure 7.17, is looked at in greater detail it also has clusters of child benefit claimants mainly around the western and north western edges of the city, with notable 'holes' towards the centre, stretching southwards. It is difficult to deduce this pattern visually due to the differing sizes of output area. There are also various 'clusters' dotted throughout Edinburgh, but no particular location(s) where there is a large concentration except a more general western trend. In terms of the change in policy to child benefit, how would Edinburgh change? Within Edinburgh City there are pockets of 'Losers' mainly on the fringes of the city map to the south and west. Whereas those 'Keepers' are concentrated to a large extent around the north of Edinburgh as well as just outside the city on the southern edge interspersed with 'losers'.

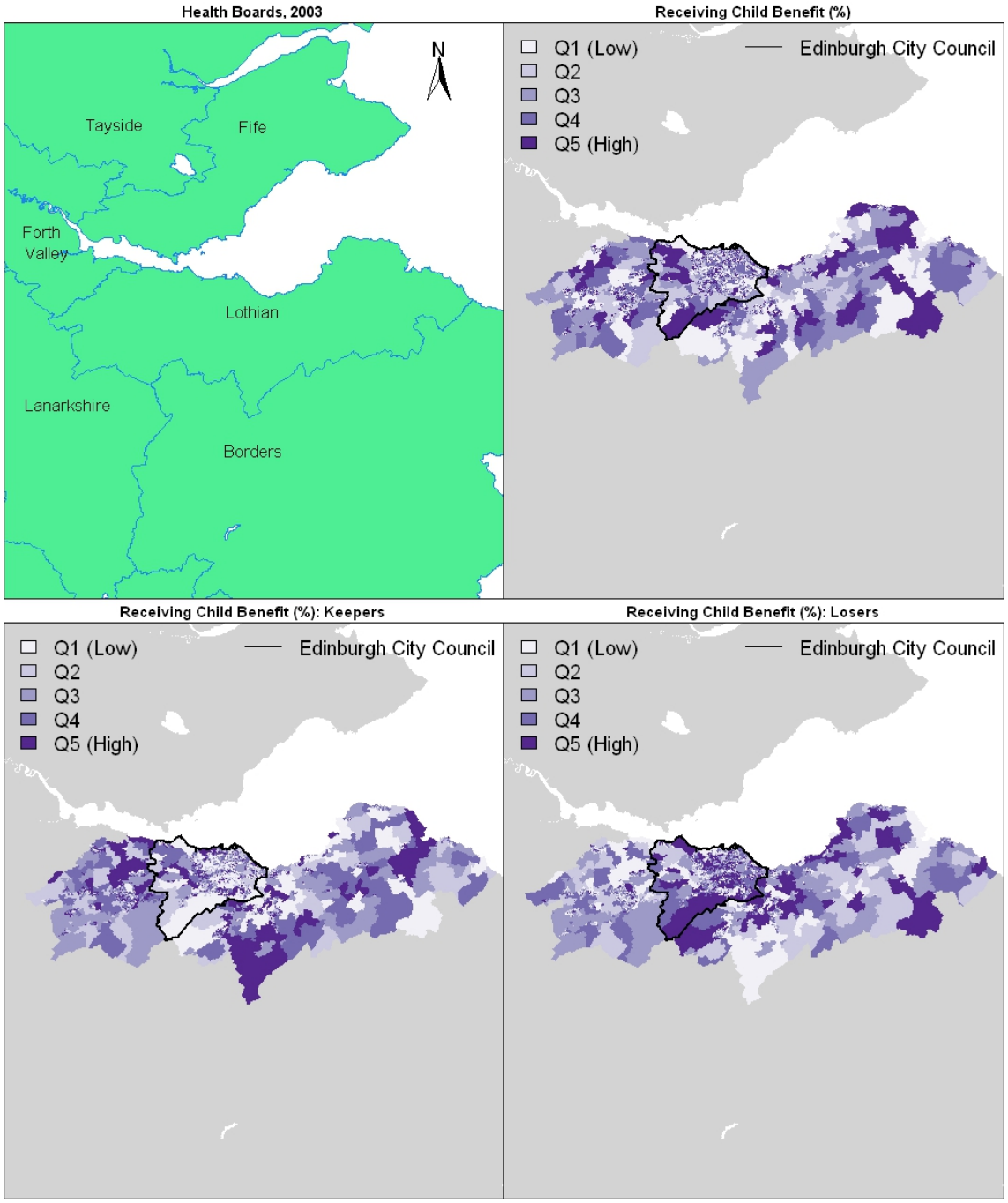


Figure 7.16: Child Benefit, Lothian OAs: Quintiles

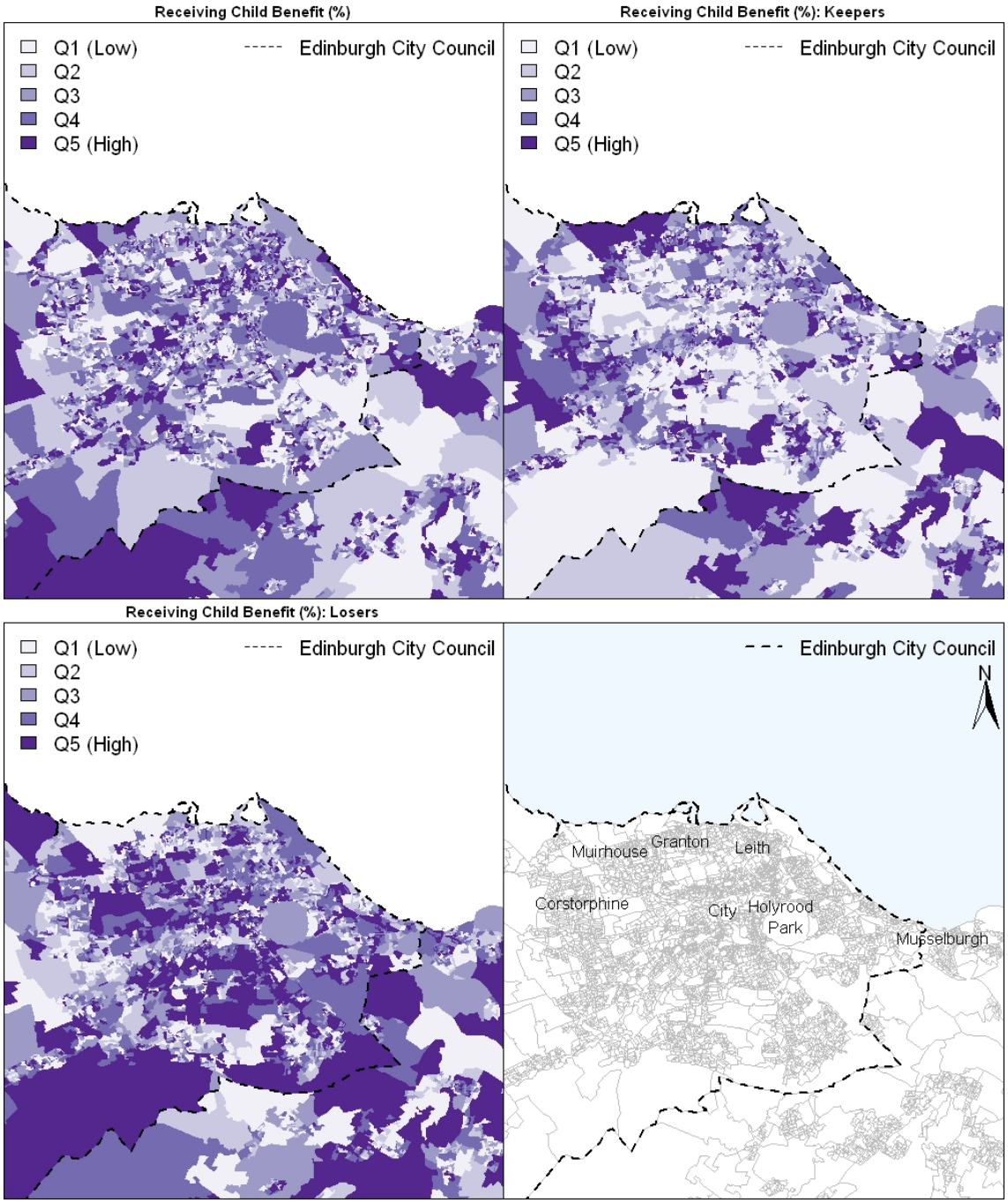


Figure 7.17: Child Benefit, Edinburgh OAs: Quintiles

Child benefit microsimulated data, mapped for Glasgow in Figure 7.18 does show evidence of clustering, with some cases to the north stretching of Glasgow and large contiguous areas in the south of Glasgow also. There are also sporadic pockets of areas with highest proportions of child benefit claimants in parts of south and central Glasgow. The areas around Shettleston and Easterhouse also feature. Also, there are areas on the very northern edge of Greater Glasgow HB that stand out visually as well as to the extreme southern edges. Comparing the 'Keepers' and 'Losers' maps, the areas with the highest proportion of 'Keepers' (Q5) feature the east end of Glasgow as well as some more rural areas. The OAs with high proportions of 'Losers' (bottom left, Figure 7.18) are visually most obvious outwith the Glasgow council boundary in the darkest shades, the opposite of the previous map (top right panel in Figure 7.18) most notably in the north of the map and the very southern tip.

So, changes to child benefit policy (in terms of who and who will not receive it) could have important spatial consequences, with areas experiencing very different outcomes due to the interaction between income and benefit take up. The main drawback of this type of analysis is that the different areal size of unit makes clusters hard to determine on visual inspection. Perhaps future work could more formally assess the existence of spatial clusters using spatial autocorrelation measures such as the Moran Statistic for example. Overall however, this does give a useful indication of the consequences of changing child benefit from a universal to a means tested benefit in Scotland. The patterns of 'Keepers' and 'Losers' does vary from place to place, so this is important to bear in mind when making decisions which alter the entitlement to child benefit.

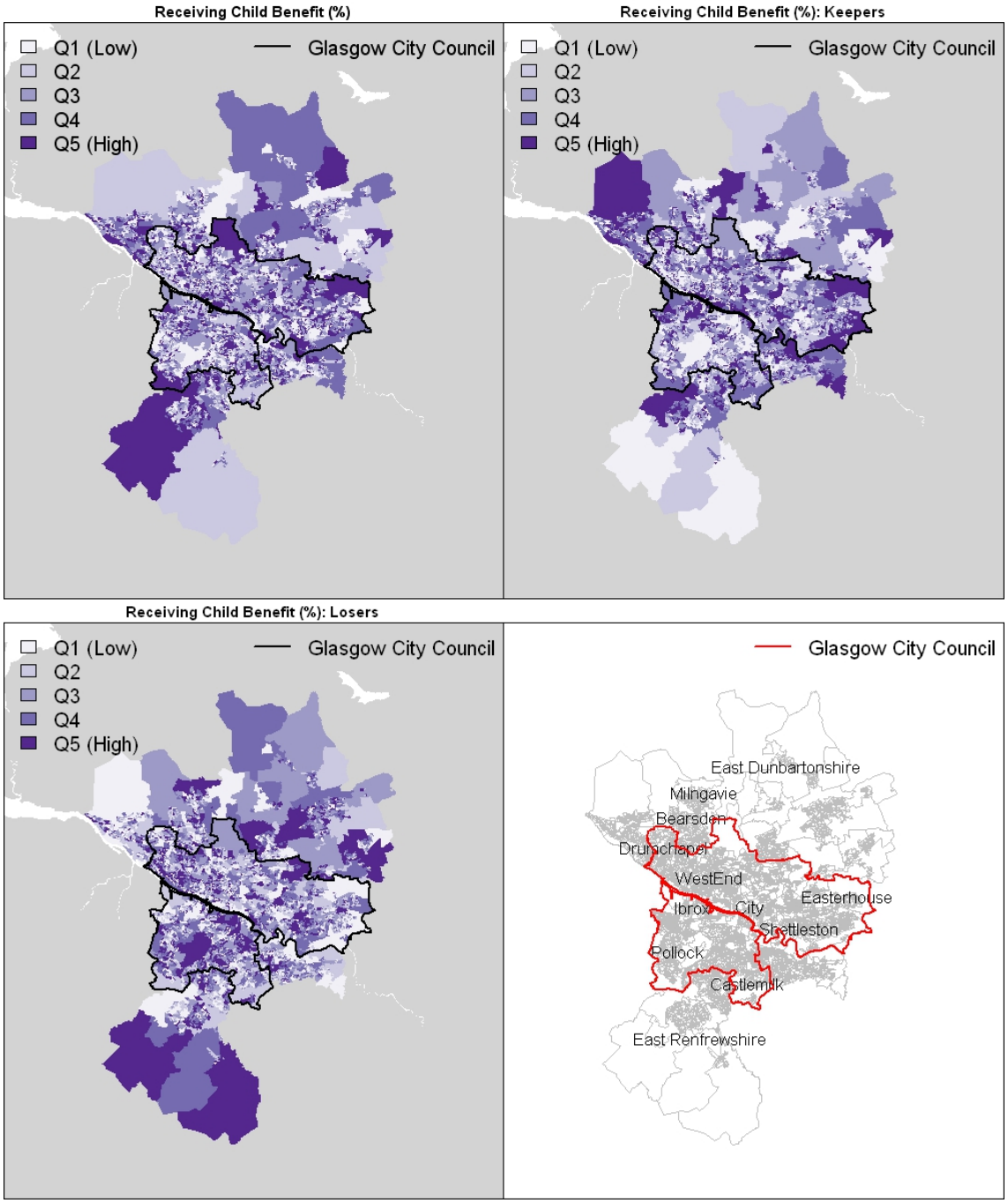


Figure 7.18: Child Benefit, Glasgow OAs: Quintiles

7.5 Case Studies

Briefly, before concluding the economic analysis, it is useful to look at the type of 'typical' households or individuals that would be affected by any changes to policy. To demonstrate this, households which meet specific socio-economic or demographic characteristics have been randomly chosen from the microdata set to serve as example cases. As income has been explored there are low, middle and high income individuals chosen. Additionally, to cover the changes to housing benefit and child benefit, individuals who both receive and do not receive this benefit have been chosen. There are several 'types' of individuals shown in Table 7.5.

The first individual is a married male aged 36 who lives in Greater Glasgow HB. He owns his house with a mortgage (OO), has level 1 qualifications and would normally work in a lower managerial or professional occupation. He also receives child benefit as a source of income and lives in the least deprived type of area.

The second person is a single female aged 50 who also lives in Glasgow, but in a more deprived area and rents her house from a housing association (HA). She is receiving housing benefit, but not child benefit. Her job is semi-routine and she has level 1 qualifications as well as having income is between £5,200 and £7,800 (category 6). This lady also has a limiting long term illness.

The third person is a single male aged 28 who has no long term illness. He has level 4 qualifications and a higher managerial or professional occupations which earns him between £20,800 and £23,400 per year (category 12). The area he lives in is a deprived part of the Glasgow HB. He doesn't receive child or housing benefits.

The fourth case study is a 54 year old married woman living in an area of Lanarkshire which is neither deprived or affluent. She doesn't receive child

Type	HBNAME	Sex	Marital	Ten	Inc	Age	Ill	nssec8	Qual	Dep	HB	CB
Low	Greater Glasgow	M	M	OO	1	36	0	2	1	1	N	Y
Low	Greater Glasgow	F	S	HA	6	50	1	6	1	7	Y	N
Mid	Greater Glasgow	M	S	OO	12	28	0	1	4	9	N	N
Mid	Lanarkshire	F	M	RF	12	54	0	1	4	6	N	N
High	Lothian	M	M	OO	31	27	0	2	2	5	N	N

Table 7.5: Case Studies

or housing benefit and is living rent free (RF). Her job is similar to the third person, as she has level 4 qualifications, a higher managerial or professional occupations and earnings between £20,800 and £23,400 per year.

The final case study is a married 27 year old man earning over £150,000 per year (category 31) and not receiving any benefits. He is not ill and lives in an area that is in the middle of the deprivation spectrum. He is a lower managerial or professional occupations worker, with level 2 qualifications.

This shows the kind of real people who could then be affected by any change in the policies mentioned in the analysis above. For example the last individual would be liable for a 50 pence tax rate. The first individual would be a 'Keeper' of child benefit, while the second individual may or may not lose some housing benefit and so forth. The first and second individuals would benefit under the policy scenario which raises the income tax threshold to £10,000. So for example, the second person in Table 7.5 may well have an altered health status if her income increases as discussed in the literature review (see chapter 2) the importance of income and income inequality (Wilkinson and Pickett, 2006) for health outcomes. So potentially if her income increases it could positively affect health outcomes. If for example, a loss of housing benefit (as previously discussed) either negated the gains from a drop income tax or reduced the income, this could have further negative health consequences for the individual who is the second case study.

This gives the reader an idea of the powerfulness of microsimulation in bringing a wealth of information to bear on policy issues. This type of analysis is continued at the end of the subsequent chapter on health policy analysis.

7.6 Conclusion

The analyses contained within this chapter have demonstrated clearly the heterogeneous impact of national policies at the local (OA) level. This is perhaps the clearest conclusion that can be drawn from the analysis in this chapter, the 'local' impact of national policies can be different across Scotland. This could only have been determined with the use of spatial microsimulation as opposed to microsimulation without the spatial element (aspatial). Of course this should be intuitive, but it has been demonstrated in this context and adds an original contribution to policy debates in Scotland. Furthermore, the power of spatial microsimulation over and above aspatial modelling has been demonstrated and this original contribution to the policy debate in Scotland adds a worthwhile spatial dimension to the debates which can have important consequences and may potentially alter a policy decision. The advantage is that both types of microsimulation (spatial or aspatial) can be conducted simultaneously. The policies considered; income tax based and welfare based have shown how the effects and unintended consequences could be judged prior to implementation, with a multitude of options being considered before choosing the most suitable. The change in the threshold of tax has shown those who would 'gain' most in contrast to those who would 'lose' most if a 50 pence tax rate were introduced in Scotland. Perhaps an avenue for further research could be formally identifying whether or not there are statistically significant clustering effects in the microdata. This could be achieved by using formal spatial statistics such as Morans I or Gearys C for example.

The microsimulation of income has been useful in exploring the potential changes to income tax rules. The 'value added' of the microsimulated data is made clear and provides a new and original perspective in this area in Scotland as well as allowing exploration of trends at the microlevel. Furthermore, the

microsimulation of child benefit and the subsequent analysis has shown the power of the microsimulation method in creating 'new' data which can be used to assess the consequences of policy. It is the ability to create customised cross-tabulation which would not be available from either the UK Census or the SHS as the raw microdata is not readily available, that is another original aspect of this analysis for Scotland. The HB level data is available in the SHS. It has been replicated to determine as fully as possible the differences between the datasets (see diagnostics in chapter 6). The advantage of reweighting this data from the SHS to microdata is that is matches the census totals for OAs in Scotland. The SHS is of course not a complete population level survey, but a sample of the population, so it could be argued that it is useful to use the SHS data as a benchmark. The disadvantage of this approach is that the precise level of acceptable error is unclear particularly in the islands and smaller HBs where sample sizes are smaller and therefore less likely to match the simulated dataset.

It does have to be acknowledged that there have been some compromises made in this analysis. Primarily the categorical nature of simulated income. It would be preferable to have a continuous variable. However, given that analysis can still be conducted the compromise is not that severe. Additionally it was decided not to update the figures for income to reflect the prices currently. This was mainly due to the fact that income is categorical, so therefore the class boundaries are merely being changed. Furthermore, in adjusting income figures by using the Retail Price Index (RPI) or the Consumer Price Index (CPI) for example, there is an assumption being made that everyone is experiencing the same rate of inflation over the years the income data would have been adjusted for. Future research could therefore explore this dynamic aspect of microsimulation modelling which is beyond the scope of the analysis that has been presented here. Another compromise is that the specific amount of housing

benefit claimed is not available in the dataset that has been microsimulated so the analysis can only show all claimants, not the specific group who would be affected by the change in amount. As referred to previously, comparing housing (and child) benefits to the official source may well be useful as a further source of validation subject to confidentiality restrictions. Another useful addition in future may be to use population weighted cartograms to more accurately determine the effect on the population, although this does compromise on the normal spatial arrangement of the cities.

Overall, the power and usefulness of SIMALBA has been demonstrated. This has been shown using by the case studies, showing the wealth of information in the microdataset. Additionally, the extra dimension of a spatial microsimulation model is made obvious through the use of maps as well as tables which provides a new viewpoint for policy makers from which to judge the consequences of a particular course of action, both by 'type' of individual and by area.

Chapter 8

Health Policy Analysis

"Health is a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity"

(World Health Organization, 1948)

8.1 Introduction

This chapter builds on the previous body of work on economic policy analysis (see chapter 7), adding to previous analyses and directing the research towards a focus on issues related more directly to Scottish health. Within this chapter, a basic outline of some of the current issues of debate with respect to health policy are covered, referring back to previous analysis in the economic policy chapter where appropriate. The focus of this chapter will be on smoking rates,

mental well-being, alcohol consumption and obesity. A brief overview of the microsimulated data is presented, followed by a more thorough analysis of what changes may be possible (or desirable) and what the consequences of a particular course of action could have on Scotland, by area or 'type' of individuals or both simultaneously. In microsimulating data for these four health variables, a new and original perspective has been added to research into health in Scotland, building on the original contribution in the previous chapter and shedding new light on policy debates and ill-health research.

8.2 The Health Policies: setting a context

The recent past has been marked by a series of deteriorations in Scottish health relative to the rest of Europe which has led to Scotland being labelled as 'the sick man of Europe'. This label has been applied to Scottish health more recently, signifying the noticeable divergence from the 1950s onwards in terms of health compared with the rest of Europe. This is a phenomenon that was discussed in depth in chapter 5. The focus on Scottish health has also uncovered a phenomenon known as the 'Scottish Effect' (Hanlon et al., 2001) or even more locally the 'Glasgow Effect' (Walsh et al., 2010) which details the excess mortality in Scotland. The 'Scottish Effect' is "a term used to describe the higher levels of mortality and poor health experienced in Scotland over and above that explained by socio-economic circumstances" (Walsh et al., 2010, p.7). In other words, after taking account of deprivation, there is still an excess of mortality in Scotland (usually this means when compared to England and Wales). A similar situation applies to Glasgow. For a wider context a report into Scottish health (see Scottish Executive (2003)), identified 'risk factors' in Scotland as tobacco, alcohol, low fruit and vegetable intake, physical activity levels and obesity. It is this kind of work that provides an evidence base to drive health policy in

Scotland.

In 2006, Scotland introduced a nationwide ban on smoking in public places and also has plans to end tobacco displays in shops as well as to ban sales from vending machines. Studies, such as Haw and Gruer (2007), report that "reductions in exposure to second-hand smoke of the order observed in Scotland may generate immediate health gains in the Scottish population as well as longer term reductions in morbidity and mortality related to second-hand smoke" (p.552) due to the smoking ban. The study by Haw and Gruer (2007), also points to policy that would intervene to "reduce smoking in the home and in cars" (p.552) as well as stating that "quitting smoking is probably the most effective way of reducing second-hand smoke exposure in the home; smoking cessation services must continue to be promoted" (Haw and Gruer, 2007, p.552). An option would be to model smokers to better target this group of the population if desired. The use of microsimulation to model smoking rates is not new, as the geography of smoking in Leeds (Tomintz et al., 2008), has previously been estimated. Moreover, some work by Ballas (2010) has estimated 'happiness' using microsimulation in Scotland and what this analysis does is to add a more complete picture of other health variables, building on the existing work that exists. The microsimulation of smoking rates builds on this type of work and brings it to a Scottish context, which would not appear to have been modelled before.

In terms of mental well-being ('happiness'), a recent report entitled "Towards a Mentally Flourishing Scotland: Policy and Action Plan 2009-2011" (The Scottish Government, 2009) encapsulates this particular aspect of health policy. This is part of the overall strategy of improving health outcomes and reducing health inequalities. The area of mental well-being is linked to policies on suicide as well as depression and a variety of other mental disorders. Mi-

crosimulation could be used to specifically target 'at risk' groups. An example of this approach would be to target young males with a high GHQ 12 score if they are assumed to be 'at risk' from low mental well-being, depression, suicide and so forth. Additionally, there is evidence to suggest that health and happiness are linked so that "happier nations report fewer blood-pressure problems" (Blanchflower and Oswald, 2008), for example. Other research by Jones and Wildman (2008), shows a links between happiness (GHQ) and income that varies by sex. So that, "Increasing income does not improve psychological well-being for men"(p.316), but the opposite for women, "women's GHQ should be affected by income, while men's is not" (Jones and Wildman, 2008, p.320). So, happiness then is both a issue of current debate in the literature (see Chapter 2) as well as a desirable public health outcome.

Alcohol policy is also of particular policy relevance currently. There has been research by Purshouse et al. (2009) on the introduction of a minimum price for alcohol of around 45 pence per unit of alcohol. The Scottish government has also introduced an alcohol bill to try and begin the process of legislating for the changes needed, such as the minimum price per unit of alcohol. A Scottish government paper (The Scottish Government, 2008a), outlined the Scottish relationship with alcohol and how this could or perhaps should be altered. This report also incorporates an estimated figure of £2.25 billion each year, spent on dealing with the consequences of alcohol misuse. In the background of alcohol consumption debates, is the framework of the recommended daily limits for alcohol consumption of no more than 3 or 4 units of alcohol per day, or 2 or 3 units per day for men and women respectively. This equates to weekly limits of 21 units for males and 14 units a week for females. The microsimulated data is therefore categorised by the number of units per week of alcohol that is consumed, which allows harmful drinking to be identified.

8.3 Analysis

The analysis section outlines the health policy analysis conducted using SIMABLA models. The analysis is visually displayed in either map or reported in table format. The first sub-section of this section addresses the microsimulated data on mental well-being ('happiness'), followed by analysis of smoking. In addition there is also analysis of alcohol and obesity data from the SIMALBA model. Each health issue is discussed separately with the differing spatial patterns produced illuminated at varying scales. If appropriate, future policy options are explored in terms of the likely changes and the location and degree to which the Scottish population would be affected is modelled where practically possible. It should be intuitive that unhealthy behaviours such as smoking or alcohol may be easier to deal with in terms of direct policy action compared with obesity or mental well-being.

8.3.1 Well-being and Happiness

It could be argued that the issue of mental well-being or of 'happiness' is becoming more of a subject of research and the focus of policy interventions over time. The gradual shift from measuring not just economic performance, but of other factors such as happiness demonstrates this trend.

The HBs in descending order from highest to lowest GHQ zero scores from the microsimulated data shown in Table 8.1 are; Western Isles (92%), Borders, Ayrshire and Arran, Shetland and Orkney (77%) HBs. All these HBs have proportions of 75% (i.e. over three-quarters) of people who are have the lowest GHQ score of zero. Those HB with the lowest proportions of GHQ zero scores are Dumfries and Galloway (56%), Argyll and Clyde (60%) and Fife (60%). On the opposite end of the spectrum are HBs with the highest proportion of those with a GHQ score of 4 or more indicating mental distress. Ordered from

the highest to lowest proportion of GHQ 4 or more scores are Dumfries and Galloway (28%), Grampian, Argyll and Clyde, Tayside and Greater Glasgow (12%). Those with the fewest people as a proportion of population with GHQ score 4 or more are Western Isles and Borders with approximately 5% of the population in this category.

Table 8.1: Microsimulated Mental Well-being

	Zero	One_Three	Four_Plus
Highland	76.48	15.04	8.48
Grampian	63.88	15.10	21.02
Tayside	71.36	13.49	15.14
Fife	59.66	31.14	9.20
Lothian	76.22	14.59	9.19
Borders	91.00	5.49	3.51
Forth Valley	75.93	17.42	6.65
Argyll & Clyde	59.55	22.22	18.23
Greater Glasgow	69.25	18.40	12.35
Lanarkshire	62.72	26.69	10.59
Ayrshire & Arran	80.42	13.42	6.16
Dumfries & Galloway	55.92	16.58	27.50
Orkney	76.92	17.51	5.57
Shetland	79.17	13.32	7.51
Western Isles	91.50	5.03	3.46

Using the SIMLOTHIAN model to analyse lower level data we can see intra-HB patterns (Figure 8.2) and the scale of heterogeneity within Lothian. The pattern for the highest GHQ zero score proportions would look to present itself as the opposite to those in the GHQ score 4 or more categories in the bottom two panels. The areas with high proportions of mental well-being clustering to the south west corner of Lothian and south eastern edges also. The pattern of low mental well being (GHQ Score 1 or more) mirrors this pattern to a degree. There is still a problem with small OAs (in terms of geographical area) in the Edinburgh City region, so further figures with closer analysis of Edinburgh are necessary.

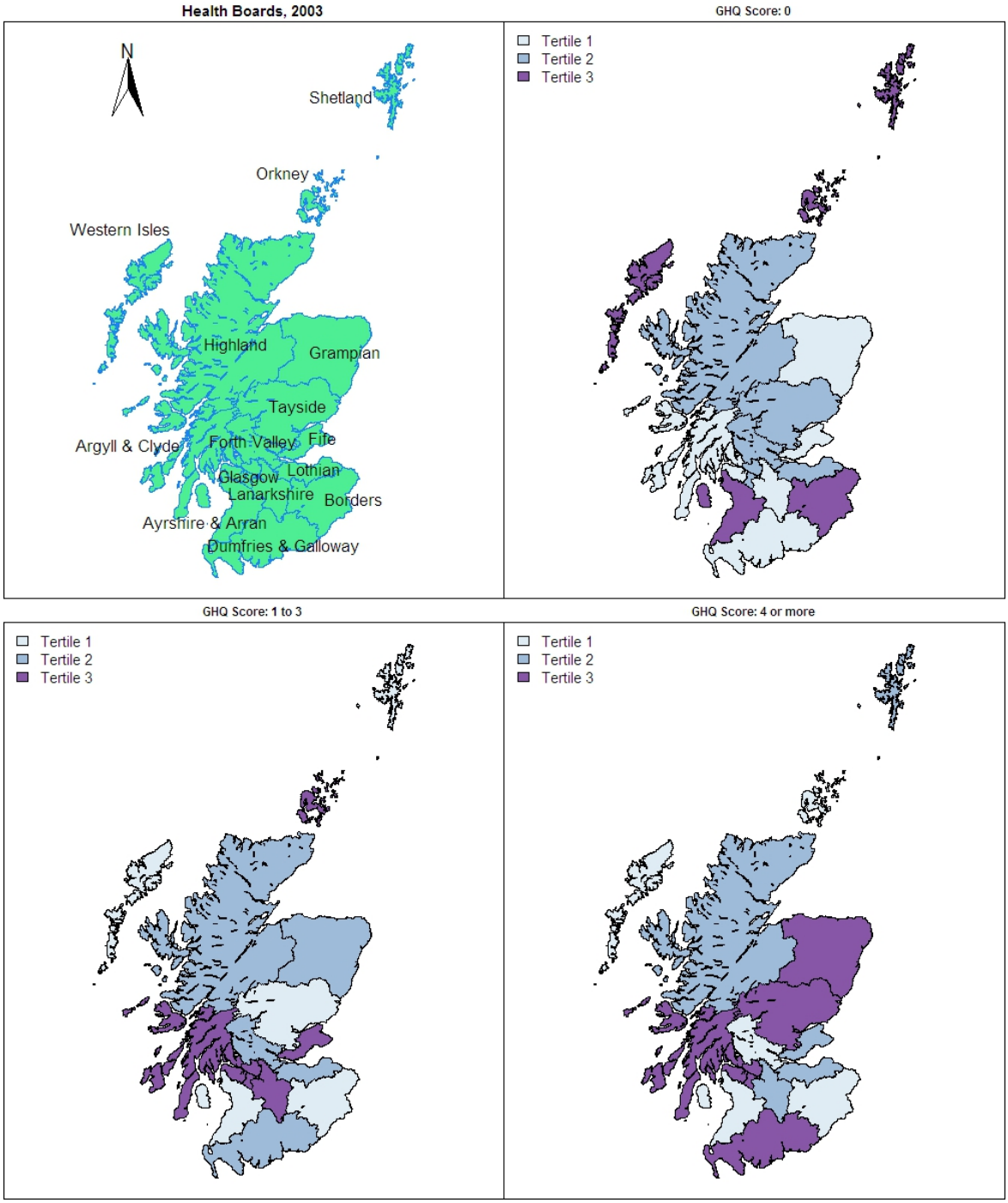


Figure 8.1: Mental Well-being (GHQ Score), Health Boards: Tertiles (T1:Low)

Within Edinburgh itself a clear pattern is difficult to deduce in Figure 8.3. Even though this is the case, there are clusters of good mental well being in the area known as the 'old town' in the centre of the map. In addition there are noticeable clusters of areas to the south of the centre of Edinburgh. In terms of the areas with the highest proportion of people with a GHQ 12 score of 4 or more, there is a concentration to the North (around Leith and Muirhouse) and it could also be argued a large linear gap stretching westwards from the centre of Edinburgh. The spatial pattern elsewhere would appear to be heterogeneous for the most part with smaller clusters of OAs spread around Edinburgh. The general trend seems to be that the north has poorer mental well being whereas the west and south are better in terms of the proportions of people in these areas with good mental well being scores.

The pattern in Glasgow, shown in Figure 8.4 is also a useful addition to the data available for health research as the patterns of mental well-being can be examined. What can be said is there is a notable series of gaps in the GHQ zero score category (top left) in the east end which is mainly lighter colours (Q1), compensated for by higher proportions of higher GHQ scores (Q5) in these areas in the top right and bottom left panels. The areas with the highest proportions of low GHQ score individuals appear to be spread around the west end and to the northern edges of Glasgow. Note that all three figures together, sum to the total population in each area, so if one area features in the lower ends of the GHQ score distribution it is unlikely to feature in the highest end of the GHQ score distribution of areas. The noticeable 'pooling' of the areas with high proportions of persons with poor mental well being around the eastern edges of Glasgow is the only obvious trend. Elsewhere, the pattern of mental well-being appears sporadic.

The microsimulated information for GHQ score is useful in terms of discover-

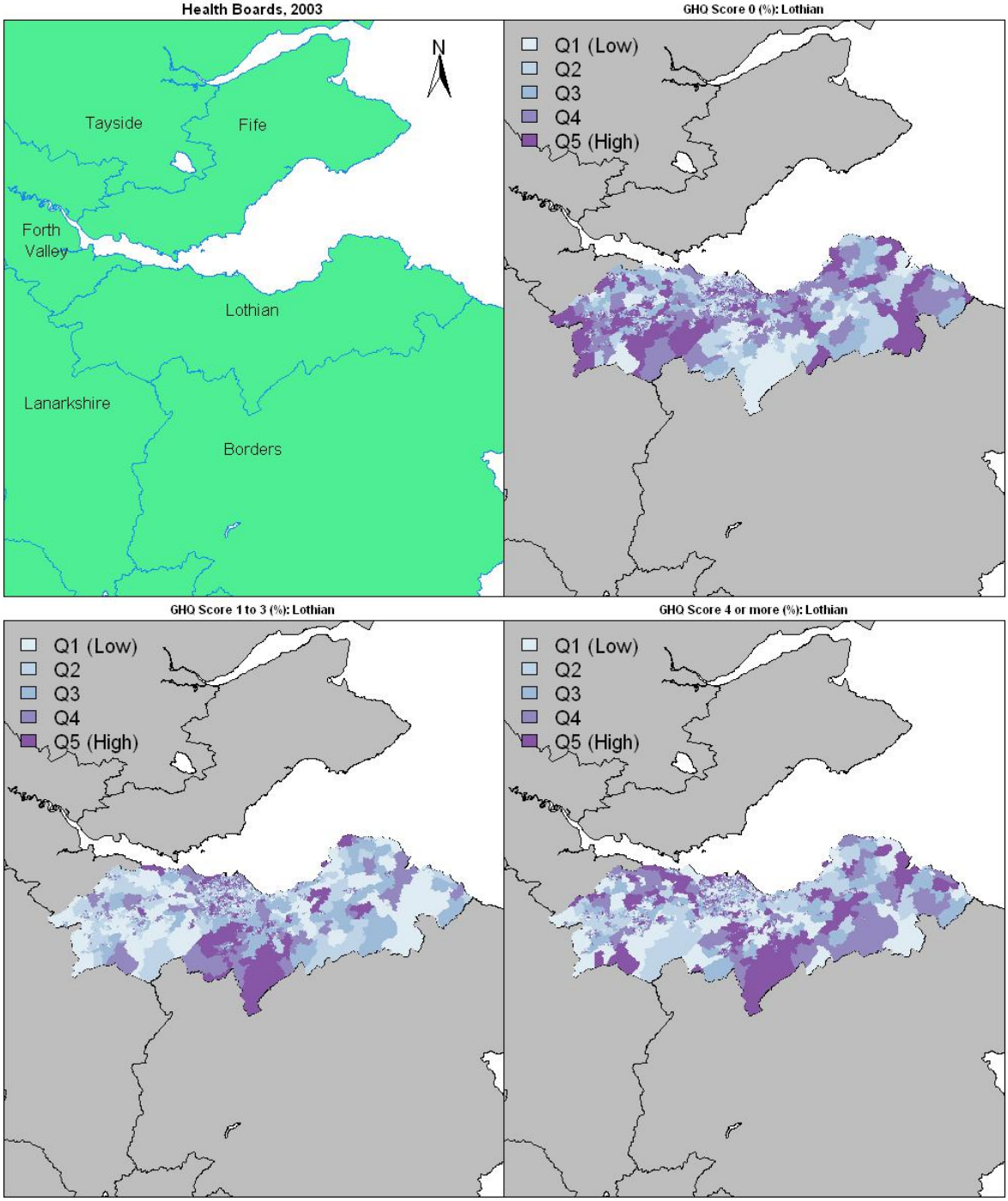


Figure 8.2: Mental Well-being (GHQ Score) Lothian OAs: Quintiles

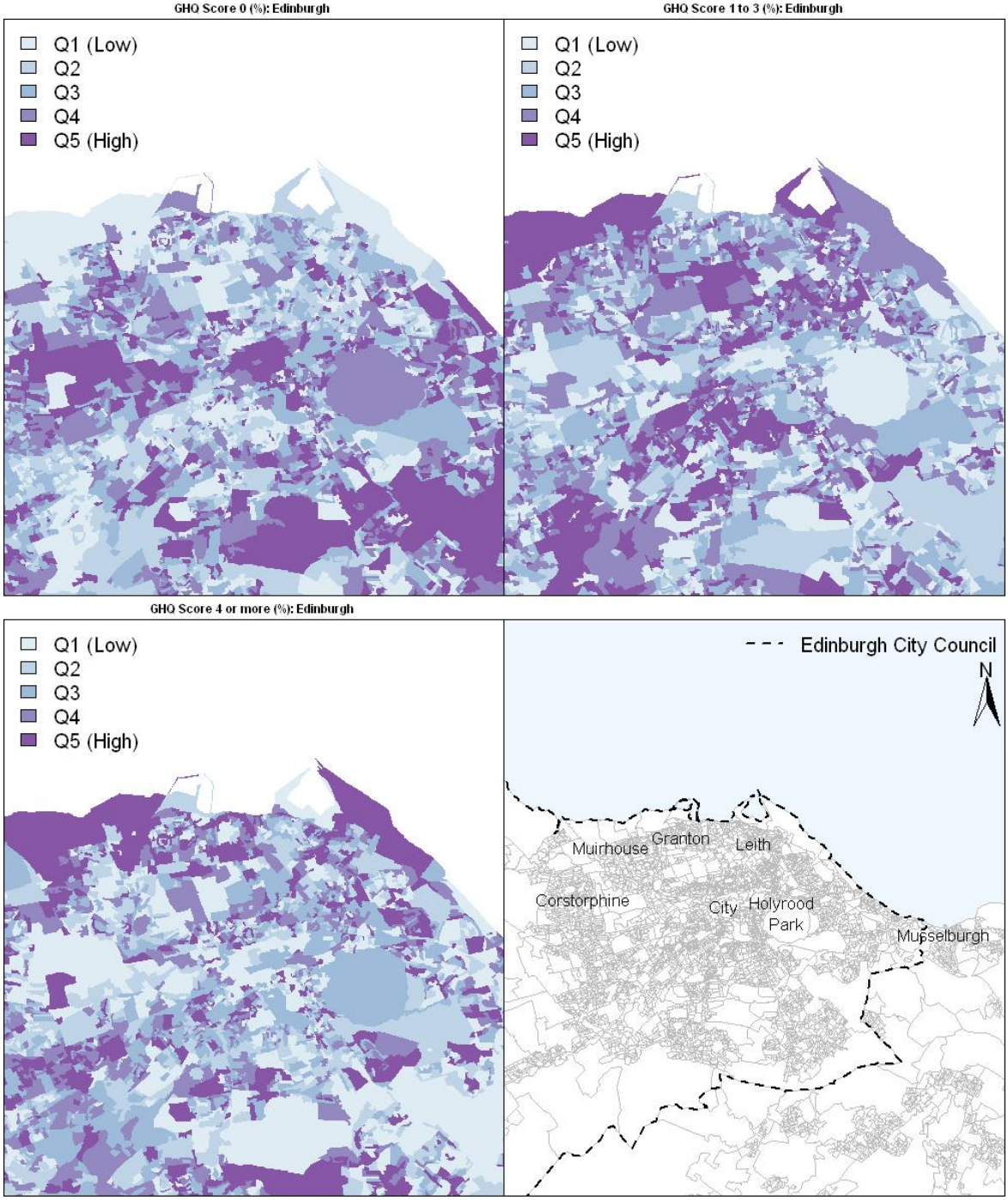


Figure 8.3: Mental Well-being (GHQ Score) Edinburgh OAs: Quintiles

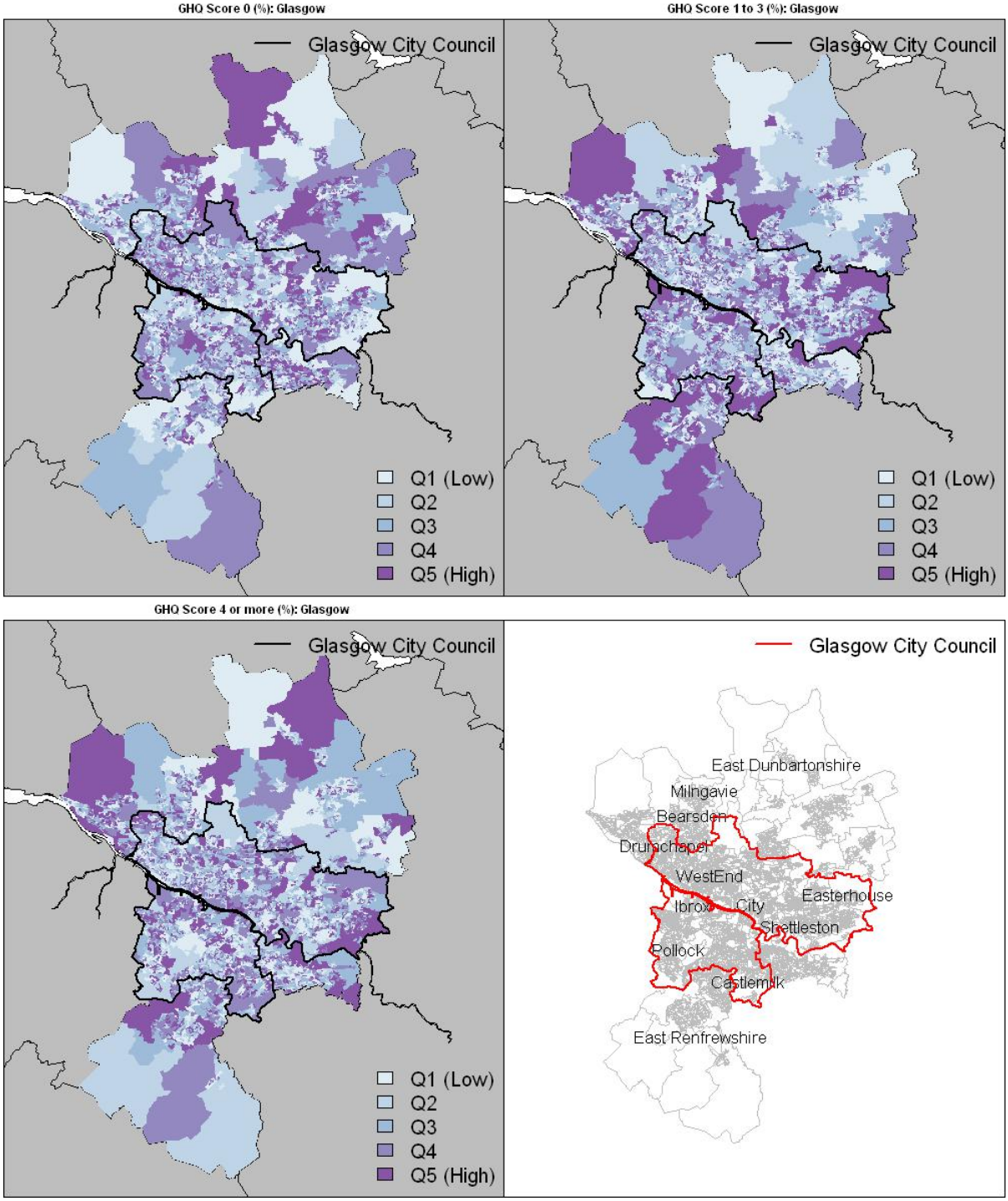


Figure 8.4: Mental Well-being (GHQ Score) Glasgow OAs: Quintiles

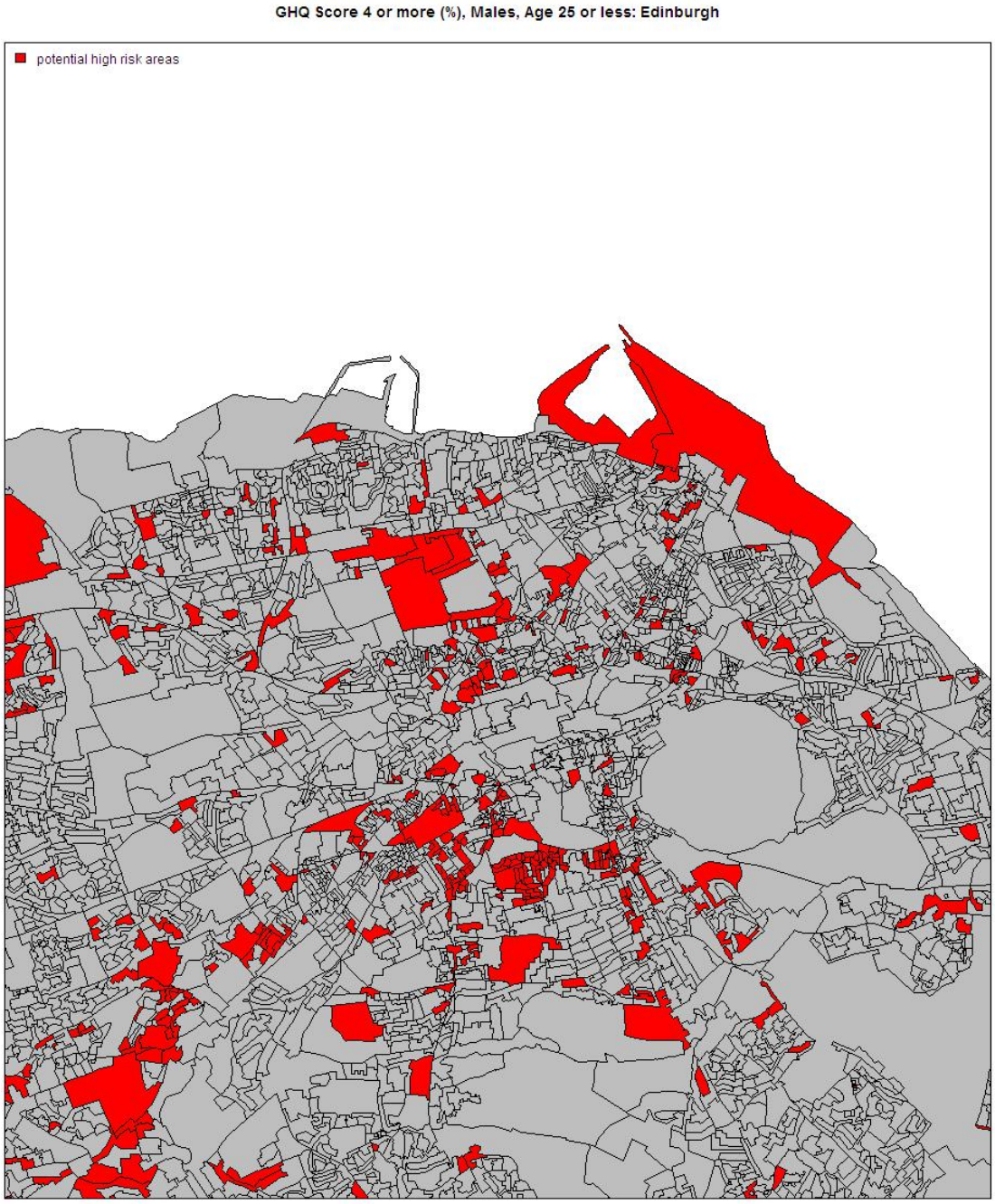


Figure 8.5: A policy scenario: targeting young mentally distressed men

ing the spatial patterns which exist at the local level but this is only part of the usefulness of spatial microsimulation modelling. For example, evidence confirms a "strong association between major depressive disorder and completed suicide" (Dumais et al., 2005)[p.2116]. The data microsimulated using SIMALBA allows the simultaneous exploration of young men (a known risk factor for suicide) and a high GHQ 12 score. This data can then be mapped to explore the areas where the highest proportions of high risk young males are likely to reside. Figure 8.5 shows the top 10 % of areas with respect to the proportions of these 'types' of individuals. These areas, such as to the north of Edinburgh around the Leith area could then be afforded special attention in a suicide prevention strategy if the evidence is correct on the risk factors for suicide. This is a demonstration of how the microsimulated data can be used in a local way to address a current health issue. Future analysis could focus more heavily on a modelling a more comprehensive set of risk factors, or on building a separate microsimulation model designed solely to simulate 'happiness' data for small areas in Scotland. In conclusion, the power of the microsimulation framework is again demonstrated with real world applications.

8.3.2 Smoking

Smoking is, and has been, on the health policy agenda for many years as was discussed at the start of this chapter. It is also discussed with respect to health in greater detail in the literature review (see chapter 2). There are well known links between smoking and a variety of diseases, especially lung cancer. What has been achieved with SIMALBA is to model smoking rates for persons in Scotland for the HB and the OA level geography using SIMALBA, SIMLOTHIAN and SIMGLASGOW to show the spatial variations of smoking rates within Scotland.

Using data from Table 8.2 for reference purposes, the HBs with the highest

Table 8.2: Microsimulated Smoking Rates

	Non	Ex	up20	over20
Highland	49.15	29.66	11.12	10.07
Grampian	52.01	21.33	12.03	14.64
Tayside	40.58	26.20	28.73	4.50
Fife	42.83	19.75	29.68	7.74
Lothian	56.97	23.59	12.10	7.35
Borders	39.12	40.25	16.29	4.35
Forth Valley	53.30	24.11	13.87	8.71
Argyll & Clyde	13.61	10.14	8.52	67.73
Greater Glasgow	50.71	19.13	17.00	13.17
Lanarkshire	50.16	23.62	13.95	12.27
Ayrshire & Arran	46.99	34.72	10.81	7.48
Dumfries & Galloway	38.83	25.71	27.36	8.10
Orkney	47.96	36.04	8.43	7.58
Shetland	17.49	29.74	46.60	6.18
Western Isles	35.72	31.83	16.04	16.41

proportions of non-smokers are Lothian (57%) and Forth Valley (53%). The greatest numbers of ex-smokers are found in Borders (40%) and Orkney (36%). In terms of smoking there are two categories, those smoking up to 20 cigarettes a day and those smoking 20 or more cigarettes per day. Of those smoking up to 20 per day, the highest proportion are found in Shetland (47%) and Fife. The heavy smokers (20 or more per day) have proportions of 67% in Argyll and Clyde and 16% in the Western Isles. In this respect Argyll and Clyde is an outlier. The smoking data has also been plotted on a series of maps using GIS (see Figure 8.6), again displaying the power of spatial microsimulation over the non-spatial approach.

From the HB maps, Lothian has among the highest proportion of non-smokers, but around average numbers of ex-smokers and smokers in Scotland. What is interesting looking at the spatial patterns, is the cluster of HBs; Lothian, Lanarkshire, Forth Valley and Glasgow, which have high proportions of non-smokers are contiguous in the 'central belt' of Scotland. Furthermore, Glasgow

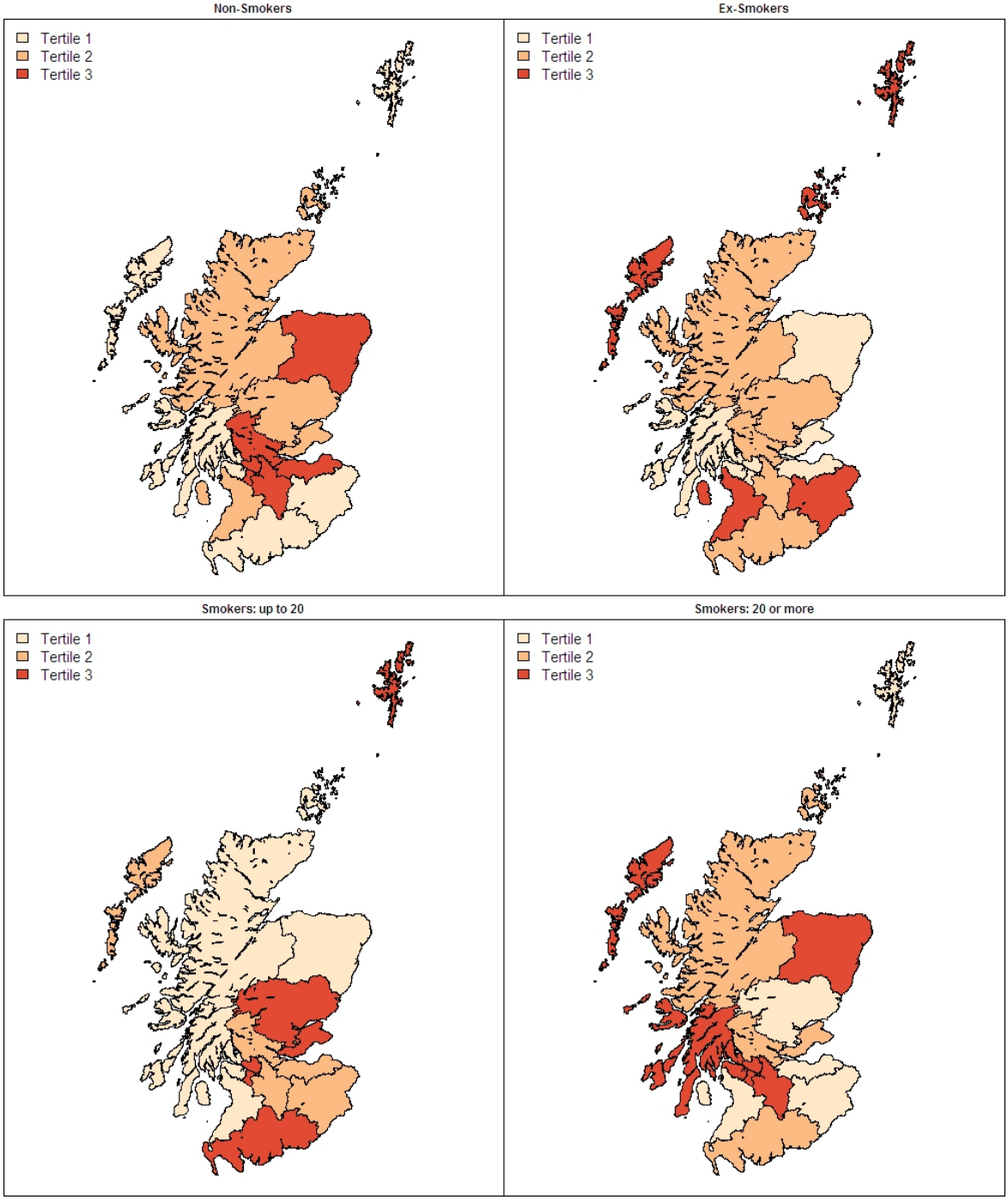


Figure 8.6: Smoking Rates by Category, Health Boards: Tertiles (T1:Low)

and Lanarkshire have high proportions of both non-smokers and heavy smokers at extreme ends of the spectrum.

What can be done with SIMALBA data is to examine at the corresponding OA maps for Lothian HB (in Figure 8.7), we can see a pattern that is somewhat similar to income patterns in the previous chapter (see chapter 7). There are clusters of non-smokers mostly in rural and 'richer' parts of Edinburgh City. The opposite end of the spectrum is those who smoke 20 or more cigarettes per day. It is difficult to identify a clear pattern in the data here due to the differing OA sizes, however there is a small rural 'pool' of smokers (both light and heavy) to the south of Lothian HB. Furthermore, there is a contiguous area to the north west of Edinburgh. Ex-smokers are spread much more randomly around Lothian.

To counteract the small urban sizes a further set of maps (see Figure 8.8) shows Edinburgh more clearly. There is a clustering of heavy smokers to the north of central Edinburgh in the areas around Muirhouse, elsewhere, there is a notable absence on areas with the highest proportions (Q5) of heavy smokers in Edinburgh, with the central areas featuring mainly areas in the lowest fifth (Q1) of the distribution. The two smoking groups in the bottom two panels of Figure 8.8 are remarkably similar, with many areas overlapping with respect to their colour coding according to the percentage of people in that area who smoke. In terms of non-smokers (top left) a polar opposite situation exists compared to the two smoking groups (bottom two panels). There are numerous areas, strongly clustering towards the centre of the map, stretching south and west. The map of ex-smokers (top right) is again rather sporadic with the east edge of the figure showing a clustering of areas with the highest proportions of individuals who are ex-smokers.

The geography of smoking in Glasgow in now discussed. It is shown in a

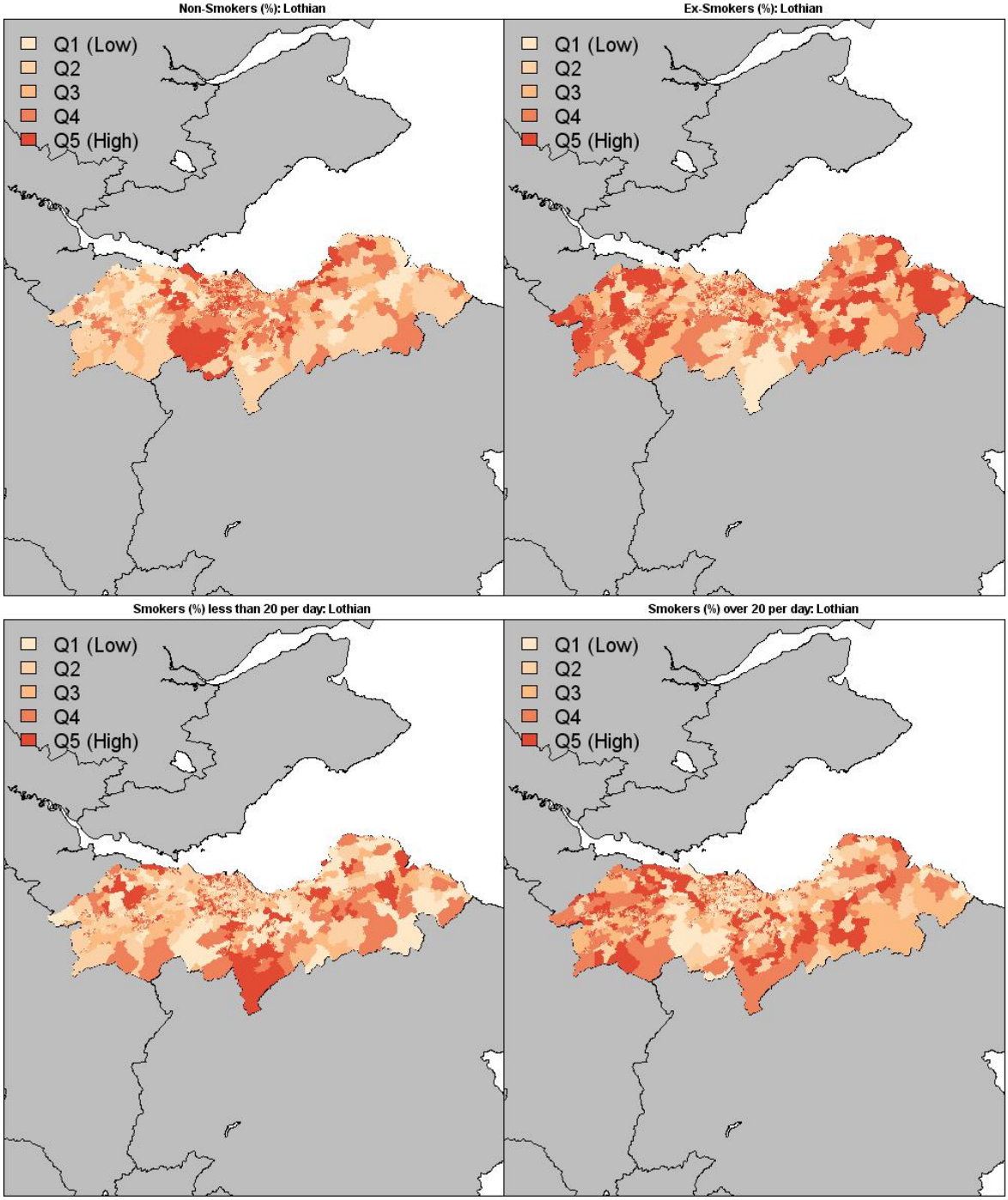


Figure 8.7: Smoking Rates by Category, Lothian OAs: Quintiles

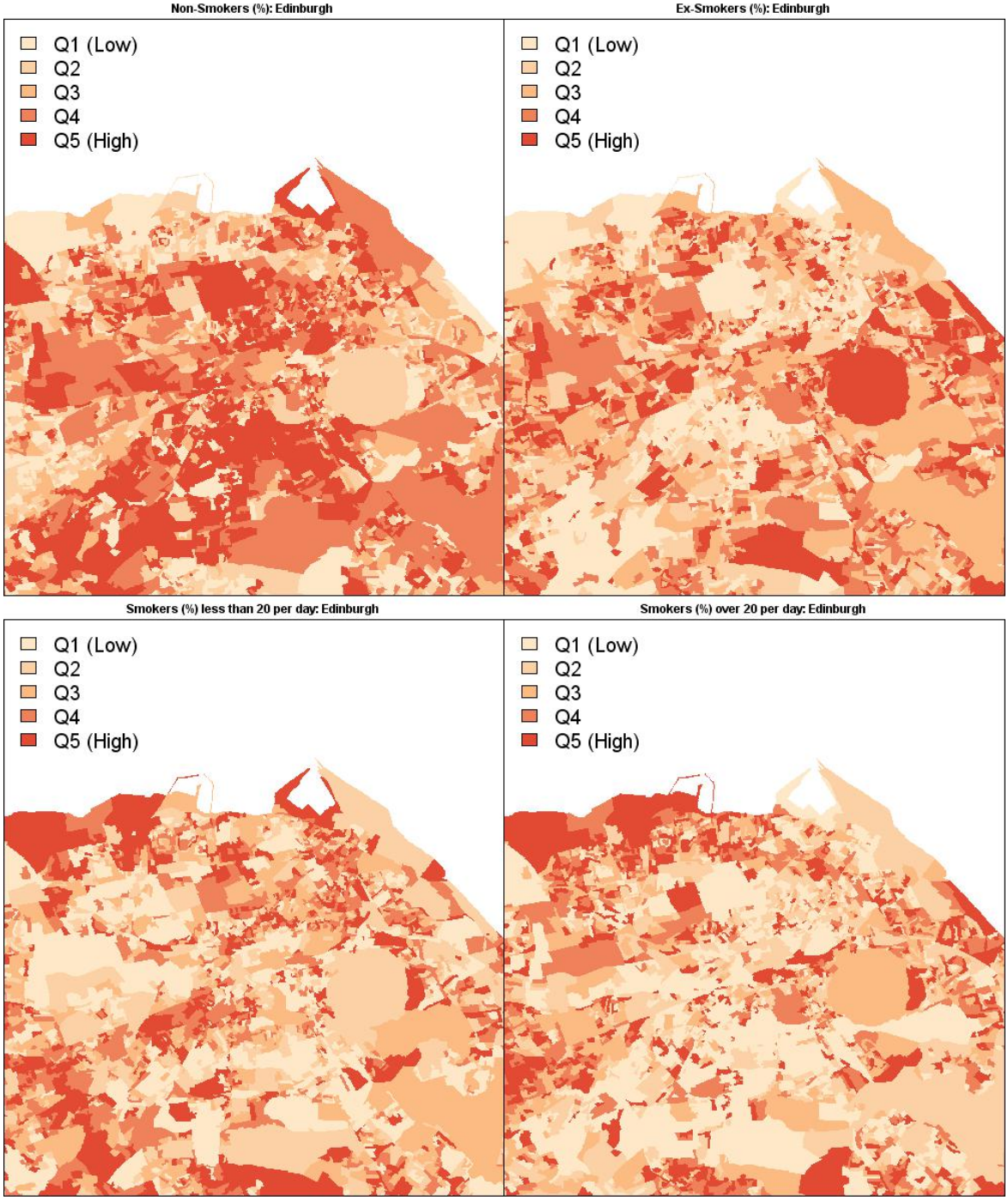


Figure 8.8: Smoking Rates by Category, Edinburgh OAs: Quintiles

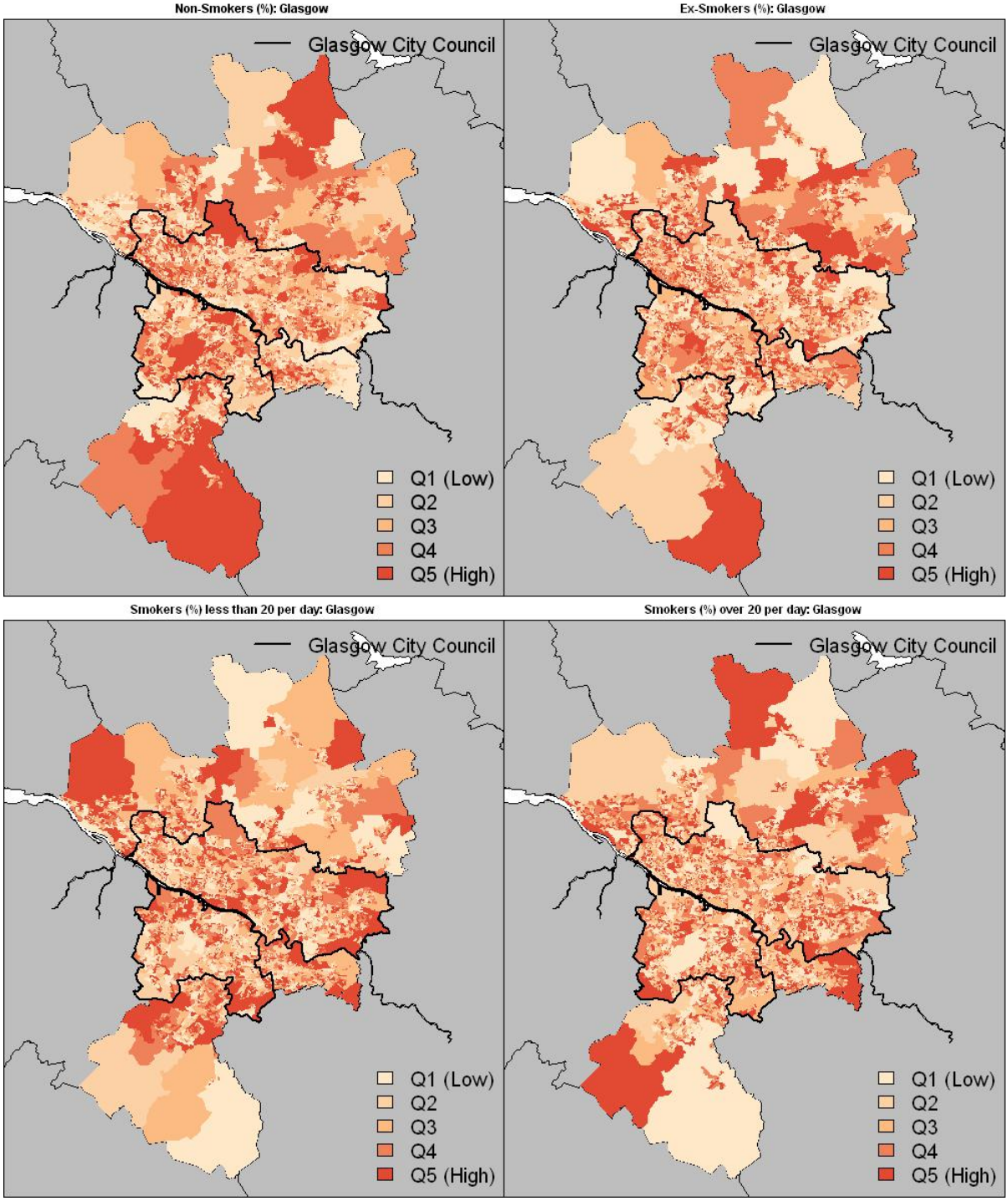


Figure 8.9: Smoking Rates by Category, Glasgow OAs: Quintiles

series of maps in Figure 8.9, with non smokers in the top left, ex-smokers in the top right, smokers less than 20 a day in the bottom left and smokers over 20 a day in the bottom right. Looking at non-smokers, who are concentrated around the northern edges of the Glasgow city boundary and to the south, stretching from inside the Glasgow city council boundary to the edge of the HB boundary. In contrast, those areas with the lowest proportions of non-smokers (Q1) in the lightest colours are visually detectable to the east as well as to the south east around Castlemilk. The pattern of ex-smokers is difficult to generalise, with pockets scattered throughout the Glasgow area of areas with both high (Q5) or low (Q1) proportions of ex-smokers. Focusing on the pattern of those areas where smokers consume anywhere in the region of less than 20 per day, the pattern highlights areas towards Castlemilk in the south east, the east end around Easterhouse as well as parts of the central areas bordering the river Clyde. The pattern for those smoking 20 or more cigarettes per day is remarkably similar, with little difference in the overall pattern.

8.3.3 Alcohol

Alcohol consumption has been identified as a public health risk in Scotland for some time. This has been discussed tersely in a previous section, so more detail is given here. Briefly, The debate has reached a point whereby measures that attempt to limit or alter the consumption patterns of Scots have begun to be discussed and implemented in Scotland. Perhaps one of the most controversial policies has been an attempt to introduce a minimum price per unit of alcohol sold in Scotland. The analysis conducted in this section therefore uses estimates from the microsimulated dataset namely the proportion of all people (as well as men and women separately) who exceed these weekly guidelines for various geographical areas in Scotland. As mentioned previously, the weekly limits of

21 units for males and 14 units a week for females of alcohol consumption have been used as a framework detecting for alcohol misuse. The microsimulated data is therefore categorised by the number of units per week of alcohol that is consumed. The compromise is that once over the limit, there is an underlying assumption that this will have similar negative consequences, which is the most pragmatic approach, but not perfect.

Table 8.3: Microsimulated Alcohol Consumption Rates

Health Board	Over Limit (F%)	Over Limit (M%)	Over Limit (%)
Highland	13.90	27.77	21.37
Grampian	11.19	17.01	14.84
Tayside	13.08	26.16	19.76
Fife	9.47	23.12	16.20
Lothian	16.01	21.88	19.53
Borders	7.33	14.26	10.56
Forth Valley	8.44	20.92	16.53
Argyll & Clyde	2.45	41.14	9.81
Greater Glasgow	16.88	28.52	23.44
Lanarkshire	12.57	24.97	19.35
Ayrshire & Arran	11.80	21.94	16.21
Dumfries & Galloway	10.62	19.75	15.38
Orkney	22.43	14.82	17.73
Shetland	6.75	12.72	10.49
Western Isles	9.51	12.68	11.89

Moving onto describing the microsimulated results in the table (see Table 8.3). What can be seen is the difference between percentages of men and women exceeding the guidelines, with men universally exceeding guidelines in greater numbers than women. Additionally, the spatial dimension can be noted with Greater Glasgow having 16.9% and 28.5% of females and males exceeding alcohol guidelines respectively and the highest of any HB with 23% of the population exceeding guidelines. At the opposite end of the spectrum is Argyll and Clyde (although 2% of females looks artificially low), as well as Shetland, the Western

Isles and Borders. This spatial dimension is shown in Figure 8.10 with the top left panel showing the situation for all people and the bottom half split into females on the left and males on the right hand side, exceeding the guidelines respectively. The other HBs that stand out as well as Greater Glasgow is Tayside, with approximately 13% of women and 26% of men drinking more than the recommended limits and Highland with 14% and 28% for women and men respectively. Shetland is the HB that stands out as the lowest across all people as well as men and women.

The Health Board maps (see Figure 8.10) show the data from the table (i.e. Table 8.3) represented spatially to better illuminate patterns in the microsimulated data. Looking at the maps the pattern is clustered around the central belt, that is Glasgow, Lanarkshire and Lothian, driven by high female drinking in Glasgow and Lothian and similarly for males in Lanarkshire and Glasgow. Elsewhere, Highland and Tayside also stand out as having higher proportions of people (both males and females) drinking more than recommended limits and are contiguous areas within Scotland.

Following the pattern of looking at a lower level geography (output areas) using SIMLOTHIAN and SIMGLASGOW, focusing the analysis firstly on Lothian OAs and then moving onto Glasgow OAs. Within Lothian HB the patterns of alcohol consumption are more difficult to categorise than the previous microsimulated variables. This would suggest that the pattern may not be determined by socio-economic variables as strongly as smoking for example. Looking at Figure 8.11, it is arranged slightly differently to the HB maps. The top two maps are for women, the bottom two maps are for men. The left hand columns are for those drinking under the limits (the guidelines per week), the right hand column for those drinking over the weekly limits. This means that the four maps combined will sum to the total population of each area. In addition the maps

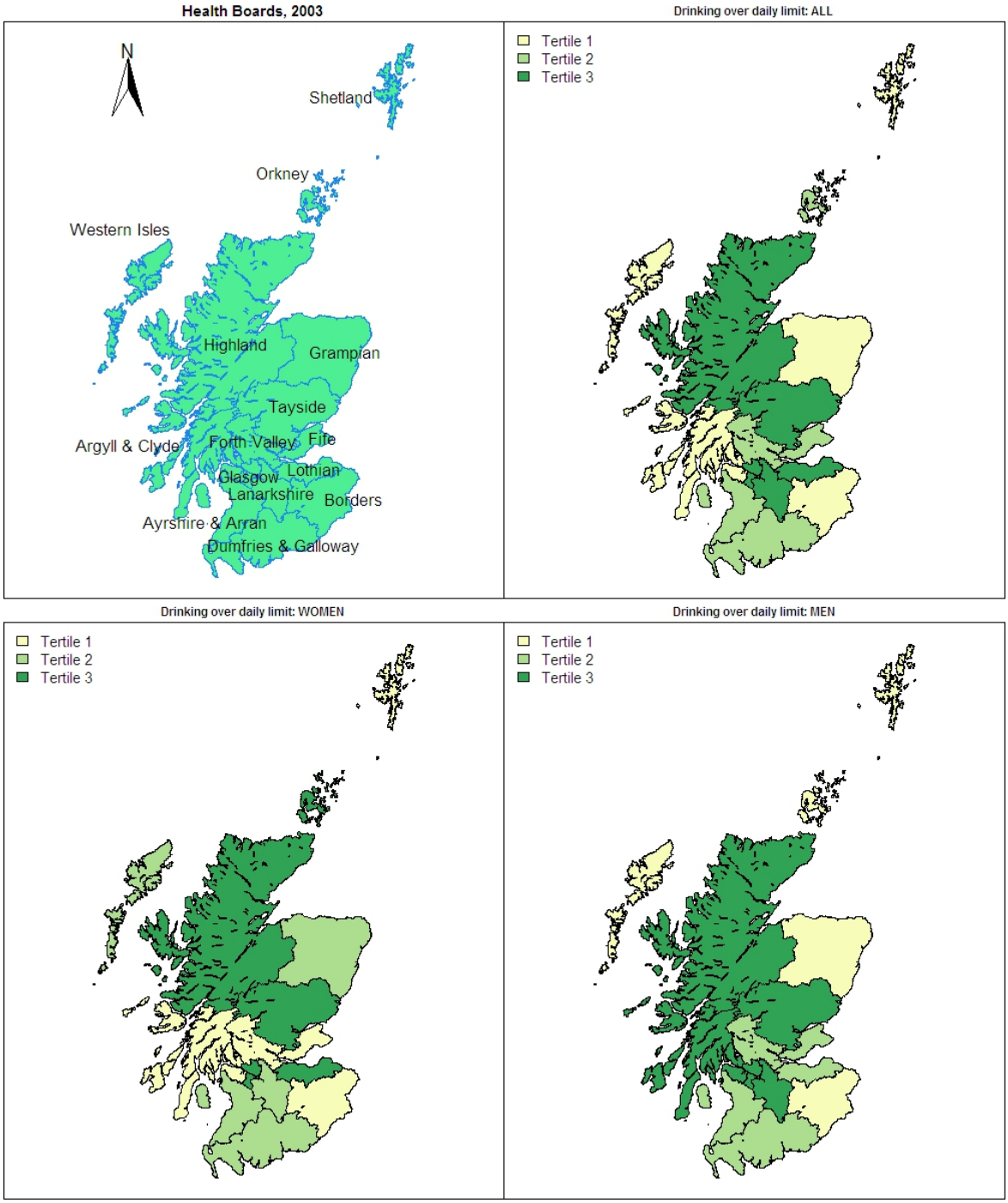


Figure 8.10: Alcohol Consumption Categories, Health Boards: Tertiles (T1:Low)

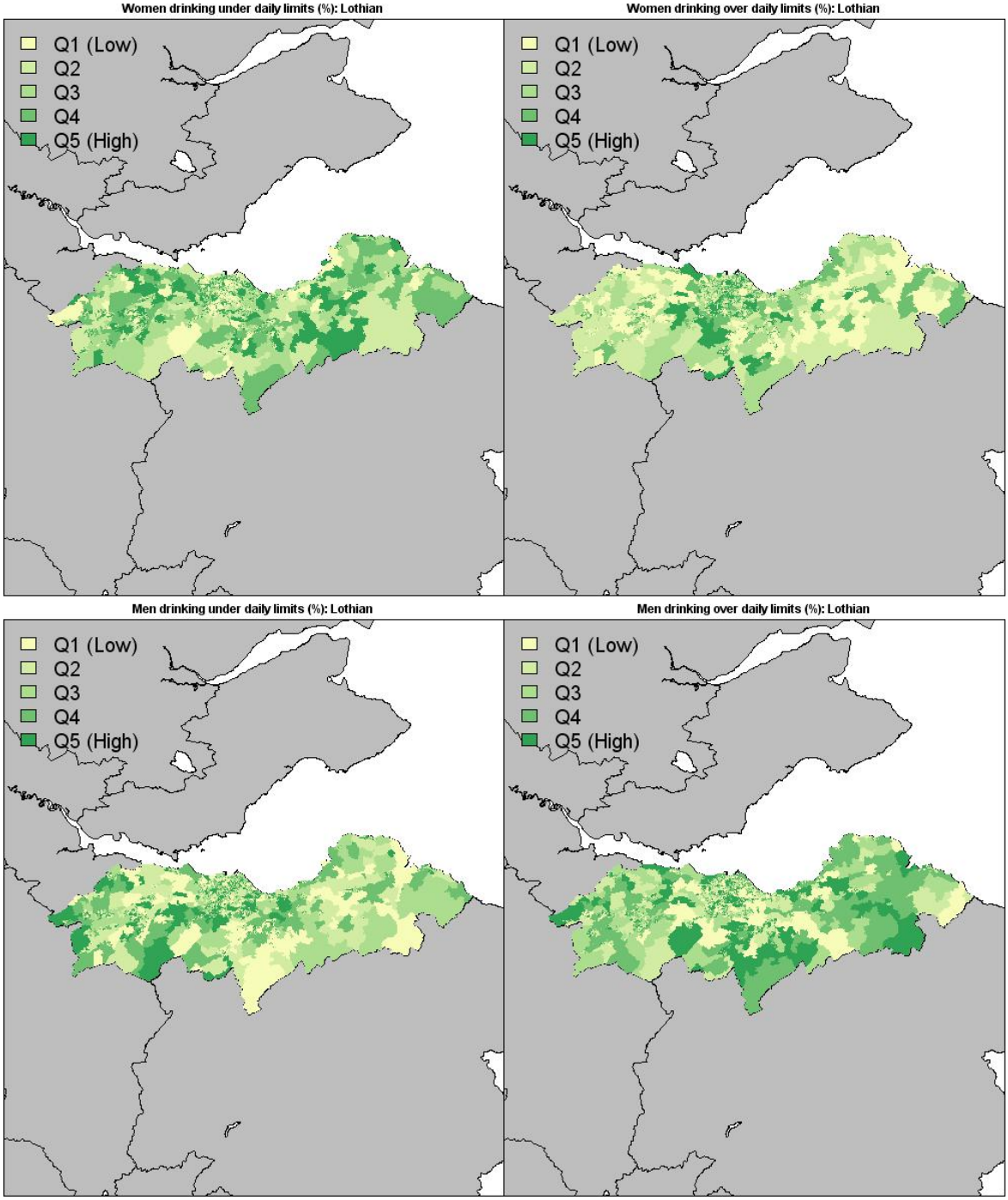


Figure 8.11: Alcohol Consumption Categories, Lothian OAs: Quintiles

to the left hand side of Figure 8.11 will mirror those maps on the right hand side, in other words the number drinking under limits combined with those drinking over limits will also sum to the total population in each area. The spatial pattern overall is that for women in particular, there is a concentration of areas with large percentages drinking over the daily guidelines immediately surrounding Edinburgh. The patterns in the other three figures would appear more sporadic and random.

The Edinburgh City figure (see Figure 8.12) layout is exactly the same as that described for Lothian OAs overall. Edinburgh City has an interesting pattern in that men and women have differing patterns by area. For men there is a large area with proportions of the population drinking over weekly limits (Q5) represented in the darkest colours to the south of the Edinburgh map and in the areas immediately bordering the city centre areas. The areas of overlap where both men and women appear to be over limits are to the south, elsewhere the pattern is somewhat heterogeneous. There is an absence of areas in the lowest quintiles from those drinking under the daily limits, both men and women in the central areas spreading to the south west which mirrors those drinking over the daily guidelines in the panels on the right side of Figure 8.12.

Moving the focus towards Glasgow, what are the spatial patterns of alcohol consumption here? Overall, the summary is that there is little in the way of a clear pattern for any of the four maps in Figure 8.13. The pattern of east end doing 'poorly' is not as apparent for this variable. The patterns for men and women will mirror each other due to the way in which the data is mapped. The message overall is that there are few 'pockets' of problem drinking for men or women, so it is more difficult to conclude that problem drinking is linked to the area.

So, overall the message for policy makers would be the non-uniform spread

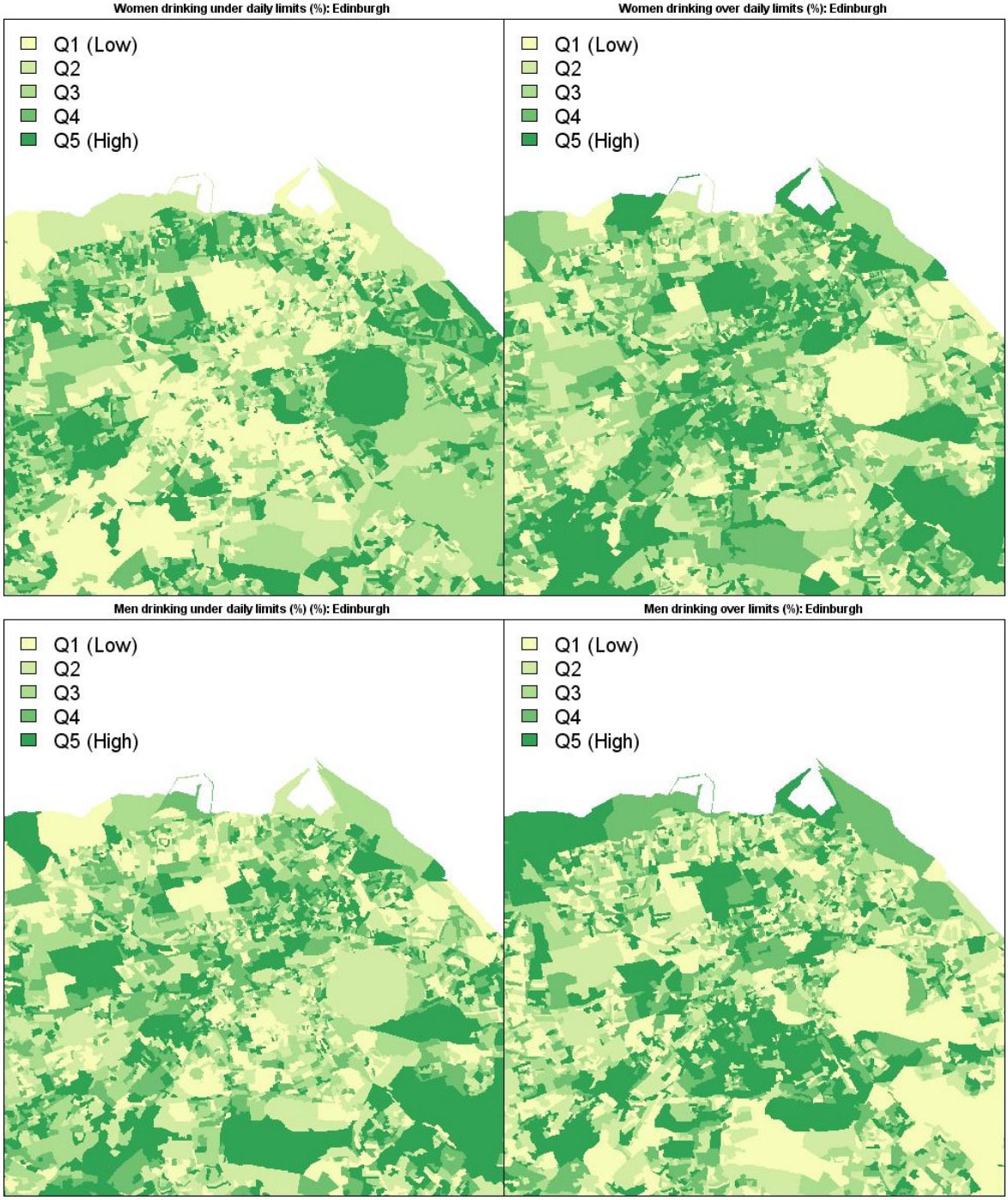


Figure 8.12: Alcohol Consumption Categories, Edinburgh OAs: Quintiles

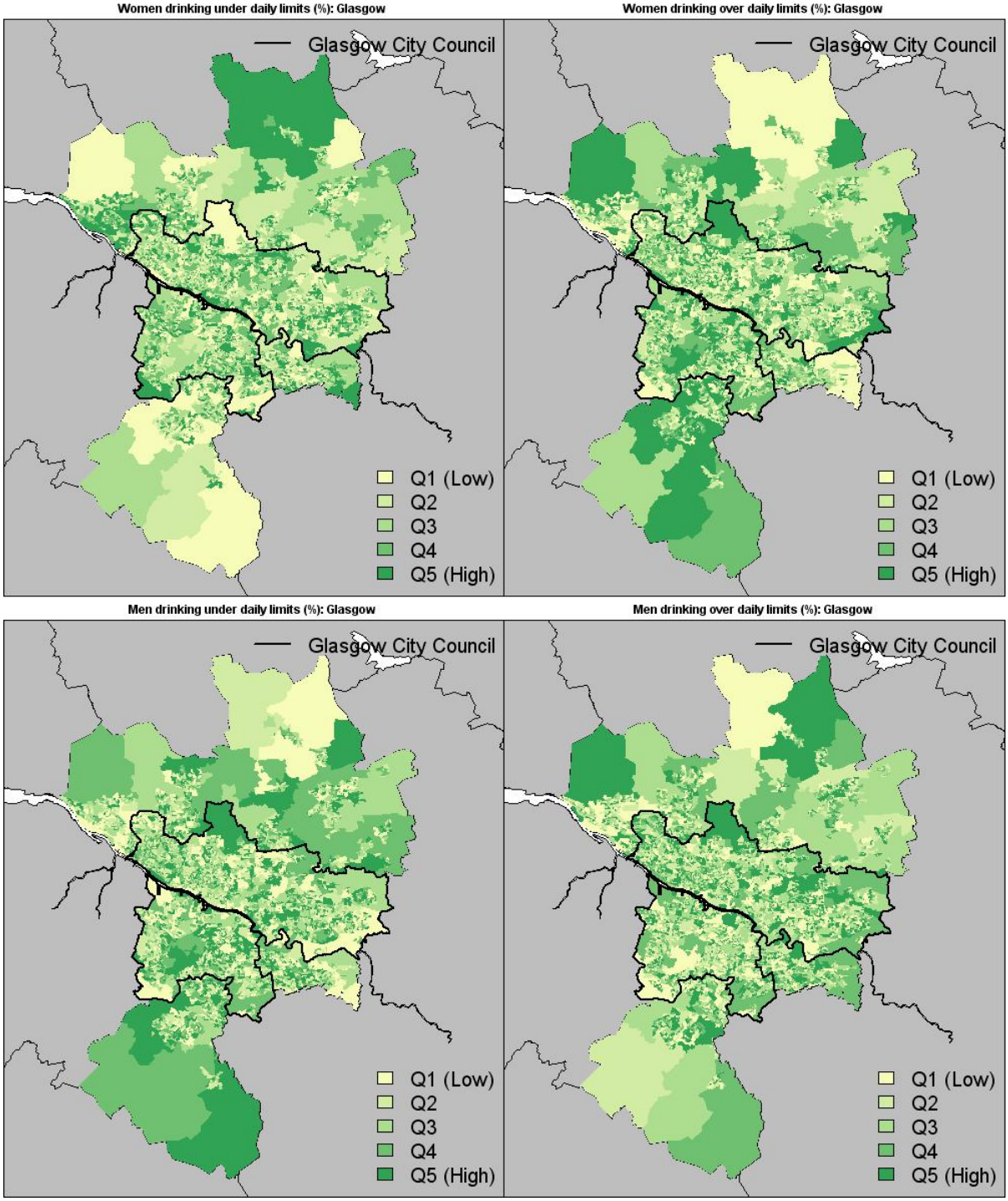


Figure 8.13: Alcohol Consumption Categories, Glasgow OAs: Quintiles

of alcohol consumption by area. With pockets of problem drinking spread across Glasgow and Edinburgh. It could be conjectured that a targeted approach may well have more of an impact than blanket messages about drinking over weekly limits. This set of figures has produced a result which suggests that it is not the socio-economic variables in SIMALBA which drive alcohol consumption.

8.3.4 Obesity

There are four maps in the figures (8.14, 8.15, 8.16) for obesity, or more precisely, corresponding to adult Body Mass Index (BMI), grouped into 4 categories. The four categories used are: underweight, which is a BMI of less than 20 in this instance; normal weight, meaning a BMI greater than 20 to 25; overweight, a BMI over 25 to 30; obese, corresponding to the BMI greater than 30. So each figure contains four maps, one for each category mentioned above. The underweight and obese categories will have negative implications for health outcomes. A study by Flegal et al. (2005) reported "increased mortality associated with underweight and with obesity" (p.1865). Being underweight is normally not raised as a major public health concern and the focus is instead on obesity. The normal category is the 'ideal' weight for the everyone, so this is the desirable BMI category to fall into. It is the two maps in the bottom half (bottom two panels) which have implications for health. Other work directly relevant to this study is work on a model named SimObesity which provided "further evidence for the existence of obesogenic environments ... showing a statistically significant relationship with childhood obesity" (Edwards and Clarke, 2009, p.1130). The SimObesity model was designed for the Leeds area and produced small-areas estimates of a "profusion of health-related variables and socio-economic variables" (Edwards and Clarke, 2009, p.1130). The work in this section builds on the literature and empirical research in this area by adding a Scottish element

to modelling of obesity at small areas levels.

The map on the bottom right of each figure corresponds to the microsimulated number of obese people in each area as a proportion of the population, so this is of particular public health importance. The maps (Figure 8.14) show a somewhat clustered pattern for the overweight categories to the south of Scotland (Borders, Dumfries and Galloway and Lothian) and Lanarkshire and Glasgow in the middle tertile. In terms of Obesity, looking northwards (Western Isles, Orkney and Highland) for obesity it could be argued there is a bigger problem. However, on balance no one HB has the most obvious obesity problem except the Western Isles, which is in no way intuitive.

Looking at the maps on the bottom half of Figure 8.15, the pattern is one that is mainly rural in nature, especially for the overweight category for Lothian with numerous areas scattered across to the south east and western extremes, with a moderately similar spatial pattern for those in the obese category. Those in the highest fifth in the dark colour (Q5) are also heavily present in the eastern edges of Lothian HB. The normal and underweight pattern is the opposite of this, with those in the areas with lowest proportions (Q1), concentrated in the rural fringes and edges of the HB. In addition there is a curious concentration of areas with high numbers of underweight persons as a proportion of all people in the south of Lothian HB. The normal weight category is concentrated in the central area of Lothian, with the darkest colours representing higher proportions of individuals congealing around this area.

Within Edinburgh, Holyrood Park stands out as being having polar extremes for underweight and normal weight (top end of the distribution of areas - Q5) compared to overweight and obese (lowest areas in the distribution - Q1). In contrast to this spatial pattern the area immediately to the south in Figure 8.16 show the highest concentrations of overweight persons as a proportion of the

Figure 8.14: Obesity Rates by Category, Health Boards: Tertiles (T1:Low)

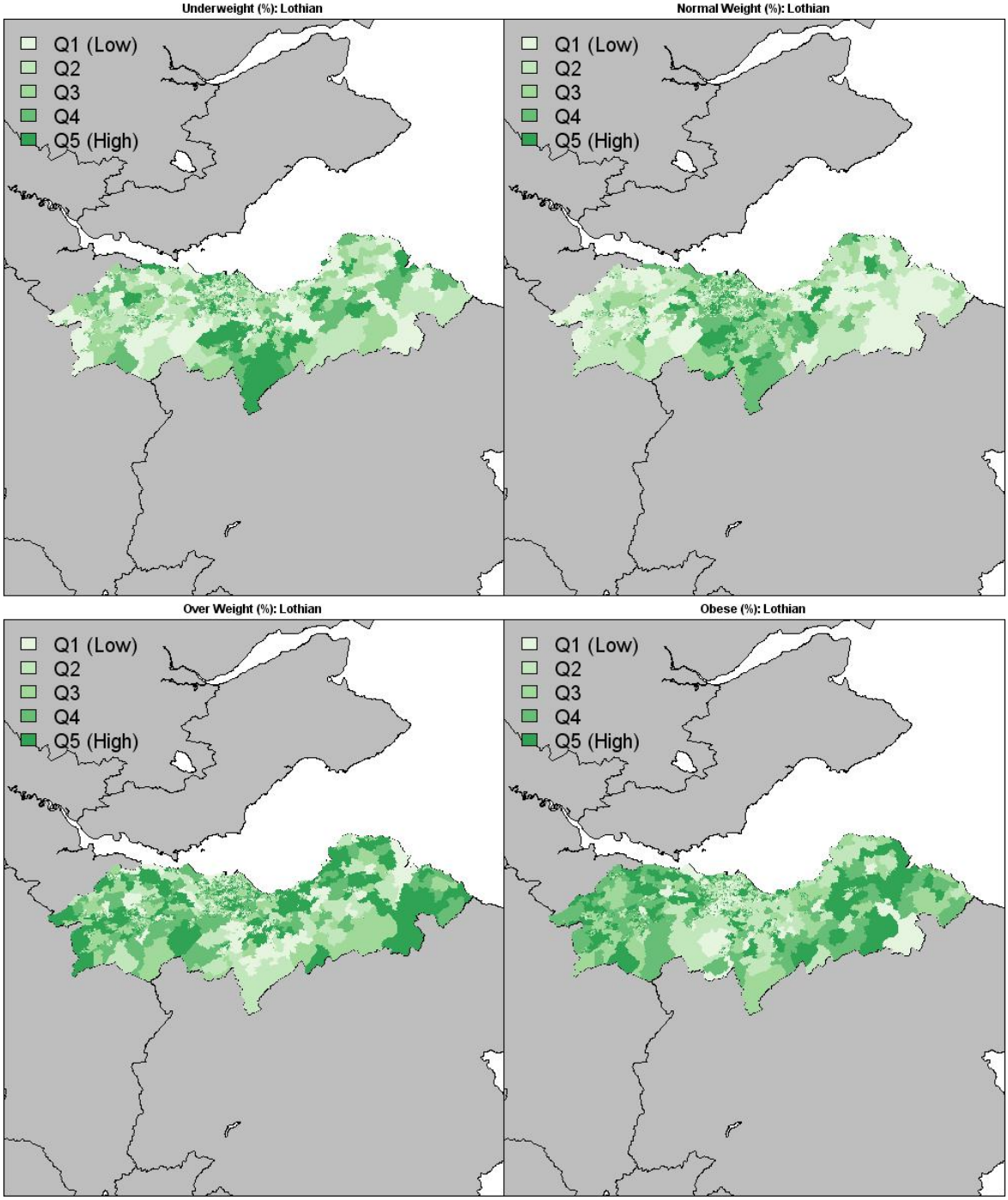


Figure 8.15: Obesity Rates by Category, Lothian OAs: Quintiles

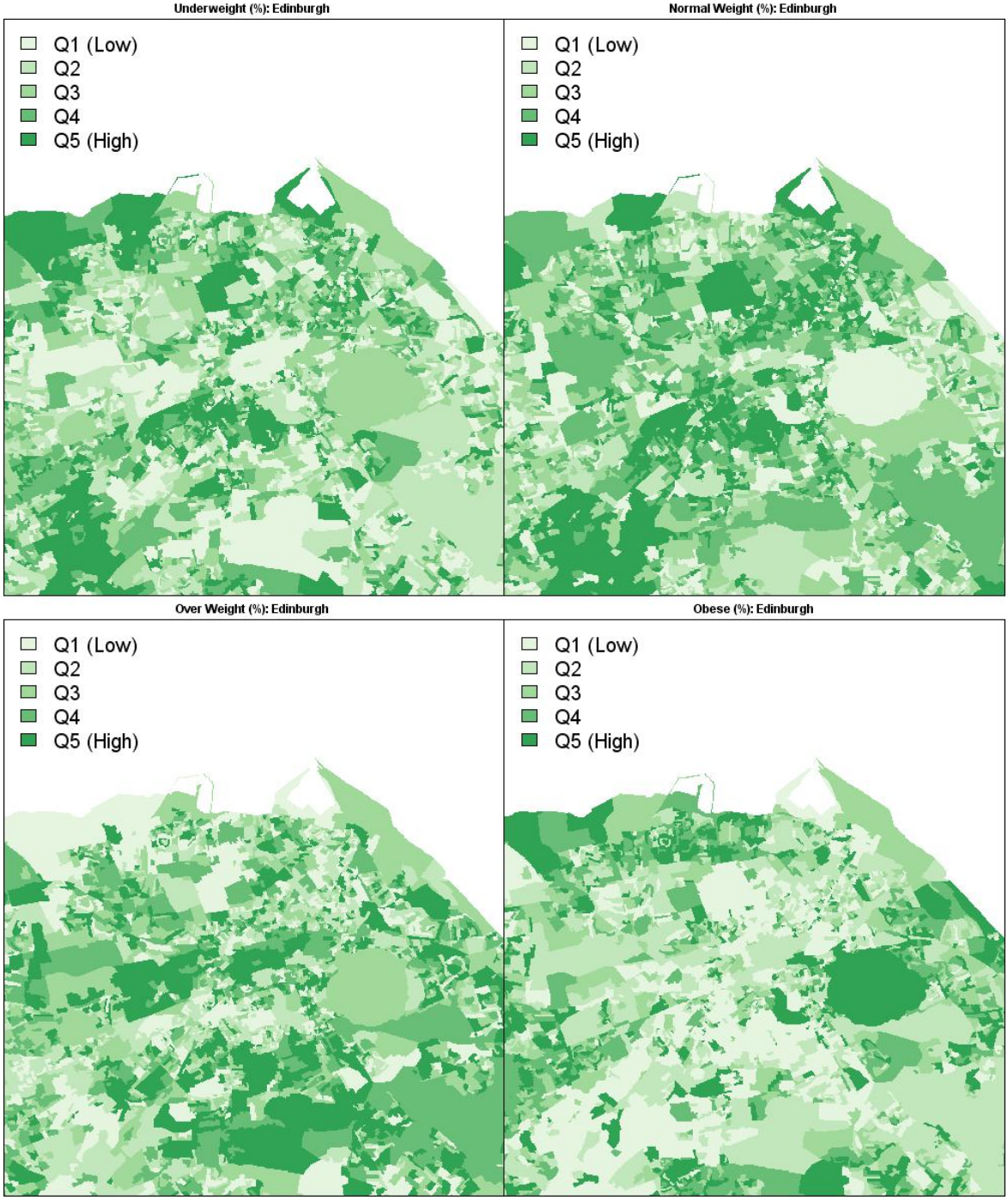


Figure 8.16: Obesity Rates by Category, Edinburgh OAs: Quintiles

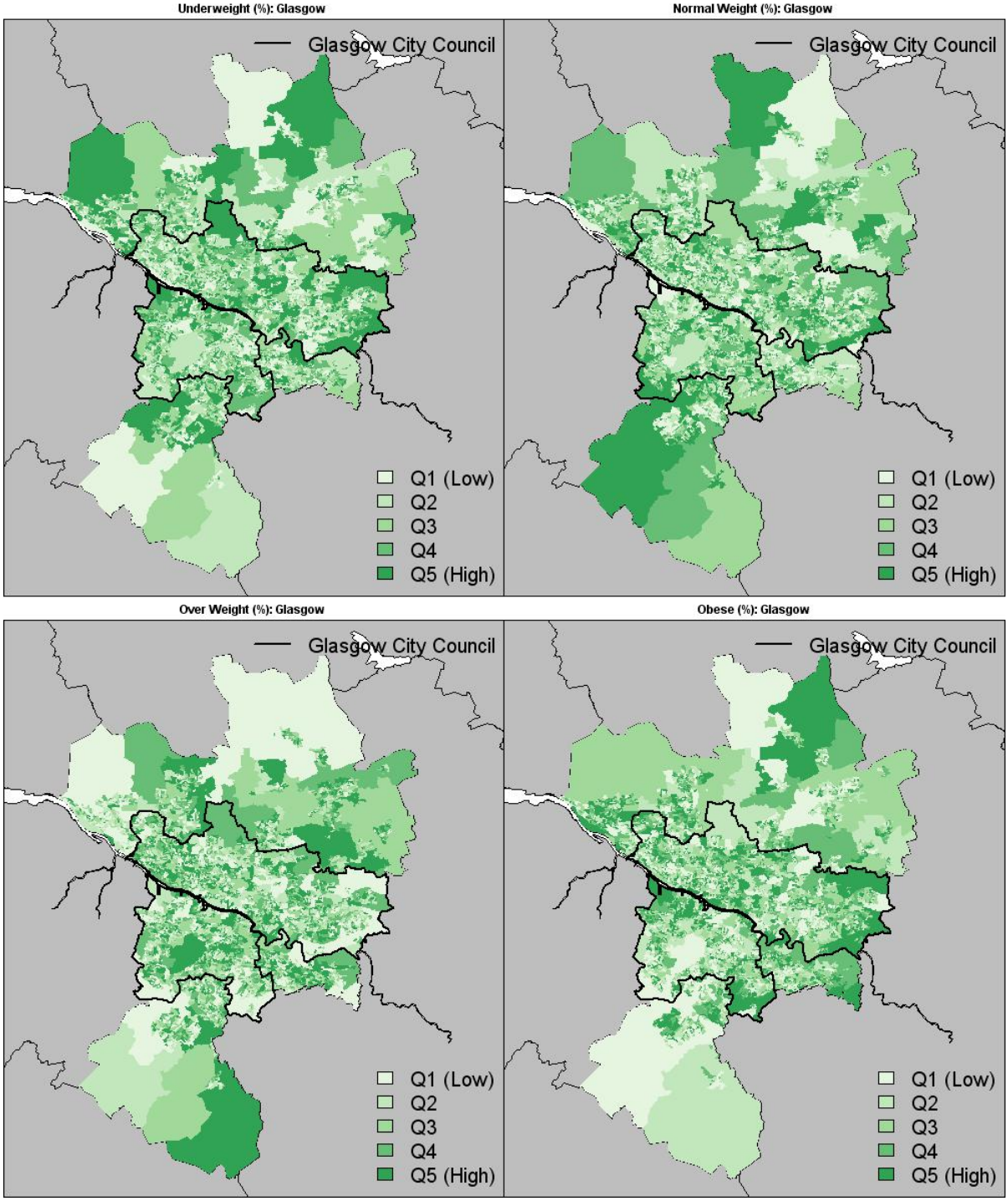


Figure 8.17: Obesity Rates by Category, Glasgow OAs: Quintiles

total population of each area. Elsewhere in Edinburgh there are some clusters of obesity to the north western tip of the map (around Leith) which stand out. Those of normal weight as a proportion of the total number of people in each area is highest in a linear tract stretching south and westwards out of Edinburgh. The main trend is that obesity is generally not heavily concentrated (i.e. Q5 area) in the centre of Edinburgh.

The geography of Glasgow in terms of BMI is looked at briefly in this paragraph. The focus on much of the health problems appear in the east end of Glasgow, the pattern is largely similar for BMI. Those areas coloured darkest (Q5) with large numbers of both underweight and obese people are in the east of Glasgow. The ideal category is the normal weight which is spread reasonably evenly through the city and Greater Glasgow HB. Obesity is also concentrated in the Castlemilk area of Glasgow to the south east with large areas of the darkest colours (Q5) in this area. There are similar small enclaves of areas in the areas bordering the river Clyde to the western edge on the south side of Glasgow city. The pattern would appear to follow an explanation of poor socio-economic conditions correlating with obesity in the Glasgow area.

8.4 Case Studies: Part Two

Another useful way in which to analyse the microdata in an aspatial way is to examine the characteristics of low, middle and high income groups by variables which have been mapped in this chapter and the previous chapter. This will give an overview of how the different economic and health dimensions are linked. Firstly, Edinburgh is examined, followed by Glasgow.

What Table 8.4 shows is the split into 'poor', 'middle' and 'rich' individuals in the Lothian HB. The 'poor' income group is considered to be the lowest third of the income distribution in Scotland, that is from no income up to £10,400.

This group has the lowest proportions of people who work in higher managerial and professional occupations (6%); of owner occupiers (37%); non-smokers (32.6%) and people who have a GHQ zero score (44.9%). There are also the highest proportion of people who are married (84.7%); unemployed (6.1%); without qualifications (61.2%) by a considerable margin or ill (30.7%) in the 'poorest' group. It is striking that there are approximately three times the numbers of ill persons, or people with no qualifications compared to the middle income group. Curiously, the number of females is also higher in the lowest income group (62.4%) compared with the middle (50%) and high (44.5%) income groups.

This is in direct contrast to the 'richest' group who experience the polar opposite situation of that described above. For example more persons in NSSEC classes 1 and 2 (55.2%); almost all are owner occupiers (95.4%); higher proportions of people with better mental well being as measured by GHQ score (64.7%) and 61.8% are non-smokers. Additionally, there is low unemployment rate (1.2%); illness rates (10.6%) and people with no qualifications (5.3%) pointing that higher income is linked to 'better' socio economic conditions for individuals .

It could be argued that this picture is what would be expected a priori, except perhaps the proportions of married and males are slightly different from what may be the case. The general trend of better socio-economic conditions for higher income groups compared to low income groups further confirms the reliability of the SIMALBA model. Note that Lothian is different in terms of the income distribution from the whole of Scotland in that more people are in the 'middle' category (50.7%), than either the 'poor' (23.7%) or 'rich' (25.6%) categories, so in this respect Lothian is different from the Scottish income profile.

What the same table for Glasgow shows is a similar but nuanced version of the same trends (see Table 8.5) it is also split into 'poor', 'middle' and 'rich'

	poor	middle	rich
Nssec1-2	6.0	26.4	55.2
Own	37.0	68.9	95.4
Married	84.7	43.6	37.8
Unemp	6.1	3.6	1.2
NoQuals	61.2	18.6	5.3
Ill	30.7	12.9	10.6
GHQ 0 score	44.9	69.6	64.7
NonSmoke	32.6	45.1	61.8
Males	37.6	50.0	55.5
Females	62.4	50.0	44.5
Total	23.7	50.7	25.6

Table 8.4: Income properties: Edinburgh

individuals, but for the Greater Glasgow HB. Firstly, focusing on the 'poor' income category of Glasgow, who have low proportions of people who work in higher managerial and professional occupations (3.4%); of owner occupiers (52.3%); non-smokers (24.6%) and people who are in the GHQ zero score category (33.2%). This is a slightly different situation to Lothian, where there are more non-smoking mentally healthy professionals in the lower income group but fewer owner occupiers. Moreover, the highest proportion of people who are married (86.5%); without qualifications (77.3%) again by a considerable margin or ill (27.7%) in the 'poorest' group. Curiously, there is less unemployment in Glasgow in the lowest income group (4.7%) compared to the middle income group (6.7%). A similar trend, but more pronounced in Glasgow is that the number of females is also higher in the lowest income group (72.1%) compared with the middle (50.3%) and high (24.5%) income groups, perhaps due to single mothers? Looking at the richest group, there are more persons in NSSEC classes 1 and 2 (58.3%); almost all are owner occupiers (95.3%) as was the case with Lothian; double the proportion of people in the GHQ zero category (67.5%) and 60.7% are non-smokers, three times higher than the poor income group. Furthermore, there are low unemployment rates (1.8%); illness rates (14.5%)

and people with no qualifications (7.1%). The no qualifications rate is ten times higher in the poor income category compared to the richest group.

	poor	middle	rich
Nssec1-2	3.4	21.7	58.3
Own	52.3	69.1	95.3
Married	86.5	36.4	25.3
Unemp	4.7	6.7	1.8
NoQuals	77.3	23.0	7.1
Ill	27.7	16.3	14.5
GHQ 0 score	33.2	70.3	67.5
NonSmoke	24.6	41.7	60.7
Males	27.9	50.6	56.1
Females	72.1	49.4	43.9
Total	25.2	50.3	24.5

Table 8.5: Income properties: Glasgow

So overall, this type of analysis shows the more general trends underlying the patterns in Glasgow and Edinburgh, that lower income groups do worse on almost all measures of socio-economic and health variables compared to those who earn more income. This would suggest that income has a strong influence in determining health outcomes, or perhaps that health determines health outcomes? The causation cannot be proven from this analysis, but the concluding point is that lower income is correlated with worse health outcomes in terms of smoking rate, illness rates, and 'happiness' so more research may be needed to determine how these mechanisms may operate.

8.5 Multivariate Microsimulation

This section aims to explore the power of microsimulation in more depth by again demonstrating some of the consideration advantages of microsimulation over more 'traditional approaches'. Suppose targeting of the most 'unhealthy' persons and the areas in which they live became a policy objective. This can be

achieved in spatial microsimulation modelling. So, the maps below show how data can be used and combined for example by constructing cross tabulations of data that do not exist in the census. The microdata has been manipulated so that the people who are smoking 20 or more cigarettes a day, drinking more alcohol than the guidelines suggest, have low mental well being and also obese simultaneously are selected, then mapped. This combination of factors could be considered 'unhealthy' so finding the areas in which these people live may be a priority so that health policy can target concentrations of 'poor' health outcomes. The maps in Figure 8.18 show the 'high risk' areas in terms of health for Greater Glasgow and Lothian HBs. The maps are coloured differently from previous figures. In these maps the top 10% of areas are emphasised in red. Looking at Lothian (top panel in Figure 8.18), there is a series of areas to the east of the HB with the highest proportions of people in the 'high risk' category. Within Edinburgh itself, the north of the city stands out as having a notable concentration of areas also which intuitively matches what can be expected as this is a combination of the previous four health maps. Elsewhere the pattern is one of small clusters, for example around the southern edges of Edinburgh City council boundary as well as a few other distinct clusters around the Lothian HB area.

Turning the focus to Glasgow, the map (Figure 8.18, bottom panel) is designed in the same way, such that those areas in the top 10% of the distribution are coloured red. The pattern in Glasgow is much harder to deduce, but some areas still stand out visually. There are areas of clustering in places that are expected to feature in the 'poor' health end of the distribution, such as areas in the east end of Glasgow, around Easterhouse and Castlemilk. Other areas such as Drumchapel have sporadic areas of 'high risk' health features. On balance the pattern is concentrated more within the city boundary than outside

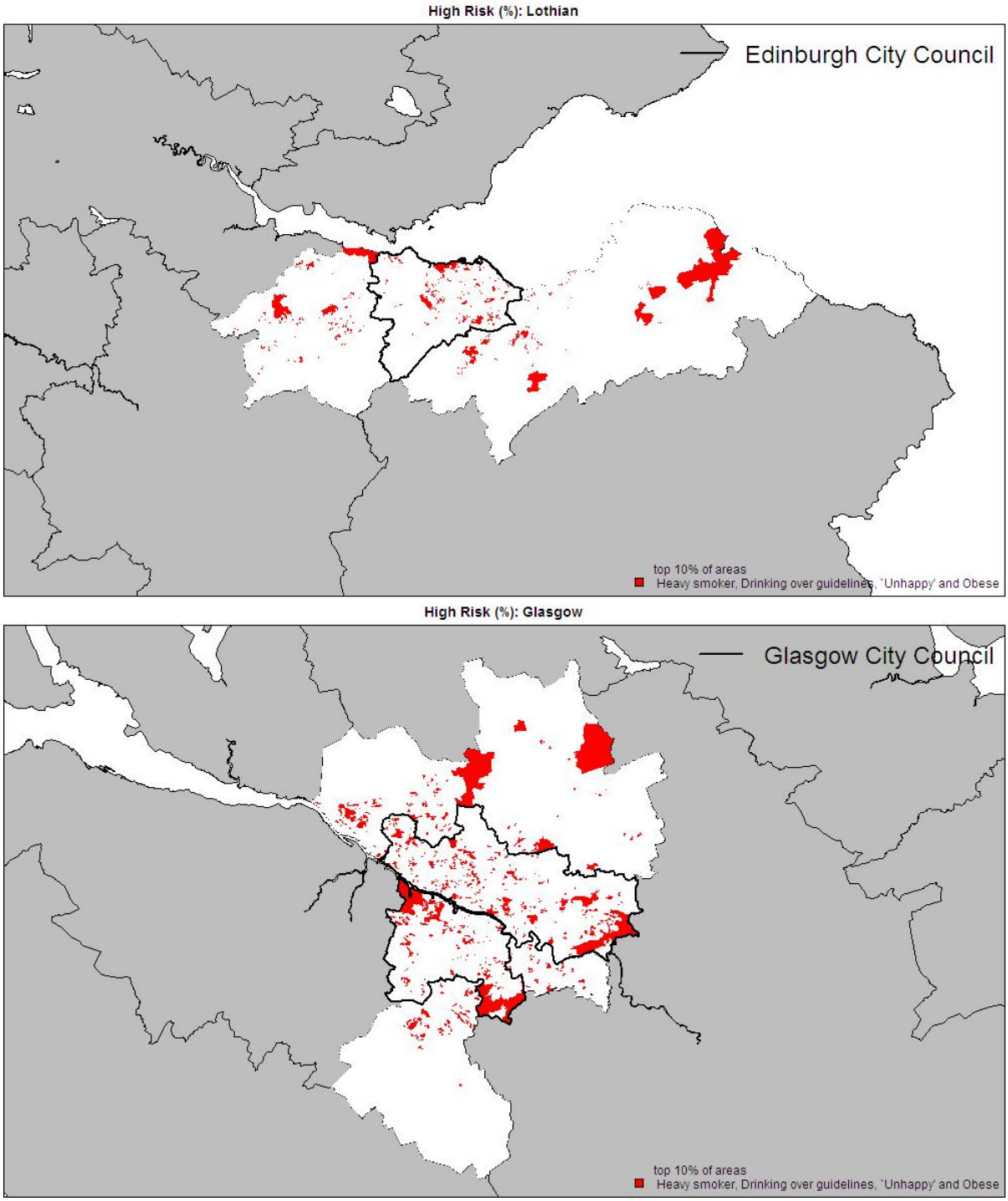


Figure 8.18: High Risk Rates: Top 10%

it, again similarly to Edinburgh, punctuated by smaller clusters spread across the city with notable 'gaps' (i.e. white space) in the more affluent areas of the city. The pattern does show elements of the other health maps, which is to be expected as it is a combination of all four of the previous health maps of Glasgow. Perhaps what is most noticeable is that there are several places in Greater Glasgow with contiguous areas experiencing larger proportions of 'high risk' individuals than compared with Edinburgh. This concentration of 'high risk' areas could have important health implications and additional effects on health that smaller isolated clusters may not exhibit. So, the maps in Figure 8.18 have shown in greater depth the power of spatial microsimulation to bring multiple factors to bear on a problem simultaneously as well as showing how this changes from place to place. This significantly strengthens the case for area based policies, i.e. targeting a specific area in Scotland, as the combination of problems is an issue which is not desirable. The combination of high alcohol consumption, smoking, obesity and poor mental health may well have longer term effects as well as compounding effects on individual and area level health. The targeting of these 'high risk' areas may well have an impact at the national or city level in terms of an improvement to health outcomes more generally.

8.6 Conclusion

In this section some of the main points are drawn together and conclusions from the analysis of health policy are forwarded. This will give the reader an overview of the analysis conducted and highlight important findings as well as to give future directions for research given the limitations of this study.

Firstly, the section relating to smoking shows how smoking is correlated with low income in the previous chapter (see chapter 7), which also was considered in the literature review (see chapter 2). The analysis in this chapter provides policy

makers with a clear sense of where smokers (light or heavy) are potentially living within Glasgow and Edinburgh and this information could potentially be used to target interventions such as stop smoking services, thus saving resources in terms or time and money compared to a whole population intervention. It also confirms that the spatial microsimulation model is likely to be producing valid smoking data, as the literature demonstrates that smoking is more prevalent among more deprived areas (or individuals).

Mental well-being (measured by GHQ 12 score) has also been examined in this chapter. At this stage there does not appear to be any other study in the literature which has produced data on GHQ scores at such small areas using the SHS for Scotland to microsimulate such data. This builds on work previously carried out in the SimBritian project (Ballas et al., 2007a). In a similar manner to the modelling and exploration of smoking, mental well being can be explored so as to target resources at particular sections of the population. Further research could look in greater detail at specific sub-groups of the population and areas simultaneously.

Alcohol consumption was also modelled using the SIMALBA framework. The simulation of data of this nature could be considered valuable to policy makers in showing the differing spatial concentrations of problem drinkers. A comprehensive, population level dataset such as this has previously not been available.

Furthermore, obesity and various weight categories were created using census and SHS data in combination with the spatial microsimulation algorithm. This information could be used in future research to provide an evidence base for where facilities to help weight loss (or gain for underweight) could be located, such as the analysis shown in Tomintz et al. (2008) for the Leeds area. This could be a valuable next step in terms of providing not only a spatial description

of the problem but also a possible practical way forward in starting to address the obesity problem in Scotland.

This chapter has also further painted the current health landscape which has been described in detail, providing an original dataset with which to look at health outcomes and behaviours in Scotland at either the individual level or small area level geography. So, SIMALBA has been useful for modelling the current health landscape in Scotland, but also to show the differing spatial patterns of various health indicators and health behaviours, demonstrating why geography matters. The issues of smoking and alcohol are current subjects of debate in Scotland as discussed in the introduction section, and hence the focus on modelling relating to these variables. Obesity and 'happiness' are also health issues in Scotland but it could be argued that an immediate change in outcome is more difficult compared with stopping smoking or drinking too much alcohol for example.

It would have been preferable to construct separate spatial microsimulation models for each variable used in this chapter. The compromise made in this analysis was that it has been assumed, with reference to the literature, that variables such as smoking for example, will have similar determinants to income. An assumption such as this is justifiable, particularly given the marginal difference to results. It is likely that separate models would in reality produce marginal differences in microsimulated data. Taking into consideration the constrained time frame of this study, was the most practical approach to adopt. Although it must be acknowledged that this is likely to result in less robust results than could have been obtained in an ideal scenario. On balance, the SIMALBA model appears to produce reasonably accurate microsimulated data where validation or use of a proxy variable to test results has been possible.

Overall, SIMALBA has again been shown to provide an original contribu-

tion to the debates surrounding Scottish health and health policy. Not only has original data been created in the form of smoking rates or happiness as well as a plethora of other health and economic variable at micro level, but this data can then be used to examine the current situation as well as potential effects of policy changes by area or a particular population sub-group, before implementation. Even the production of these variables; smoking, alcohol, happiness, obesity at small area level geography is a step forward in understanding what the patterns of health behaviours or health indicators are likely to be. The results are potentially useful for policy makers, particularly when targeting particular sub-sections of the population of Scotland, as such data is not always readily available. There is still significant potential to use the microdataset created for future research in a variety of fields.

Chapter 9

Conclusion

"In the end, it's not the years in your life that count. It's the life in your years."

Abraham Lincoln (1809-1865)

9.1 Introduction

The aim of this chapter is to summarise the research and analyses that have been presented in the previous chapters. This chapter is split into a series of summaries of each of the chapters in the thesis followed by a discussion of policy implications and directions for future research. This allows conclusions about the research findings as well as key messages to be drawn out and highlighted. The aim of this chapter is to bring to a close the research project and to make the findings as clear and simple as possible. There is also a discussion on how well the aims and objectives of the project were met (see research questions section 1.3, in chapter 1) given the methodological, data and time constraints. The

underlying theme is contained within the title, exploring the social and spatial inequalities of ill-health in Scotland: A spatial microsimulation approach. What has the research done to shed light on this area that adds to the body of research already available? It is this question that the research project has been driven and framed by. There is an obvious Scottish focus in this study as well as a focus on microsimulation.

9.1.1 Chapter 1: Introduction

At the outset of this thesis a short synopsis of the overarching direction of the research was set out in a lifecourse (cradle to grave) story format. This summarised key life events along the journey and their possible health effects on individuals. This story was an attempt to describe and explain as simply as possible the complexity of how the health of individuals can be changed over a lifetime. An individual's health therefore, depends not only on present, but on past circumstances and events in combination with the influence of demographic and socio-economic variables. The purpose of following a hypothetical individuals life, was to demonstrate the role of a multitude of variables that could potentially have a beneficial or a detrimental impact on health. Following this a short overview of the pertinent literature on health inequalities and microsimulation was forwarded to ease the reader into the issues surrounding research in these areas.

The next stage was that a series of substantive research questions were formulated and the aims and objectives of the study that were to be addressed by the subsequent analysis. This allowed the research project to have a clear direction and focus throughout while maintaining a unifying theme relating to ill-health in Scotland. The research questions framed the research so that the study moved from a gentle introduction to health in Scotland via mainly descrip-

tive analysis before moving to a more complex set of policy analysis questions. An outline of the structure of the thesis was also discussed so that the contents of each chapter were made clear as well as the specific sequence of the chapters.

9.1.2 Chapter 2: The Literature Review

The literature review (chapter 2) provided a critical analysis and discussion of the relevant literature pertaining to health and its possible determinants. As previously alluded to, the literature review began to provide an evidence base with which to identify the potential socio-economic and geographical determinants of ill health in Scotland which were then used as a basis for microsimulation modelling. The literature review addressed key areas such as the individual and household level determinants of health, that is to say who we are and what we do. This section covered variables such as age, sex, genes, marital status, religion, childhood and ethnicity, showing that all have an impact on health. A further section looked at more controllable factors in other words behavioural factors. This covered smoking, alcohol consumption, diet, drug usage, exercise and sexual behaviour as the main behavioural determinants of health. A more subtle set of processes were covered in the socio-economic determinants of ill-health, which was a major focus of this research. The socio-economic determinants covered employment and job type, income deprivation, poverty, housing, social mobility, social capital and social exclusion which all had varying degrees of importance in determining health outcomes. Furthermore there are area-specific influences on health, such as deprivation, crime, transport issues, housing and so forth. Also explored was a broader perspective in terms of the UK, Europe and Worldwide. This was followed by an important discussion of the various theoretical perspectives; lifecourse, materialist and psycho-social are the main 'camps' of explanation. Finally, the literature review critically eval-

uated the debate about income inequality as the source of many of the social problems, including ill-health. Overall the literature review gave a context with which the study is framed and provided a guide to the likely determinants, both socio-economic and geographical, of health for the modelling work that would follow using SIMALBA. The literature review therefore was used as an evidence base from which to select appropriate constraints for the SIMALBA model as well as to begin the exploration of health inequalities in Scotland and to begin to untangle when the divergence in health terms between Scotland and western Europe began. The literature review also provided a framework for the subsequent analysis of policy in Scotland by identifying key areas of health concern in Scotland and policy aimed at addressing these issues.

9.1.3 Chapter 3: The Data and Methods

The data and methods chapter (see chapter 3) discussed and evaluated the wealth of possible data that could have been used. As a result it was determined that not all the data sources discussed were appropriate to address the research questions. The data sets used in this study were those with a particular health focus, or which contained important socio-economic or demographic data and which were most appropriate for addressing the proposed research questions. This resulted in the Scottish Health Survey (SHS) 2003, The U.K. Census of population 2001 and mortality data for England and Wales as well as Scotland from 1950-2005 being used in this study. In a similar manner to the data sets, there were a wide range of methods that could feasibly have been applied to the chosen datasets and which would have potentially answered the research questions. Each of the methods were critically evaluated in terms of pros and cons before being either selected or discounted. It was also important to bear in mind that access to appropriate data would determine whether or not a

method was utilised. In order to successfully deal with the research questions a wide variety of data and methods were brought to bear. The main method was microsimulation (discussed subsequently in greater detail) which used SHS and census data to model the population of Scotland at small area geographies. Additionally, descriptive mapping, lexis diagrams and regression analysis were also used on the same two data sources as well as on the outputs of SIMALBA and on mortality data.

9.1.4 Chapter 4: Spatial Microsimulation

The spatial microsimulation chapter (chapter 4) explained the different types of microsimulation and the different algorithms that could have been used and provided a justification for the use of deterministic reweighting as a methodology. There was also a debate over various microsimulation models as to their individual pros and cons, using this as a context from which to build the SIMALBA model. The use of deterministic reweighting was chosen for SIMALBA, taking into consideration that policy practitioners may use the model, as it allows the same results to be produced each time the model is re-run. The microsimulation chapter therefore demonstrated the rationale for using spatial microsimulation (with deterministic reweighting) for analysis of the health of Scotland.

9.1.5 Chapter 5: The Health Landscape

The chapter describing the health landscape (chapter 5), using both the Lexis diagram technique and descriptive mapping of weighted survey data from the Scottish Health Survey (SHS) 2003, illuminated the areas of interest for Scottish health. This chapter aimed to address the research questions pertaining to the health divergence and which individuals this affected as well as the pattern and prevalence of illness in Scotland. The chapter discussed the situation with

respect to Scottish health inequalities in a UK context over the recent past, to set the analysis of historical mortality in context. The use of the Lexis diagram to visually display mortality information and comparisons between Scotland and England and Wales provided an answer to the research question on the timing on the divergence in mortality (and health) between Scotland and England and Wales as well as which 'groups' of the population were driving this trend. The analysis of mortality showed the importance of age and sex as factors in determining mortality rates, revealing how the deterioration in the aggregate position came about since the 1950s. Additionally, it could be argued that young Scottish men (since 1970) were driving the deterioration in mortality relative to the rest of Great Britain (G.B.). A further interesting conclusion relates to young men (ages approximately 16 to 25) experiencing over twice the mortality of women of the same age beginning around 1960 reaching forwards to 2005. Overall, the divergence in mortality between England and Wales, and Scotland is notable in successive male cohorts and to a lesser extent in women. Looking at the situation through a more current lens, the analysis and descriptive mapping of illnesses in Scotland illuminated the most prevalent illnesses (and their spatial arrangement) in a simple and straightforward manner. The important point to note is that the figures are not adjusted for age (or any other confounding factors) in any way, but reflect the burden of disease. The more recent health context also highlighted the 'top 5' diseases from most to least prevalent which were: Arthritis, rheumatism and fibrositis; Asthma; Back problems or slipped disc or spine or neck injuries and Other problems of bones, joints and muscles and Hypertension or high blood pressure. This list was not what would have been expected if the evidence base was constructed from media headlines. Rather it more accurately reflects the 'true picture', where the age component is a driving factor behind the burden of disease. The prevalence

analysis therefore highlighted which illnesses were most common in Scotland and addressed the research question relating to the place and prevalence of illness in Scotland.

9.1.6 Chapter 6: The SIMALBA Model

The SIMALBA chapter (outlined in 6) is an exploration of the construction of the spatial microsimulation model. It made it clear how the model was constructed and the datasets used to do so. There was also a validation exercise carried out, which was original in that it simulated data that could be directly checked and found that it could be concluded that the results were reasonably robust. It also explored some of the outputs from the model, showing the power of the spatial microsimulation modelling technique. Creating and running SIMALBA was the most time consuming, resource intensive aspect of this research project. Additionally, a further validation exercise was to map the socio-economic geography of parts of Scotland to give a background with which to compare model outputs against.

9.1.7 Chapter 7: The Economic Policy Analysis

The two chapters (chapters 7 and 8) were a series of analyses using SIMALBA to explore 'what-if' scenarios and policy analysis, as well as future policies that may have an impact. There was also an analysis of 'case studies' from the microdataset. People who could be considered 'typical' individuals selected at random and the effects of policy explored given the characteristics of each person. The economic policy chapter focused on economic issues. Firstly, there is a focus on personal taxation levels (which will affect the income distribution) and 'what-if' analysis of policy options if tax rates change. Secondly, income in the form of benefits, child and housing detailing 'what-if' options on entitlements

to benefits. This gave an overview of four policy areas namely: increasing the income tax threshold; a new 50% tax rate; a means tested threshold to child benefit; housing benefit claimants.

9.1.8 Chapter 8: The Health Policy Analysis

The health chapter (see chapter 8) was focused on some of the health issues that are facing Scotland: alcohol and its consumption; smoking rates and its effects; 'happiness' and mental well-being; obesity rates. This series of variables were explored due to the lack of data available in Scotland at small area geographies. Additionally, these issues were highlighted as important current health problems within Scotland. Pragmatic considerations meant that it was prudent to explore a select few health 'areas' in Scotland at the micro level geographies. The spatial patterns of each were estimated and commented upon, demonstrating the power of the spatial microsimulation framework and the potential for future expansion of this model and this technique.

9.2 Aims and Objectives

In this section, the aims and objectives set out at the beginning of the thesis are revisited. A discussion of whether or not the various aims and objectives have been met is also outlined. There were eight key objectives outlined in chapter 1 (see Table 1.1). The first aim was to assess the literature on social and spatial inequalities and to provide a theoretical and empirical background to the research that would follow. This was carried out in the literature review (see chapter 2) which covered a wide range of the possible determinants of health. The second aim was linked to the data and methods that could potentially be used in the research and which would be the most appropriate. The data and methods chapter met this aim by explaining and assessing a wide variety

of data sources and methods that could have been applicable to the research project. The objective related to the critique of microsimulation techniques was addressed in both the spatial microsimulation literature discussion (see chapter 4) as well as to an extent in the SIMALBA chapter (see chapter 6). The focus on potential applications for health analysis was discussed in various parts of the microsimulation chapter but demonstrated more explicitly in the SIMALBA chapter. Similarly to the third objective, the fourth objective centred on explaining microsimulation and demonstrating the potential policy applications was addressed in the SIMALBA chapter (see chapter 6) with a clear example of the type of application given as a case study. Additionally the two policy analysis chapters showed the applied nature of microsimulation. The SIMALBA model was developed for the Scottish population and enabled a huge variety of queries to be made on the microdata set that was constructed. This met the aim of building and developing a microsimulation model that would be capable of analysing different demographic and socio economic variables at different geographical scales. The sixth aim concerned the validity of the microsimulation model. This was discussed and addressed in the microsimulation model chapter (see chapter 6) which demonstrated the accuracy of microsimulation results within defined error margins. The objective covering the use of SIMALBA to analyse different policy scenarios is met by the analysis contained in chapters on health and economic policy (see chapters 8 and 7). The 'what-if policy options cover an array of policy scenarios including both economic (e.g. tax rates) and health (e.g. suicide risk) areas. The aim of setting an agenda for future research using spatial microsimulation has been addressed in sections in this chapter covering directions for future research as well as the data sets that could be used in future research. In conclusion, the aims and objectives at the outset of the research project have been met through the discussion and analysis contained

in the chapters of this thesis.

9.3 Policy implications

The policy implications of this research are mainly derived from the Economic and Health Policy analysis chapters (see chapters 7 and 8). The policy implications relate most directly to these chapters as they contain the bulk of the analysis related to policy in Scotland. In terms of economic and health policy generally, an overarching message for policy makers is that geography matters. The added spatial dimension highlights a different aspect of the impacts of policy as well as the distributional impacts by population groups. There is clear heterogeneity across Scotland in the distribution of all the variables that have been microsimulated using the SIMALBA model at various geographical scales. This was also the case in the socio-economic geography section for example in the SIMALBA. Moreover the power of the microsimulation framework for policy analysis is clear, offering new and original perspectives on long-standing health issues in Scotland by adding a spatial element and a microdata element to modelling.

9.3.1 Economic policy implications

In the economic policy chapter policies relating to income tax rates, child and housing benefit were examined. The analyses of economic policy showed the heterogeneous impact of national policies at the micro level. The microsimulation of income, explored the potential changes to income tax and benefit rules, which provided a new and original perspective for Scotland. The possibility of customised cross-tabulation is another original aspect for analysis or economic policy Scotland. The analysis of a new 50% rate of tax as well as an increase in the tax threshold showed the different areas which would 'lose' or benefit

from such policies respectively. The microsimulation of child and housing benefits also was conducted. The child benefit policy was analysis to determine the impacts if it was not paid over a certain income threshold. Furthermore, the proportion of housing benefit claimants for small areas in Scotland were microsimulated, calculated and then mapped giving an indication of the areas most likely to be affected by changes to the rates of benefit claimable. The economic policy chapter was useful in terms of showing the 'winners' and 'losers' of particular policy options as well as the places in which these groups resided

9.3.2 Health policy implications

In the health policy chapter the policies looked at covered; smoking, mental health, alcohol consumption and obesity. From this analysis it could be argued that taking account of spatial and distributional change is important. The analysis of health indicators show where interventions within the population may be most effective. Rather than a universal (whole population) approach the spatial microsimulation model gives a way in which it is possible to target interventions by querying the model according to either area or socio-economic and demographic factors. This has clear advantages over universal interventions as the specific population that is most at risk can be targeted more effectively, assuming that the model accurately predicts the locations and socio-economic and demographic characteristics of these individuals.

Looking at each variable microsimulated, firstly smoking, then mental well-being, alcohol consumption and obesity. It could be argued that smoking is correlated with low income (also considered in the literature review chapter 2) which is what would be expected a priori. The mapping of smoking data can provide policy makers with a clear sense of where smokers are potentially living in Scotland (Glasgow and Lothian) so could target interventions more precisely.

Moving towards the microsimulated 'happiness' data, there does not appear to be any other study except for work by Ballas et al. (2007a) and the Sim Britain model did who create some small areas estimates. However, 'happiness' at such small areas using the SHS for Scotland has not been conducted previously. The maps of 'happiness' show the complex pattern of this variable and a hypothetical 'high risk' group of young males with high GHQ scores that could be targeted for example. The Scottish relationship with alcohol was also examined at the small area level, showing the differing spatial concentrations of each category of alcohol consumption. A comprehensive dataset such as this has previously not been available at small area level in Scotland. This could provide a platform to inform policy decisions about targeting specific health problems or groups of people accepted to be at high risk of illness for example. A growing problem is obesity in Scotland. The SIMALBA model gave an indication of where this problem is most acute.

At the risk of repetition the analysis using SIMALBA showed that the place in which one lives is important when considering health, as different places may have very different health profiles. It could be argued that even microsimulation of health variables such as smoking rates or obesity at small area level geography is a step forward in understanding what the patterns of ill-health in Scotland are. The micro-dataset is potentially useful for policy makers when specific 'groups' or areas of the population of Scotland are to be focused on.

9.4 Limitations of the research

This section aims to identify and discuss the limitations of the research that has been undertaken. There are of course limitations in the analysis that has been presented in this body of research and it is important to identify and explain the potential shortcomings so that future research could address these short-

comings if possible. There are several points to be considered which have been identified throughout this thesis that are collated and explained here. The most straightforward approach is to deal with the issues in a chronological manner, finishing with a summary.

When using Lexis diagrams the following limitations should be taken into account, primarily the simplicity of this approach could be considered its major strength, but also a potential source of weakness. If for example, there are very small numbers behind some of the calculations which produce the mortality rates or ratios, this could effect the stability of the Lexis map. The way to mitigate against this was to use a geometric mean of the two cells above and below each data point so as to 'smooth' the data and avoid highlighting any instability in the dataset, as discussed in Rigby and Dorling (2007).

Descriptive mapping is a useful technique for identifying spatial patterns in the data, but not for quantifying these spatial arrangements. The economic and health policy chapters contained numerous maps which visually displayed the quantitative spatial data that was microsimulated. The drawback of simple descriptive mapping is that to a degree it relies on the subjective views of the researcher to determine class boundaries within the data for example and also the colouring of the map. This is the main drawback of this approach.

The microsimulation modelling framework while powerful has several drawbacks which are important to bear in mind for a number of reasons. It should be pointed out that microsimulation modelling could be considered a complex task which requires a certain technical knowledge. Additionally, there is a very real possibility of human error, particularity if the programming of algorithms for the microsimulation model is conducted by the researcher, as is the case with SIMALBA. More importantly, it should be emphasised that the SIMALBA model estimates data, it is only as robust as the series of constraints that have

been used in its construction and as such is subject to error. It is the measurement of this error that is problematic in microsimulation modelling. Attempts have been made in this study to quantify the error and to judge the data against a benchmark, for example using diagnostics and comparing microsimulated and SHS data. The limitation is that microsimulation is used (and is potentially most useful) when data does not already exist with which to make comparisons. Therefore there is a certain degree of subjectivity in assessing the acceptable level of error in a microsimulation model. The approach taken when designing SIMALBA was to use 5% and 10% confidence intervals with which to objectively judge measure the error for each OA in the model.

It would have been preferable to construct a separate spatial microsimulation model for each of the socio-economic or health variables simulated. In this sense, a pragmatic approach was taken given the constraints of this study, based on early prototype models, which was that the determinants of income would be similar to many of the determinants of other variables. In future, it would be beneficial to choose and then re-design the model algorithm based on the set of 'best' constraints for smoking for example, to ascertain whether or not there are major differences in outputs. Moreover, there have been some compromises made in the economic analysis, namely the categorical nature of simulated income. It would be preferable to have a continuous income variable, but this would have required additional data and potentially is not pragmatic within the given times frame. Furthermore, the income data was not adjusted for inflation. However, the compromise is that by adjusting income figures by using the Retail Price Index (RPI) or the Consumer Price Index (CPI), there would be an assumption that all individuals experience the same rate of inflation over the years. In fixing one issue an additional issue is created.

Overall, the limitations do not alter the usefulness of the analysis conducted,

rather it is worth bearing in mind the caveats involved in the exploration and explanation of results so that the reader is aware of the strengths and weakness. This allows the results from the microsimulation model to be used most effectively.

9.5 Applications for the research

The research presented in this thesis has covered a number of research areas. The microdata produced has already been applied to specific areas of interest in terms of economic and health policies. This major strength and original aspect of the research that could be further applied to other policies, which is explored in a subsequent section. The creation of the microdata weights means that all the variables contained in the SHS could potentially be explored and mapped. This is a significant and original contribution to the datasets which could be used for research on ill-health or of taxes and benefits in Scotland. Moreover, the SIMALBA algorithm can be adjusted and re-run (recycled) with a variety of different datasets if desired. Therefore, if new data becomes available the model can be updated with this (or other) datasets. On a different note, models for countries of similar sizes with similar health issues and contexts such as Ireland and New Zealand could benefit from a similar approach as the one taken in this research project. If research such as this was conducted, comparisons could be made between nations such as between Scotland, Ireland and New Zealand, further lessons could be learned about the differences or similarities and potential solutions could be found. As this is the only example of a model which has analysed health and economic policy issues using a spatial microsimulation framework with census and SHS data, there is significant potential to further utilise the data created. Moreover, as the model was programmed using the R statistical software, there is also the possibility of reproducing this model in

a relatively straightforward manner in different contexts (although computing time will still be an issue), such as the previously mentioned application to other countries. The use of Lexis diagrams to analyse the 'macro' level picture in Scotland (with England and Wales) could also be used in different contexts to uncover patterns of divergence (or convergence) and which sub-groups of the population are affected. In more general terms, SIMALBA has added to the relatively small literature on spatial microsimulation of health based issues such as the work by Edwards and Clarke (2009) on obesity, Tomintz et al. (2008) on smoking and the SimHealth model (Smith et al., 2007) in the UK. The spatial element of the microdata can be considered a 'bonus' as the case studies in chapters on economic and health policy (chapters 7 and 8) demonstrate. The power of microsimulation modelling is apparent in the case studies, which do not necessarily require the spatial element, but can be utilised to demonstrate the 'typical' characteristics. The case studies show a wealth of information about the impact of policies and the effects on individuals circumstances for a user defined group of people.

9.6 Directions for future research

The research outlined here was bounded by a series of research questions. This was prudent given the resource constraints every study and established clear boundaries for the research project. Over the course of the analysis and during the preparation of this thesis a number of directions for future research became apparent, both through 'gaps' in the literature, or as the analysis was carried out. For example, several datasets that could have been used, have not been used given the research questions posed at the outset. The data sources not used here may further illuminate the possible determinants of ill-health in Scotland (or further afield) and could be an avenue for future research. There is also

potential for further exploration of social and spatial inequalities in Scotland more generally using microsimulation specifically.

Future research could also try to measure precisely and in a quantitative manner the spatial arrangement of the microsimulated data, for example is there clustering of smoking in the data, which could be used as the basis of a policy response. An additional avenue of research could focus more thoroughly on sensitivity analysis of the models to determine in general terms the optimal level geography (e.g. OAs, wards, HBs) and optimal number of constraints and iterations for microsimulation models similar to SIMALBA or more generally.

Future work could explore much more explicitly the relationship between policies directly related to economic areas (such as income tax) and the subsequent effects on health. So, for example does raising the income tax threshold have a positive, negative or neutral effect on population health? This would be of use to policy practitioners as they may be unaware of the effects of economic policy on health outcomes in the population. A further area of research could explore the links between income inequality and ill-health attempting to uncover the precise nature of the relationship or the effects on health of a more equal income distribution for example. These are just some of the possible research strands and by no means an exhaustive list of the possible future research avenues using the SIMALBA model in Scotland.

The microsimulated weights data could be used in future research to provide an evidence base for where facilities to help weight loss (or gain for underweight) could be located, such as the analysis shown in Tomintz et al. (2008) for the Leeds area. This could be a valuable next step in terms of providing not only a spatial description of the problem but also a possible practical way forward in starting to address the health problems relating to smoking, alcohol, mental health or obesity in Scotland.

9.6.1 Future research data sources

This section deals with data that could have been used in this thesis but is now explained here, setting a context for future research. Several datasets that could have been used were detailed in the data section of the data and methods chapter (see chapter 3). This would include the British Household Panel Survey (BHPS), which has been used previously by Ballas et al. (2007a) in the SimBritain model. The BHPS has been superseded by the UK Household Longitudinal Study (UKHLS) in 2009 and continues the process of collecting data which is useful for analysing changes over time. Other potential data sources include the British birth cohort studies, which again were outlined in the data and methods chapter. Perhaps the most useful dataset to include in future research, even given the access constraints and issues surrounding confidentiality is the Scottish Longitudinal Study. Longitudinal data allows the temporal relationship between exposure and outcome to be established, if such a relationship exists. Therefore any study which wished to determine whether or not there was a link between a particular factor and ill-health would benefit from longitudinal data. This could help answer a different set of health questions, such as does unemployment precede ill-health or vice versa, for example and as such could used to further examine temporal relationships between health and a variety of demographic and socio-economic factors. This dataset could also be potentially included in a microsimulation model which could be expanded to include a dynamic component. As mentioned previously, the microsimulation model SIMALBA was designed to be a static spatial microsimulation model, but could be potentially expanded in future to include a dynamic component, thereby projecting trends forward over time as well as at a point in time.

9.7 Concluding statement

At the very outset of this thesis, a story unfolded (see chapter 1) that postulated the various pathways and key events in life which could determine or alter an individuals health. The research presented has in essence examined a series of 'snapshots' of this story and offered a description along various points of this story and possible explanations of why or how an individuals health may be altered. The research presented in this thesis has shown the potential for microsimulation modelling to be applied in the debate over the best way forward to begin to address poor health outcomes in Scotland. The approach taken has given a more detailed picture of the possible implications of policy decisions at a small scale which is not normally the case. The microsimulation model SIMALBA, has provided a policy relevant tool which can provide applied analysis to begin to uncover and address health issues. The research has shown that there are solutions and possible policy responses to health issues in Scotland and this is the happy ending.

To be continued...

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