The Changing State Pension Age: Health Impacts and Ability to Remain in Employment

by

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Abstract

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By Gregory Michael Payne

The main research questions examined in this thesis concern the interaction between an increasing State Pension Age (SPA) and health in the UK. The conclusions drawn from this investigation cast further light on the equality of an increasing SPA, including whether individuals in different circumstances will be able to continue working until reaching retirement age. In particular, this research suggests that inequality and the social gradient of health should be taken into account when designing a policy as influential as the State Pension.

To explore the relationship between continued employment and health, a Dynamic Microsimulation Model is constructed. This projects individual health trajectories using English Longitudinal Study of Ageing data onto a representative Census base population. Within this framework, current and counterfactual SPA policy scenarios are used to assess the relative impact. This thesis furthers our understanding of the impact that the currently legislated SPA policy may have over the next 30 years.

The study found a decline in overall health within the population of the UK throughout life. Each year the SPA was delayed resulted in an increasing proportion of individuals projected to fall into poor health before reaching the SPA. The results indicate that those in lower NS-SEC groups experiencing poor health at significantly earlier ages. This was found to be likely to lead to a much larger proportion of those in low NS-SEC groups experiencing difficulty remaining in employment before reaching SPA than their high NS-SEC group counterparts. The level of feedback between employment status and health was additionally found to be influential when defining the impact of a SPA change. It was found that if employment leads to an improvement in health, additional working years might protect individuals from an overall decline in health. If however continued employment is detrimental to health, declines in health may be exacerbated, leading to a rapid reduction in health state when nearing SPA.

It was identified that allowing individuals to retire following 45 years of contributions has the potential to significantly decrease the number of individuals falling into poorer health while being under SPA. Conversely, the 50 years of contributions suggested by the Cridland (2016) Independent Review of the State Pension Age was found to pose little benefit in this regard. The health measure utilised was found to be influential when assessing the impact of policy. The study utilised the subjective Self-Reported Health measure, as well as an objective Hand-Grip Strength measure. Significantly different results were obtained, dependent on both the measure of health used and the manner in which conceptualisations of health were made.

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Academic Thesis: Declaration Of Authorship

I, Gregory Payne

Declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

The Changing State Pension Age: Health Impacts and Ability to Remain in Employment

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. Either none of this work has been published before submission, or parts of this work have been published as: [please list references below]:

Signed: Gregory Payne…………………………………………………

Date: 01/03/2017……………………………………………………….

Chapter 1 Introduction

This thesis aims to investigate the interaction between health and the ability of individuals to continue in employment until the increasing state pension age in the UK. Health throughout life is characterised by the socioeconomic conditions in which individuals live their lives, both worldwide and in the UK. Meanwhile, the ability of individuals to continue in employment until a rising state pension age is likely to be characterised by their health. This thesis investigates this interaction in three ways, set out in detail in Section 1.3. The thesis investigates: the ability of individuals to remain in employment until state pension age, alternative state pension age policies that could mitigate the negative impacts that may be encountered and finally, investigates the impact that health measure may have on the analysis of state pension age policy.

1.1 General Introduction

The UK population is experiencing rapid population ageing, coupled with a historically low labour force participation rate of older workers. In order to maintain the sustainability of state provided pension systems, the government is investigating a number of measures to enhance the labour force participation of older workers (Marin, 2013). In the UK, this has been manifested as an increase in the State Pension Age (SPA) alongside a number of other reforms, simultaneously removing barriers and providing incentives for elongated workforce engagement (DWP, 2011). The government intends for these measures to result in individuals being encouraged to remain in the workforce for longer, increasing contributions to tax revenues. In the UK, the SPA forms a critical component in the retirement decision and the financial viability of retirement for individuals (Cridland, 2016). The SPA however is undergoing a change; with a series of new legislations being put in place to increase the age at which state pension income can be accessed. This new legislation is being implemented in three phases. First, the SPA of women has increased from age 60, meeting male SPA at 65. Following this, the SPAs of both males and females are increasing together from 65 toward 68 and beyond. Following the current legislated increases, it is proposed that further increases in SPA should be undertaken in line with average life expectancy. The third phase of this transition following the Pensions Bill 2011 is the advancement of the timeline surrounding these increases, as shown in Table 1.1 below (DWP, 2014). Following this period, it has been proposed to follow the set changes with a linkage of SPA with average life expectancy (DWP, 2013a). A timeline of state pension implementation and more recent reforms are provided below in Table 1.1.

Table 1.1 - Overview of UK Pensionable Age Reforms

State Pension Age Timeline		
Date	**Event**	**Characteristics**
01/07/1948	Basic State Pension Introduced.	SPA Set at 60 for Women, 65 for Men.
29/11/1991	Benefits Available from Age 50.	
06/10/2009	Conservative Shadow Chancellor Outlines Plans to Increase the SPA.	Pensions Bill due 2011.
06/04/2010	Minimum Retirement Age Change.	Minimum Retirement Age Increased to 55.
12/01/2011	Pensions Bill 2011 Introduced to House of Lords.	
04/04/2011	Publication of *A State Pension for the 21st Century.*	Sets Out Equalisation of Male and Female SPA's and Subsequent Overall Age Increase.
17/10/2011	Amendment to Pensions Bill 2011.	Phasing-in of SPA Increase From 65-66 More Rapidly Than Originally Planned.
Proposed Changes		
04/04/2011	*SPA for Women Increasing to 65.*	*Phased in April 2010 - December 2018.*
04/04/2011	*SPA Increasing to 66.*	*Phased in November 2018-October 2020.*
04/04/2011	*SPA Increasing to 67.*	*Phased in 2034-2036.*
04/04/2011	*SPA Increasing to 68.*	*Phased in 2044-2046.*
05/12/2013	Proposal for Average Life Expectancy Link From SPA 68.	Proposition to Link SPA to Advances in Average Life Expectancy.
Ratified Changes		
09/05/2013	Pensions Bill 2013/14 Introduced to Parliament.	Bill Received Royal Assent 14/05/2014.
14/05/2014	Pensions Act 2014 Gains Royal Assent.	Single-Tier Pension System.
		SPA Increase to 67 Brought Forward - 2026-2028.

Sources: DWP (2013b); Pensions Act (2014).

Given a number of population level demographic trends such as population ageing and decline in health at older ages, these changes raise a number of questions regarding the ability of all individuals across society to remain in employment. Specific difficulty is likely to be experienced by key populations including those with low life expectancy, those in manual or otherwise strenuous occupations, those with disabilities, those experiencing poor health at a young age and those unable to retrain in the event of needing to change employment type. The following study seeks to investigate the impact that a change in the SPA has the potential to induce. This is investigated through tracing the declining health of individuals through life and resultant ability to continue working until the rising SPA. By doing this, it is hoped to identify those groups of individuals that are likely to 'win' or 'lose' from the proposed increase in SPA. This is crucial to ensure the equitable distribution of the state pension system, a factor that is proposed to have far-reaching impacts on the wellbeing of the population (Wilkinson & Pickett, 2010).

This thesis will explore the interaction between increasing the SPA and change in health through life through the construction of a dynamic microsimulation model. Microsimulation models have been recognised as powerful policy evaluation tools and allow the construction of 'what if?' type scenarios. The unique contribution this study provides is the ability to investigate the impact changes in SPA legislation will have on individuals, as well as the ability to implement counterfactual policy assumptions and assess the relative impact. While alternative studies have looked at overall impacts of the policy shift (Behncke, 2012; ONS, 2012b; Cridland, 2016), this research provides a greater depth of analysis in ascertaining which groups of individuals may be more or less affected under the current legislation and how this might vary by socio-economic status. Additionally, this study will investigate and compare these results with the impact of plausible alternative policy scenarios.

This chapter will first set out the key demographic and societal trends that have the potential to interact with an increase in the SPA, comprising societal inequality, health, exit from the workforce and the differential experience between males and females. Following this, a further discussion will take place regarding the key populations that have the potential to be impacted by this new policy. Finally, the knowledge gained through this review will then be utilised to introduce the questions that this study will address and the remainder of the thesis will be outlined.

1.2 Outline of Key Influences to the Increase in State Pension Age

This section will first discuss the history of the debate on sources of inequality, the methods used to try and combat the growing inequality in the UK and the reasoning behind deciding to do so. This is done to first contextualise the sources of the social gradient in health apparent in the UK, and secondly to provide a basis on which suggestions may be made on how the adverse impact of changing the SPA on health can be minimised.

It is established within the literature of population health and social equity that there is an observable association between an individual's socioeconomic status and a wide variety of health outcomes (WHO, 2005; 2008). As a wide range of factors including standards of living, medical technology and other influences improve, individuals at the top of the socioeconomic hierarchy experience greater improvements in lifetime health, resultant life expectancy and healthy life expectancy than those at the bottom. This can result in a divergence between top and bottom. The greatest adverse effects on health are additionally found towards the bottom of the hierarchy. For example, employees engaging in poorer quality routine and semi-routine occupations as well as those with lower social resources often show a significantly lower life expectancy and healthy life expectancy not only at birth, but also at the age of retirement (Marmot, Shipley & Rose, 1984; Wilkinson &

Pickett, 2010). The gap in disability prevalence between those in high and low socio-economic groups is additionally greatest during the years surrounding retirement (ONS, 2014d). It is claimed that this effect may be due to accumulation of disadvantage over the life course (Siegrist, 2000; 2016). These effects have the potential to result in significant variation in the duration of life spent in retirement across society in the UK, with those individuals with lowest resources likely to be particularly affected. This section will in turn discuss each of these key trends.

1.2.1 Socioeconomic Status and Health

Some individuals are healthier than others. This is equally true at an individual and at population level. Socioeconomic status has been found to indirectly influence a large number of the features that define individual health. At a population level, those in better socioeconomic positions regularly experience better outcomes across a wide range of health, morbidity and mortality measures (Chandola & Jenkinson, 2000; Graham, 2009). This socioeconomic gradient in health is firmly established within the literature (Marmot, 1999; Giesinger *et al.*, 2014; Adler & Newman, 2017). Despite this widespread identification of the relationship between socioeconomic position and health, the specific causal pathways, mechanisms and direction of influence are still comparatively little understood. However, it is accepted that health determinants are multiple and intertwining, impacting individuals differently throughout life.

The UK experiences a wide variation across the population in both longevity and health (ONS, 2014c; 2015a). The World Health Organisation (WHO) identifies these as '*avoidable'* inequalities in health between both individuals and groups across society (CSDH, 2008). In light of this effect, an increase in SPA imposed or enacted uniformly across the population is likely to impact individuals differently. While the social gradient of health observation has been made by a wide range of studies (Marmot *et al,* 1991; Chandola *et al*, 2003; ONS, 2006; Dorling, 2009), there is no single consensus within the literature as to the source of this variation. Rather this is believed to be due to the impact of variable social conditions throughout the life course (Lynch *et al*, 2000).

Socioeconomic status (SES) encompasses a wide range of factors that are able to influence the health of an individual including but is not limited to: educational attainment, financial security, quality of life, privilege and employment quality (covered later in section 1.2.3) (Mackenbach et al., 2008). Contrary to the biomedical view of health being defined solely by biological factors or individual actions, the social determinants of health focuses on a much wider range of influences. Adler & Newman (2017) suggest that health and health stock can be defined by the interaction between healthcare, environmental exposure and health behaviours. It is the exposure to negative impacts or access to protective forces that serves to define the health of an individual.

Competing explanations exist as to how the social gradient of health came to exist. A variety of non-causal links between socioeconomic status and health have been hypothesised. First, the selection or reverse causation effect is discussed by Bartley (1988), considering whether those with the poorest health are self-selected into lower job statuses, as a result of difficulty maintaining economic productivity to the same degree as those with good health (Clougherty, Souza & Cullen, 2010). Stress theory alternatively suggests that risks are accumulated through the life course through potential chronic stressor or socioeconomic factors (Baum, Garofalo & Yali, 1999; Schreier & Chen, 2013). These risks then play out in later life, causing those individuals with greater stressors to experience greater levels of poor health, at earlier ages.

Socioeconomic position during childhood has been widely found to be influential for later health and mortality risk. It is suggested that exposure to adverse conditions in early life may hinder the full development of organs and the immune system (Bateson *et al.,* 2004; Barker, 1995 & 1998, Sigelman & Rider, 2014), leading to poorer defense against disease and morbidity in later life. Alternatively, others suggest that poorer conditions in early life impacts health from an early age, leading to lower educational and socioeconomic attainment (Kuh & Ben-Shlomo, 2004). This is particularly the case for prenatal exposure, which has been found to affect health and health inequalities through the life span (Lindeboom & van Ewijk, 2013). Some have additionally identified a link between emotional and cognitive brain development in early life and health in later life. It is believed that the internalising of health perceptions and behaviours at early ages permeates into adult life and thereby future health (Hackman *et al*, 2010).

The early life inequalities theory has links with the theory of cumulative advantage or disadvantage throughout life (Dannefer, 2003), suggesting that later health is a product of exposure to risks throughout life. If a large number of risk factors are experienced in early life, this is can translate to poorer health at older ages (Crystal & Shea, 1990; Holland *et al*., 2000; Siegrist, 2016). Specifically of interest to this study, it has been identified that accumulated disadvantage in terms of household wealth is a powerful predictor of mortality in early old age (Demakakos *et al*, 2015). Classical theory suggests that exposure to risk factors varies between socioeconomic groupings. It is claimed that this leads the health of individuals in higher economic groups to accelerate away from those in lower groups. However, this idea is refuted by Watt & Ecob (1992), claiming that it is unlikely that there is any unique difference between poor health and good health regions. They suggest that indeed it is not the risk profiles, but the difference in general indicators of socioeconomic status fuelling the discrepancy. This view was not shared by Crombie *et al*. (1989), noting that socioeconomic status and inequality are responsible for 73% of the geographical variation in mortality for coronary heart disease within Scotland. A similar relationship has been found in the USA, with those in the bottom half of the income distribution experiencing a 27% higher risk of mortality than those in the top half (Waldron, 2007). It is clear that socio-economic disparities identified in health are a result of interplay between a multidimensional range of factors.

There is also a well known large and persistent association between education and health (Cutler & Lleras-Muney, 2006). While some have suggested that education may form an influential factor in long-term health, the causal link remains less clear. Education is intrinsically linked with not just socioeconomic status, but also a wide range of other influential health behaviours such as exercise, smoking, drinking and use of preventative care (Cowell, 2006). Bago d'Uva *et al.* (2008) stress that the causal factor between education and health may not be the education itself, rather greater levels of reporting and greater utilisation of services amongst those with higher education may be influencing the relationship.

Early research into inequalities in health identified income as a prevalent factor, however among a number of developed countries, the difference between top and bottom incomes has been shown to be a better predictor of health than income itself (Wilkinson & Pickett, 2010). This suggests that inequality within society and individuals' perceived position within this hierarchy is more influential than simply the wealth of the individual or country. Such a theory has particular implications within those societies that are shown to be less equal, such as the United Kingdom (Atkinson, Rainwater & Smeeding, 1995; Lindert, 2000). The Income Inequality Hypothesis (IIH) proposes that more egalitarian societies will have greater life expectancies, a result of improved health, than more unequal societies (Coburn, 2004).

Critics of the income inequality hypothesis however claim that the relationship represents an ecological fallacy. It is proposed that the observed relationship is not a product of the inequality itself, but rather of other, unobserved confounding health variables (Judge, 1995). This argument is assisted by difficulties in studying and quantifying the mechanisms through which inequality might influence the health of an individual. Critics claim that inequality is tightly linked with the effect of social policy, increasing the difficulty in isolating its effect on health (Lynch *et al.,* 2004). However Wilkinson & Pickett (2006) suggest that studies of income inequality find greater evidence among larger, more structured populations, as in this context serve as a measure of social stratification. This theory therefore leads that in countries in which social stratification is greatest, inequality should also be more pronounced.

As well as differentials in morbidity, a link has also been found between social status and mortality. The interest of UK public policy with inequalities of health date back to the Black Report of the 1980's (Townsend & Davidson, 1980). The Department of Health and Social Security report examined the health condition of the British population in significant detail. The document concluded that despite the founding of the National Health Service in 1948 and general improvement in health, health 'inequalities' had been increasing since the 1930's (Wagstaff, Paci & Doorslaer, 1991). The paper had three key findings. Firstly the study found significant mortality variation between social classes, at all ages for both males and females. Secondly, the report proposed that the main cause of inequalities was due to economic inequality across society (Townsend & Davidson, 1980), a conclusion that was subsequently reinforced by those of the Acheson Report (Acheson, 1998) and the Marmot Review (Marmot *et al.*, 2010). Finally, the report found that significant variation in mortality between regions of the UK.

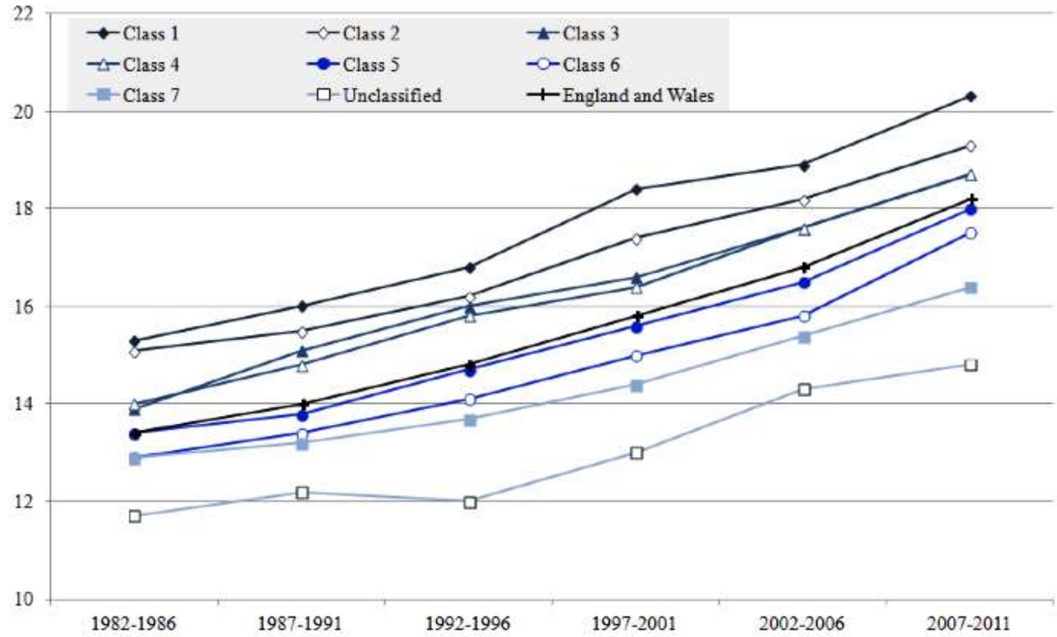
This relationship between a range of indicators of deprivation extends to experienced life expectancy. While this effect has been identified throughout the nineteenth century, the link remains on-going. A number of poignant investigations into this topic have been undertaken, an example in the UK was the research of Watt & Ecob (1992), studying differences in mortality between two nearby cities in Scotland, finding wide variation in mortality levels. This highlighted the variation that can be experienced between Glasgow and Edinburgh, cities in the same country and just 40 miles apart. While the overall mortality rates were observed to be falling through time for both cities, this fall was not equal, leading the gap between the cities to increase. This study epitomised the wide discrepancy in mortality rates that can be observed between similar populations under differing conditions. This variation has been subsequently shown to be relevant, not only between cities, but between disparate groups across the country (Woods *et al,* 2005). The UK government green paper '*Our Healthier Nation: a contract for health' (Department of Health,* 1998) utilised longitudinal studies to show that social gradients in health were indeed widening during the 1980's (Hattersley, 1997; Harding *et al.,* 1997; Smith & Harding, 1997).

Alternatively, the landmark Whitehall Study and subsequent Whitehall II studies presented longitudinal assessments of the risks of mortality from coronary heart disease between Registrar Generals Occupational Social Classes (Reid *et al,* 1974; Marmot, Shipley & Rose, 1984; Mein *et al,* 2003). All 19,019 participants were taken from levels of the UK Civil Service and classified according to employment grade (van Rossum *et al.,* 2001). The study began with an initial screening of participants through a self-reported questionnaire, followed by a number of clinical observations. The participants were initially followed for a period of 10 years, beginning in 1967, however research has continued on this cohort within independent studies.

The Whitehall Study concluded that there was a steep inverse relation between employment grade and mortality (Marmot, Shipley & Rose, 1984). Indeed, the study concluded that men in the lowest employment grade experienced three times the mortality rate of those in the highest grade. Despite a to some extent homogenous sample used in the study, covering only civil servants. The core finding of an identifiable inverse relationship between socioeconomic status and numerous measures of disease incidence, prevalence and mortality has been replicated subsequently in most developed countries (Clougherty, Souza & Cullen, 2010; Mackenbach *et al,* 2008).

A number of speculations and theories on the source of this variation have been put forward since the publication of the study. Around one quarter of the variability has been attributed to social differentials in risk factors such as smoking, cholesterol, blood pressure, height, obesity and physical activity (Marmot, Shipley & Rose, 1984; Marmot & Bosma *et al.,* 1997). However, this leaves much of the variation unexplained, suggesting that there are other unobserved factors contributing to this relationship. It has been recognised that beyond some individuals with increased exposure to behavioural risk factors, the remainder of the social gradient of health is a function of those social and economic conditions that individuals find themselves within (Colgrove, 2002).

Figure 1.2 - Remaining Life Expectancy of Males at Age 65 by NS-SEC in England & Wales.



Source: ONS (2015a)

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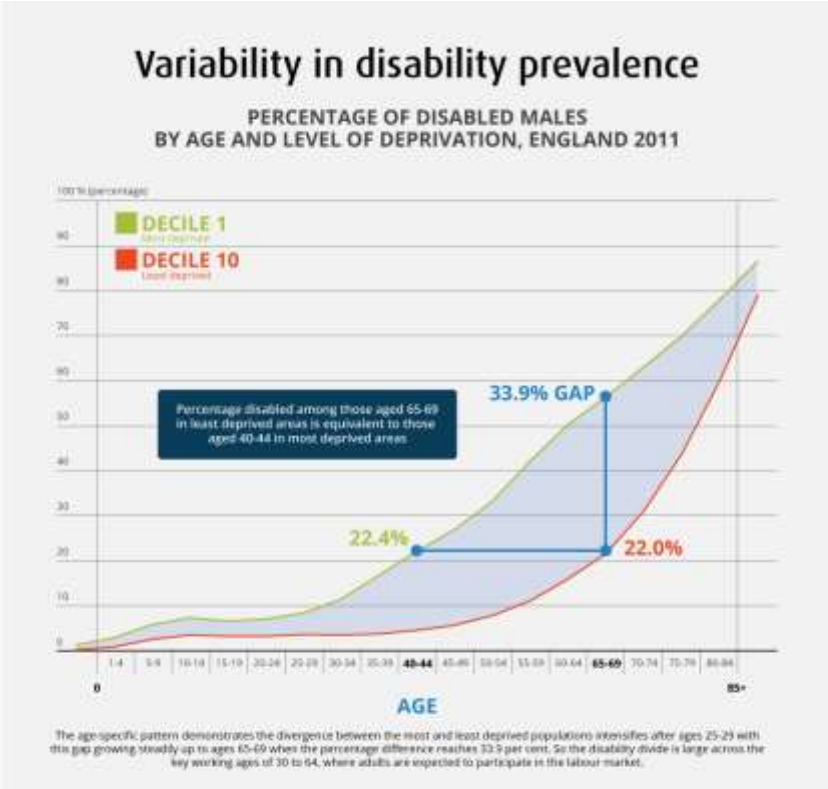
The outcome of this social gradient in health in England and Wales can be seen in Figure 1.2 above, plotting the variation in remaining life expectancy of males at age 65 by NS-SEC socioeconomic group. The overall life expectancy at age 65 is increasing for all groups with the England and wales average increasing from just over 13 years in 1982-1986 to 18 years in 2007-2011. However higher NS-SEC socioeconomic groups consistently outperform their lower counterparts with the remaining life expectancy in 2007-2011 for Class 1 totalling just over 20 years, while Class 7 can expect just over 16 years in the same year. This trend is remarkably consistent across time, with some commentators arguing that there is a divergence, leading to a greater gap between the highest and lowest socioeconomic groups (Bosworth, Burtless & Zhang, 2016). This concentration of poor health outcomes is not limited to areas with high levels of known health risks such as poor housing, there is an observable gradient in health across society in both harsh and agreeable conditions. Figure 1.3 below documents the variance in the prevalence of disability between the top and bottom economic deciles in the UK in 2011.

<u>Figure 1.3 - Variability in Disability Prevalence by Economic Decile in the UK.</u>



Source: ONS (2014d)

As can be seen from Figure 1.3, those in decile 1 (most deprived) of income deprivation are significantly more likely to experience a disability at all ages than those in decile 10 (least deprived). Significantly, this divergence in experience between top and bottom peaks during the ages of 65 to 69, which represent the critical years for SPA legislation. Between the ages of 65-69, 22% of those in the least deprived decile are classed as disabled (having some limitation in day-to-day activities in the last 12 months), compared with 55.9% of those in the most deprived decile, a gap of 33.9%. Indeed, this divergence in experience is shown to be increasing rather than reducing, suggesting greater health inequalities may be expected in the future.

The role of modern medicine, technology and access to healthcare has complicated the relationship between life expectancy and health across society. Intuitively, it should serve that better health is linked with greater life expectancy, however, the relationship is rarely this simple. Medicine and technology has allowed many sufferers of long term or chronic illnesses to continue to function, ameliorating symptoms but not curing the disease (Crimmins, Preston & Cohen, 2011). Crimmins, Garcia & Kim (2010a) claim that several different dimensions of health – risk factors, diseases and disabilities may all be related to life expectancy in a number of ways. The direct mechanisms and interactions between these variables have yet to find consensus within the literature. Social inequalities are suggested as having a symbiotic relationship, influenced by and being influential in the shaping of society (CSDH, 2008). This is being driven by the way society shapes itself both at the national and local levels, giving rise to an inherent hierarchy between individuals. Such a hierarchy influences the access to social resources and conditions in which lives are created, raised and completed.

Despite the sources of inequality, wide discrepancies in health at older ages across the UK may introduce problems when linked to a nationwide SPA or a SPA linked with average life expectancy, as proposed for further advancements of the SPA. This effect has the potential to create 'winners' and 'losers' of policy outcomes. Those experiencing higher than average life expectancy may expect to gain, in terms of increased pay out and years spent in retirement, while those with below average longevity will comparatively lose out. This is likely to go against the cross sectional redistributive ethos of the UK state pension system, redistributing not from high to low incomes, but from low to high (Marin, 2013). The change in SPA is likely to have far-reaching effects on the lives of its recipients, influencing financial and social conditions as well as health and life-course plans.

1.2.2 Employment and Health

The relationship between health and employment is complex and was described by Marmot (2010, p. 68) as "close, enduring and multi-dimensional". Conditions and quality of employment are claimed as an important determinant of adult health, particularly when nearing retirement years. The effect of employment not only impacts individuals during their working life, but also has lasting effects that permeate into later life and retirement. The influence on lived conditions additionally extends far beyond the time spent at the place of employment, serving to define not only economic resources, but also status within society, lifetime stress, social resources and living conditions (Benavides *et al*, 2000). Employment type and job role are argued to form a crucial component in the relationship between socioeconomic status and health.

Disentangling the specific influence employment on observable health outcomes is greatly complex. Depending on context, employment has been found to correlate both positively (Ross & Mirowsky, 1995) and negatively (McDonough, 2000) with health. This appears to depend on the circumstances, conditions and security of the employment in question. Precluding this, the mechanism through which individuals find themselves in good or poor quality employment remains unclear.

A number of different perspectives have arisen attempting to explain this relationship. First, Continuity theory (Atchley, 1989) claims that employment can lead to better health in later life through the value of continuing socially meaningful roles during these years. Additionally, the theory suggests that an inability to remain socially active and productive is detrimental to healthy ageing. The social causation hypothesis meanwhile suggests that security of employment can improve the health of individuals (Chandola *et al*, 2003). Conversely, the health selection hypothesis poses that those with initially poor health will be less likely to both obtain and keep jobs in their lifetime. This thereby limits the degree to which they can improve their social position during their economically active years (Lichtenstein *et al,* 1993; Macintyre, 1997). While evidence has been found for on all sides, it is likely that all three elements are influential. While these perspectives are important for explaining the observed heterogeneity in health trajectories, it is important to note the importance of individual circumstances when considering health. Health state in older age is likely to reflect a wide spectrum of individual influences. The influence of a single element can be either important or insignificant, dependent on the context.

The same can be said about the link between health and income, with the causal relationship being found to operate in both directions, dependent on context. Low pay often leads to worse living conditions and thereby worse health. Numerous studies have provided support for this 'absolute income hypothesis' (Wilkinson, 1992; Adler *et al,* 1993; Pritchett & Summers, 1996; Wilkinson, 2002), however the causal mechanism remains unclear. Poor health is additionally likely to lead to a reduction in income. The complex nature of health and difficulty separating confounding variables from the main effect during analysis has provided a challenge to researchers. Indeed, some researchers have concluded that the relationship observed between income, health and mortality is nothing more than a statistical artefact (Kennedy *et al,* 1996; Gravelle, 1998). However this effect is regularly and robustly identified despite such difficulties.

As shown by the Whitehall and subsequent studies, more than simply the state of 'being employed' is important within the health-employment link. Not just employment, but the quality of employment is found to be important for health (Marmot *et al*, 1991). Those in jobs with lower social status but similar employment conditions showed higher prevalence of angina, evidence of ischaemia and symptoms of chronic bronchitis. Similarly, self-reported health showed an inverse relationship with employment grade (ibid). This complicates the relationship between employment and health. The effect of employment on health is not as simple as positive or negative, a great number of nuances exist depending on employment type, social standing and a range of other contributory factors.

Unemployment and specifically long-term unemployment has a widespread impact on individual health, as found by Morris, Cook & Shaper (1994). The study found that mortality doubled in the five-years following redundancy for men following a long period of employment and aged 40-59 in 1980. This effect was additionally found irrespective of more common protecting factors, such as higher socio-economic status, previous health behaviours and other health indicators (Dorling, 2009). It is possible that this finding is of increased importance under a scheme increasing the SPA. Those that are unable to continue working until a later SPA may run the risk of further damaging their health through periods of unemployment leading up to the SPA. The health effects of unemployment range from having a worse general health status, increased incidence of depression or increased risk of mortality, as well as a wide range of other effects (Bartley, Sacker & Clarke, 2004; Gerdtham & Johannesson, 2003).

Meanwhile, the mechanisms through which employment states impact health remains under debate. A wide body of literature exists on certain aspects of employment and their effects on health. Research in this area can be broadly categorised into three distinct approaches. Firstly, the perspective of occupational health examines the direct health effects of the work environment. This often encompasses the physical elements including ergonomic design of workspaces, exposures to dangerous materials or habits and exploring the effect these elements can have on observable health outcomes (Benavides *et al*, 2000; Campos-Serna *et al*, 2013). Secondly, often being undertaken from a sociological perspective, studies investigate how functional aspects of work routines and obligations may have on personal health. This encompasses such elements as the effect of shift work and variable work patterns on health, as well as the influence of employment perceptions such as prestige on employment adequacy and health (Guest, 2004; Braveman, Egerter & Williams, 2011). Finally, the study of occupational psychology explores the relationships between the individual and those around them, and the positive or negative effects these may have on health. Similarly, this division of employment health is engaged with the effects of autonomy and the demands of the role on health outcomes (Spector, 1986). Each of these three areas brings an individual perspective to the effects that employment can have on the health of an individual, however consensus remains far from conclusive. A unifying framework that would provide information of all health impacts from employment remains elusive. The lack of such a unifying framework hinders the ability to reliably separate the effects of employment on health from health more generally, undermining the field's ability to make recommendations in any single direction. For this reason, this study will focus exclusively on health as a general concept and its effect on the probability of exit from the workforce.

Employment stress has also been regularly identified to influence the health of individuals. Stressful work conditions, particularly those with high psychological demands and low levels of control (Karasek, 1979; Karasek & Theorell, 1990) are suggested to be risk factors for both mental and physical illnesses. This model of job strain was later updated with a third dimension, suggesting that social support at work (Johnson & Hall, 1988; Johnson, Hall & Theorell, 1989) was also influential in these 'high strain' employment types. Alternatively, Peter & Siegrist (1999) find that high levels of effort and low levels of reward are linked with increased levels of cardiovascular illness. Referred to as the effort-reward imbalance (Siegrist, 1986), the theory has its roots in social reciprocity. It is claimed that satisfaction with an exchange such as that of employment and reward is defined by the satisfaction and compensation derived from the work. Employees that perceive that this reward is not adequate were found to be susceptible to strong negative emotions and sustained stress. Conversely if the reward was found to be appropriate, positive impacts on health and well-being could be identified. These factors are likely to be influential when defining the impact of continued employment.

While a number of different conceptualisations of employment exist, this thesis defines 'employment' as the existence (or non-existence) of long-term paid work and does not make specific reference to the type of work being undertaken by the individual. While the type of work being undertaken is likely to be significantly influential when determining the health impact of continued work, the relationship between these and other factors are complex. The modelling of health an employment type is restrictive as there is currently no consensus within the literature as to the direction or magnitude of influence of continued employment. A small element of employment type will be included through the use of social status within the study, however this is significantly intertwined with other influences. For these reasons, this thesis opts to define employment as simply the existence of long-term paid work.

1.2.3 Retirement

In most developed countries, populations are ageing as a result of falling birth rates and increasing life expectancy (Coleman, 2006). Despite advances in the mean age of the population, time spent in the workforce has historically been shown to be stable rather than the expected increase (DWP, 2015). This was a result of a number of influences including the elongation of the education period at the beginning of life, as well as a typically early labour force exit at the end of life. Early workforce exit and the trend towards earlier retirement had become one of the most important labour market forces in recent years. The financial impact of decreased labour market involvement is considerable, through lower tax revenues and increased social security payments (Dorn & Sousa-Poza, 2010). This trend has now begun to reverse, in light of a number of government policies intended to increase labour force engagement in older years. The average age at which people leave the labour market rose from 63.8 years to 64.6 years for men between 2004-2010, when the state pension age of these men was set at 65 years of age (DWP, 2013b). Within the same period, average age for women increased from 61.2 years to 62.3 years (ONS, 2012b), when the state pension age of these women was 60 years of age (DWP, 2013b).

The pathway to retirement has been characterised as the combination of 'push' and 'pull' factors (Beehr, 1986; Feldman, 1994; Taylor & Shore, 1995; Shultz, Morton & Weckerle, 1998). 'Push' factors represent those influences that make continuing to work difficult or undesirable, while 'pull' factors represent those that facilitate the exit or make retirement desirable. While there is dispute over the strength of the predictors, it is recognised that poor health and disability are two of the most common factors 'pushing' people out of the workforce (McNair *et al.*, 2004). Humphrey *et al.* (2003: pp.71) identified within a quantitative study of labour market withdrawal within those aged 50-69 that "*…the earlier the retirement, the more it is driven by considerations of health rather than* money". Conversely, pull factors often represent matters of financial security such as the existence of a workplace pension, facilitating the exit, or willingness to engage with retirement while health allows (ONS, 2012a). These factors weigh in on the decision making process across the years preceding retirement and are not completed until years after the retirement decision was first made (Atchley, 1971; Kasl; 1980; Minkler, 1981).

Traditionally, the SPA at 60 for women and 65 for men has anchored social norms, suggested as indicating the 'appropriate' time to retire (Behncke, 2012; Cribb, Emmerson & Tetlow, 2014) and has developed into one of the greatest certainties in the life course, particularly for men (Hirsch, 2003). However, in more recent years the SPA has increased for both men and women towards 68, meanwhile the pathways to retirement have diversified and now represent a spectrum. In the past decade, the average timing of retirement favoured early exit from the workforce, as noted by the lower than SPA average age of retirement (ONS, 2012a). However, this has begun to reverse, employment rates of females between age 50 and SPA rose from 58.0% in the third quarter of 1993 to 70.9% in the third quarter of 2011 (ONS, 2013c). However, the changing SPA needs to be taken into account when interpreting these figures. In mid 2012, 35.8% of women and 55.3% of men were working between the ages of 60 to 64, due to the lower SPA of women (ibid.)

The reasons behind this shift to early retirement are debated across different scientific spheres. Economic literature argues that a worker's retirement decision is a function of an assessment of future income streams and pension payments and a retirement date is selected to maximise future expected utility (Dorn & Sousa-Poza, 2010). Conversely, Desmet *et al* (2005) argue that early retirement was the result of large-scale industry re-structuring, often favouring younger workers. Additionally, classical life-cycle models predict that greater availability and generosity of retirement benefits will increase the incidence of early retirement (Gordon & Blinder, 1980; Mitchell & Fields, 1982; Gustman & Steinmeier, 1986). This has led to the distinction within the literature between so-called 'voluntary' and 'involuntary' retirement (Desmet *et al*, 2005; Smith, 2006; Dorn & Sousa-Poza, 2010).

'Voluntary' early retirement refers to retirement as a preference for greater leisure time in contrast to a feasible alternative of employment continuation. Conversely, 'involuntary' early retirement describes retirement as a result of unexpected factors, health shocks or employment constraints outside the control of the worker (Dorn & Sousa-Poza, 2010;

Schuring, 2010). It is important to distinguish between these two influences as 'voluntary' and 'involuntary' retirement can lead to significantly different post-retirement behaviours.

While the impact of health on workforce engagement has been well studied, little is known regarding the health effects of retirement (Behncke, 2012) and the effect that retirement has on numerous health outcomes remains under debate (Minkler, 1981; Ekderdt *et al,* 1983; Coe & Zamarro, 2011). Establishing causal links between health and retirement is difficult, since the retirement decision is not exogenous to health, with a number of different confounding factors also likely to be influential in the decision making process (Behncke, 2012).

Actual or 'effective' retirement ages are often below the SPA, as either those with the ability to choose can enter retirement early, or individuals withdraw from the labour market due to alternative reasons such as poor health (as discussed previously in section 1.2.2). However, it remains inconclusive whether giving individuals the ability to retire early is optimal for policy. Within economic theory, retirement can be thought of as having both a beneficial and detrimental effect on health. It is proposed that with the devaluation of time following retirement, the relative cost of time-intensive undertakings such as visiting a doctor, exercising or eating healthily may decline. This has the possibility to lead to an improvement in health following retirement. However, the relative value of improving health may be shown to decrease following retirement, resulting from the same devaluation of time (Dave, Rashad, and Spasojevic, 2006). Research has found the impact of retirement within the real world to be equally ambiguous and variable between heterogeneous individuals (Behncke, 2012). The relationship between retirement and health is likely to be crucial when assessing the desirability of changing the SPA across society.

It is worth noting that it is not necessarily the act of retirement itself that is said to cause health change, rather the change in circumstances associated with retirement. However, again previous studies have provided conflicting results, with associations with improvement (Drentea, 2002; Mein *et al*, 2003) as well as deterioration (Bossé *et al*, 1987; Alavinia & Burdorf, 2008) in mental health subsequent to retirement (Jokela *et al*, 2010). The conditions under which one retires are likely to form a large portion of this relationship. Those retiring voluntarily and with adequate resources to maintain a desired standard of living are likely to fare better than those retiring involuntarily. Consequently, the modelling of health or ill-health as a result of employment is likely to be complex. The true mechanisms remain unknown, but form a key part of the relationship between increased working years and health.

Traditional accounts initially found that retirement had a negative effect on health (Minkler, 1981). These accounts regard retirement as a stressful life event, stating that the degree of control an individual has on the process is key to the amount of impact caused (Carp, 1967; MacBride, 1976). This is likely to have a particular impact on the mental health of those undergoing a stressful transition (Minkler, 1981). More recently however, this has been suggested as an out-dated but persistent hypothesis (Coe & Zamarro, 2011). The real relationship between employment and health appears more complex and despite the on-going debate, no single conclusive theory has been found. It is suggested that retirement can lead to a break in support networks and isolation, leading to a negative impact on the mental and general health of the retiree (MacBride, 1976; Bradford, 1986). Meanwhile, Salokangas and Joukamaa (1991) find that retirement can lead to benefits for mental health, but not for physical health. This effect was attributed to the diminishment of work-related stress as a result of retirement. Conversely, Ekerdt *et al* (1983a) finds that although physical health is shown to decline generally over time, no significant impact of the retirement transition was found. Ekerdt *et al* (1983b) additionally found no evidence that those individuals reporting an improvement in health following retirement were experiencing significantly better health. However, the study found that those most likely to report an improvement in health were those for whom retirement entailed a significant reduction in strain.

The degree of choice in the retirement decision has been brought into question. The level to which retirement is a stressful process is dependent on the element of choice of the individual (Coe & Zamarro, 2011). This choice is often influenced by the health of the individual or those around them, often for many years leading up to the retirement decision. This complicates the analysis of retirement impact, as it is regularly influenced by factors spanning far outside the years up to retirement (Dave, Rashad & Spasojevic, 2006). Whether retirement improves or worsens one's health depends on how the retirement is experienced. Those with the greatest degree of choice and resources are likely to see the most positive impacts of retirement. Meanwhile, those for whom retirement is forced, unexpected, untimely or unwanted may experience significant negative impacts (Dorn & Sousa-Poza, 2010). This study investigates the influence of the exchange between health and labour force engagement. As this section has identified, the experience of retirement is multifaceted and subject to a wide range of influences. For this reason, this study will model the physical ability to continue engaging in employment, rather than expressly willingness.

Alternatively, if an individual is unable to remain in employment until an increasing SPA as a result of health or disability, they may be required to change employment, retrain or experience a workforce exit. However, as noted by De Jong (2003) and others, the concept of disability, sickness, functional limitation and inability to continue working are ill-defined and complex phenomena. This has led to difficulty in both defining and assessing the degree to which an individual may be limited by health. What is clear is that the experience of health is heavily subjective and can rarely be observed directly. This leads to problems when assessing individual ability to work, both within the context of this study and by governments for the purposes of designing welfare provision. Complicating this relationship health, socioeconomic status and workforce engagement are intertwined in a complex manner, potentially all contributing to either improving or worsening health, dependent on context. The World Health Organisation (Dahlgren & Whitehead, 2007) and European Union (Atkinson *et* al, 2005) acknowledge that poor health is a risk factor for non-employment, poverty and social exclusion (Whitehead, 2010). Additionally, these factors are found to follow a social gradient, becoming more severe with decreasing social position, generating and reinforcing social inequalities in health. Returning to work following an incidence of ill health has been found to be increasingly unlikely with increasing duration of absence (DWP, 2008a). While the figures vary, shorter-term absence from work was found to result in a return rate of between 18-35% (Audhoe *et al,* 2012; Bailey et al., 2007; Kemp and Davidson, 2010). Conversely, those with absence periods of greater than two years reported return to work rates of between 1.6-9% (Hales, 2008; Magnussen *et al*, 2009; Sejersen *et al*, 2009).

A large body of literature forms the view that continued ill health can be incompatible with workforce engagement (Cai & Kalb, 2006; Alavinia & Burdorf, 2008). Indeed, one's 'own ill health' formed the most commonly cited reason for early retirement for both women and men in the early 1990's (Disney, Grundy & Johnson, 1997). As described by Disney, Emmerson & Wakefield (2006), measuring the impact of health on retirement itself is methodologically challenging for a number of reasons. First, those who have long standing health problems that impact their ability to work may have been unemployed for a long period of time, excluding them from the sample of early retirees. This effect may also have an implication on the workforce position of those who have experienced health 'shocks' or the burden of long-standing ill health, leading health to be endogenous to the individuals' labour market state (Kerkhofs, Lindeboom & Theeuwes, 1999). Secondly, heterogeneity in personal perceptions of health may exist substantially between individuals. Finally, those individuals economically inactive as a result of ill health may have a self-esteem incentive to over-state the impact of their health on ability to engage in employment, possibly skewing results.

1.2.4 Consequences of Exiting the Workforce

In response to the increase in number of individuals receiving a variant of incapacity benefit having trebled during the 1970's and 1980's, worklessness and those out of employment in the UK are a group regularly targeted by policy interventions (Whitehead, 2010). As individuals are required to work longer under an increase in SPA, it is likely that a greater number of individuals will interact with an inability to continue working. However, this is not merely an economic issue, the increase in numbers of individuals in poor health states when leading into retirement draws into question the ability of a large number of individuals to participate fully in society. The lengthening of working life may have drawbacks on an individual level. Health status arguably represents the single most influential factor 'pushing' people out of work toward retirement decisions and reducing the likelihood that they will return to employment (Quinn, 1977). A vast amount of research has proposed that health status may heavily influence exit timing from the labour force (Schuring *et al,* 2013; Cai, 2010; Alavinia & Burdorf, 2008; Bartley, 1994). Additionally it is claimed that the earlier one's retirement takes place, the more likely the decision is driven by health as opposed to financial factors (Humphrey et al., 2003). However, health itself and the subsequent link with labour force participation may not be equal across society (Kristensen, 2008). For example, as movements are made across NS-SEC social classes toward routine occupations, health problems are more likely to lead to severe negative employment outcomes (Whitehead, 2010). Additionally, lower NS-SEC groups are more likely to cite health-related reasons for leaving work ahead of the SPA (Kristensen, 2008). As a result of the social gradient of health effect discussed in Section

1.2.1, those in lower socioeconomic groups are more likely to encounter health problems before reaching the SPA (Schuring *et al,* 2013). Individuals in physical or heavy manual jobs are noted as being especially likely to have low expectations of working up to or beyond SPA (Banks and Casanova, 2003).

Meanwhile, engaging in secure and favourable working conditions is shown to greatly reduce the risk of developing a limiting illness (Bartley, Sacker & Clarke, 2004). Compounding these effects, the likelihood of someone who left work through ill-health or disability after age 50 re-entering the labour market is significantly reduced, declining rapidly as the length of unemployment and age increase (Alcock et al., 2003; McNair et al., 2004). This measure is similarly variable by resources across society, for example by education, occupation and income (Schuring et al, 2013).

Such differential social and life conditions divide the experiences of the richest and poorest members. The difference in disability free life expectancy between the highest and lowest neighbourhood income deprivation percentiles currently stands at 17 years. Additionally, these least well off percentile experience 7 years less life expectancy at birth than the highest percentile, resulting in not only a shorter life, also a greatly expanded proportion of this life spent in ill health (Marmot et al., 2010). This results in approximately one third of UK residents over 50 years of age suffering from a chronic illness (Griffiths, 2007).

This effect can serve as a barrier to increased labour force participation, concentrated amongst those in less affluent NS-SEC groupings (Kristensen, 2008). As such, those groups least likely to be able to contribute to additional private pension schemes and thereby most reliant on state pension income may be the most affected (Disney & Johnson, 2001; Ring, 2010), however the degree to which this is the case is unclear.

This health barrier to continued labour force involvement draws into question the ability of a large number of individuals to remain in employment until a SPA that is equal across society, where health is observably not. Restricting access to state pension income until later ages may result in a discrepancy between ability to work and access to pension incomes, heavily skewed towards impacting those less well off. The result may be that the proposed SPA change has the potential to create systematic disadvantage for certain groups whilst acting to the benefit of others. This research will investigate individual ability to remain in the workforce until an increasing SPA. Following the literature discussed in this section, this will be done taking the heterogeneity of the population into account.

1.2.5 Alternative Support when Exiting the Workforce

When an individual is unable to remain in the workforce, it is usually necessary to consider one's financial position. Depending on the age of the individual at the time of inability to continue working or need to temporarily drop-out of the workforce, different support structures and rules of eligibility exist. It is possible that under an increasing SPA, if an individual is unable to remain in employment they may be 'pushed' from the workforce onto alternative forms of support. Where an individual may previously have retired during periods of ill health, they may be increasingly required to seek alternative forms of support. This effect has the potential to significantly diminish the financial savings the government expects to make through the change in SPA. This section will review the most common support types encountered by those unable to continue working as a method of contextualising the experience of being unable to continue in employment on health grounds. However, it must be noted that the benefits described here are in a state of flux, largely as a result of austerity measures being undertaken by the UK (O'Hara, 2015).

Statutory Sick Pay (SSP)

When an individual is first unable to continue in employment, whether in the short or long term, Statutory Sick pay is often the first form of support an individual will encounter. SSP is available for up to 28 weeks if the individual is employed, but unable to work and has earned more than £112 a week for the two months preceding stopping work. The standard rate for SSP is £88.45 a week (2015-16) and is paid by the employer. However, some employers may have more generous schemes and will assess cases individually. If an individual remains unable to work after 28 weeks, they may apply for Employment Support Allowance.

Employment Support Allowance (ESA)

Employment Support Allowance is a benefit provided by the government that is intended to provide financial support to those within the population that are unable to work, as well as providing help for individuals to get back to work if they are able to. This is a benefit that you are able to claim if your entitlement to Statutory Sick Pay (SSP) has run out or if you are unable to claim SSP. However, the ESA is also intended to be a temporary benefit for the majority of individuals able to claim it (DWP, 2008b). In order to qualify for the ESA, an individual must undertake a Work Capability Assessment, intended to investigate the extent to which illness or disability impacts your ability to work. The ESA was brought in as the replacement of Incapacity Benefit (IB) and was intended to tighten the rules of eligibility and cut the inflow of new-claimants. Initial assessments of rejection rates suggested that the work capability assessment would increase rejection rates from 39% under IB to 50% under ESA (Kemp & Davidson, 2010). However, more recent official sources have put this figure closer to a 69% rejection rate of claimants to ESA (DWP, 2009). As mentioned previously in section 1.2.2, the experience of ill-health is hard to define and is specific to the individual, drawing into question the ability of a government or government-appointed body to assess this factor on a population scale.

Following a Work Capability Assessment (WCA), individuals will then be placed in one of two groups. If the outcome of the assessment indicates ability to continue working, individuals are placed into a work-related activity group, in which they have regular interviews with an adviser. Alternatively, individuals are placed into support groups, in which no interviews are required. Enforcing regular meetings with a work-adviser may risk placing undue stress on individuals if they feel that the results of the WCA contradict their own feelings of ability to continue working. The proportion of individuals expected to be in receipt of ESA and have a health condition severe enough to preclude return to work at any point is estimated at 10%, with 90% able to return to work (Kemp & Davidson, 2010).

The quantity of ESA received by individuals varies depending progress through the assessment and on circumstances. For the first 13 weeks after the initial claim, individuals receive £75.10 a week if aged 25 or over. This amount then increases following the WCA group placement, with those in work-related activity groups receiving £102.15 a week and those in support groups receiving £109.30. Additionally, it is possible to receive a 'severe disability premium' of an additional £61.85 per week. The standard of living achieved when receiving these payments is not high, with those in the support group subsequent to assessment taking home £5,683.60 per annum before other benefits are taken into account. Representing the primary scheme for income-support following inability to work, this does not provide a substantial income, when compared to the median gross annual earnings for a full time employee in the UK in 2015 of £27,600 (ONS, 2015d).

Personal Independence Payment (PIP)

The Personal Independence Payment or PIP replaced the Disability Living Allowance (DLA) and is intended to help with the extra costs incurred through long-term ill health or disability for those aged 16-64. Specifically, PIP's are intended to assist individuals that have difficulties with activities related to 'daily living' or mobility. In order to claim a PIP, the individual must undergo an assessment by the DWP or a subsidiary agency. This assessment also serves to define the rate of support that an individual will receive; however this is between £21.80 and £139.75 a week. The payment is assessed and paid through a 'Daily Living Component' and a 'Mobility Component', depending on how the individual is impacted by the condition. Conversely to the ESA, an individual may apply for a PIP whether they are in employment or not.

This section has covered the primary support mechanisms available to those who are unable to remain in the workforce due to ill health. A number of alternative schemes are also available for specific cases (such as the Industrial Injuries Disablement Benefit) or for help with specific costs of living when living with ill-health (such as Council Tax reductions). However, it must be noted that all benefits discussed here are often subject to assessments, on-going review processes and the threat of benefit cessation or fines. These factors of insecurity have been claimed to contribute to increased levels of stress and other factors that pose an additional health risk on those claiming (Bartley, 1994; Ferrie *et al*, 1998; Barr *et al*, 2012). Additionally, much of the support that individuals require when finding themselves unable to continue working or requiring reduced hours is not met by the state but through informal caring and support from those close to the individual, often leading to reduced working hours of the carer (Carmichael *et* al, 2008; Heitmueller & Michaud, 2006). The additional cost and requirement of support by these groups should also be considered when assessing the impact of a change in SPA.

When considering the transition between economic activity and retirement, the interplay of a number of factors are crucial. When considering a change in SPA, policy should take into account differing ability to retire, dependent on circumstances.

1.2.6 Gender

The recent significant reform to the SPA in the UK is likely to impact male and female individuals significantly differently. Due to the historically lower SPA of females at 60, as opposed to 65 for men, women are experiencing a significantly larger jump in SPA. In addition to this, the timetable of changes has been advanced by the government (described later in Section 2.2.5), leading to a cohort of individuals experiencing a rapid advancement in the date they can claim state pension income. An example of this rapid jump, a woman born on 5th March 1953 would reach SPA on the 6th January 2016. Meanwhile, a woman born exactly a year later would reach SPA on 6th July 2019, working an additional two and a half years (DWP, 2013b). This rapid increase has the potential to create difficulties for specific cohorts of women, resulting in a discrepancy between the date state pension income was expected when creating financial plans and new state pension date. Additionally, this delay in SPA for select cohorts will result in an individual financial loss equating to missed state pension payments for the duration SPA is delayed. Due to this differential experience between the sexes, this thesis will consider splitting analysis of interaction with a changing SPA by gender.

Men and women additionally experience different trajectories of health through life. Male life expectancy, healthy life expectancy and disability free life expectancy is consistently lower than that of women both at birth and age 65 (ONS, 2011). Critically for this study, at age 65 women in 2013-2015 had an average of 20.9 years of life remaining, compared to 18.5 years for men (ONS, 2016a). Similarly in 2009-2011 women in the UK had an average healthy life expectancy of 12.1 years compared to 10.7 years for men (ONS, 2014f). This effect however is reversed when considering self-perceptions of health, with men reporting higher levels of good or very good health than women (ONS, 2011). It is claimed that this discrepancy is in part a reaction to cultural stereotypes of ageing, leading to a gendered perception of the ageing process (Barrett, 2005). Much of the ageing process and identity is intertwined with institutional context such as a workplace or the home and role identities such as husband or paid worker (McCall & Simmons, 1996). The potential for a gendered perception of ageing (Barrett & Von Rohr, 2008) or a gendered perception of retirement (Loretto & Vickerstaff, 2013) have been suggested within the literature to explain differential perceptions of health, longevity and mortality at older ages. It is proposed that these variations could be explained by differential feelings toward the ageing process between men and women. It is alternatively suggested that variation in self-perception of health could have arisen through different priorities between men and women at retirement (Henretta, Angela & Chan, 1993). What is clear however is that the retirement decision is a very personal decision achieved through weighing up a large number of factors. These differential attitudes to ageing and retirement may contribute to the impact of a change in state pension age between men and women, further justifying the splitting of analyses by gender.

1.2.7 Measures of Life

The way in which age is conceptualised is crucial when setting policy variables such as the SPA. Current SPA policy utilises chronological age, however this is not the only method available. The method selected is likely to define the impact that a change in SPA will have across the population. Application of policy utilising a single measure of ageing such as chronological age or life expectancy could cause outcomes to rapidly become out-dated or manipulated, as a result of the variability in longevity increase across society. This section will explore alternative conceptualisations of ageing in order to assess the impact a shift to SPA in line with average life expectancy (as discussed in section 1.1) may have.

Traditionally age has been measured simply through chronological age – the years since birth. In the wealthier nations however, the rapid and on-going increases in longevity (Oeppen & Vaupel, 2002) have made them an unsuitable metric through time. Some authors suggest that not just the life expectancy, but also the lifespan disparity should be considered when defining the success of ageing (Edwards & Tuljapurkar, 2005; Smits & Monden, 2009). Vaupel *et al.* (2011) identified that the age at which reductions in mortality are made influences variation in lifespan across the population. Improvements made at younger ages reduce lifespan variation, whereas improvements at older ages increase lifespan variation. This has led to those countries that prove most successful at decreasing mortality at younger ages, becoming those that have consistently the highest overall life expectancies.

A number of alternative measures have been suggested that may be more appropriate conceptualisations of ageing than chronolical age. Riffe, Chung, Spijker & MacInnes (2016) propose the concept of 'time-to-death', the thanatological dimension of age. This is defined by the mortality rate schedule a cohort is subject to until its extinction. Riffe *et al.* argue that some life transitions, states and changes in state intensities are almost exclusively a function of time to death. This could be said of state pension age policy. Once a necessary threshold of contributions has been paid to receive a level of state pension, the returns gained from the state pension are defined entirely by time to death. If a SPA is based on chronological age, this will include an inherent bias towards those who will eventually live, and therefore gain more from the state pension. The time to death conceptualisation is particularly important in the context of population ageing (ibid), in which the overall future cost of a policy such as the state pension will be defined by the amount of time an individual is in receipt of the benefit.

When considering the impact of ageing within a population, it is worth noting that not all individuals will experience the ageing process similarly. Wide heterogeneity exists in how 'successfully' individuals interact with the ageing process and subsequently experience health into later years. The concept of healthy ageing has produced debate among academics; average life expectancies hide tremendous heterogeneity in individual experience. This individual variation hints towards the influence of additional unobserved factors. These can include impact of genetics, individual behaviours, exposure to environmental hazards, availability of health care and social factors on the experience of ageing (Victor, 2005). Early research on the field of successful ageing focused on comprising criteria that might be used to define 'healthy' or 'successful' ageing (Jagger, 2001; Ouwehand, Ridder & Bensing, 2007). It was believed that through the identification of those factors that lead to individual variation, interventions could be implemented to reduce the heterogeneity. The term 'Successful Ageing' was coined by Rowe & Kahn in the late 1980's and later elaborated in 1997 (Rowe & Kahn, 1987; 1997). This proposed that success of ageing was built upon three main components: low probability of disease & disease-related disability, high cognitive and physical functional capacity, and active engagement with life. They suggested that successful ageing required more than simply the absence of disease. Additionally, high functioning capacity and engagement with life are also necessary components to achieve successful ageing and thereby a high quality of life into the older ages. This model of ageing has since been updated with Rowe & Kahn (2015). The authors propose a number of extensions to the concept of successful ageing, proposing that the body of literature already developed focussing on the individual be complemented with research at the level of society (ibid). In particular, the authors suggest that the three main goals of ageing research should be the re-engineering of core societal institutions, adopting a life course perspective (discussed later in section 1.2.11) and focusing on human capital. These objectives seek to meet both the challenges and the opportunities associated with population ageing.

An alternative and much broader theory was proposed by Baltes & Baltes (1990), in which they suggested that ageing could be defined as a changing balance between gains and losses, comprised of selection, optimisation and compensation. This suggests that the older population are able to compensate for experienced losses and remain satisfied with their lives. This theory re-categorises the experience of ageing to no longer engender a gradual but inevitable decline. Rather, it suggests that there are coping mechanisms available to the population and that the ageing population can continue to actively develop themselves on a variety of fronts (Ouwehand, Ridder & Bensing, 2007). The theory of healthy ageing remains far from conclusive and unresolved in definition, measurement, thereby hindering the link between research and tangible policy. When considering the way in which individuals age, it is additionally important to consider the trajectory of morbidity alongside longevity within the population. Under observable life expectancy increase, decreasing morbidity will lead to an overall improvement in the health of a population into older age. If however, this relationship is working in the opposite direction, individuals may live longer in poor health.

The ability of individuals to age 'successfully' and utilise these coping mechanisms is likely to define the experience of individuals at older age. These effects have been found to differ widely across society, suggesting that the use of a single measure such as average life expectancy when formulating policy may be unsuitable.

1.2.8 Compression of Morbidity

The compression of morbidity hypothesis proposes that if the age of infirmity can be postponed at a faster rate than increases in longevity, a compression of morbidity will take place, with individuals living a greater proportion of their lives in good health (Fries, 1980; 1983). The existence of a compression of morbidity is likely to be crucial in the extension of working lives, as proposed and found desirable by the UK government. If SPA is increased, in response or even in line with increasing life expectancy, it is critical to assess the health experienced within these years. Public desirability of extending working life depends on perception, whether recent gains in life expectancy are expected as additional active healthy years, or if the public expects to work longer only to face greater years of ill health (Pensions Commission, 2004). This section will discuss the extent to which the compression of morbidity has taken place, assessing the impact this may have on continued ability to work until an increasing SPA.

Subsequent to the Epidemiological Transition, early research suggested that human longevity would increase, maintaining the same onset of morbidity (Gruenberg, 1977). Kramer (1980) suggested that the increase in life expectancy experienced was a result of improving medical technology sustaining those with illnesses that would under normal conditions have died, resulting in an expansion of morbidity. This was termed the "failure of success" (Gruenberg, 1977) as medical advances continued to prolong life, and this 'extra' duration would be spent in ill health, with low quality of life. A middle ground was proposed by Manton (1982); suggesting that due to medical advances in the management of chronic illness, rather than cure, maximum human longevity may improve faster than true reductions in morbidity. This is suggested to lead to elongation, rather than compression of morbidity termed 'Dynamic Equilibrium' (Manton, 1982).

Subsequently, Fries (1980; 1983) proposed that those populations at the peak of healthcare development and receipt are beginning to enter a new phase, which is termed the compression of morbidity. Fries suggested that given the assumption of a fixed maximum duration of human life, those same reductions of lifetime risk factors that led to a decreased infant and young age mortality, would accompany morbidity being compressed further towards the end of life. It was proposed that improved health care, active lifestyles and improved preventative behaviour would succeed in preserving individuals' health even against the effects of increasing longevity (Mor, 2005). This compression should result in a 'rectangularisation' of the survival curve, therefore an increase of proportion spent in good health, or healthy life expectancy (Fries, 1980). If this compression is evident within the population, the extending of working lives may be seen as the natural progression of the population in line with longevity. If however, this effect is not apparent or not keeping pace with advancements in longevity, increases in SPA may result in a greater proportion of average working life spent in poor health.

The original premise of Fries (1980) was borne through a belief that human life expectancy had a limiting biological maximum level, citing the lack of oldest old persons who have been fortunate enough to avoid disease. The idea of biological maximum duration has been prevalent throughout demographic history, but proposed maximums continue to be surpassed (Oeppen & Vaupel, 2002). Debate continues on the existence of a compression of morbidity. A systematic review by Freedman *et al.* (2002) found evidence in the last decade of improvements in measures of old age disability and limitations in the population of the USA. However, Fries (2003) later concedes that the reasons behind this decline are multifactorial, with no single identifiable cause. Following the conceptualisation of 'active life expectancy' by Katz *et al.* (1983), this hypothesis could be tested. Two decades later, Mor (2005) concluded through systematic review, that prevailing opinion was positive toward the compression of morbidity (Cutler, 2001; Hubert *et al.,* 2002; Freedman *et al.,* 2002; Manton, Corder & Stallard, 1997). It was found that an approximate 1% reduction in mortality was complemented by at least a 2% reduction in morbidity in the USA over the last several decades (Manton & Gu, 2001). However, it is accepted that these rates of disability and limitation vary systematically according to a number of other variables such as age, gender, race and educational attainment (Freedman *et al.,* 2002; McNeil, 2001).

Current debate has since shifted, now acknowledging that morbidity is a multidimensional concept (Crimmins & Beltrán-Sánchez, 2011). The analysis of morbidity must encompass a much broader scope of constituent influences to lifestyle including a number of factors related to, but not intrinsic to strict definitions of health. Historically, much of epidemiological work has focused on disability, but this represents only one dimension of reduced personal health (Freedman *et al,* 2004). Alternative and arguably more influential factors to the SPA debate can include elements such as frailty, functioning loss and organ deterioration (Crimmins, Kim & Vasunilashorn, 2010; Martin, Schoeni & Andreski, 2010; Martin, Freedman, Schoeni & Andreski, 2010). These influences all encompass the innate morbidity process and health change through time, which can limit capabilities but is ignored in earlier studies of morbidity (Crimmins, Kim & Vasunilashorn, 2010). Such elements of disability are also influenced not only by functioning, but also should include the role of the physical environment in which the individual lives (Crimmins & Beltrán-Sánchez, 2011). This can include the effect of assistive medical and functioning technologies that may facilitate capabilities where previously impossible (Freedman *et al.,* 2002).

The extent to which the compression of morbidity is said to have taken place and the impact this may have on the continued health of the population now remain unclear. While advances have been made, the compression has not been experienced to the full extent anticipated when the theory was first put forward. Subsequent research has acknowledged the difficulty in conceptualising health and morbidity, as well as the numerous variables that influence perception and experience of ill-health. For these reasons, this study will seek to include not only measures of health in isolation, but also include contextualising variables that have been shown to impact the prevalence and experience of ill-health. This will assist the analysis in evaluating the extent to which ill-health is likely to impact individual ability to continue to work, and therefore the impact that a change in SPA may have.

1.2.9 Life Course Theory

Longitudinal research and life course theory often have a number of synergies. Both concepts claim that better contextualisation of information can be gained by collecting and analysing information about individuals through time. Life course theory proposes that different social, psychological and biological factors accumulate and interact throughout life, determining one's mortality or morbidity experience (Bambra, 2012). This cumulative effect is argued to give rise to individual heterogeneity in a given characteristic or population through time (Dannefer, 2003). This thesis proposes that life course theory can assist with problem identification and contextualise the impact of a change in SPA (Elder, 1994). The relationship between individual health development throughout life and the SPA is likely to form a crucial element when assessing the impact a change in pensionable age may have.

Life course theory (LCT) recognises the choices made by individuals in the construction and outcomes of their lives (Bengtson *et al,* 2012). It attempts to explore and contextualise current and future experience through the investigation of previous life exposures. Four major themes of the life course approach were identified by Elder (1994) and continue to be influential. These comprise the interplay of human lives and historical time, the timing of lives, linked or interdependent lives and finally human agency in making choices (Hutchinson, 2010). In the context of this study, LCT proposes that the ability to continue working in light of a change in pensionable age is likely to be decided years or even decades before the policy change. The theory connects individual development with the theory of the social and cultural constructions, as well as the time in which it is placed (Bruhn & Rebach, 2014). The life course approach is used to 'sensitise' researchers to the importance of historical context in explaining current effects (Bengtson *et al.*, 2012).

Life course researchers aim to identify how the exposures and conditions get 'under the skin' throughout life and go on to produce differential health outcomes (Ferraro & Shippee, 2009). Traditionally, the life course is further segmented into three defined periods: education, economic activity and retirement (Riley *et al.,* 1994), recognising the importance of the timing of critical events through all conceptualisations of age, not just chronological age (Hutchinson, 2010). Additionally, the life course theory recognises the diversity of life journeys, with recent evidence suggesting a 'de-standardisation' of life courses, expressed through greater individual diversity in timing of lifetime transitions (Anxo *et al.,* 2010). This has encompassed not only differentiation in timing but also reversals, such as individuals leaving employment to return to education. This effect is readily observed in the domain of pensions; traditional final transitions to retirement have become less common, favouring instead a transitional period in which an individual may move to part time employment when nearing SPA. Similarly, individuals may cease economic activity, only to return at a later date. This has been fuelled recently through legislation change away from mandatory retirement age discrimination and the change in the cultural perceptions of 'retirement' (Banks & Smith, 2006).

A number of different life course models have emerged from the literature, however these are sometimes criticised for their interlinked nature and lack of theoretical underpinning (Niedzwiedz *et al.*, 2012), however can be used to illuminate the causal mechanisms driving differential health. The accumulation or cumulative effects model suggest that inequalities in health are the result of an accumulation of advantage or disadvantage through the life course (Bartley & Blane, 2009). Conversely, latent or pathway effects suggest that early experiences are the most significant driver of later health, finding that individuals are particularly sensitive to adverse effects during these years. An association has been found between childhood socioeconomic disadvantage and adverse health outcomes (Pollitt *et al.*, 2005; O'Rand & Hamil-Luker, 2005). Finally, social mobility models, comprising inter-generational and intra-generational mobility have been identified as influential in producing life course differentials in health (Niedzwiedz *et al.*, 2012). Some authors have identified a link between being upwardly socially mobile and health (Otero-Rodriguez *et al*, 2011).

Subsequent to the compression of morbidity hypothesis, the frailty hypothesis is offered as an additional theory for the link between morbidity and mortality. This theory provides a useful conceptualisation of the effect the ageing process has on individual health. Clinically, frailty equates to the loss of organ reserve in each of the organ systems, equating to a roughly linear decline of 1.5% per year in such reserve, at or before the age of 30 (Fries, 1989; 2005). Frailty describes an aggregate expression of risk, accumulated as a result of age or disease, often affecting multiple physiologic systems (Fried *et al,* 2004). This relationship can be accelerated through the advent of accident or disease (Strehler & Mildvan, 1960).

Although decline in health may initially be clinically silent or asymptomatic, risks aggregate, becoming detectable and possibly leading to serious vulnerability. The state of frailty is not defined by any single altered system; rather the accumulation of impact from multiple systems must be involved (Fried *et al,* 2004). Clinical consensus as to the phenotype of frailty has been reported to include a loss of endurance, decreased balance and mobility, slowed performance and relative inactivity, as well as wasting and decreases in cognitive function (Fried & Watson, 2003; Ferrucci *et al,* 2004). However, this relationship has been shown to be heterogeneous across the population and therefore generalised quantification is problematic. Coping mechanisms vary between individuals, heavily influencing the impact that health risks may have on an individual (Fried *et al,* 2001).

However, the life course perspective emphasises the impact of a wide variety of effects on the outcome of individual lives. These are from areas as diverse as the interplay between individual lives, the social environment, individual background and early life conditions. The adequate modelling of a full conceptualisation of the impact life course variations have on individual outcomes can be prohibitive. For this reason, a limited perspective of LCT will be included within this research. This reduced form will comprise individual health history and socioeconomic background, serving to contextualise further health experiences. This will assist the research with determining the impact of a change in SPA. This research will incorporate the contextualisation effects of LCT. This will be done through building up 'health histories' of individuals and using these to contextualise subsequent analyses.

Questions this Thesis will Address

This section has identified a wide range of factors that are likely to influence the experience of individuals when interacting with an increase in SPA. In line with the influences identified here, this research will focus on the relationship between the advancing SPA and individual health by focusing specifically on ability to remain in employment until SPA. This will be undertaken through the development of a microsimulation model of the UK. This will explore the interaction between a changing SPA and individual health, measured through Self-Reported Health and Hand-Grip Strength. This framework will be of particular use to investigate questions of continued labour force involvement and health, contextualising current health through modelling individuals through life. Additionally, taking these findings into account, this project will investigate the projected impact of the current SPA policy and compare this against possible alternative SPA policies that may assist in minimising this impact.

1.3 Research Questions:

Discussion of the trends likely to be influential in the way individuals experience a change in SPA across the UK has led the study to address four key research questions.

Question 1: How does the projected health of individuals interact with current State Pension Age legislation?

Question 2: How might employment status influence the health of individuals during later life?

Question 3: What alternative State Pension Age policies could assist individuals to remain in employment, compared to current State Pension Age change legislation?

Question 4: How do alternative measures of health influence the projected ability of individuals to remain in employment?

1.4 Outline of the Thesis

Following the introductory chapter, this thesis will be broken down into a number of sections as follows:

- Chapter 2 presents a country profile of the UK. This will begin with a broad overview of the current demographic and socioeconomic conditions within the UK, in order to contextualise the study. This section will then explore the current SPA policy, and the proposed need for reforms to the system. Following this, the chapter will discuss the ability of policy to influence population level effects, focusing on the tackling of inequality.
- Chapter 3 will discuss the measures used within the study. The measures utilised are likely to define both the scope of the study as well as the results that may be obtained. This chapter will investigate the key measures of age and ageing used within the literature. Following this, the chapter will discuss different approaches to measuring health, a notably multifaceted concept.
- Chapter 4 will review the current status of microsimulation literature. First, the justification behind the use of a microsimulation model will be discussed. The chapter will then investigate the formation a microsimulation model, breaking this down into the constituent modules and the decisions that are required before model construction can take place. From here, the chapter will then consider similar works within Microsimulation that have taken place, and assess these for lessons and best practice that can be taken forward and incorporated into this study.
- Chapter 5 will consider the specific steps taken in the construction of the Pension Health Microsimulation Model. This will begin by setting out the aims and objectives of the model, evaluating possible data sources and establishing those variables to be used within the model. From here, the assumptions used during the

first stage of the modelling process will be set out and model construction discussed. Finally, the chapter will discuss techniques for validation and verification of a microsimulation model.

- Chapter 6 will put forward the implementation of the base model parameters and assumptions. The chapter then presents the preliminary results generated under this base scenario of current state pension age reform.
- Chapter 7 will present the results obtained through the use of more advanced model parameters. This will focus on a variety of plausible feedback assumptions regarding the direction of influence of employment on health. A social gradient of health assumption will also be utilised and the results under this assumption discussed. Finally, model results will be presented, under alternative scenarios of mortality.
- Chapter 8 will utilise the PENHEALTH model to undertake a policy assessment of the change in SPA. Both the currently legislated policy and plausible or suggested alternative policies will be investigated. These alternative scenarios will be assessed against currently legislated policy to identify routes that may assist in minimising the impact of the SPA change.
- Chapter 9 will conclude the study by discussing the findings in a wider context and identifying key messages. Additionally, limitations of the study will be set out and routes for further investigation will be identified.

Chapter 2 The UK Pension System

2.1 Introduction

Within the United Kingdom, the SPA is undergoing a period of change that will see funds from a state pension being unavailable until age 68 in 2046 and beyond (DWP, 2013b). The proposed SPA increase opens the possibility of dividing experience, placing the greatest burden on those who are most reliant on the state pension system for income in later life, while impacting those less reliant to a smaller degree. It is plausible that under this new proposal, this policy would be to the detriment of those in lower income groups, while providing a negligible impact to those experiencing greater than average longevity, characteristically the high-income groups (Turner, Drake & Hills, 2005). The context in which these current and proposed policy changes are implemented is a crucial element when investigating the potential for impact. This section will explore this policy context, investigating recent demographic trends in the UK, socioeconomic characteristics of the country, the current landscape of pensions policy and provision and finally the ability of policy to impact crucial population level trends.

2.2 Population Ageing in the UK

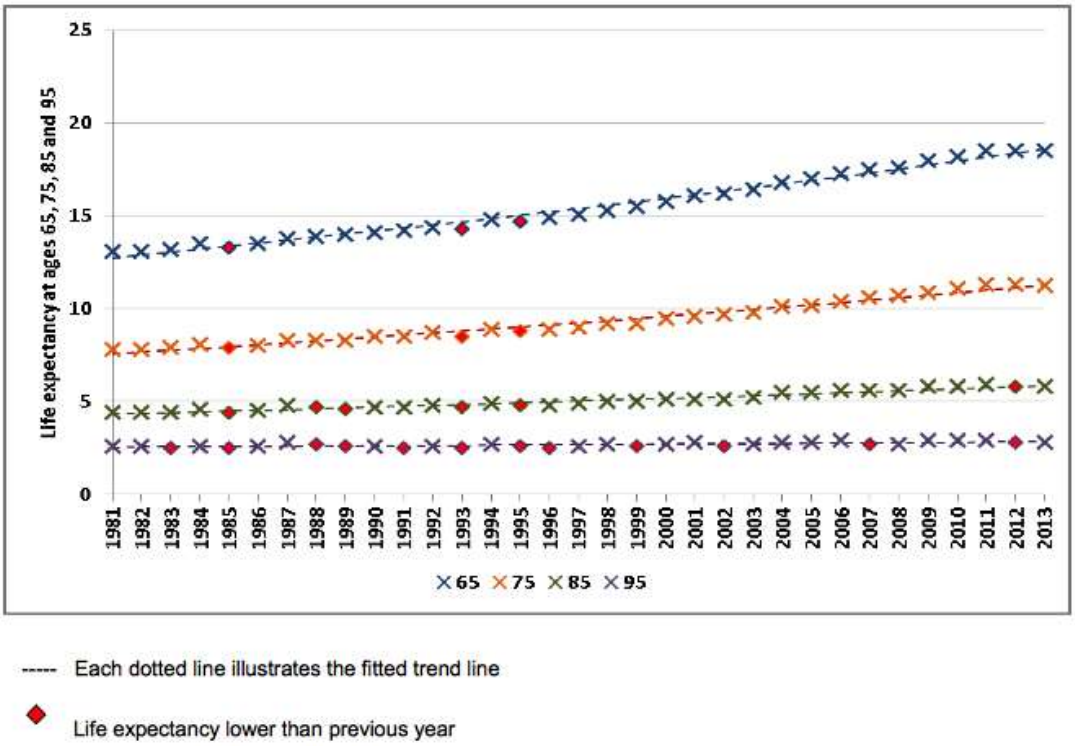
In order to successfully investigate the concept of pension reform to counter the effects of population ageing, it is first useful to explore the reasons behind this demographic shift. This is done in order to contextualise the population dynamics responsible for the currently observable trends. It is anticipated that the investigation of historic trends will highlight the reasoning behind the necessity of pension reform. Similarly, for the purposes of this research, this will assist in the identification of trends in population health that may impact the success of the proposed pension reforms.

The UK has a median population age of 39.9 years (ONS, 2013a), upon which the UK is experiencing rapid population ageing. Within the United Kingdom, 16% of the population were aged 65 or over at the 2011 census (ONS, 2013b), representing 9.2 million people. This number has increased by almost one million from the previous 2001 census, previously recorded at 8.3 million people, but still representing 16% of the total population. This is jointly a result of population ageing as well as general population growth experienced within the 2001 to 2011 period. Such a proportion represents a large and increasing population group, all of whom will be eligible to receive a state pension, providing they meet the minimum requirement discussed later (Section 2.4).

As a result of the demographic transition, in the last century, populations of most countries worldwide have undergone some period of longevity increase (Van de Kaa, 1987). The most developed countries have seen modal age at death rise dramatically, leading to accelerated population ageing. Life expectancy for males in the UK has risen from 48 years in 1900 (Jagger, 2001), to close to 78 years in 2012 (Self, Thomas & Randall, 2012). Addressing the consequence of this increase has been identified by the UK government as critical for the continued viability for the state pension system (DWP, 2011). Population longevity increase is likely to increase the duration of benefit receipt during retirement, financed by a shrinking working age population. Suggested reforms plan to tackle such increasing longevity through increasing the duration of labour force involvement, while intending to maintain a set proportion of life spent in retirement (DWP, 2014). This is expected to result in an increased number of years spent paying into rather than drawing from the state pension system, improving the financial viability of the state pension system.

Many developed countries have experienced an extremely long period of stable increasing longevity. While comparing life expectancies between countries is challenging, Japan is usually credited as the country with the current highest life expectancy at birth. Japan has experienced a surprisingly linear increase in life expectancy of almost 3 months per year for the past 160 years (Oeppen & Vaupel, 2002; Christensen, Doblhammer, Rau & Vaupel, 2009). Globally, this trend shows little signs of slowing; in 1900 mean female life expectancy in the UK at age 65 was 11 years. Today, a woman could expect to live another 21 years (Spijker & MacInnes, 2013). The recent trajectory of this trend over the past 30 years can be seen in the graph below, Figure 2.1.

Figure 2.1 - Remaining Life Expectancy Change at Ages 65, 75, 85 and 95, 1981-2013.



Source: Public Health England Analysis of ONS Data (2015)

As can be seen from the above graph, significant improvements in remaining life expectancy have been experienced at older ages. However, it has been suggested that this longevity increase has pushed survivorship further into ages more greatly afflicted by chronic disease and disability (Crimmins & Beltrán-Sánchez, 2011). Additionally, increases in Healthy Life Expectancy (discussed further in Section 3.3) are allowing individuals to remain active further into older age, allowing increased years of employment and leisure (Sanders, 1964; Jagger *et al,* 1999). Such trends are providing issues for those industries that are linked to population ageing, including pension and healthcare providers, as well as the state pension system. As members of the population are likely to be in receipt of their pensions for longer periods than ever before, the cost borne by the government is likely to increase unless there is an extension to individual working lives. Concerns have been raised over the financial solvency of state provided benefits, particularly health care and state pensions (DWP, 2011). As a result, the UK government has sought alternative methods to ensure continued viability of the state pension system. This has culminated in the Department for Work & Pensions (DWP) proposing a rise in the SPA (DWP, 2011). Initially, this rise will take place with a defined link between specific birth cohorts and rise in age (as discussed previously in section 1.1). However, in line with a number of other countries, it is proposed to raise the entitlement in line with increasing average life expectancy (Marin, 2013). It is suggested that such a shift will be enacted through maintaining a one third proportion of life spent in receipt of state pension (DWP, 2013a).

2.3 Employment Trends of the UK Labour Force

This section will explore the economic and social characteristics of the residents of the UK, in order to develop a picture of the study population, specifically the variation observable amongst this population. As will be seen in this section, the UK represents a diverse and heterogeneous population. Any measure to modify policy will impact the population significantly differently depending on socioeconomic background, an element which should be taken into account when designing and studying the impact of potential policy change.

Within the UK, employment participation rates vary both geographically, by gender and across age groups. However definitions of what is meant by economic 'activity' 'inactivity' and 'unemployment' can vary between countries or indeed between surveys. The outputs made by the Office for National Statistics (ONS) are usually standardised and utilise International Labour Organisation (ILO) definitions. Within surveys such as the Labour Force Study (LFS), an individual is defined as unemployed, as opposed to inactive if the individual is looking and available to work in the four weeks preceding the survey. However, in order to be categorised as employed, an individual must have completed only an hour or more of work in the survey reference week. This can include being an unpaid employee in a family business or as a participant in government-supported training schemes (ONS, 2015c). Conversely, an individual is defined as inactive under the ILO definition if they are aged 16 and over and are neither in employment or unemployed. This can encompass a wide range of individuals and can include those who are looking after homes or families, those who have long-term illnesses, are unable to work or are retired.

Of the total population, the majority are defined as 'economically active' by the ONS, representing 73% of the population (ONS, 2014b). Meanwhile, the group defined as unemployed and currently seeking work stands at 4.8% of the population at risk (ONS, 2017). The general trend in employment is towards increasing employment rates for those aged 16-64 years, with all but one region of the UK having higher employment rates in 2014 than the previous year (ONS, 2014a). Employment rates are highest in the East of

England and South East at 76.5% employed, conversely Wales exhibits the lowest total employment rate at 68.5% (ONS, 2014a)

Employment rates vary significantly between age groups, falling sharply when nearing the SPA in the UK; 16% of those aged 65 to 74 years remained economically active in 2011 (ONS, 2013b). This number is however increasing as a result of reforms to working life policy (Daniel & Heywood, 2007), rising from 8.7% at the previous 2001 Census. The proportion then decreases further after age 74, falling to just 3.6% of the population remaining economically active over 75 years of age (ONS, 2013b). Such a pattern has resulted in an average retirement age of 64.6 years for men and 62.3 years for women in 2010 (ONS, 2012a). Both of these figures remain below the SPA.

A large portion of the population is designated as economically inactive at any given point, representing 22.3% of those of working ages 16-64 in 2014 (ONS, 2014b). This group may be significantly impacted by an increase in SPA, particularly if they are unable to continue working on health grounds. This is likely to be problematic if the individual is reliant upon the state pension for income in later life. Alternatively, if an individual has adequate financial resources to allow earlier than legislated retirement, this change in SPA may have little impact.

2.4 Pension System in the UK

When considering the policy impact of a change in SPA, it is necessary to clarify the role that pensions and the state pension have as part of a diverse welfare provision for older individuals. This section will investigate the complex system of later life incomes available in the UK and the relative importance of the state pension in the retirement plans of individuals. Access to alternative sources of income later in life will influence the pathway to retirement, as well as the reliance on the state pension system. However as noted later in this section, the nature of these income redistribution schemes often lead to inherently large variations in uptake across society. This may lead to individuals and families with less economic means to be influenced more by a change to the age of state pension eligibility.

Pensions in the UK represent one of the most complex systems worldwide. Private pension schemes attempt to fulfil the objective of a personal redistribution of incomes from the working years to later life (Sass, 1997). Whereas public schemes such as the state pension in the UK traditionally combine this purpose simultaneously with the redistribution of funds from those more to less wealthy individuals (Gregg, 2008). As the same percentage of income is deducted for National Insurance payments across the whole of the UK, wealthier individuals usually pay more in than they are set to receive out.

Additional pension incomes are however available from a range of different providers depending upon payments earlier during the working career. At the simplest level state pensions, also known as First Tier Pensions, were first conceived by Chancellor of the Exchequer David Lloyd George under the Liberal Government with the Old Age Pensions Act in 1908 (House of Commons Briefing Paper, 2008) and have since undergone a number of reforms, resulting in a complex and multi-layered system today. These are then optionally followed by second-tier pensions such as State Second Pensions (S2P) and third-tier private pensions.

State pension age is the first age at which those with adequate contributions can draw their basic state pension. This age is dependent on the citizen's date of birth and is currently in a state of flux. Along with signifying the receipt of the pension, the pension age represents an important marker of expectations regarding retirement timing (Duval, 2003). First Tier pensions are provided by the state and are available to all citizens reaching SPA who have accrued a specified number of 'contributory years' (DWP, 2014). These contributions are made through a 'pay-as-you-go' system through National Insurance (NI) payments during the working life. Contributions can be made through any combination of national insurance payments, national insurance credits or voluntary national insurance contributions. Basic State Pensions and Pension Credit were replaced by the Single-Tier Pension system on the 6th April 2016 (DWP, 2014). Single-tier pension is set above Guarantee Credit, currently providing a basic income of £148.35 per week at SPA (from April 2014). In order to qualify for a full UK state pension, an individual is required to accumulate 35 years of 'contributions', with a minimum qualifying period set at 10 years (DWP, 2014). This replaces the current system in which 30 contributory years are required for a full pension and there is no minimum qualifying period (DWP, 2016). Single-tier pensions replace the former basic state pension system as an attempt at simplification of the system. UK state pension rules are complex, comprising a number of methods to contribute to the system, as well as additional rules for married couples, those with incomplete contribution records, those with disabilities and older pensioners (PPI, 2014). In addition to the state pension, a number of alternative means-tested benefits are available from the government to assist in certain circumstances, such as the Pensions Credit comprising Guarantee Credit and Savings Credit, as well as Housing Benefit, Council Tax Support, Winter Fuel Allowance, Bus Passes, TV license exemptions and others.

For any income that is desired on top of the single-tier rate, individuals may have an additional public, private or workplace pension. Alongside the state pension, a number of different schemes attempt to provide additional income in later life. Second-Tier Pensions can take the form of: State Second Pensions (S2P) or State Earnings-Related Pension Scheme (SERPS) forming the Additional State Pension, Defined Benefit (DB) or Defined Contribution (DC) schemes, making up employer or occupational pension schemes.

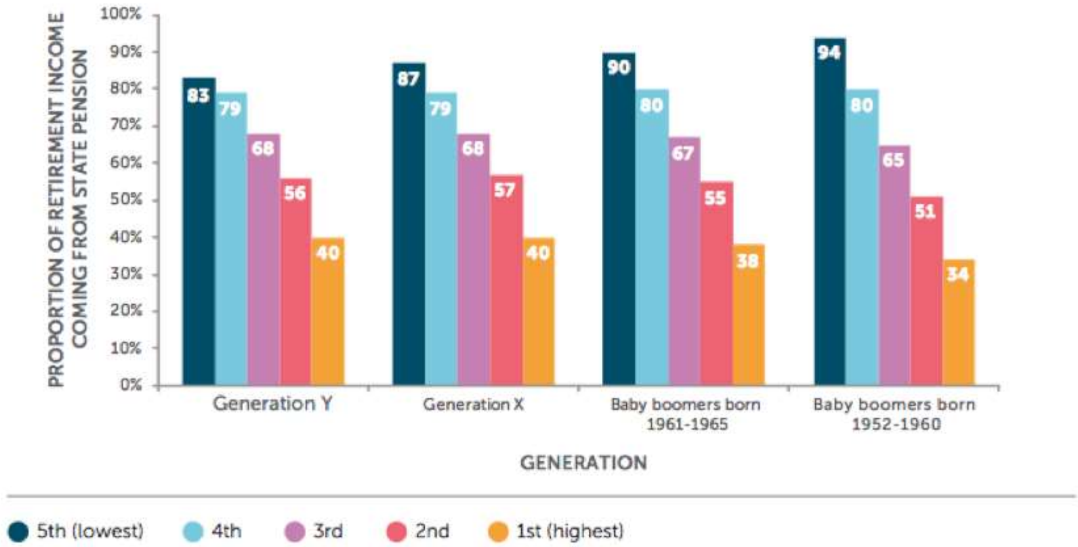
A defined contribution pension is based on how much is paid in to the pension pot. Your pension provider often invests money and the value of the pot can go up or down, depending on the performance of the investment. Conversely, defined benefit schemes are pension pots that are usually not invested but are based on a number of factors including your salary and how long you have worked for your employer. These are sometimes referred to as 'final salary' or 'career average' pension schemes.

While these schemes operate differently, the original aim of the second tier pensions was to provide further pension income to employees that are more closely linked to their workplace earnings than the basic state pensions (DWP, 2014). This is done through working-life contributions to an additional pension scheme between a minimum and maximum limit. Benefit pay out upon retirement reflects the level of earlier contribution and therefore represents a less redistributive scheme than first tier state pensions. However, more recent provisions of state second tier pensions have sought to counter the creation of inequalities through the provision of two earnings bands and two accrual rates. Lower earners can be guaranteed a flat-rate pay out of S2P, alongside those who may have disabilities or caring responsibilities that limit earnings.

Finally, Third-Tier Pensions or Private Pensions represent schemes unfunded by the state that provide additional incomes in later life (DWP, 2014). While state funded systems often attempt to redistribute wealth both within individual lifetimes and across society (Banks & Emmerson, 2000), private pensions only attempt to redistribute wealth within an individual's lifetime (Creedy, Disney & Whitehouse, 1993). This is achieved through redistribution of wealth from employment years to later years. Schemes are variable and influenced by market forces to a greater degree than first or second tier pensions, resulting in a higher level of risk. Pay outs from third tier pensions can be made in the form of annuities, as a lump-sum payment or for the possibility of higher returns may be reinvested in an investment fund or Self-Invested Personal Pension (SIPP) (Blake, 2003). The age at which one is able to begin drawing third tier pensions is variable across providers, however strong tax penalties are levied before the age of 55, rising to 57 in 2028. All incomes after SPA remain taxable at standard rates if income is above tax-free allowances, however no national insurance is paid (DWP, 2014).

Payment into additional schemes above first tier pensions however is highly susceptible to the social gradient, as explored below in Figure 2.2. Those in lower socioeconomic groups are generally significantly less likely to possess the resources to contribute to an additional pension system (Crystal & Shea, 1990). This can result in individuals having complete reliance on state pension incomes to survive in later life (Disney & Johnson, 2001; Ring, 2010). An indicator of this from the Cridland independent review of the state pension age (Cridland, 2016) can be seen below. The figure shows the proportion of retirement income coming from state pension by generation and income quintile, within the PENSIM2 model. Those in the lowest income quintile in the early (born between 1952-1960) and late (born between 1961-1965) baby boom generations are expected to rely on the state pension for 94% and 90% respectively of all income in the first year of retirement. These generations represent the target populations for the current change in SPA policy and are therefore particularly vulnerable to changes. These figures compare with 34% and 38% reliance respectively for those in the top income quintile. This effect is likely to divide experience between top and bottom income quintiles in the face of a SPA change. Those with a low reliance on state pension income may be comparatively less impacted, while those more reliant may experience more adverse outcomes. Interestingly however, the model projects that the gap in reliance between top and bottom income quintiles will narrow across the generations. This projected result is based on the introduction of automatic enrolment, assuming that a greater number of individuals will have access to private or workplace pensions upon retirement.

<u>Figure 2.2 – Proportion of Retirement Income in First Year of Retirement Coming from State Pension by Generation and Income Quintile Within the PENSIM2 Model.</u>



Source: Cridland (2016) Independent Review of the State Pension Age: Smoothing the Transition, p.40

2.5 Need for Reforms to State Pension System

Following recent increases in longevity and a trend toward decreasing fertility, the UK is projected to face heavy declines in the dependency ratio of the nation (Dunnell, 2001). While the impact of this effect is never certain due to the volatility of labour markets and pension systems, proposals are underway with the UK government to minimise the potential impact of this demographic change on the pensions system by attempting to increase the labour force participation rates of older workers. Through discouraging early retirement and elongating the working life of citizens, the government aims to increase the number of contributory years to taxation and national insurance payments (Price, 2008; DWP, 2014). Additionally, remaining in employment is likely to reduce the challenge faced by pension systems through providing a further source of financial support in older age or delaying the age at which pensions are first drawn. The government hopes that through these combined measures, dependency ratios can be restored to 1970's levels of around 300 people aged over SPA per 1,000 of working age (ONS, 2010a), thereby improving the sustainability of the state pension system (Shaw, 1999). This objective is being facilitated across a number of initiatives known as 'Extending Working Lives' (EWL) or later 'Fuller Working Lives' (FWL) aimed towards increasing the labour force participation rates of older workers (DWP, 2012; 2017). For example, such initiatives have taken the form of reduced barriers to staying in employment such as improved employment legislation and reduced discrimination against older workers, as well as financial incentives to remain in employment past state-pension age (Smeaton, Vegeris & Sahin-Dikmen, 2009).

It is intended that through increasing the age at which citizens are able to first access their state pension funds, a significant increase in effective retirement ages will result. The generosity of the state and private pension system represents an influential factor in retirement decisions (Gruber & Wise, 2008). Through the utilisation of a set pensionable age, workforce members are subconsciously encouraged to utilise this as an objective to be met, with retirement occurring with increasing proximity to this date (Gruber & Wise, 2008). However the influence of this policy is likely to vary heavily across society. Large portions of society are likely to predominantly rely on either private pensions or non-pension state provided benefits to support themselves during earlier retirement (Banks & Smith, 2006). Availability of additional pension funds has been found to measurably reduce the age of retirement (Stock & Wise, 1990). This is likely to result in a patterning of the ability to retire at specific ages across society, impacting groups unequally. Similarly, availability of alternative income is likely to impact the ability of individuals to mitigate the effect of being unable to continue in employment until a rising SPA. This has the possibility of polarising the impact of a change in SPA, negatively impacting those with less social resources while providing a comparatively smaller impact to those with greater resources.

2.6 Inequality in Health as a Concern for Public Policy

While there has been little conclusion as to the source of inequality, or indeed the optimum level of inequality in the country, it is argued that social policy should take the lead in minimising its impact (Mechanic, 2002). Research into differentials in mortality and other health measures is of growing concern for public policy due to the rapidly widening inequality gap between those with most or least social resources. The Green Paper '*Our Healthier Nation'* and subsequent White Paper '*Saving Lives: Our Healthier Nation'* conceded that health inequalities in the 1990's were in fact widening, and that those poorest in society are hit harder by most of the major causes of death (Department of Health, 1998; 1999). Quantifying these variations in individuals' health within a society is a necessary prerequisite to creating strategies to tackle this issue (Fitzpatrick, 2003).

During the 1970's and 1980's it was increasingly recognised that the improvement in overall population health throughout the last century may largely be a product of improvements in economic advances, rather than strictly healthcare (McKeown & Brown, 1955; McKeown & Record, 1962; McKeown, Brown & Record, 1972; McKeown, Record & Turner, 1975). While this hypothesis was largely disproved by further work (Wilkinson & Pickett, 2010), this issue remains a point of controversy in the literature and begs the question: are public health goals better served by specific health interventions, or by broader efforts to redistribute social, economic and political resources? (Colgrove, 2002).

Margaret Thatcher's Conservative government, amongst the governments of other countries, took up the World Health Organisation's (WHO) '*Health for All by the Year 2000*' initiative. This proposed 38 targets to reduce inequalities in health across the globe (WHO, 1981). Despite the uptake of these targets by both the Thatcher and subsequent Blair Labour administration, and the success of the fourth cornerstone, increasing life expectancy, inequalities in health and wealth continue to persist in Britain (Shaw, Smith & Dorling, 2005). This target was further backed up by the Sustainable Development Goals (SDGs), intended to provide a more universal and inclusive set of goals than the Millennium Development Goals (MDGs), addressing a wider range of socioeconomic differences that lead to inequalities. Specifically Goal 10 of the SDGs seeks to reduce inequality both within and among countries (Sachs, 2012; Griggs *et al*, 2013).

The UK government formally acknowledged the influence of health variations on the lives of citizens in 1995. This culminated in the production of the DoH paper '*Variations in health: What can the Department of Health and the NHS do*?' (Department of Health, 1995), the DoH paper '*Tackling Health Inequalities: A Programme for Action*' (DoH, 2003) and the subsequent National Audit Office review '*Department of Health: Tackling inequalities in life expectancy in areas with the worst health and deprivation*' (National Audit Office, 2010). In more recent years, the recognition of the need to provide a cohesive strategy for reducing health inequalities into the future resulted in the production of the independent Marmot Review '*Fair Society, Health Lives*' (Marmot *et al,* 2010). While the former DoH (2003) paper fell short of tackling many large issues that scholars within health inequalities may have desired, such as identification of risk factors within the scope of government to change; the paper opened a dialogue and acknowledged the responsibility of the Government and the NHS as the largest UK employer and provider of healthcare in tackling these issues (Wilkinson, 1995).

However, the strategy proposed within the DoH paper also went against the recommendations of much of the literature including Rose (1985, 1992) and the Marmot *et al* (2010) strategic review. These authors stressed that focusing on only the most disadvantaged areas will not adequately reduce health inequalities. Rather, they argued that the concept of proportionate universalism (Marmot *et al,* 2010) should be employed and that actions should be undertaken universally, with proportional intensity to the level of deprivation. This approach acknowledges that deprivation needs to be tackled at all levels of the social stratum, rather than only targeting the areas most affected. The DoH paper focused efforts on single indicators of health inequalities, namely infant mortality and life expectancy at birth. It was aimed that by 2010, local authorities should reduce the gap in life expectancy between the 'spearhead group' and the population as a whole by 10% (Department of Health, 2003). The 'spearhead areas' constituted at first the bottom fifth of local authorities in 1995-97 across a number of health metrics, comprising 28% of the England population. These areas were largely located in the North East, North West of England and London. It was subsequently found by the National Audit Office that the original strategy lacked the effective mechanisms necessary to deliver the desired target (National Audit Office, 2010).

This chapter has investigated the characteristics of the UK, identifying the justification behind increasing the SPA. It was identified that the influence a change in SPA may have on individuals is likely to be significantly impacted by both the health and the resources of the individual. The following chapter will investigate the trends and measures of ageing. Those measures used to characterise the experience and measurement of ageing will be discussed. This is done in order to identify the most appropriate indices of age and ageing to be used within this analysis.

Chapter 3 Trends and Measures of Ageing

Within the UK, there remains vast individual heterogeneity in longevity, as shown by the large number of people reaching extreme ages within the last century, while others continue to die significantly before country average life expectancy (ONS, 2015f). These effects are not isolated to more developed countries; developing countries are also experiencing greatly improved longevity, as well as inequality (Kalasa, 2001). Different disciplines have attempted to disentangle the complex experience of ageing and mortality. Why do some age more or less 'successfully' than others, if success is to be defined by longevity? This was once thought to be an isolated and predetermined natural phenomenon (Fries, 1980). However, it has since been identified that the effect of nurture and social conditions are equally, if not more, important in explaining the experience of longevity than merely genes. The conditions that influence the quality of ageing and thereby the quality of later life have not been conclusively identified.

The global increase in the older population can be seen as one of the greatest success stories of modern medicine and social policy, but this also brings with it a range of challenges. With this 'greying' of the population, issues of social policy aimed towards the older population will assume greater societal importance (McLaughlin *et al.*, 2010). It is clear that the experience of ageing is varied worldwide and the measurement of successful ageing is not easily quantifiable by a single measure. This section will review the different facets and measures of ageing, as well as conceptualisations of health throughout life. The choice of concepts and measures used is likely to form a critical component in defining how health is experienced throughout the lifetime, as well as defining both the quality and nature of the results produced by studies. This section will explore the range of measures available, ensuring the appropriate conceptualisations of ageing and health utilised meet the needs of the research model.

3.1 Life Expectancy

Life expectancy at birth is a popular and widely utilised tool for understanding not only population longevity, but also as an indicator of public health and wellbeing (Judge, 1995; Marin, 2013). The definition of life expectancy refers to the average number of years an individual can be expected to live at age x. This typically, unless otherwise stated will refer to average life expectancy at birth. Life expectancy provides a generalised measure, often taken at the population level and therefore wide variation in personal experience and risk factors weaken the strength of the utilised metric. Those countries with effective infrastructure, social wellbeing and healthcare provisions can see their population surviving many decades longer than their antitheses. Measures of life expectancy pose influence on areas as broad as insurance, social policy and health care. Such measures provide the reader simply with the number of years an average individual may be expected to survive from a specified age when exposed to a defined mortality risk over their lifetime.

Measurements of life expectancy are divided into period or cohort measures. Period life expectancies use the mortality rates from a single year or period and assume that these rates will continue for the rest of the individuals life, not allowing any future changes. Cohort measures meanwhile allow for future changes in mortality rate and attempt to define the experience of an actual cohort of individuals. Cohort life expectancies are often therefore regarded as a more appropriate measure of remaining life (ONS, 2016b).

The period life expectancy at birth of children born in 2012-2014 stands at 79.5 years for males and 83.2 years for females (ONS, 2015f). This provides information on the average experience within the population, given no future changes in mortality rates. A wide variance of personal experience will surround these mean figures however, depending on lifetime exposure to mortality risks. The cohort life expectancy at birth is currently projected at around 10 years higher for both males and females over the projection period of 1981 to 2064 (ONS, 2015g). The measure of life expectancy is crucial in the equitable planning of social policy reforms, such as those posed by recent pension legislation.

The summary measure of life expectancy at birth is highly dependent on early life conditions, such as infant mortality. Infants who pass away early pose an unequal weight on the distributions of life expectancy and similarly, deaths in young adulthood from accidents adversely affect the distribution of mortality through greatly reduced longevity. Due to the influence of early-life mortality risks, life expectancy at birth should be used with caution when referring to the older population, as it may present a lower than experienced average longevity (Spijker, 2004). Alternatively a measure such as a life expectancy at age 5 can be used to exclude a portion of cohorts at a greater risk from the calculations that may distort the 'true' experience of mortality. Alternatively, a measure that will be of particular use to the study of pensions is life expectancy at age 65. This life expectancy measure gives an approximation of remaining life years left when nearing SPA. The variability in this measure across society is likely to be crucial when determining individual benefit gained from the state pension system.

While this measure is useful as a guideline for social policy, it provides no information as to the quality of those years lived by the population. Mortality reductions are often seen as a result of improving population health, however over the last 30-40 years a shift towards a greater burden of long-standing chronic conditions has taken the place of mortality (Jagger & Robine, 2011). Utilised measures of life expectancy are likely to be crucial in determining those who 'gain' and those who 'lose' under the proposed SPA policy reform of linking SPA with average life expectancy. This draws questions on the relevance of this measure in an area as crucial as social policy. The UK exhibits not only a North-South divide in life expectancies but also variability by gender, location, socioeconomic status, lifestyle, social interaction, genes amongst a number of other contributory factors (Raleigh & Kiri, 1997; Ben-Shlomo, White & Marmot, 1996; Jagger, 2001). Such factors interact so that those with greatest resources are often those who experience the least ill effects accumulating over the lifetime (Jagger, 2001).

Utilising a life expectancy measure within the calculation of SPA in the future (as discussed previously in section 1.1) has the potential to only equate for 'average' experience, leaving a wide range of individuals either more or less impacted at each end of the social gradient. This effect will be discussed further in section 8.1.3.

When considering the equity of a proposed SPA change, Hupfeld suggests we consider:
"… whether differences in duration (and hence in internal rate of return from the pension system) are systematic. If they are not, the public pension system fulfils its task as insurance against longevity, and individual deviation from the average rate of return is random. If, however, the duration under benefit spell varies systematically, then a potential for unintentional redistribution amongst different groups arises".
(Hupfeld, 2009, p.428).

3.2 Measures of Socioeconomic Status

A number of different methods exist for socioeconomic stratification within the population. The chosen method is likely to be crucial in the analysis of the health effects and limitations to employment across a spectrum of heterogeneous citizens.

Social stratification attempts to group together broadly similar individuals and can be understood through a number of different approaches (Blackburn & Prandy, 1997). The most common of these include stratification by wealth, income, employment/labour type and education. Simple measures such as income or household consumption, while readily available do not alone serve as adequate markers of socioeconomic position (Kolenikov & Angeles, 2009). This is due to the multifaceted experience of socioeconomic position that cannot be simply generated or assessed through wealth or consumption alone.

Social class is generally considered to be a means of stratifying a population into hierarchical categories. While the concept of class has been pervasive within the history, society and politics of the UK, the definition is rarely agreed upon, with a number of different prominent theories arising. Karl Marx and Friedrich Engels considered social class in economic terms and argued that in the context of people's relationship to the means of production, society can be divided into two classes: those that own the means of production, and those who work under the control of those that own the means of production (Marx & Engels, 1975). Meanwhile, Weber provides an alternative theory to the 'exploitation' and 'domination' theories of Marx, giving a more multidimensional concept of social position. Weber devised a three-component theory of stratification in which social position is determined by class, status and power (Weber, 1946).

However, since initial description, some have claimed that the conceptualisation of social class had outlived its usefulness. During the 1980's and 90's, sociological debate heavily critiqued the concept of social class, claiming instead that this patterning of inequality was being replaced by variations in consumption (Bottero, 2004). This theory argued that it was not a person's position in the labour market that defined them, rather people's positions as consumers, how they expressed individuality through consumption. Discourse has since challenged these views, suggesting that there is little evidence that social class is losing its importance in defining the unequal lives of the population (Goodman & Shepherd, 2002; Brewer *et al*, 2005). This view has been particularly prominent within the field of social policy. It is rather suggested that socio-economic inequality continues to grow more entrenched, as suggested by the increase in wealth inequality (Graham, 2007; Piketty, 2014). For this reason, the concept of social class remains of relevance for the analysis of social policy and social outcomes.

The notion of socioeconomic position is complex; many contrasting theories have attempted to distil the mechanisms through which society stratifies itself. While many theories have been put forward, two broad themes can be deduced from the sociology literature. The first conceptualisation suggests that the experience of socio-economic position is shaped through the setting of inequitable structures, around which life is experienced (Graham, 2007). The second theory posits that socio-economic position is the product of decisions and actions taken through life. Therefore, position in the hierarchy is constantly produced and re-produced throughout life (Graham, 2007).

More contemporary outlooks are leading towards an amalgamation of these two theories, suggesting that position is continuously fashioned through a combination of social determination and individual generation (Graham, 2007). Graham (2007) claims that unequal socioeconomic positions within society lead people to experience variable access to resources. These encompass many elements crucial in determining quality of life such as suitable employment, living conditions and cultural capital. Those with abundant resources have greater likelihood to obtain those things that society requires and values: financial security, education, adequate employment and thereby, often health. Those who lack these resources suffer in comparison with those better placed within society. However, while the true mechanisms through which socioeconomic status is produced remains under debate, the effects brought by differential exposure remain clear.

Two methods of socio-economic classification have been widely utilised within public policy and academia in the UK over the past 100 years. These consist of Social Class (SC), formerly the Registrar General's Social Class (RGSC) schema, based on occupation. This social designation sought to quantify 'standing within the community', reduced into six categories (Szreter, 1984). Secondly, Socio-economic Groups (SEG) represented an alternative classification, sorting people by level and employment sector, rather than employment type. The concept of social stratification has now reached its third phase of conceptualisation and analysis.

Following a review, the Economic and Social Research Council (ESRC) found that previous social class measures (SC and SEG) lacked a coherent theoretical basis required to make robust estimates of social conditions (Rose, Pevalin & O'Reilly, 2005). The recommendation was made to replace these two metrics with a single National Statistics Socio-economic Classification (NS-SEC). This new measure was based upon a widely utilised sociological classification, the Goldthorpe Schema (Goldthorpe, 2000; Goldthorpe, Llewellyn & Payne, 1980; Erikson & Goldthorpe, 1992; Goldthorpe & Jackson, 2007). This decision was made in deference to the international acceptance and conceptual clarity provided by the Goldthorpe Schema. Originally, the classification was conceived in order to group together members of society that experience similar work and market situations (Goldthorpe, Llewellyn & Payne, 1980). Not all employees are treated the same by employers through the medium of employment contracts, an effect that manifests itself through the mode of payment, promotion prospects and autonomy of the position (Lockwood, 1989).

The NS-SEC has been widely utilised within official statistics, surveys and publications in the UK since 2001 (ONS, 2010b) and is well regarded as a primary measure of socioeconomic status. The primary function of the NS-SEC metric is to classify groups of individuals that are defined as experiencing similar employment relations and conditions of occupation (Goldthorpe & Jackson, 2007). This leads the measure to be of particular use when categorising the experience of individuals of working and early retirement ages. The NS-SEC measure is intended to define socioeconomic status through comprising a number of elements such as method of enumeration, job security, autonomy and promotion prospects (Rose & Pevalin, 2003). While other measures are available that serve as a proxy measure to socioeconomic status such as education or wealth, these variables are often intertwined with other influences. Education is influential in defining SES, however much of education is defined many decades before retirement. While the effect of education permeates through to later years, the association is likely to be less strong. Income meanwhile does not capture a large proportion of the influence of employment type and conditions on socioeconomic status, rather providing a measure of position within the labour market. NS-SEC was found to provide the most rounded and influential measure of socioeconomic status available to this study. This provides this study with a useful proxy for the variation in a range of employment and social life conditions that are likely to influence the health of individuals.

The analytic classes of the NS-SEC comprise:

1. Higher managerial, administrative, professional or large employers

2. Lower managerial, administrative and professional occupations

3. Intermediate Occupations

4. Small employers and own account workers

5. Lower supervisory and technical occupations

6. Semi-routine occupations

7. Routine occupations

8. Never worked and long-term unemployed.

(Source: ONS, 2010b)

A number of variations exist of this basic scheme, comprising greater or fewer categories to suit the specific needs of the investigation. This classification does however fail to include three categories comprising: students, occupations not delineated within the criteria or otherwise not classifiable individuals. Those who fall under these categories are often amalgamated into a ninth category - 'Not Classified'.

All versions of the NS-SEC are described as strictly nominal or categorical (Rose, Pevalin & O'Reilly, 2005). This can be seen as disadvantage to those undertaking analysis, rather preferring continuous or hierarchical measurement scales. However, an alternative is shown by Graham (2007, p.55), the NS-SEC can be reconstituted down from a nine to a three-category measure, which can then be treated as hierarchical; however this new measure has reduced accuracy in comparison with the original metric.

3.3 Measuring Health

The primary focus of this study is the health of the population. In the assessment of ability to work until defined SPA, the measurement of health is likely to form a key component of the study findings.

Health is acknowledged as one of the most important indicators of well-being and is influential to a number of policy outcomes. However, 'health' is additionally a multi-dimensional and unobservable quality (Bolin *et al*, 2008). There is no single gold standard measure that can encompass all measures of health and healthy ageing. For this reason, this study will seek to use two alternative health measures, one objective and one subjective. Through doing this, it is hoped to not only capture the variance in results dependent on health measurement scheme utilised, but additionally to encapsulate the various different dimensions of health pertinent to the question of continued economic activity and health.

Conceptualisations of 'health' and health indicators are constantly shifting and often reflect current thought on how we define and think about health. The way in which we conceptualise health, how the needs and restrictions, opportunities and drawbacks that individuals experience throughout life is an expansive and constantly shifting area. However, definitions of health are crucial when investigating the impact of a public policy such as the state pension.

It is common within medicine to refer to health as merely the absence of disease, illness and sickness (Bowling, 2005). This has led to many measures taking the concept of 'health' as a baseline, measuring deviance from this. However, due to the comparatively small number of individuals within the population experiencing severe deviation from good health, this gives little information on the health of the remainder of the population

(Stewart *et al*, 1978). Broad agreement has been made that the concept of health should encompass more than simply the absence of disease. However, beyond this there is no single accepted definition. Over half a century ago, the constitution of the World Health Organisation (WHO) defined health as '*a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity*' (WHO, 2006). Alternative definitions have also been put forward by other theorists. Saracci (1997) sought an ambitious definition of health as *' a condition of well-being, free of disease or infirmity and a basic and universal human right'*. Meanwhile, Bircher (2005, p.335) defined health as '*a dynamic state of well-being characterised by a physical and mental potential, which satisfies the demands of life commensurate with age, culture and personal responsibility'*. However, as can be seen, these definitions feature broad description of health that few within the population of a country would be able to meet. While these definitions serve as ambitious targets for populations to achieve, they serve as little practical use when defining individual health. At a conceptual level required for policy, these definitions lack the specificity required to guide policy in the conflict between resources and health needs within a nation.

For this reason, more specific health definitions are required. The WHO has more recently updated the health classification to distinguish between *impairments, disabilities* and *handicaps*. Impairment is defined as *'a temporary or permanent loss or abnormality of anatomical, physiological or psychological structure or function'*. Meanwhile, a disability is defined as '*a restriction or inability to perform an activity in the manner or within the range considered normal for a human being, mostly resulting from impairment*'. Finally, a handicap is defined as '*the result of an impairment or disability that limits or prevents the fulfilment of one or several roles regarded as normal, depending on age, sex and social and cultural factors*' (Barbotte, Guillemin & Chau, 2001, p.1047). As can be seen, these definitions lack mutual exclusivity, as well as relying heavily on cultural, social and personal norms when defining health. As noted by many authors, the search for operational definitions for health, working ability and disability that are 'complete', 'global' and 'stable over time' is often fruitless (Grönvik, 2009). This leads to a challenge when defining health, ill health and ability to work in the context of a large-scale microsimulation model such as the one presented in this study. Alternative definitions are often contradictory in nature or too narrow to be of use. This is an issue when defining health for the purposes of policy and analysis of policy. The meaning of 'health', 'impairment' and 'disability' will have a different meaning between individuals. For this reason, difficulty has been found in creating a single index of health and impairment that can function across society. As a compromise, different measures have been created to capture the different components of health, however much interplay exists between these.

Alternative health indicators are often categorised into two fields, biomarkers and health scales. First, biomarkers seek to find a single or combination of observable quantities that can define health. However, given the biological complexity of the ageing process along with the heterogeneity expressed across populations, no single reliable measure of health and ageing has been found. Secondly, health scales recognise that health is an abstract concept that can rarely be directly measured. Health scales therefore often score individuals on a number of health indicators and combine these into a health measure. Currently no single indicator of health state is widely accepted above all others within the literature. Rather, there are a number of measures that lend themselves to different enquiry types. This has led to different measurement scales for physical disability, emotional and social well-being, life satisfaction, as well as many others (McDowell, 2006). This difference in components of health captured by specific health measures is likely to be critical when assessing health in a policy context. This study opts to use two different conceptualisations of health to attempt to capture this effect. Doing this allows the study to assess the impact choice of health measure may have upon final results. A subjective health measure will be utilised as this brings in how an individuals perception of their own health is likely to impact their ability to remain in employment. Additionally, a subjective measure of health will allow serve as a measure of physical capability to continue working.

Physical capabilities and ability to undertake tasks represent a crucial marker in the ability to work (as discussed earlier in section 1.2.2). Health has been found to be the most important determinant of the labour activity of older workers (Lindeboom, 2006). Alternative measures of health discuss the impact that reduction in muscle strength through later life can have, significantly associating with ability to complete tasks, as well as to predispose people toward functional limitation and disability (Rantanen *et al,* 1999b; Verbrugge & Jette, 1994; Sakari-Rantala *et al*, 1998). This can be assessed subjectively either by self-report or more objectively through the use of tests on physical ability. The self-reporting of health may suffer from the impact of cultural norms, economic motives or labour market status of the individual (Lindeboom & Kerkhofs, 2009). This systematic bias in reporting poses danger of the over-estimation in health and under-estimation of the impact of economic incentives in the retirement decision. The influence of these factors additionally varies between groups as well as internationally, adding increased complexity to the assessment of health across large populations. However, an objective measure of health can serve to ignore other facets of health promotion or degradation that may be influential.

A growing body of evidence suggests that simple objective measures of health can form useful markers of present as well as future health and mortality (Cooper, Kuh & Hardy, 2010; Kuh *et al,* 2006). Interest in the potential of these measures to be used as simple screening tools in clinical environments to characterise health and mortality is increasing. A number of metrics have been suggested to predict mortality at later ages, including Slow Walking Speed (Harwood & Conroy, 2009), Chair Rise Time (Guralnik *et al,* 1994), Standing Balance (Cesari *et al,* 2009) and Hand Grip Strength (Bohannon, 2008). Additionally, studies have investigated the relationship between measures of physical capabilities and subsequent health, such as cognitive outcomes (Camicioli *et al,* 1998) and Cardiovascular Disease (Silventoinen *et al,* 2009). Some measures, such as Grip Strength have been observed to be associated with both health and mortality outcomes (Bohannon, 2008; Dodds *et al,* 2014).

The association between muscular strength and musculoskeletal disorders was identified in traditional studies of grip strength, relating the measure to the risk of fracture and reduced bone density (Hughes *et al,* 1995). However, more recent research has additionally identified associations between grip strength and a number of other outcomes (Bohannon, 2001; 2008), including a robust association between grip strength and long-term survival (Syddall *et al*, 2003). Not only is functional use of the hands invaluable in the completion of a number of activities of daily living, Sasaki *et al* (2007) found hand-grip strength to be a strong and consistent predictor of all major causes of mortality in middle-aged and elderly persons. This predicted not only all major causes of mortality, but additionally heart disease and stroke mortality. This relationship has been found elsewhere at both mid-life (Rantanen *et al,* 2000) and in later life (Laukkanen *et al,* 1995). Low grip strength represents a consistent predictor of frailty and mortality (Rantanen *et al,* 1999a). The relationship that has been identified is rarely regarded as causal; rather that grip strength provides a useful proxy for other vitality type measures. Most commonly cited amongst these is frailty (as discussed earlier in section 1.2.9) (Fried *et al,* 2001; Syddall *et al,* 2003). However, additional variables suggested as important include nutritional status and vitality (Bartali *et al,* 2006). Grip strength is discussed to be representative of overall muscular strength, the maintenance of which through life is suggested to prevent injurious accidents, functional limitations, metabolic disorders and poor recovery from acute disease or injury that may lead to early death (Sasaki *et al*, 2007).

Information regarding subjective measures such as self-reported health is regularly and widely collected within national surveys. The simple measure has become prominent as it encompasses several different facets of health that would be otherwise unobservable to researchers. These include perceptions of health, coping strategies, social elements of health and mental health considerations. The belief of the individual about what is important to his or her own health and well-being is likely to form a crucial part of the retirement decision (as discussed earlier in section 1.2.3). However, it has been claimed that these results of self-rated health enquiries will vary between different groups. Some (Maddox, 1964; Lehr, 1983), but not all (Ferraro, 1980; Mitrushina & Satz, 1991) find men to be more optimistic about their own health. However, others claim that a single self-report of health is not likely to adequately predict future health state, favouring multiple response measures (Grant et al, 1995).

This study will utilise both an objective and a subjective measure of health. By doing this, the analysis aims to compare the results between the two measures, highlighting the importance of measure selection when considering public policy. This study will utilise Self-Reported Health as the subjective measure (as discussed later in section 5.4.1) and Hand-Grip Strength as the objective measure (as discussed later in section 5.4.3).

Chapter 4 Microsimulation – Options and Choices

4.1 Introduction and Background

This study aims to assess the impact of the legislated increases in SPA on individual ability to work until retirement age. Additionally, this study investigates the impact alternative health measures can have upon the analysis of this effect. The primary research method chosen for use within this investigation is a Microsimulation Model. This chapter will describe a microsimulation model and justify why this method has been chosen as the most appropriate method to answer these research questions. Following this, the constituent parts of a microsimulation model will be broken down and assessed, gathering best practice from similar models within the field. Similar microsimulation efforts in modelling health through life will also be considered for how they approach the problem and investigate what knowledge can be drawn from similar studies.

Simulation modelling refers to a computational reduction of the real world. These models benefit policy analysis through simplification of a structure or system for the purposes of analysis. Microsimulation further advances this by focusing on micro-level units such as individuals, households or firms. This allows a more detailed analysis, allowing a greater number of effects to be included than commonly possible, such as interaction between units or global rules. Microsimulation models are commonly used to explore policy outcomes and perform experiments that would not be possible in the real world. Examples of microsimulation use in policy analysis include the use of PENSIM2 to estimate future pensioner incomes in the UK (Emmerson, Reed & Shephard, 2004) and the use of SESIM in the analysis of future health and social care needs in the context of population ageing in

Sweden (Klevmarken & Lindgren, 2008). Simulation models aim to gain a better understanding of the system under analysis, identifying observable trends or projecting current trends into the future.

In the 1950's, models of socio-economic systems predicted only aggregates, failing to predict distributions of constituent individuals (Orcutt, 1957). Techniques such as System Dynamics Models characterised populations as indivisible wholes, not taking into account that these aggregates are built of individuals or subpopulations (Gilbert & Troitzsch, 2005). This served to limit the predictive power of models, even over short projections. In order to avoid the errors associated with the simulation of aggregates, the social science microsimulation approach of simulating a large number of individual units such as persons, households or firms was developed Guy Orcutt and colleagues in the 1950's and early 1960's (Orcutt *et al,* 1961). The principal aim of such models was to simulate policy scenarios, in particular assessing the impact of policy across heterogeneous individuals (Morand *et al,* 2010). It was identified that by using this modelling strategy, it was possible to assess possible policy outcomes over a range of individuals, allowing optimisation of public policy before implementation. These models have been widely utilised within the sphere of social and economic policy within Europe, North America and Australia. This utilisation draws on the power of Microsimulation to provide forecasts of future events through analysis of historical trends (Morand *et al,* 2010).

The ideas of Orcutt and colleagues have identifiably branched into two major simulation disciplines, Microsimulation Modelling (MSM) and Agent Based Modelling (ABM). MSMs focus on the application of rules to a base population, observing outcomes (Li & O'Donoghue, 2013). Meanwhile, ABMs focus on the interactions between autonomous agents, this is most often utilised to study the emergence of features, preferences or trends from the 'bottom-up' (Billari & Prskawetz, 2005). The way in which MSMs and ABMs react to rules also varies. In a MSM, rules are simply imposed upon a population and the outcomes observed. Individuals are not able to modify their characteristics or responses based on behaviours or preferences. Within an ABM however, the individuals or agents have agency, and are therefore able to modify their responses to rules or policies to best benefit the individual.

ABMs are primarily utilised to develop and explore theories, whereas microsimulations seek to evaluate the consequences of rules placed upon the population (Billari & Prskawetz, 2003). ABMs comprising Cellular Automata additionally attempt to model the complexity of social systems (Birkin & Wu, 2012). While microsimulation efforts often serve to answer 'what if?' type questions and responses to inputs such as policy, ABM's often seek to explore micro-level behaviours for their 'own sake'. However, with advancements in both fields, the definition between the two methods grows increasingly blurred, with many investigating the benefits of hybrid type models (Birkin & Wu, 2012).

MSMs have proven successful in modelling social systems and investigating public policy. However MSMs have heavy data requirements, are computationally intensive and are generally only applicable for investigation in one direction, for example the impact of policy on individuals (Birkin & Wu, 2012). Seeking a solution to such drawbacks, hybrid models have begun to emerge, seeking to utilise the benefits of both methods within the same framework. However, the specification and subsequent validation of such models is complex, leading them to currently be of limited use within a policy modelling investigation.

Within MSM, two broad model types have emerged, static and dynamic models. The distinction between these terms varies depending on the method used. Static ageing models are the most conceptually simple and simulate time through "uprating" and "reweighting" variables of interest (Dekkers, 2015). The ageing of static models is usually undertaken through the re-weighting of the individual micro-units, often to match projected trends without allowing change in the individual attributes in response. Conversely, dynamic ageing changes the individual characteristics of the micro-units in response to experience. Brown and Harding (2002) use the example of ageing individuals and stochastically undergoing transitions, while also being subject to modified policy regimes.

Static models can also use no ageing element, rather moving from base population to forecast horizon in a single step (Mitton, Sutherland & Weeks, 2000). Static models are claimed to be models that do not have a direct interaction between the microanalytic units throughout the simulation. Static models in this definition may be deterministic or stochastic, estimating the impact of a further simulation year or period. In Dynamic models however, individual entities, behaviours and responses are allowed to vary as a result of exogenous factors within the model (Harding, 1996; Merz, 1991). An example of this is allowing labour supply or retirement timing to change as a result of changes to government policy (O'Donoghue, 2001).

Output of both static and dynamic models usually contains individual longitudinal data covering the duration of the model (Mitton, Sutherland & Weeks, 2000). Given the difficulties and expense of creating dynamic MSMs, why would governments or researchers seek to develop these models? Alternatives such as a hypothetical or typical taxpayer model can simulate the impact on types of individuals under policy reform. Cell-based models have the ability to model transitions over numerous individual types simultaneously. Survival models are able to investigate the time until occurrence of a given parameter. Multistate models build on this, allowing more than one transition between more than two states. However, MSMs surpass these through having the ability to model the impacts of policy over a full and representative range of heterogeneous individuals, throughout any number of states. This allows policy analysis to be undertaken on a population much like that of the real world.

The combination of longitudinal, cross-sectional and aggregate outputs allows microsimulation to be utilised within a number of settings. LIAM (O'Donoghue, Lennon & Hynes, 2009) and DESTINIE (Blanchet, Crenner & Le Minez, 2011) investigate intergenerational transfers; SAGE (Zaidi & Scott, 2001) and DYNAMOD (Bækgaard, 1998) examine educational finance; CORSIM (Keister, 2000) examines wealth accumulation, whilst FAMSIM (Lutz, 1997) explores the demographic behaviour of women. The models are heavily utilised to evaluate the future performance of policy. This is especially true of policies with large time spans between implementation and outcome, making them particularly applicable to areas such as pensions, public service financing, health care objectives and long-term care (Li, 2011). Models that have sought to explore such objectives include PENSIM2 (Emmerson *et al*, 2004), DYNACAN (Morrison, 2000) and MOSART (Andreassen *et al,* 1996). Additionally, the inclusion of spatial data to the microsimulation process can open the model up to predict geographical trends of activities through spatial analysis. These models are usually referred to as Dynamic Spatial Microsimulation Models (Li, 2011). Studies that utilise this approach such as MOSES (Wu *et al,* 2008) usually restrict analyses to small areas to limit computing and data requirements. However, some studies have attempted to investigate policy change at a national level, such as the SVERIGE model simulating demographic processes in Sweden (Holm et al, 2006).

Microsimulation however suffers from similar drawbacks as other projection models, where results provide only 'plausible scenarios'. As the future remains unknown, care must be taken to fully justify each step of model construction. Similarly, the benefits and drawbacks of each model must be taken into account when interpreting any results generated. There are a number of key sources of uncertainty in microsimulation modelling. Foremost, the base data used in the construction of the model defines the uncertainty of the model as a whole. The degree to which this data fully describes the composition and experience of the population of interest will also define the outcomes of the model. The projection of current trends into the future is likely to bring increasing degrees of uncertainty as the time between observed and expected data increases. Any projection or alignment procedures will introduce uncertainty whether the future trends in health are likely to follow the same profile as those experienced in the present. Similarly, the way in which future characteristics are defined and implemented is likely to influence the uncertainty of the model. Within a MSM, characteristics are selected based on models and random draws, while this approximates the experience of reality, a much larger number of factors are likely to be involved in the real world.

4.2 Reasons for Selecting Microsimulation Approach

Microsimulation is commonly, but not exclusively used when it is not feasible to test impacts of changes on real populations and is therefore put to a number of different uses. Microsimulation is a powerful tool that through its flexibility is increasingly the only available study tool capable of following modern research paradigms (Spielauer, 2011). Traditionally, the field of microsimulation has been hindered by inadequate computational power, lack of individual longitudinal data and macro approach to research. However, in the wake of computing advances, these drawbacks have been reduced, leading microsimulation to be the most suitable approach to investigate a range of the most pressing problems facing society. Simulation in the context of social science can be thought of simultaneously as a means to results, as well as facilitating experimentation and 'what if?' scenarios that would not otherwise be possible. This can lead to deeper understanding of the problem, side effects and probable outputs of a change (Gilbert &

Troitzsch, 2005). Meanwhile, modelling on the individual level leads microsimulation to be the natural modelling approach applicable to studying public policy, where rules are predominantly made on an individual, household or familial level (Brown & Harding, 2002).

MSMs have been utilised for a number of purposes since first conceptualised. Modelling serves to abstract the studied phenomena, reducing complexity so that generalised rules that apply to large groups or populations may be identified. Separate from ABM, for microsimulations to serve as predictors of policy outcomes, they must be, as far as possible, firmly based within empirical reality (Klevmarken, 1997). This study opts to utilise a microsimulation approach for a number of reasons.

Firstly, the microsimulation approach excels where heterogeneous populations exist with varying characteristics such as that of the UK, behaviours that are complex at the macro level and results that are dependent on individual histories, such as retirement timing. Within classic macroeconomic theory, individuals are often presumed to be identical, utilising a 'representative agent', or only differ by some small degree. However, this is not the case seen in real populations, individuals differ greatly on a range of characteristics and behavioural responses and are often indivisible into a set number of sub-groups. In this study, individuals will vary by age, gender, employment status, health, social group, highest educational qualification, housing tenure, marital status and pathway to retirement. It is the heterogeneity of the individuals that brings the complexity of the distributional impacts or 'winners' and 'losers' of public policy to this study. For this reason, classic macro models based on representative individuals would not be appropriate to assess this.

Secondly, other models than microsimulation also account for heterogeneity, such as cell-based or multistate models (Rogers, 1966; Keyfitz, 1977). These models seek to group individuals by combinations of relevant characteristics, creating a scenario-based approach based on dominant observed individual profiles. Such an approach is particularly useful for investigations such as population projections in which only a limited number of characteristics require specification. In addition, this approach shares synergies with microsimulation in the way data is stored and processed, specifying base data and re-weighting to suit the needs of the analysis. Similarly to microsimulation, if more than just basic characteristics are modelled, the number of simulated individuals or possible cells increases exponentially (Spielauer, 2007). However, this modelling of typologies abstracts the modelled individuals from the observed population, thereby adding difficulty when assessing the distributional impacts of policy. Additionally, cell based models do not allow for bi-directional effects, such as implementing a policy and the response of that individual to the change in policy. Due to the complex relationship between employment, retirement and health (discussed earlier in Chapter 1), these effects are likely to be influential in the relationship between individuals and the change in SPA.

Thirdly, the microsimulation approach excels in modelling the interaction between policy and the socio-economic behaviours of individuals. Microsimulation is able to simulate a range of responses to policy and interactions at the level of the decision-making unit. The use of microsimulation is particularly utilised within the analysis of taxation and benefits, pensions, transport and healthcare.

Finally, microsimulation models allow the implementation of feedback effects between states. As identified within chapter 1, a wide range of influences impact the ability of individuals to remain in employment until SPA. One key element to this relationship is the degree to which employment or retirement provides a protective effect for individual health. However, while this key influence remains under debate as to direction and strength of effect, this study is required to model plausible scenarios, assessing the difference between scenarios. For this application, microsimulation provides a useful framework where the same population can interact with policy, dependent on a number of user-specified scenarios.

4.3 Microsimulation Construction

Most demographic MSMs follow a similar construction method. First, a target population is selected, from which a representative sample is taken, forming the base population of the model. From here, the simulation population is updated or 'simulated' forward through utilising a mix of deterministic or stochastic events, following trajectories or transition probabilities. At each simulated time period, this gives a hypothetical population, based on the assumptions utilised within the model. This population can be projected either within or outside the bounds of observed data. After a number of model iterations the results can be assessed, yielding a possible projection of the target population after time has passed (Gilbert & Troitzsch, 2005). Due to the predictive power of the approach, MSM can be thought of as the generation of 'missing information' from future or past populations on which trends can be projected (Mitton, Sutherland & Weeks, 2000).

There are a number of methodological issues that should be taken into account when developing MSMs. The process of model development involves a number of decisions that will define the output that the model generates, as well as the questions the model is able to explore. This section will discuss the advantages and disadvantages of a number of approaches to model development, these include base data selection, time period utilised within the model, model population structure, complexity of the model, open vs. closed populations, case vs. time based models and model validation or alignment.

4.4 Base Data

Most microsimulation models are built upon a large base sample of data, specifying the behaviours or attributes of the target population at baseline of the model. This data can be taken either from a single source, multiple sources or be synthetically generated. Selection of base data is critical to the outcome and overall strength of the model, often determining the quality of the output. Microsimulation is often very demanding in terms of data requirements. An ideal solution exists in countries with national registration such as Sweden, where creation of MSMs can be achieved using a real and full base population. However, in most populations this is not possible, requiring compromise to be made. Some models use census data to give the most realistic base population possible, such as CORSIM, DYNACAN or DYNAMOD. While census data often has significantly better coverage than most surveys, data depth is often limited as a result of monetary or privacy concerns. As a result of this, it is often required to impute additional variables from other sources to fulfil the needs of the study (Scott *et al,* 2003). The difficulties posed by the selection of base data are discussed by Cassells *et al* (2006); they state that a trade off is often required between representativeness of the population, the reliability of the data and the selection of variables provided by the dataset.

Survey data is often used as a base within MSMs. This data often falls into four categories, longitudinal, administrative, cross sectional and synthetic (Cassells *et al,* 2006). Varying opinions exist as to the most suitable data type to utilise as a base for microsimulation modelling.

Longitudinal data is likely to form the most realistic base for specifying transitions (Li & O'Donoghue, 2012); this refers to data collected through repeatedly re-sampling a selection of individuals through time. This data type contains rich information about individual change over time and trajectories, as well as difference between individuals.

However, such datasets take very long periods to develop, requiring large samples of individuals over significant portions of life to develop the depth necessary. Additionally, these datasets are very costly to collect, requiring continued interaction with a single sample of individuals and often resulting in a limited choice of longitudinal datasets available to the modeller. Similarly, due to the limitations of longitudinal data collection, sample sizes are often not sufficient to reliably capture the processes and change of the population attributes over time. This long-term acquisition of data is often at odds with the requirements of microsimulation. A large portion of microsimulation modelling efforts investigates the impact of policy, which often predisposes the model to require large amounts of data during a short period. Models that study elderly persons or pensions often require longitudinal components to the modelling procedure to characterise the current situation of an individual. This can include past pension contributions or health impacts.

Administrative data has been claimed to contain the most accurate data for the purposes of microsimulation modelling (Cassells *et al,* 2006; Li & O'Donoghue, 2012). This is data that is often collected by government bodies or other large organisations, utilising a large amount of resources. For this reason, administrative data is characterised by large sample sizes and usually surround a topic of interest. Due to the resources expended in the data collection, data is often more robust than longitudinal datasets, providing a snapshot in time of a sub-population. The depth of data provided can be limited due to being collected for administrative purposes. Administrative data can however be imputed onto other broader or more specific datasets in order to improve the depth of the results. An example of this is within the DYNASIM model; in which administrative data was matched with survey data to achieve a broad yet detailed base population. This approach was also used in the CORSIM model, which simulates a historical profile from cross-sectional data, matching this to historical aggregate information (Caldwell, 1996; Li & O'Donoghue, 2012).

Cross sectional data is the most common data form, making up much of administrative and survey data. Cross-sectional data aims to provide a 'snapshot' of a population at a point in time and for this reason be of limited use to the modeller. A single dataset is unlikely to capture the broader range of issues and variables that are of interest to the modeller. Generalisations from this cross-sectional data can also be problematic, as this provides limited information on change in variables over time, external influences to data or measures to counter survey-error (Li & O'Donoghue, 2012).

Within countries that lack universal national registration or where no appropriate data exists, many studies alternatively opt to develop 'synthetic' microdata to form the base of simulations. Examples of this are the DEMOGEN, HARDING or NEDYMAS models. As the datasets utilised are synthetically generated, models are able to investigate single issues in depth as all data requirements are met. However care must be taken when generalising these results to represent reality, as large unforeseen variances may exist between proposed figures and reality (Müller, 2010). Two main techniques are used to achieve these synthetic populations, '*Synthetic Reconstruction*' and *'Combinatorial Optimisation'* (Müller, 2010). Creating synthetic data can help to provide a characterisation of unknown variables, however are largely based on expert opinion of the expected trends. This forces these models closer to theoretical experiments, rather than empirical studies, often hindering their acceptance among policy makers and the general public.

4.5 Data Manipulation

Due to data limitations, hybrid data structures are often used within public policy analysis, reflecting the variety of sources required to build such models. Often extensive data manipulation and alignment is required to conform the data to the needs of the model. When MSMs seek to investigate the impact of pensions-type benefits that are reliant on historical contribution data, hybrid approaches are often used. Analyses of pensions often require long-run historical data that is not available to the modellers. For this reason, models such as DNYNASIM3 create hybrid base data through the combination of datasets from multiple sources. These datasets are combined utilising statistical matching and simulation techniques to complement and add additional detail to a base dataset. This approach allows a representative base sample to contain far more information, on a wider range of variables than originally available.

An additional approach available to modellers is data alignment. The microdata utilised within MSMs is often subject to sampling error, does not fit completely with the needs of the modeller or does not capture trends that are expected to occur after the data collection date. For these reasons, modellers often seek to 'align' the data as a crucial component of the modelling process. An example of this is the adjustment of microsimulation results to meet population level health responses taken from a future data source, often aggregated at single year of age and sex. Alternatively, the model can be aligned with figures that represent the beliefs of the modeller, such as re-weighting a fertility model to represent an expected but not yet observed increase or decrease in fertility rate. This ensures that the model operates within expected boundaries (Kelly & Percival, 2009). Alignment of the model often seeks to improve credibility and acceptance of the figures through alignment with estimates from other official information bodies. This area has been the subject of a large quantity of methodological work in the past decade, indeed almost all dynamic MSMs are claimed to adjust estimates to meet expectations within policy analysis (Anderson, 2001). However, there are two opposing views on alignment apparent within the literature. Firstly, it is proposed that requiring alignment suggests that the model itself is incorrectly specified. Alignment serves to push macro results to no longer be the sum of the micro inputs (Kelly & Percival, 2009). This suggests dominance of methodologies used within the production of alignment figures by groups such as national statistical bodies, over that of microsimulation. However conversely, this view is often accepted as compromise, resulting from the difficulty in fully specifying interaction and transition probabilities within the model. While alignment should not always be necessary, data inputs are rarely perfect and alignment with other sources provides an additional level of security surrounding estimates (Kelly & King, 2001). Most alignment procedures minimise adverse influence through accepting change in the aggregate outputs of the model, while preserving the distributions of data, maintaining the microeconomic content (Anderson, 2001; Cassells, Harding & Kelly, 2006). Alignment procedures will be discussed further in section 4.10 and implemented later in section 5.11.

4.6 Time Period

MSMs are often delineated into either continuous or discrete conceptualisations of time. Discrete time models utilise set periods, time remains constant, occurring in sequence. This is often enacted through the projection of calendar years, months or days (Morand *et al,* 2010). Comparatively, continuous time simulations model on an event basis, modelling time between events (Zaidi & Rake, 2001). Both discrete and continuous models can incorporate probability models that help define the occurrence of specified transitions. Probabilities are applied to simulated individuals at each time period in the model (usually a year) in order to determine their simulated life histories. This approach assumes that the probabilities of events are independent of each other, as well as independent of those in the network surrounding the individual. Care should be taken in the specification of the transition matrices to take account of any additional interdependencies that may influence the critical outcomes of the model. Additionally this approach provides a characterisation of real processes such as births or deaths, giving the year in which they happen. However if additional detail is required within the model to enhance specificity of the model, a greater number of time periods needs to be simulated, impacting efficiency of the modelling procedure. Time period duration decisions should be made in accordance to the model outcomes desired. For example, for a model of labour force involvement, a time period of calendar years may be unsuitable, as this assumes that no transitions between employment and other non-employment states are made during the course of a year. Such assumptions are unrealistic and will hinder the applicability of the model as a characterisation of the real world.

By contrast, continuous time conceptualisations allow events to delineate the periods used within simulation, modelling time until event and updating the simulation following event occurrence. This allows histories to be simulated through a range of transitions between states. Although this approach has some theoretical advantages, such as ability to investigate exact time spent within states, it also has a range of limitations. Continuous time scales are adversely affected by some of the problems experienced by discrete models. The interdependence and interaction between events become harder to specify in a continuous time model, as proximity to events must be considered. Utilisation of discrete time or cross-sectional adjustments would serve to erode the advantages intended by using a continuous time period. The data requirements to specify a continuous model are rarely matched by the data (Zaidi & Rake, 2001). The majority of surveys providing information for MSMs are collected on at most an annual basis, greatly improving the attractiveness of discrete time period characterisation to modellers.

4.7 Model Population Structure

MSMs can also vary by population structure, being further defined into *Cohort/Longitudinal Models* or *Population/Cross-sectional Models*. These model types vary primarily by the base dataset selection and data structure inherent in this dataset. Cohort or longitudinal models follow a single cohort over their lifetime, modelling the life events that they interact with. This approach is often used within later-life analyses, such as the impacts of population ageing or pension analyses when only a single cohort is of interest

(Li & O'Donoghue, 2012). Conversely, population/cross sectional models attempt to model a population cross section over time, representing the whole age spectrum. This approach can serve to make models more comprehensive and applicable to a wider range of research questions, such as intergenerational fairness (Li & O'Donoghue, 2012). Cohort models are simpler computationally, as they do not require the simulation of complete lifetimes. As the focus of this study surrounds interaction with the SPA, combined with a forecast horizon of less than a lifetime results in a cohort approach being most appropriate.

4.8 Complexity of the Model

The complexity included within the model is often guided by the research questions of the study. Ideally, MSMs should aim to have capacity to capture all variables of interest, as well as all interacting variables. This approach is of greatest importance when building large, generalised models utilised for a range of policy analyses. An example of this is the PENSIM2 model utilised by DWP in the UK (Emmerson, Reed & Shephard, 2004). However, this approach is not always possible due to a combination of time, monetary and data requirements. For this reason a balance is often struck, maximising model validity and comprehensiveness, while taking into account the objectives and requirements of the model output. Model complexity also has an impact on efficiency and run-time of the model, extrapolating with each additional variable simulated. For these reasons, Harding (2007, p.5) suggests that developers *"place a much greater importance on developing the simplest possible (but functioning) version of a model"*, especially during the initial development and testing phase of the model. Upon this verified base model, additional modules and complexity can be built, allowing impact assessment of individual model components. This also assists in diagnosing significant interaction effects between components, such as those that may be identified between ability to continue working and health benefits or detriments of retirement.

4.9 Open vs. Closed Models

The purposes of the model often assist in the decision between an open and closed population. A model is defined as closed if the population simulated within the model is fixed (Li & O'Donoghue, 2012). If a model allows for the inclusion of new individuals to the model, traditionally characterised as either births or migration, the model is classified as open. This decision changes the way in which the model is programmed. Within a closed format, if the model requires a marriage, an individual already included within the model must be selected. This approach requires greater specification of the marriage transition, requiring that the individual utilised is suitable for the transition, for example not already married. If however, the model operates within an open format, the requirement of a marriage can be facilitated through the creation of a new individual. However, open models are more difficult to align to real populations, as the creation of new individuals is harder to control to ensure alignment with realistic data. In order to achieve aggregate targets, models require constant dynamic re-weighting, risking distortion of the data or nullification of benefits brought about by open modelling. For these reasons, this research will opt to utilise a closed model format.

Table 4.1 – Microsimulation Choices

Microsimulation Choices			
Choice	**Options**	**Decision**	**Justification**
Base Data	Administrative Data Survey Data Longitudinal Data Census Data Synthetic Data	Census base data, longitudinal survey data used for health transitions	Census data provides a very large and representative sample at a specific point in time. Longitudinal health transition data provides information on how the health of an individual changes through time, which is likely to be critical to this study.
Data Manipulation	Hybrid Base Data Data Alignment	Data Alignment	The microdata used for specifying transitions is often subject to error. The alignment of the model allows validation with a known point in time, before projecting trends into the future.
Time Period	Discrete Time Continuous Time	Discrete Time	Discrete time models in set time periods (e.g. annually). This was found to be most appropriate to the modelling SPA policy, which varies depending on date of birth.
Model Population Structure	Cohort/Longitudinal Models Population/Cross Sectional Models	Cohort Model	Cohort models follow a single group of individuals over life. This was found to be more appropriate than simulating a full population cross-section as a change in SPA policy is unlikely to directly impact younger individuals for a large number of years.
Open vs. Closed Model	Open Model Closed Model	Closed Model	A closed model minimises the computational complexity of the model. As open models account for elements such as births and migration, these significantly impact the complexity of the model. However, the time from birth to SPA was outside the scope of the model. Similarly, those migrating into the population later in life are less likely to be impacted by changes in SPA policy as they have not had time to accrue sufficient National Insurance contributions.

4.10 Model Validation, Verification and Alignment

4.10.1 Model Validation and Verification

Within the literature of microsimulation, validation and verification are often conflated. Within software engineering, validation is concerned with the operation of the model and whether it performs the correct function. Conversely, verification is defined as establishing whether the model performs the function correctly (Somerville, 2006). After creation, a model will provide a large number of outputs per simulation period for the full length of the simulation. It is important to fully investigate and validate the output of models, allowing the modeller to ensure that no errors have been made during programming and that all elements are working as intended. Additionally, it is crucial that model output is verified, ensuring that model results are within plausible ranges, this often includes the process of checking produced model output against known totals. Quality of output in a Microsimulation model is crucial for the model to be seen as credible to policy makers and government (Kelly & Percival, 2009). However, it is often recognised that not enough effort is placed into validating models (O'Donoghue, 2001; Morrison, 2008; Harding, Keegan & Kelly, 2010; Li & O'Donoghue, 2012). Indeed, alongside the challenge of data requirements, model validation was historically listed as one of the top two challenges facing microsimulation modelling as a field (Wolfson, 2000). Little has changed since the publication of this document, with relatively little available to advise researchers on best practices when creating, validating and verifying MSMs. Similarly, no single standardised set of definitions and constructs is evident from the literature. One notable exception is the summary of validation procedures utilised by Morrison (2008) in the creation of the DYNACAN model. Therefore, here the term 'validation' of model construction is used in broad terms in the similar manner as Montgomery (2007) and Harding, Keegan & Kelly (2010, p.47) meaning that the model is *'one with a high level of fitness for use, that is free from manufacturing defects and conforms to the design specifications'.* Meanwhile the verification of outputs will take place within the Pension Health model (PENHEALTH) in line with the views of Caldwell and Morrison (2000, p.202.), '*to assess whether the outputs are reasonable for their intended purpose'*.

A large quantity of data is likely to be generated by the microsimulation procedure, often creating a dataset at least the size of the base population for each period of the simulation. The core principle of model validation used within the DYNACAN framework is comparison of outputs with counterpart values. Through comparison between modelled and known results of single or multiple processes, this suggests that the mechanics of the model are operating in a reasonable manner.

The DYNACAN framework is often regarded as one of the most successful and dynamic models in the world due to its validation and continued use (Kelly & Percival, 2009). While model validation is often overlooked in model development, the DYNACAN framework is one of the most comprehensive and well documented schemes available. For this reason, this study will follow the DYANCAN validation framework. This approach splits the validation efforts used into five types which will be considered in turn:

- Data, coefficient and parameter validation;
- Programming / algorithmic validation;
- Module-specific validation;
- Multi-module validation;
- Policy impact validation.

(Morrison, 2008).

First, validation begins with assessment of a number of aspects of the base data utilised within the model. Base data and choice of parameters is likely to form one of the most important components of model validity. Often if data is not available directly from survey data, additional variables need to be imputed, added or re-coded to suit the purposes of the model. Often, age and gender distributions of the base input need to be varified and shaped to those apparent in a reliable national sample, such as a census. The assessment of equation coefficients will have already have largely been undertaken during the estimation phase of relevant modules (Morrison, 2008). During this phase, equation and parameter checks are undertaken in a number of ways. The equations themselves are checked for appropriateness for the target population or sub-population, additionally the data used in estimation of each of these parameters is checked for appropriateness to the task. This includes consideration of sample size, representativeness of the sample, potential for selection bias and adjustments that have been made to the data. The equations are then checked for consistency with the available literature and justifications provided if modifications or deviations from such are made. Base data is checked for consistency in definition across waves and the outputs of the model are considered for their validity or reasonableness given input parameters.

Additionally, checks may be applied to the model to ensure appropriate operations are made within the model, for example age profiles of births across the simulation run. Many microsimulation modelling efforts aim to compare model generated figures with external estimates of the same variable. This can be done in many different ways, a number of simulation models have opted to use *ex-post* analyses to validate the operation of the model. Models such as CORSIM and DYNASIM take historical datasets as a baseline and allow the model to project these forward to the present day. Through utilising this approach, the model forecasts can be compared to present-day figures and model operation can be assessed (Morrison, 2000; Caldwell & Morrison, 2000).

The second phase involves programming or algorithmic validation. This process involves the validation of the way the model is programmed, whether the control logic, utility routines and procedures of the model are operating correctly. This is regularly thought of as simply 'debugging' of the model, however Morrison (2008) argues that analysis should go further than this. It is argued that thorough checking of model parameter intentions, operation and output should be considered for correct operation as well as specification and computational efficiency.

Thirdly, module specific validation investigates the impact individual modules are having in themselves. This study seeks to include modules covering life expectancy, three health trajectory modules and pension age assumptions. Each of these modules need to be considered individually for whether their operation meets with expectations at time of programming. Morrison (2008) advocates the use of programming the ability to generate 'debug' files, in which transitions are simulated and printed, alongside the specific transition probabilities used in that transition. This allows for ex-post analysis of model operation for a sample of individuals to ensure correct operation. Additionally, common techniques include the generation of time series data showing number of transitions made within a model run, that if using a historical base data, can be compared against current figures to ensure reasonable operation. This data can verify whether convergence is made between generated and expected future values for key variables.

Fourthly, multi-module validation techniques are utilised. This approach assesses the impact and interaction of several modules being run simultaneously. The results generated under interacting modules are less clear than if modules operate individually. Again, through utilising a historical dataset, the model is able to first validate against known current figures to assist in diagnosing correct operation over the full forecast horizon. This is of particular importance if more than one module seeks to influence a single variable. However, within the context of this study, with the exception of the impact of health trajectory on premature inactivity, variables are mutually exclusive. This allows this study to concentrate on specification of individual parameters, minimising the need for multi-module validation. Additionally, a similar approach is suggested by Caldwell (1996), in which an indirect or multiple module approach is used to verify parameters. This approach verifies the operation of single model parameters through simulation. An example of this is the investigation of married persons with a private pension through simulating the two combined individual parameters of marriages and private pension contributions. This approach is particularly useful when no aggregate sources with deconstructed variables are available for validation. However, this approach may fail to capture the exact interactions and behavioural features of the variable, it does serve to create a stylised version of the variable that may suit the needs of the model.

Finally, policy impact validation involves investigating the impact of prospective policy option projections. This forms an important aspect in most policy-oriented MSMs, the same is true of this study. When models compare base and alternative policy options, results are generated from two or more distinct model runs. This can result in variations between models due to a variety of stochastic processes operating within the model. Due to this, it is necessary to validate the outputs of the two runs, as well as the impact measures used to compare between the two.

4.10.2 Model Alignment

Even well specified microsimulation models often drift away from the totals observed in reality. This is often due to discrepancies between the data underlying the transition probabilities and the true effect occurring in the population. It is likely that a number of unknown parameters additionally influence the real population, being visible as variability in modelled versus observed results. Additionally, historical datasets will include specific characteristics and period effects that may differ from current and future populations (Li & O'Donoghue, 2014). These combined effects can lead to models under or over predicting the occurrence of a certain event (Duncan & Weeks, 1998). Alignment therefore constrains the output of the model to conform to match either observed data, official projections that are considered reliable or to match a hypothetical scenario that the modeller wishes to include (Scott, 2001). While a useful tool, it must be noted that model alignment does have some drawbacks and should not be used to hide avoidable model misspecification (Bacon & Pennec, 2009). However, if model misspecification remains following extensive modelling, model alignment may be used to negate the influence.

Bækgaard (2002) suggests that such alignment can be done in one of two ways, either through the adjustment of the regression equation parameters themselves, or through ex-post manipulation of the numbers or proportions of selected individuals. While the intended end result is the same, the method used to align the totals can significantly modify the profile of individuals undergoing a state transition. As previously noted in section 4.11, the benefits and drawbacks of this procedure must be taken into account when deciding whether to align data. The decision must additionally be made in line with the best interests of the research questions and the specification of the model itself. As noted by Bækgaard (2002), the nature of the deviation in results is critical when deciding what type of alignment process is necessary. Misspecifications of the model should be countered through manipulation of model parameters in order to align results. However, if accounting for unknown information, ex-post alignment is often more appropriate. A number of model alignment methods have been put forward and each has its own positive and negative aspects.

4.10.3 Parameter Alignment

The simplest alignment method involves the adjustment of transition probabilities following computation by the model. Within parameter alignment, transition probabilities are multiplied by an adjustment term defined as the ratio of the benchmarks and the simulated aggregates. This process is similar to the process used to create a feedback loop between employment and health in the PENHEALTH model. This alignment can be embedded within the running of the model and is often used for its computational simplicity (Bacon & Pennec, 2009). However, when using this alignment method, it must be ensured that transition probabilities remain between 0 and 1 (Bækgaard, 2002). This method has the benefit of maintaining the proportional probabilities, which many alignment methods break.

4.10.4 Ex-post Alignment

Ex-post alignment concerns the adjustment of the outcome of a simulation by means of controlled sampling (Bækgaard, 2002). While many different methods exist of which individuals to select with varying benefits and drawbacks, the methods operate in fundamentally the same way. In the simplest possible method, known as Sorting by Predicted Probability (SBP), model generated transition probabilities are ranked and the appropriate number of individuals with the highest transition probability are selected to undertake the transition (Harding, Keegan & Kelly, 2010). This thereby ensures that the model matches with a reliable external benchmark. The SBP alignment mechanism pays little attention to the distribution of the data, simply selecting those who are at highest risk of transition. This can result in heavy manipulation of the sub-group proportions within the output, greatly varying high-risk groups while leaving low risk groups comparatively untouched.

Alternative methods vary the method of individual selection in order to introduce a stochastic element to the process and ensure not exclusively those with the highest probability are selected (O'Donoghue, Lennon & Hynes, 2009). This assists the model in conforming to reality, in which not only those most likely but some less likely individuals experience state transitions. A number of different methods exist to introduce this stochastic element. Bækgaard (2002) recommends using the difference between the model generated probability and a random number, also known as Sort by Difference (SBD) sorting. This type of adjustment method is often suggested as a sound method of model alignment, however as noted by Galler (1997), the statistical properties of such an alignment are very complex. Ex-post manipulation of the transition numbers raises concerns regarding the level of disaggregation at which this should occur and the consistency of the final data (Li, 2011). Additionally, the SBD alignment method has been criticised for the range of possible sorting values not being the same for each individual (Li

& O'Donoghue, 2014). Such alignment methods can be computationally intensive when used on large datasets and depending on the level of disaggregation utilised, requiring ranking and often re-ranking by transition probability for each iteration of the model.

Kelly and Percival (2009) meanwhile propose a variant of the SBD method, which forces a proportion of low-risk individuals (typically 10%) to undertake the transition, this will be referred to here as Sort by Difference with Manipulation (SBDM). This is intended to better mimic reality, while maintaining computational speed, which can be worth considering as an alignment method, when used on large datasets. Depending on the level of disaggregation utilised, it may require ranking and often re-ranking the dataset by a number of variables during each iteration of the model. Ex-post manipulation of the transition numbers additionally raises concerns regarding the level of disaggregation at which this should occur and the consistency of the final data (Li, 2011).

This range issue is addressed in an alignment mechanism described in Flood *et al.* (2005), Morrison (2006) and O'Donoghue *et al.* (2009). The Sort by Difference Logistic (SBDL) alignment mechanism sorts transition probabilities by the difference between a logistically adjusted predicted probability and a random number (SBDL). This mitigates the range problem through utilising a predicted logistic variable from a logit model, combined with a random number drawn from a logistic distribution to produce a randomised variable (Li & O'Donoghue, 2014).

What is clear from the microsimulation alignment literature is that there is no single best practice for alignment method available. Each alignment method has benefits and drawbacks that vary from model to model. For these reasons, four different types of alignment procedures will be trialled and assessed by their impact upon the model. The four selected methods will comprise Sort by Predicted Probability (SBP), Sort by

Difference (SBD), SBD with forced inclusion of lower probability individuals (SBDM) and SBD Logistic (SBDL) alignments. These alignment strategies are summarised in table 4.2 and will be considered further in section 5.12 below.

<u>Table 4.2 – Alignment Methods Trialled</u>

Name	**Acronym**	**Description**
Sort by Predicted Probability	SBP	Sort individuals by predicted probability and select those most likely to undergo a transition
Sort by Difference	SBD	Sort by the difference between predicted probability and a random number
Sort by Difference with Manipulated forced inclusion	SBDM	Sort by difference, force inclusion of 10% of low ranked individuals to mimic real world experience
Sort by Difference Logistic	SBDL	Sort by difference between the predicted probability obtained from a logit model and a logistically distributed random number

When assessing the effectiveness and appropriateness of a microsimulation procedure, Li & O'Donoghue (2014) suggest that first it is important to define what needs to be compared and what the criteria are to be utilised. They go on to suggest that a 'good' microsimulation alignment algorithm should:

- Replicate as close as possible the external control totals for the alignment totals
- Retain the relationship between the deterministic and explanatory variables in the deterministic component of the model (O'Donoghue, 2010).
- Retain the shape of distributions in different subgroups and inter-relations unless there is a reason not to.
- Compute efficiently, based on needs of the modellers.

(Li & O'Donoghue, 2014, pp. 6)

The final selection of the most suitable alignment algorithm should however be based on a balance or compromise between the performance of the alignment mechanism, the research question that the study aims to address and those criteria stated above. Different mechanisms will have differential benefits, depending on which groups or sub-groups are of interest to the study.

4.11 Lessons from Previous Experience

The full review of similar microsimulation approaches can be found in Appendix H, presented here is a summary of this review. The review of similar microsimulation methods focused on those modelling attempts that included an element of health projection, but also included other models with approaches of interest. This encompassed eight models including DYNASIM, CORSIM, DYNAMOD, DYNACAN, SAGE, MOSART, PENSIM and EUROMOD.

The approach taken by this study was informed by a number of previous modelling strategies employed elsewhere. The study most influential to this project was SESIM3, developed by the Swedish Ministry of Finance to investigate pensions, including the influence of health, regional mobility and health (Flood, 2008). The SESIM model utilises multinomial logistic regression and ordered probit models to project health and mortality, aligning these results with external long-range population forecasts (Klevmarken & Lindgren, 2008). The SESIM3 model utilises a mixed measure of health, simulating self-reported health, mobility, long-standing illness and working capacity. This approach was considered, but was eventually rejected due to limited data availability, particularly for the purposes of alignment. The approach to modelling was utilised within the PENHEALTH model using two health measures, investigating how self reported health and hand grip strength impact individual ability to remain in employment through time. This involved utilising a multinomial logistic regression model and aligning these figures onto externally derived totals.

The production of the DYNASIM (2,3) model lent a number of elements to this analysis, namely developing the model in a modular format and the imputation of health variables (Spielauer, 2007). The use of a modular format within the DYNASIM models allowed systematic working of the model and facilitated troubleshooting during the model development stages. Meanwhile, the method of utilising a module to impute data that was not included within the base sample was influential in the development of the projection of grip-strength data as this was not included within the census base sample.

The CORSIM project showed the benefits of utilising a historical base dataset (Spielauer, 2007). By using a historical base dataset, this opens the possibility of aligning the operation of the model with known data. Many alternative studies have aligned model results with external projections, however these remain projections and are ultimately unknown values. Through utilising a historical dataset and aligning with a known present total, it is hoped that the model accuracy can be improved.

As discussed previously in section 4.10, the review process developed within the DYNACAN project was also influential to this project. This methodology suggested explicit statements of model suitability and splitting the model review process into defined stages (Kelly & Percival, 2009). This maintains the transparency of the model review process and will be utilised in this study (the implementation of which will be discussed later in section 5.11).

4.12 Chapter Summary

This chapter has discussed the key elements of microsimulation literature. The chapter explored why microsimulation was selected as the appropriate method for use in this study. Within the construction of a microsimulation model, the modeller must make a number of decisions that will define the operation of the model. Because of this, the key elements of microsimulation construction were discussed, investigating similar models implemented elsewhere for best practice that could be brought to the PENHEALTH model. The following chapter will describe the methodology used within this study. This will focus on justifying the individual modelling choices made when designing and constructing the PENHEALTH model.

Chapter 5 Data & Construction of the Model

5.1 Introduction

This chapter presents the development of the Pension Health Dynamic Microsimulation Model (PENHEALTH) used within this study. First, the aims and objectives of the model will be set out in reference to the research questions that this study seeks to explore (see Section 1.3). Due to the nature of microsimulation, assumptions or simplifications of the real world are required in order to facilitate modelling.

Second, the development of the model will be discussed and justification of the included variables will be put forward in reference to literature and drawing on knowledge gained by similar studies implemented elsewhere. These will cover the building blocks of the model, describing what elements need to be included and what can be intentionally excluded to achieve the desired scope of the model. These will be selected to provide the simplest model possible that will adequately explore the research questions set out. The model will be built with limitations in mind due to data availability, and all attempts made to minimise these impacts will be discussed.

Thirdly the sources of data available will be put forward and assessed for applicability to the study. Following selection of the adequate data, the manipulation of the datasets to achieve the appropriate input format will be put forward.

Fourthly, the assumptions utilised in stage 1 of the modelling process will be proposed and explored. This process will begin with a simplified baseline scenario that will be used for model validation to ensure the accuracy or plausibility of model results, as well as to provide a benchmark against which to compare alternative scenarios. The scope of the modelling procedure includes the ability to modify parameters to explore alternative scenarios of SPA legislation, health conceptualisation and feedback effects between employment and health, however these will be discussed further in chapters 7 and 8.

Finally, technical details and validation procedures will be discussed. This section will explore those areas identified earlier within section 4.10.1, ensuring that the produced model is fit for purpose.

5.2 Desirable Properties & Objectives of the Model

Desirable Properties

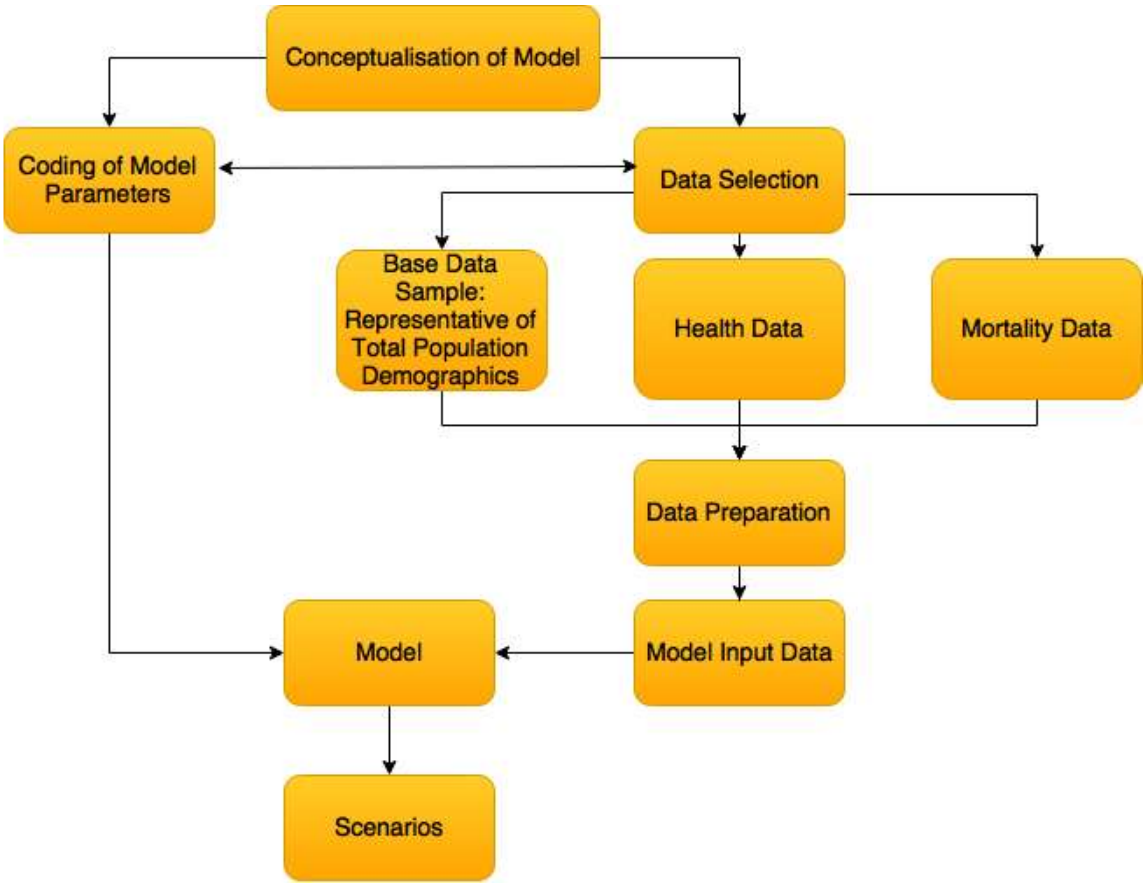
- The model should:

- Adequately assess the impact of a variety of SPA scenarios on individual ability to remain in work.
- Provide an understandable representation of the relationship between work and health for the purposes of academic and policy analysis.
- Incorporate the ability to model feedback scenarios in the relationship between work and health.
- Provide a representative and plausible final population at the end of the simulation run.
- Include the ability to explore the impact of different measures of health on the outcomes of the model.

5.3 Development of the Pension Health (PENHEALTH) Model

The below Figure 5.1 shows a simplified diagram of the steps taken when developing the Pensions Health Model.

<u>Figure 5.1 - Flow Diagram of Steps Taken During Development of the PENHEALTH model</u>



Source: Author's own research.

The development of the Pensions Health model took place in three stages. The data preparation took place within IBM SPSS, while model development and implementation took place within R to give flexibility in the coding parameters.

First, a conceptualisation of the model was developed, assessing the abilities of the microsimulation approach and programming approach that will be taken. Following this, the first stage of the data selection procedure involved a review of the necessary variables to be included. These variables were selected to give an accurate representation of variations in health across the population (Bowling, 2005), as well as provide adequate covariates to accurately project health into the future.

Following variable selection, the next stage in model development was to select and prepare the input data. A number of data sources were available to this study, each with their own limitations. The first step involved a review of possible datasets that could be applicable to the needs of the final model and included the necessary variables. This comprised investigating the Census, Labour Force Survey, English Longitudinal Study of Ageing, Understanding Society, Annual Population Survey and Health Survey for England. The final selection included the 2001 and 2011 Census, as well as the English Longitudinal Study of Ageing datasets.

After selection of the necessary datasets, the second step was to prepare this data to be utilised within the model, as discussed later in section 5.7. This involved recoding of variables, manipulation of data categories and imputation of missing data to give a full and complete sample from which to model. The use of data imputation was a choice taken to overcome the problem of missing data within the base sample. A number of different methods were available to account for missing data, each with benefits and drawbacks.

Missing data is a common problem when utilising real world data and may arise for a number of reasons. If the data is missing completely at random, it is often justifiable to ignore or simply remove these cases (Little & Rubin, 2014). However this is rarely the case, requiring additional measures to be taken. Missing data often falls into one of three categories, ‘Missing Completely at Random’, ‘Missing at Random’ and most commonly in real-world data, ‘Not Missing at Random’ (Little & Rubin, 2014). Data that is not missing at random is often the result of selective response or data censoring during the data collection process. Missing data can result in a number of issues to the study including reduced sample size and associated statistical power, a biased sample, or a biased analysis and inference (McCleary, 2002). For these reasons, care must be taken when encountering, as well as selecting the correct analytic technique to account for missing data. Before deciding how to proceed, it was first necessary to undertake a process of exploratory data analysis to assess the nature of the missing data.

Missing data and survey attrition are important factors to consider when using a longitudinal dataset and should be defined. Attrition is when a cohort member either prefers to no longer be interviewed for the study. Additionally, this may cover those who have passes away, moved house or are otherwise unable to be contacted for the following wave. Missing data or item non-response however is when an individual requests to not answer a specific question on a survey (Watson & Wooden, 2009).

Attrition between the waves of the ELSA longitudinal dataset was important to consider and led to the exclusion to a number of individuals from the original sample as no follow up data was available. Following exploratory data analysis, it was observed that the data was not missing completely at random (MCAR). As no sample of the missing data was available, it was not possible to distinguish whether the data was either missing at random (MAR) versus missing not at random (MNAR). However, it is possible to distinguish that the data was at least MAR, compared to MCAR. The missing data analysis took several steps, first patterns of missingness were identified within the survey for each missing variable, this allowed the assessment of whether certain groups were more likely to have missing values. Second, responses themselves were assessed, investigating whether some variables were more likely to include missing data. This information was cross-referenced with survey methodology to identify reasons for missing data. This helped to narrow the search for the appropriate method to account for this missing data. Deletion methods were defined as inappropriate measures to deal with missing data in this context, therefore this study considered model based methods including Multiple Imputation and Hot Deck Imputation.

Data imputation, developed by Rubin (1987) and later Multiple Imputation allow the substitution, simulation or filling in of missing data through draws from a predictive distribution, based on observed data. The predictive distributions are built through regression models and the quality of the regression model will define the quality of the outputs given. This will give possible values that the missing data may have held, based on observed data. However, the true value of the missing data can never be known and as such, imputed data should not be treated as true data, merely as plausible values. To overcome the variability between draws, multiple imputations are often undertaken in which successive draws are taken from the predictive distribution to allow assessment of the uncertainty in the imputation process. Multiple imputation is beneficial as it allows the maximum amount of information to be retained within the sample.

Conversely, hot deck imputation replaces missing data with values from similar responding units within the sample (Andridge & Little, 2010). This is often undertaken through nearest neighbour analysis. Nearest neighbour develops a metric of distance between units, based on response to a variety of covariates. The algorithm then sorts the dataset and selects the unit that it defines as most similar, copying the response variable of interest to the missing value (Sande, 1983).

Some statisticians criticise the application of Multiple Imputation (MI) within research. Most MI methods assume that data are at least Missing at Random, if not Missing Completely at Random. This is often a strong assumption and hard to determine within social surveys as the data needed to confirm is often unobserved (Liu & De, 2015).

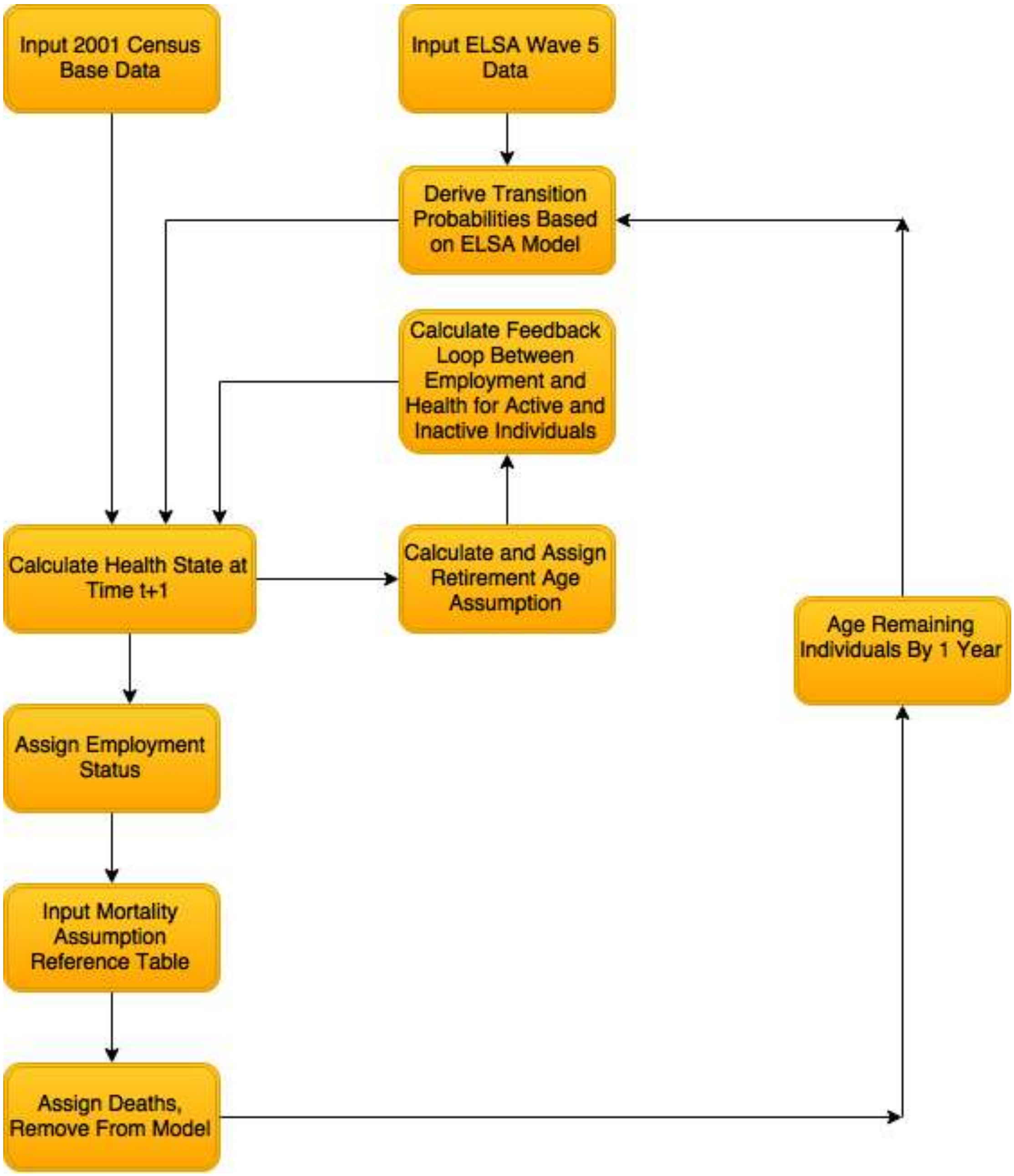
Additionally, the model used to impute the missing values is required to be accurate. Again, this is unlikely to be completely true within social research, in which it is rare to be able to completely define the factors that influence a single variable (Rubin, 1987). One drawback of the multiple imputation method is that it implicitly generates similar individuals. When used on a dataset that has more than a small amount of missing data, such an approach can risk the creation of multiple similar individuals, which lends little to the analysis. As this study seeks to investigate the impact of a change in SPA across a spectrum of individuals, the variance between individuals is an important factor. For this reason, this study selects to use Multiple Imputation to account for missing values within the base sample.

The data for the base sample within this study was multiply imputed within the IBM SPSS software. The imputation of data results in a number of 'complete' datasets with no missing values, however the imputed values in each dataset may vary. SPSS utilises a MCMC algorithm known as Fully Conditional Specification (FCS) or chained equations imputation. This process utilises a regression model, built upon known data to predict the values of missing data through a MCMC process. Following analysis, the imputed datasets were analysed separately and combined, assessing both the within variance for each dataset, as well as the between variance for each dataset (Azur *et al*, 2011; Schafer & Graham, 2002).

Once this data preparation had taken place, the model parameters were coded within R. As discussed later in Section 5.8, this took place in a modular format, ensuring that all module prerequisites were available to the model, which allowed the generation of first results.

The following section will discuss the variables and assumptions used in the initial base scenario. The base scenario is intended to provide the closest representation of reality possible within the model. For this reason, the ONS prime projection of mortality rates will be used and no additional manipulation parameters will be used at this point (alternative mortality scenarios will be covered in Section 7.5). Additionally, current legislation regarding SPA will be utilised, as set out in Section 5.8.1. Attaining this base scenario is intended to give a marker against which to compare subsequent alternative scenarios (discussed later in chapter 7) and assess the alternative impact these may have.

<u>Figure 5.2 – PENHEALTH Model Structure</u>



Source: Author's own research.

The PENHEALTH model is divided into modules, each determining the change in individual status during a single year. This begins with the input of the base data. From here, calculation of health status transition probabilities takes place based on attributes of the individual in the base Census data using a Multinomial Logistic Regression model, specified on the health transition ELSA data (discussed further in sections 5.4.1 and 5.4.3). Following calculation from the original data, health transition probabilities are then re-weighted, based on the current assumption of feedback between employment and health. A random draw is then used for each transition probability to determine if the event will occur during this iteration. This is done through drawing of a random number from a uniform distribution between 0 and 1. This is then compared against the calculated cumulative transition probabilities for each individual and each state, which by definition also fall between 0 and 1. Based on the outcome of this comparison, the transition will then either be deemed to have occurred or not occurred. This value is then utilised as the lagged health variable for the following iteration for the model.

Following the allocation of the health state at time t+1, subsequent parameters of the individuals state can also be defined. The next variable to be defined is the individual's employment status. For this module, the age is compared against retirement age and if the individual is older than the retirement age for that year, they are defined as retired. If however, they are within economic activity years (in this case defined as under the age of retirement), the health of the individual is referenced. The age of retirement during this year is sourced from a reference file defining the retirement age assumptions for this run of the model. If the health of the individual within this year is defined as being in state 3 ('Poor Health') and the individual is below retirement age, the individual is defined as 'Prematurely Inactive'.

Once economic activity states have been defined, mortality is assigned. This is allocated in line with a reference table supplied by the modeller before the model is run. These values are obtained through use of the ONS prime and alternative projections of mortality. The mortality rate by year and by single year of age is then again used in conjunction with a random draw and the appropriate individuals are removed from the model.

Finally, the age of all remaining individuals within the model is increased by 1 year, the date is increased by 1 year and a new model iteration begins.

5.4 Variables Utilised Within the Model

This section will investigate the variables that will be utilised to characterise both health and socioeconomic status within the model. Once this has been undertaken, a review of datasets will investigate which available data sources contain the selected variables. Additionally, the benefits and drawbacks of the individual datasets will be assessed.

In order to accurately predict variations in health across society in the context of a microsimulation model, first one should establish a quantifiable selection of independent variables. Health can be seen as a continuum, varying both between individuals and within individuals through time (Segovia, Bartlett & Edwards, 1989; Fýlkesnes & Førde, 1992). The impact that such a perception of health can have varies depending on a range of external and internal factors at that point in the individual's life (Menec, Chipperfield & Perry, 1999). These internal and external factors include the current stresses and strains of modern life, including influences such as current coping mechanisms, availability of employment, financial and social support during a period of ill-health and perceived health status (as discussed earlier in Section 3.3). These variables should seek to capture this variability, providing a model that can predict accurately into the future. While there are many different markers of socioeconomic status available to the potential modeller, this section will discuss and justify those selected for use in this study.

The health of the individual can be seen as a product of the economic, social, cultural and political environment in which the individual's life is lived. By including covariates that can approximate the effects of these influences, the accuracy of health status projection can be improved. The inclusion of socioeconomic status provides a useful approximation for a number of these health-defining factors. Socioeconomic status has been found to correlate with health (see section 1.2.1) and can be used as a means of contextualising health declines of individuals within the model through life. Socioeconomic status provides an insight to the employment and living conditions, and resources of the individual, all of which have been found to impact health (Glymour, Avendano & Kawachi, 2014). This fits into the socioeconomic determinants of health framework put forward by Marmot (2005).

Selection of the socioeconomic status variables was made in line with health literature (Winkleby *et al,* 1992; Singh-Manoux, Marmot & Adler, 2005), previous health microsimulation modelling attempts (Flood, 2008; Klevmarken & Lindgren, 2008), data availability and strength as a predictor of health status within the selected dataset. Additionally, in order to answer the research questions set out in section 1.3, it is important to include the impact of mortality across the population. This is done to assess the impact of the change in SPA across society, as well as investigating the number of years of life spent both pre and post retirement under a variety of SPA reform scenarios.

5.4.1 Health Transition Model I - Self-Reported Health

As discussed previously in Section 3.3, Self-Reported Health represents one of the most commonly used markers of health and is widely available within a number of official surveys. Subjective health assessment reflects not the incidence of disease in the population, rather the individual's perception of health. This includes a wide conceptualisation of health, encompassing a number of biological, psychological and social dimensions of health that would not be observable to an external individual (Miilunpalo *et al,* 1997). While fairly crude in conceptualisation, self-rated health has been shown to be a good predictor of mortality and various indices of morbidity (Mossey & Shapiro, 1982; Idler & Benyamini, 1997; Jamoon et al, 2008).

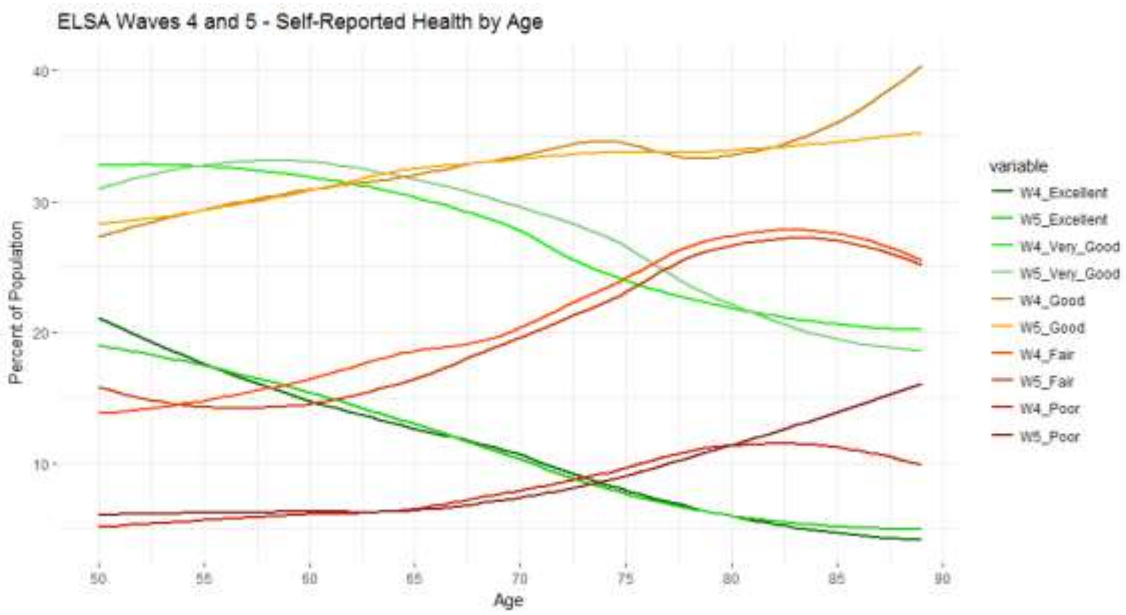
Critically for this study, the predictive power of self-reported health is additionally apparent in declining functional ability and health outcomes within working age populations (Miilunpalo et al, 1997; Idler, Russell & Davis, 2000). It has been noted by some that variance may exist between an individual's own perception of health and the appraisal of medical experts (Sen, 2002). However, perceptions of health from sources other than the individual in question remain of less importance to this study, as self-perception of health is likely to form a crucial component of workforce exit timing (Cridland, 2016). Additionally, it is claimed that perceptions of health are often socially motivated, utilising a comparison against what the individual considers to be '*socially normal'* (Sen, 2002).

Perception of health is likely to form a crucial element in the belief of ability to continue working to a SPA, as well as the relevant retirement decision. This study opts to first use a self-reported measure of general health, rather than the projection of individual health conditions, as individual health conditions can impact individuals differently, dependent on a wide range of variables such as coping mechanisms, resources and strategies. Self-reported health measure combines a number of different health influences within a single measure. By doing this, it is hoped to provide a robust baseline measure from which to compare other conceptualisation of health.

Information on self-reported health is widely available and commonly collected on general health and longitudinal surveys alongside a number of other health covariates, making it attractive to this study. Self-reported health is additionally commonly used within similar microsimulation models. Within the UK, the SAGE model compressed self-reported health to a binary good/poor health variable for inclusion in the model (Scott, 2004). Additionally, the Swedish SESIM model utilised a four point self-report of a composite measure of health. Response categories utilised included full health, not full health, some illness and severe illness (Bolin *et al*, 2008). This provided a broader conceptualisation of health pertinent to the SESIM analysis, encompassing self-perceived health, mobility, longstanding illness and working capacity.

The inclusion of this question within surveys sometimes asks the individual to compare their health against others of the same age, but not always. However, this has the possibility of including a cultural and generational bias, which can result from common attitudes of pessimism or optimism amongst a cohort (Marmot & Wilkinson, 2001; Lindeboom & Kerkhofs, 2009). However, due to the individual level of this analysis and the impact that personal perception is likely to have in the economic activity decision, the impact of this issue is likely to be minimal to the study.

Figure 5.3 – ELSA Waves 4 and 5 – Self-Reported Health by Age



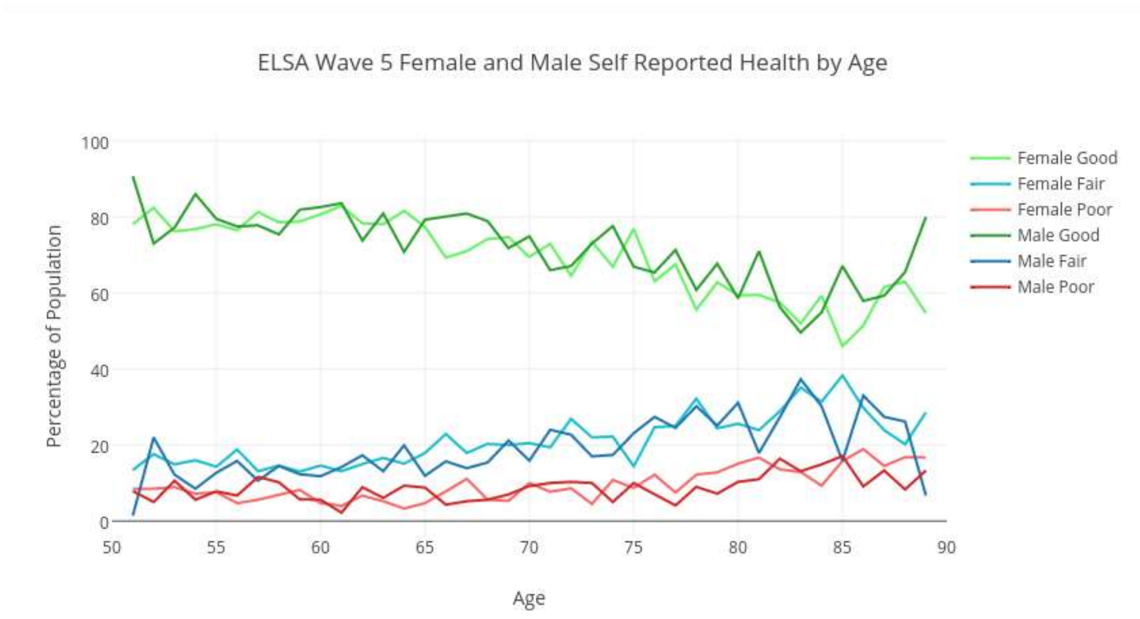
Source: Author's own analysis

Due to the categorical nature of self-rated health, individuals within the model will occupy one of three Likert-scale states, comprising 'Good', 'Fair' or 'Poor' health. This decision was made to maximise the data available to this study. This allowed simultaneous utilisation of both surveys using an 'excellent' through 'poor' health scale, as well as those reporting 'very good' through 'very poor' health. The pre-compression responses can be seen above in Figure 5.3. The extra categories of 'Excellent' 'Very Good' provide little further information to the study and so were compressed into the 'Good' category. As can be seen from the figure however, 'Fair' presents a significantly different response to 'Poor' at old ages. In particular, fair can be seen to increase at a steeper gradient from an earlier age. In addition, if these groups were combined into binary measure of good or poor health, a large amount of information would be lost regarding the nuance of declining health state. For this reason, the study opted to use a three-point measure, comprised of 'Good' 'Fair' and 'Poor' health. The modelling of this three-point scale will utilise a Multinomial Logistic Regression modelling procedure, as discussed later in Section 5.9. A predictive model will be built in order to specify the category probability of transitioning to each health state, given a range of socioeconomic characteristics, in line with the research questions set out in Section 1.3.

Figure 5.4 below shows the response of self-reported health by age in the English Longitudinal Study of Ageing wave 5 (2010/2011) dataset for males and females. As can be seen in the below figure, the proportion of individuals reporting ‘Good’ health declines as age increases. This decline is particularly pronounced following age 65 after which the proportion reporting good health declines rapidly. This decline in ‘Good’ health leads to a proportional increase in those experiencing ‘Fair’ or ‘Poor’ health as age increases. This increase in fair and poor health reporting around age 60 to 67 is critical to defining the impact of a change in SPA policy on one’s ability to work. If the true population experiences this trend, each year the SPA is delayed, more individuals are likely to experience fair or poor health before reaching their applicable SPA.

At older ages in particular, men appear to identify as having better self-reported health, with a slightly greater proportion reporting good health. Conversely, the number of female individuals reporting poor health at older ages is higher than that of male individuals following age 75. This discrepancy is likely to contextualise the impact that the change in SPA will have on individuals, thereby impacting the analysis. This adds to the justification of separating the models by gender, suggesting that males and females experience different health trajectories over life. It is worth noting that while wave 5 was selected due to data consistency considerations, Wave 5 is one of the later waves of the longitudinal ELSA dataset. Due to the long-range longitudinal nature of the ELSA dataset, the use of wave 5 will provide a somewhat biased sample due to survey attrition in early waves, particularly following wave 1 in which high sample attrition was experienced.

<u>Figure 5.4 - Male and Female Self Reported Health by Age in ELSA Wave 5</u>



Source: Authors own analysis of ELSA Wave 5

5.4.2 Lagged Health

As discussed previously in section 3.3, is claimed that due to short-term fluctuations in health, a single self-report of health is not likely to provide a reliable estimate of longer-term health status (Grant *et al,* 1995). For this reason, it was elected that the model should include an element of lagged-health from the previous model iteration. This effect was used both in the initial specification of the transition probabilities, as well as in subsequent model advancement through time. As would be expected, there was shown to be strong inter-temporal correlation between health state at time t-1 and health at time t (as can be seen in the later regression results detailed in section 5.9), assisting the strength of analyses. As suggested in Bolin *et al* (2008), this could be viewed as an incorrect way of introducing time-dependence to the health measure, as the health measures themselves remain an imperfect measure of true health state. However, in the absence of large-scale alternative health data, this was assessed as providing the best possible approximation of stability of the true health state of the individual. As data was collected longitudinally, the same perception of health should have been utilised by the individual at both reference points, providing coherence through time.

The decision to include a lagged health measure is likely to have an impact on the results of the study. Firstly, the inclusion of a lagged dependent variable includes an explicit and strong assumption into the model that health in time t+1 is highly correlated with health at time t. While it is logically consistent that the future health of an individual is related to past health, this may result in unrealistic stability in the overall trajectory of health through life. By explicitly linking past and future health, each individual becomes significantly less likely to experience health 'shocks' in which they may experience rapidly improving or worsening health. These health shocks are prevalent within the real world, but are likely to be under-represented in the model.

5.4.3 Health Transition Model II – Grip Strength

In order to assess the impact of alternative health measures on the outcome of this study, it was decided to re-run the model utilising an alternative measure. As discussed previously in Section 3.3, epidemiological studies have identified a link between hand grip-strength and a range of muscular strength and musculoskeletal disorders, as well as disability, morbidity and long-term survival (Dodds *et al*, 2014). Crucially for this study, hand-grip strength additionally serves as an important factor in frailty and thereby ability to continue in employment until a changing SPA (Fried *et al,* 2001; Clegg *et al,* 2013).

Measures of health capture different aspects of an individuals' well-being. While no single indicator can capture all elements of one's health, the measure used by an investigation is likely to be crucial in contextualising the results. The use of the primary self-reported health measure within this study was intended to give a baseline measure, encompassing physiological, psychological and social perceptions of health. The second measure utilising grip strength is intended to assess the discrepancy between an objective measure of grip-strength against a more subjective measure of self-reported health. This variation is critical in the assessment of policy implications, as objective ability to continue work does not always correlate to a self-perception of ability. Variation between these two measures is intended to highlight the impact that choice of health measure can have on the policy analysis enacted within this study.

Hand-grip strength data for the UK population is available from a number of studies, covering different age ranges and sub-populations. It was decided to maximise consistency between the two measurements of health through utilising the English Longitudinal Study of Ageing as the data source for both measures. As both measures are drawn from the same sub-population and in a lot of cases from the same individuals, it is possible to maximise the accuracy in the comparison of the two measures. The ELSA dataset provides grip-strength data as a result of a nurse-visit, which is provided on an alternate wave basis (ELSA, 2004). In order to maintain maximum consistency with the SRH measure, waves 2 and 4 of ELSA were selected to provide grip-strength data. Grip strength data was collected for both primary and secondary hands and comprised three measurements from each hand. This investigation opted to utilise a mean value of the individual's respective primary hand measurements. This approach was chosen in line with Haidar *et al* (2004), as it was found that the average of three attempts as a single value has test-retest reliability and provided high consistency (Shiratori *et al,* 2014).

It has been suggested that the main drawback of utilising grip strength as a measure of health, as well as a predictor of ill-health is the lack of consensus regarding a baseline or low level cut-off value (Kamarul, Admad & Loh, 2006). A wide range of suggestions have been put forward for this value, often varying by outcome characteristic of interest or task in question. Nalebuff (1984), as well as Rice, Leonard & Carter (1998) put forward a minimum grip strength of 9kg to facilitate most activities of daily living and occupational tasks. Kamarul, Admad & Loh, (2006) also note the difference of figures across geographical areas, suggesting that minimum figures may additionally be region-specific. A comparative example is a Taiwanese study of healthy volunteers that found the optimum cut-off level of 28.5kg for men and 18.5kg for women in order to perform a standard heavy task (Wang & Chen, 2010). Meanwhile, a Japanese study found a cut-off point of 17kg when screening for falls risk factors within a community-dwelling population (Shimada *et* al, 2009). Amongst the Finnish population, the grip-strength cut-off for increased likelihood for mobility limitation was 37kg for males and 21kg for women (Sallinen *et al*, 2010). An additional interaction between grip-strength and Body Mass Index (BMI) is often found, with higher grip-strength required for overweight individuals. Within the study by Sallinen *et al* (2010), this modified the cut-off point to 33kg for normal-weight male individuals but 39kg for overweight individuals and 40kg for those classed as obese. A number of individual characteristics such as age and gender (Sayer, 2010), height, co-morbidities (Cesari *et al*, 2006), cognitive function (Taekema *et al,* 2010) and nutritional status (Kerr *et al*, 2006) additionally influence the measurement and interpretation of grip-strength values. For these reasons, the establishment of a single grip-strength cut-off figure is challenging within the context of a microsimulation model with limited background and medical data.

For this reason, two different cut-off levels will be utilised within the modelling process. These will be the 9kg value suggested by Nalebuff (1984) and Rice, Leonard & Carter (1998) representing the minimum grip strength required to facilitate most activities of daily living and occupational tasks. Meanwhile, 30kg for males and 20kg for females will be utilised to serve to identify subjects with mobility limitations, as put forward by Lauretani *et al* (2003). The higher threshold value of 20/30kg is intended to identify moderate mobility limitation that may impede some forms of work, while the lower grip strength value of 9kg is intended to identify more acute limitation that may severely affect ability to remain in employment. These two thresholds will allow the modeller to assess the change in the proportion of individuals defined as encountering moderate or severe difficulty continuing in employment and the respective impact that choice of threshold has on the policy analysis of SPA change.

As grip strength data provides a continuous measure, there are a number of different ways that the data can be utilised modelled. These alternative approaches are likely to give different results, highlighting the importance of not just the measure used in the assessment of health, but also the manner in which it is used.

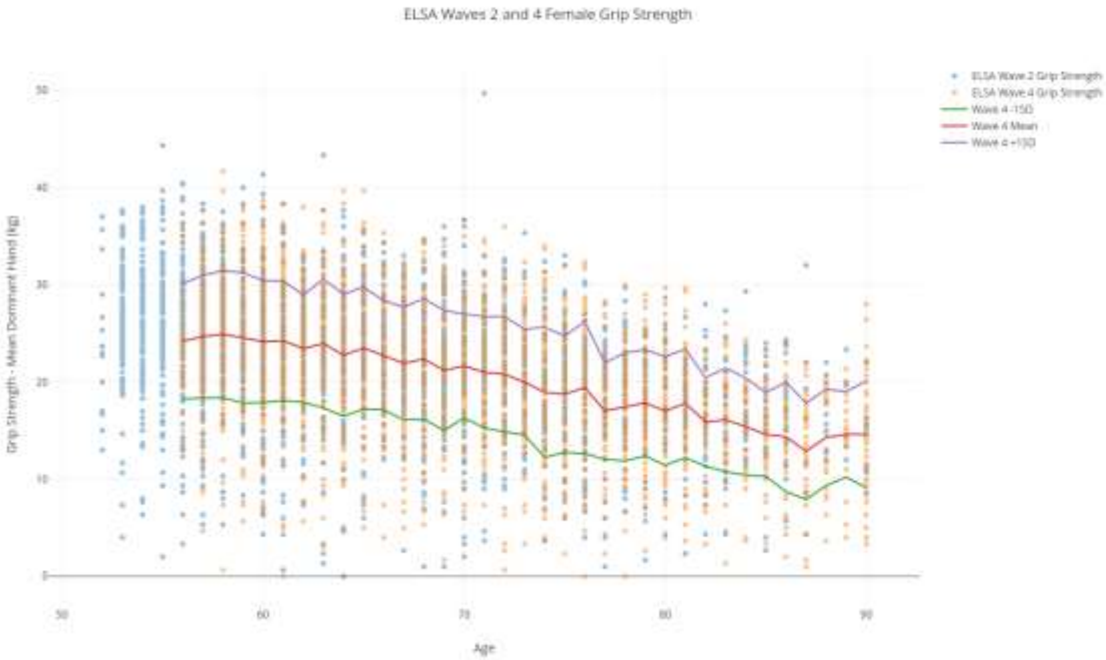
The first approach will utilise the ELSA grip strength data as a trajectory, applying this trajectory to the 2001 Census base data through a regression model, based on a common set of covariates. This will allow the trajectories of individuals to differ by covariates, however all individuals with the same set of covariates will deterministically follow the same trajectory. This initial method approximates the decline experienced throughout life, in line with frailty theory or the 'wear and tear' hypothesis (Rockwood, Hogan & MacKnight, 2000). This will approximate the gradual and constant decline which many individuals (but not all) experience throughout life. This will be undertaken in two stages, first applying a model of ELSA wave 2 data to the Census dataset in order to achieve an initial data-point. Secondly, the model will apply the wave 4 regression model, utilising the wave 2 data as a lagged variable of grip-strength. This is necessary due to the lack of grip strength data available within the Census base dataset and the improvement in regression model power when utilising a lagged health variable.

The second approach aims to introduce a stochastic element to the modelling of grip strength through re-coding of the health trajectory data into a categorical measure, based on standard deviations from the mean. Those with a GS greater than one standard deviation below the mean for their age group will be assigned into the 'low grip strength' category. Those with a GS greater than two standard deviations below the mean will be assigned to the 'very low grip strength' category. Similarly, those individuals with greater than one standard deviation above the mean will be assigned to the 'high grip strength' category. The remainder will be categorised as 'normal grip strength' (Sirven & Debrand, 2011). A logistic regression model to predict change in grip strength will then be specified according to the health trajectory dataset and projected onto the 2001 Census base data set utilising a Monte-Carlo approach.

Finally, the third approach categorises individuals into one of two states, 'normal grip strength' or 'low grip strength'. A defined minimum threshold can be set in line with literature and similar studies to define the point at which individuals fall into the 'low grip strength' category and therefore may have difficulty continuing in employment (as discussed further in section 5.4.3). Due to the lack of consensus within the literature, this level will be adjustable within the model to suit the needs and views of the modeller. This data will again be modelled utilising a logistic regression model and predicted onto the 2001 Census base data. A stochastic element will then be included through utilisation of a Monte-Carlo process.

The below Figure 5.5 shows grip strength trajectories for females within wave 2 and the linked data at wave 4 of ELSA. As can be seen in the figure, individuals experience a mean reduction in grip strength throughout later life. While the overall trajectory of the data is a reduction in grip strength, the spread of the data across the population is maintained throughout later life, reducing only slightly toward the oldest old. The comparison of this data with a reference dataset is shown below in Figure 5.5. The reference dataset used is the article published by Dodds *et al* (2014), exploring grip strength across life in the UK utilising twelve studies of grip strength in adulthood.

Figure 5.5 – Female Mean Dominant Hand Grip Strength by Age in ELSA Waves 2 and 4



Source: Author’s own analysis of ELSA Waves 2 and 4

5.5 Measures of Demographic and Socioeconomic Status

Taking into account the limitations discussed previously in section 3.2, the NS-SEC measure which reflects occupational social class, was selected for use in this study due to the availability and consistency across a number of different surveys, as well as the inclusion of crucial employment characteristics of note in this study. The following section sets out the measures of demographic and socioeconomic status used within this study.

5.5.1 Marital Status

Marital status has been reported by various studies to impact both health and mortality (Gove, 1973; Verbrugge, 1979; Hu & Goldman, 1990; Robards et al, 2012). Those who are married have consistently lower mortality rates than those who are unmarried, specifically within males (Joung et al, 1995). This is generally attributed to a combination of psychosocial factors and greater adherence to beneficial health behaviours of those within married couples (Belloc & Breslow, 1972; Umberson, 1992). Conversely, the negative impacts of health behaviours are seen particularly among those who are divorced or widowed (Verbrugge, 1979). Marital status is commonly associated with the social resources and coping strategies that have been suggested to allow mitigation of some health ill effects. The benefits of marriage have also been linked with increased longevity amongst elderly individuals (Goldman, Korenman & Weinstein, 1995). As such, marital status is likely to form a crucial link with the health status of the individual, as well as improving insight to the existence of support structures surrounding the individual.

The categories used within the analysis comprised:

1. Single or Never Married
2. Married or Civil Partnership
3. Separated or Divorced
4. Widowed or Surviving Partner

5.5.2 NS-SEC Group

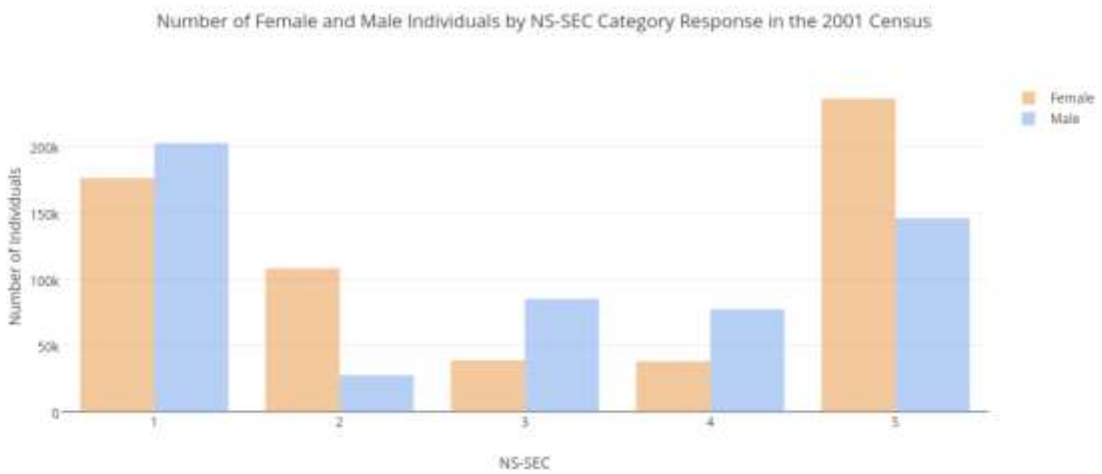
The analytic classifications of the 5-point NS-SEC measurement are as follows:

1. Managerial and Professional Occupations
2. Intermediate Occupations
3. Small Employers and Own Account Workers
4. Lower Supervisory and Technical Occupations
5. Semi-routine and Routine Occupations

As discussed in section 3.2, a number of variations of the NS-SEC measure are available. The decision to use a five-point measure was made as a compromise between data depth and sample size, allowing adequate depth of analysis while reducing the number of available states to facilitate analysis. The compression to a five-point measure was assessed to provide enough detail for analysis, while maintaining adequate sample size in all cells.

As can be seen in Figure 5.6 below, the socioeconomic sector proportions between males and females vary. Within the Census dataset, a greater number of females are involved in routine & semi-routine occupations, as well as intermediate occupations, whereas a greater number of males are involved in small employers/own account workers, lower supervisory/technical occupations and crucially higher managerial or professional occupations. This lends further justification for the splitting of male and female models.

Figure 5.6 – Female and Male Individuals by NS-SEC Category Response in the 2001 Census



Source: Author’s own analysis of 2001 UK Census for Females aged 30+

Notes: NS-SEC Labels: As above in Section 5.5.2

5.5.3 Housing Tenure

Historically, a strong link was found between inequalities in housing and inequalities in health (Dunn, 2002). It is proposed that those in poorest quality housing simultaneously experience the poorest health. It is debated whether the reasoning behind this association is causal, meaning that the poor quality housing is leading to poor health or a product of more general socioeconomic conditions, meaning that those in poor housing may also experience poor conditions in other aspects of life. The benefit of affluence and material resources is believed to improve health through the limitation of physiological and social stress through the life course (Macinko & Starfield, 2001). The ability to own housing is indicative of suitable resources over the long-term and as such serves as a good predictor of socio-economic status and health. While housing tenure does not provide a true representation of material resources or security, the inclusion of a housing tenure variable is an important element of overall wealth. This variable acts as a useful proxy for material resources and security.

The categories utilised within the analysis comprise:

1. Own Outright
2. Mortgage or Part Mortgage and Part Rent
3. Private Rented or Rent Free
4. Social Rented

It was selected to separate Private and Social rented accommodation in order to account for the socioeconomic status difference between the groups. Social Rented housing is intended to provide secure and affordable housing for those who are in most need or struggling with housing costs. Such facilities are often provided by County Councils or non-profit organisations (Shelter, 2016), and allocations in social rented property are often made based on a 'points system'. This system takes into account factors such as time on the waiting list, level of need and other priorities. Those who are granted social rented accommodation within a climate of scarce social housing are often those in most need. This justified the decision to separate the experience of this group from the rest of the 'Private Rented' category.

While the experience of 'Rent-Free' dwellers may arguably be somewhat different to that of the rest of the 'Private Rented' category, it was selected to combine these two groups. The cell count within the census data of those living rent-free was too small to build a category of their own. However, not enough information is available as to the situation of those living rent-free. While it is possible that being categorised as living rent-free may imply a lower socioeconomic status, the reasoning behind living rent-free may happen for a number of reasons. Private renting is a large and diverse category and therefore the allocation of the small rent-free group will not significantly alter the characteristics of the group.

5.5.4 Highest Educational Qualification

The respondents' highest educational qualification was selected to consider the impact of changes in education on health. Education forms an important single measure that can allow stratification of socio-economic position, as well as having an independent impact on health (Graham, 2007). The benefit on health of greater educational attainment and contrasting detriment to those with low educational attainment is well noted (Feldman *et al*, 1989; Guralnik *et al,* 1993; Ross & Wu, 1995). Ross and Wu (1995) suggest that the positive relationship between education and health works in three ways. Firstly, improved conditions of work and economic security are facilitated by higher education. Secondly, the social-psychological benefits that come with the greater sense of control following higher education and greater autonomy are said to benefit health. Finally, greater adherence to positive health behaviours are found to link with higher educational attainment. The direction of influence between health and education or socioeconomic status is however debated (Anderson & Armstead, 1995; Kaplan, 1995). What appears clear is that multiple indicators of health can be impacted by socioeconomic status through multiple pathways (Kubzansky *et al,* 1998). The education measure selected was the highest qualification achieved at the time of survey. Due to the selected age range of 30 years and over, stabilisation of educational attainment and the impact on health and living standards is likely to have been achieved.

The classifications of educational attainment used within the model comprised:

1. Degree or Higher
2. Below Degree / A Level
3. O Level / NVQ1
4. Foreign Qualification
5. No Qualification

5.6 Data Considerations

Dynamic microsimulation models follow individuals over life. Due to this, ideal data to inform the microsimulation model would be longitudinal in nature. However, longitudinal studies are expensive to conduct, often resulting in limited scope. Longitudinal studies therefore rarely provide all the variables needed for a microsimulation model. The data needed to construct this model will include:

1. A representative base data sample including necessary socioeconomic status and health variables, sufficient in size to allow disaggregation of the sample by a number of covariates. These covariates will focus on demographic variables and measures of socioeconomic status, including

age, gender, highest educational attainment, housing tenure, marital status and NS-SEC socioeconomic group.

2. Longitudinal health data, comprising the same indicators as available in the base data, from which to specify health transitions.
3. Mortality data by single year of age.

Data sources considered for utilisation were those available through the UK Data Service, comprising the Census Individual Sample of Anonymised Records (I-SAR), Labour Force Survey (LFS), English Longitudinal Study of Ageing (ELSA) and Health Survey for England (HSE). The UK Data Service is a platform provided by the Economic and Social Research Council (ESRC) that provides access to a wide range of official surveys, international microdata and survey data for the purposes of research.

Two data sources were found to be suitable in size and scope to fulfil the needs of the base population, the Census I-SAR and the Labour Force Survey. The Census Individual Sample of Anonymised Records (I-SAR) of 2001 and 2011 was first investigated for its suitability for this investigation. While the full census sample is not readily available to users, a 3% sample of these records is provided to registered users, reflecting the trends apparent in the full population. These large, nationally representative datasets have a number of benefits for this study. Due to the census objective of a full account of individuals within the country on census date, data is consistent with limited missing data within the sample. Additionally, the large sample size of approximately 2.8 million individuals allows disaggregation by a number of variables, with sub-populations remaining sufficiently large for meaningful analysis. The census additionally provides a selection of demographic and socioeconomic variables such as age, gender and marital status, as well as socioeconomic variables. Critically for this study, the census data includes a self-reported health variable. This self-reported health variable is not consistent between the base and verification years of 2001 and 2011 respectively. To solve this issue, a three-point Likert scale of health will be utilised, as was discussed in Section 5.4.1.

The Labour Force Survey was additionally considered to form the base data, due to inclusion of a wider range of demographic and socioeconomic variables than available in the census sample. However, limited health information was available and the sample size was comparably small. It was judged that the imputation of less influential variables to the base data was to be preferable than imputation of the primary health outcome to the base sample. Due to this combination of sample size, consistency and representativeness, the Census I-SAR was selected as the most appropriate to form the base data of this study.

When considering the specification of health trajectories, two datasets were put forward. The Health Survey for England was considered due to the representative nature of the sample and inclusion of self-reported health, as well as a number of demographic and socioeconomic variables, in line with the census base data. While this source has three available waves, spanning twenty years, the cross-sectional nature of the data would require a pseudo-cohort approach, limiting the input of a lagged-health status variable. Additionally, as this survey covers the whole working population, the number of respondents of older ages was limited in size, leading to poor model prediction at the older ages critical to this study.

The second dataset considered was the English Longitudinal Study of Ageing (ELSA). ELSA is a representative longitudinal sample of individuals aged over 50 in England, covering six waves from 2002 to 2012. The survey is designed to investigate a wide range of ageing-related topics, such as health trajectories throughout later life, the interaction between health, disability, economics and social participation and networks (Scholes *et al*, 2009). Due to the multidisciplinary nature of the dataset, a wide range of health and socioeconomic variables are included, forming a key dataset for the examination of the inter-relationship of variables. This dataset includes key variables of importance to this study, including a wide range of socioeconomic position variables and resources, as well as self-reported health and hand-grip strength. The original wave 1 sample of ELSA was drawn from households that had previously responded to the Health Survey for England in 1998, 1999 and 2001 (Scholes *et al*, 2009). This sample included those partners who had joined the household since the initial HSE interview. During the fieldwork period of March 2002 to March 2003, 11,391 age-eligible sample members were taken, forming wave 1. These same individuals were again approached two years later between 2004-2005, going on to form wave 2. Wave 2 consisted of 9,433 main interviews being conducted, of which 8,781 continued from wave 1, representing 93% of the sample. The remaining 7% (652) of the sample consisted of partners. Additionally, at wave 2 nurse data was collected, providing more in depth health variables. This nurse visit was then undertaken every other wave, constituting waves 2, 4 and 6 (Banks *et al*, 2017).

One drawback identified for the ELSA dataset is the variability of measures used between waves of the survey. Self-reported health in the survey alternates between Likert scales ranging from very good to very poor, to those ranging between excellent through poor. Waves 1 and 3 used the measure of very good to very poor, waves 1, 2, 4, 5 and 6 used excellent through poor.

It was decided to utilise ELSA waves 2, 4 and 5 and combine self-reported health into a three point Likert scale measure. This compromise reduces the level of detail in the initial health measurement, reducing the specificity of the subsequent analysis. However, this approach significantly improves the robustness and consistency of the data used in the estimation. Additionally, this combines the small category of very poor health, for which the model predicted poorly into a more general poor health measure.

Waves 4 and 5 of ELSA were used to derive self-reported health transition probabilities and waves 2 and 4 were used grip-strength transition probabilities. This selection was made due to waves 4 and 5 both using the excellent through poor self-reported health scale, while grip strength data is provided on an even alternate wave basis. When self-reported health was subsequently combined into the three point measure, this provided consistency in the measure between base and lagged health sample, minimising the introduction of additional error.

As the ELSA data covers only individuals aged 50 and above, this was determined to be suitable for the study as these are the ages most critical when assessing the interaction between health and SPA. For this reason, while the model population will include those aged 30 and above, the model will only consider health transitions for those aged 50 and above. This additionally holds the benefit of allowing stabilisation in critical variables such as highest educational attainment, housing tenure and NS-SEC social group within the population. The sample size of those identifiable at the selected waves of 4 and 5 give a sample size of 4,524 males and 5,571 females, totalling a population of 10,095. The full details of the wave respondent numbers for self reported health are detailed in table 5.7 below.

Table 5.7 - Self-Rated Health Response by ELSA Wave Proportions

Self-Rated Health by ELSA Wave

			Wave Number						
			Wave 1	Wave 2	Wave 3	Wave 4	Wave 5	Wave 6	Total
Self-Rated Health	Good	Count	2416	6712	6536	7820	7175	7260	37919
		% within Wave	41.0%	72.2%	68.6%	73.8%	73.8%	72.8%	68.9%
	Fair	Count	1771	1877	2331	1994	1792	1919	11684
		% within Wave	30.0%	20.2%	24.5%	18.8%	18.4%	19.2%	21.2%
	Poor	Count	1711	706	666	781	757	800	5421
		% within Wave	29.0%	7.6%	7.0%	7.4%	7.8%	8.0%	9.9%
Total		Count	5898	9295	9533	10595	9724	9979	55024
		% within Wave	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Author's own analysis of ELSA data waves 1-6.

Notes:

- Self-reported health categories have been combined into a three point Likert scale to allow comparibility between waves.
- These figures use unweighted ELSA data
- Waves 2, 4 and 5 were used in the final analysis

Waves 4 and 5 were found to have adequate consistency in response between the waves, as well as limited between-wave attrition, with conditional response rates relative to previous wave of 74% in wave 4 and 78% in wave 5 (Steptoe *et al*, 2012). It must be noted however that as with many other studies, the attrition of individuals between waves is socio-economically graded. Those in the less-affluent quintiles of the sample are significantly more likely to fall out of the sample than those in the highest. Those remaining in the wave 5 sample having first entered at wave 1 represent 74% of the sample for highest quintile, compared to 56.5% of the lowest quintile remaining (Steptoe *et al*, 2012). Attempts have been made to account for this attrition through the use of cross-sectional and longitudinal weights to adjust for differential non-response. Weights are used to account for differential non-response and sampling strategy by allowing us to reconfigure the sample as if it were a simple random draw from the total population. These are particularly important when comparing longitudinal surveys, as the response rate, profile and sample attrition is likely to vary between years.

5.7 Data Preparation for Input to Model

The choice of data used within the microsimulation is important as this forms the base of the outputs the model will generate. The modeller should aim to use data that is as rich in detail as possible, while attempting to maintain a representative sample of the target population. While the best available datasets were used to form the base and transition samples used within this study, a number of compromises and data manipulations were required to achieve the desired input to the model. This section will describe the choice of data sources, as well as the modifications made to the sample before inclusion in the model.

5.7.1 Census Data

The census data provided a base sample of individuals within the year 2001. The required variables consisted of demographic variables, socioeconomic variables and contextual variables to facilitate further analysis. While the census provides an almost full sample, some modifications were required to achieve a full dataset that could be used by the microsimulation model.

Missing data was found within the Age and NS-SEC variables. First, the Age variable will be discussed. Within the Age variable, the data available was continuous for ages 0-16, however the variable grouped categorical age from ages 16-74. The data then returns to being continuous for ages 75-94, before condensing all individuals aged 95 and over into one 95+ category. As the model only utilises those aged 30 and above, these are the only ages of concern to the model.

In order to provide consistent data for input to the microsimulation model, the age data required manipulation. The decision was made to re-allocate single years of age within the categorical brackets, in line with the aggregate population data by single year of age from the 2001 census. To do this, population level data by single year of age for males and females was obtained from the ONS (2002). Data was then converted into proportions and subsequently cumulative percentages within the age bracket. Pseudo-random numbers were generated between 0-100 from a uniform distribution and used to allocate individuals within their age bracket.

Additionally, those who in the base sample had continuous ages above aged 75 were condensed into categorical age groups and re-allocated using the same procedure. The decision was taken in order to maintain consistency of error across the sample, as well as ensuring that accurate proportions of individuals were present in the model, consistent with the aggregate totals from the census. Such an approach will necessarily introduce error into the base sample through the incorrect allocation of ages within the brackets. This will impact on the link between age and initial health state within the population. However, this impact of this was deemed to be minimal for two reasons, first due to this constituting only the initial health state, with transitions specified by an external dataset consisting of continuous age. Secondly, the age bracket size was smaller at older ages that are the most at risk of health states below 'Good'. This results in a minimised error to within 5 years accuracy within this group. The full specification of this re-allocation is provided in Appendix A.

The second variable that required manipulation was the NS-SEC social group variable. In order to ensure consistency with the ELSA data, as well as ensuring adequate size for disaggregation within each sub-group, the NS-SEC measure was compressed from an initial twelve-point measure, to a five-point measure. This was done as follows:

Table 5.8 - NS-SEC Recoding

NS-SEC 8	Code	New Classification	Code
Higher Managerial and Professional Occupations	1	Managerial and Professional Occupations	1
Lower Managerial and Professional Occupations	2		
Intermediate Occupations	3	Intermediate Occupations	2
Small Employers and Own Account Workers	4	Small Employers and Own Account Workers	3
Lower Supervisory and Technical Occupations	5	Lower Supervisory and Technical Occupations	4
Semi-Routine Occupations	6	Semi-Routine and Routine Occupations	5
Routine Occupations	7		
Never Worked & Long-Term Unemployed	8		
Other	9		

Additionally to the compression of the above categories, the decision was made to impute the values of those previously categorised as (8) Never Worked & Long-Term Unemployed and (9) Other. This was done for a number of reasons, those reporting 'Other' provided no additional information as to the reason for this classification. Similarly, those within the Never Worked & Long-Term Unemployed group represented a very small proportion of the population, comprising 1.4% and 0.8% of the population respectively. As this group was not significantly relevant to the research questions and the data required a full working population at baseline, it was elected to re-classify this data as missing and multiply impute this population within the 5 point NS-SEC classification. For the imputation, the predictors of Health, Marital Status, Highest Educational Qualification and Housing Tenure were used and run for 10 iterations.

5.7.2 ELSA Data

The second dataset used was the 2nd, 4th and 5th waves of ELSA. Waves 2 and 4 were used for hand-grip strength data, as this is only available on alternate waves and waves 4 and 5 were used for self-reported health. Wave 3 uses the 'excellent' through 'poor' Likert scale for self reported health and was therefore not selected to maintain consistency between measures (discussed earlier in section 5.6). This population was used to specify the health transitions based on Self-Reported Health and Hand-Grip Strength. Again, a number of modifications were required in order to achieve a suitable input population to the model.

First, data linkage was utilised on the unique ID number of the individual to link the wave 2 health data to wave 4 and separately wave 4 with the wave 5 data. Socioeconomic variables were taken from waves 4 and 5 respectively, as this provided the starting year of the model. While the data from wave 5 for the base scenario was collected between June 2010 and June 2011, it was necessary to use these figures to represent health transitions from the start of the model run in 2001. The model run from 2001 to 2011 is intended to serve as an alignment period, ensuring that projected transitions match observed transitions. Using data from 2010/2011 was intended to give the most accurate representation of health transitions following the alignment period and into the future, when the impact of the change in SPA policy can be best assessed. The final sample size used from ELSA for Self-Reported Health was 5,710 for Females and 4,524 for Males. Similarly, the final sample size for Hand-Grip Strength was 2,882 for Females and 2,278 for Males.

The choice of ELSA waves was a compromise made in line with data issues within earlier waves and variability of measurement between waves. Waves 2 and 4 represented the closest time period to the census base data available for grip strength data. This will have opened the model up to possible error if population health trends were to differ significantly between 2001 and 2010-11. However, alignment of the model with 2011 census data (as discussed later in Section 5.1) will assist in minimising this impact. Waves 4 and 5 of ELSA both utilised the five-point Likert scale of 'Excellent' through 'Poor', whereas other waves used 'Very Good' through 'Very Poor', or a combination of the two scales. This data was then compressed to a three-point Likert measure from 'Good' to 'Poor' to allow comparability with the Census 2001 base data. In order to maintain consistency in the measurement of the key measure, self-reported health, it was elected to use the earliest wave in which two waves used the same measurement scale. This led to the utilisation of wave 5 for the SRH trajectory, with the use of a lagged health state from wave 4. It is possible that taking this decision may impact theoretical population health changes over time, however, the impact of this will be minimised within the study through the use of alignment of the health transition data to match aggregate totals published in 2011 (as discussed later in Section 5.12). This will provide a basis for further alignment throughout the remainder of the model run.

The model uses multiple measures of socioeconomic status within the specification of health transitions. These each capture a slightly different element of socioeconomic position, however several of the covariates refer to the same primary effect. This is likely to impact the analysis through introducing the possibility of overfitting and reducing the explanatory power of the covariates used.

To reduce the number of possible cells within the model, a number of variable response categories were compressed. The specifications of the compressions undertaken are outlined below:

<u>Table 5.9 - Highest Educational Attainment Recoding</u>

<table>
<tr><th>Highest Educational Qualification</th><th>Code</th><th>New Classification</th><th>Code</th></tr>
<tr><td>Degree</td><td>1</td><td>Degree or Higher</td><td>1</td></tr>
<tr><td>Below Degree</td><td>2</td><td rowspan="2">Below Degree/A-Level</td><td rowspan="2">2</td></tr>
<tr><td>A Level</td><td>3</td></tr>
<tr><td>O Level</td><td>4</td><td rowspan="2">O Level/NVQ1</td><td rowspan="2">3</td></tr>
<tr><td>NVQ1</td><td>5</td></tr>
<tr><td>Foreign Qualifications</td><td>6</td><td>Foreign Qualifications</td><td>4</td></tr>
<tr><td>No Qualifications</td><td>7</td><td>No Qualifications</td><td>5</td></tr>
</table>

Table 5.10 – Housing Tenure Recoding

Housing Tenure	Code	New Classification	Code
Owner Occupied	1	Owner Occupied	1
Mortgage	2	Mortgage/Part Rent and Part Mortgage	2
Part Rent/Part Mortgage	3		
Private Rented	4	Rented - Private/Rent Free	3
Living Rent-Free	5	Rented - Social	4
Squatting	6		

The Housing Tenure variable required additional manipulation. Through utilisation of the "Who is your Landlord?" question within ELSA, it was possible to divide up the 'Private Rented' (4) category into those renting from a private individual and those renting from the state or housing association. Additionally, no individuals within the sample were classified as squatting, so this category was removed from the analysis.

Table 5.11 - Marital Status Recoding

Marital Status	Code	New Classification	Code
Single	1	Single	1
Married	2	Married/Civil Partnership	2
Legally Recognised Civil Partnership	3		
Re-Married, Second or Later Marriage	4		
Spontaneous - Civil Partner and Has Been Married	11		
Legally Separated	5	Separated/Divorced	3
Divorced	6		
Separated from Civil Partner	8		
Former Civil Partner	9		
Widowed	7	Widowed/Surviving Partner	4
Surviving Civil Partner	10		

5.8 Assumptions in Stage 1

After establishing a flexible model that is able to undertake the required analyses accurately and answer the desired research questions, scenario-based analyses can begin. A number of assumptions are required from the modeller at each stage so that the model accurately expresses the scenario under exploration. This section will discuss the assumptions utilised within the first and simplest iterations of the model. This will establish what the model is able to undertake and describe the most theoretically simple expression of the model.

5.8.1 Retirement Age

For the first run of the model, SPA will represent the current legislation in place at the time of undertaking for SPA (see Section 1.1 and table 5.12 below). This will establish a scenario that the population is most likely to experience given no additional inputs or modification. The first iteration of the model will form baseline figures against which to assess alternative SPA assumptions.

Table 5.12 - Increase in State Pension age from 66 to 67, men and women

Date of birth	Date State Pension age reached
6 April 1960 – 5 May 1960	66 years and 1 month
6 May 1960 – 5 June 1960	66 years and 2 months
6 June 1960 – 5 July 1960	66 years and 3 months
6 July 1960 – 5 August 1960	66 years and 4 months (1)
6 August 1960 – 5 September 1960	66 years and 5 months
6 September 1960 – 5 October 1960	66 years and 6 months
6 October 1960 – 5 November 1960	66 years and 7 months
6 November 1960 – 5 December 1960	66 years and 8 months
6 December 1960 – 5 January 1961	66 years and 9 months (2)
6 January 1961 – 5 February 1961	66 years and 10 months (3)
6 February 1961 – 5 March 1961	66 years and 11 months
6 March 1961 – 5 April 1977	67

Source: Department for Work and Pensions (2013b).

Due to the annual time period utilised (as discussed in section 4.6), the model is limited in the degree of precision available in expressing SPA assumptions. As the model iterates on an annual basis, no further degree of precision is available to the modeller within this. For this reason, where a change in SPA takes place, a degree of resultant error will be included where such a change does not take place at the end or beginning of a calendar year.

Additionally, no further information was included in the base dataset regarding the individuals' exact date of birth, as only the year of birth was available. For these reasons, it was opted to compress all SPA changes and ages of eligibility to a nearest calendar year basis. This is likely to introduce some error when compared to the true population, however it should not affect the primary investigation of this study, which is the comparison of alternative SPA scenarios. The assumption used within the first male scenario of the model is as follows:

Table 5.13 - Male Retirement Age Assumption

Birth Year	Retirement Age
1900 - 1953	65
1954- 1960	66
1961-1977	67
1978-	68

The retirement age assumption differs for the Female model. Due to the equalisation of Female SPA with Male SPA from age 60 to 65 between April 2016 and November 2018 (see Section 1.1), it was necessary to create a separate assumption for Female SPA, as is detailed in table 5.14 below:

Table 5.14 - Female Retirement Age Assumption

Birth Year	Retirement Year	Actual Date
1900-1950	Birth year + 60	
1951	2012	Sept/2011 - Sept/2013
1952	2014	Sept/2013 - Sept/2015
1953	2017	Sept/2015 - Mar/2019
1954	2020	Mar/2019 - Sept /2020
1955-1960	Birth year + 66	
1960	2026	
1961 - 1976	Birth year + 67	
1977	2045	May/2044 - Sept/2045
1978	2046	Sept/2045 - May/2046
1979	Birth year + 68	

As can be seen from Table 5.14, the timing of female retirement is somewhat more complex than for males. For a female born in 1951 the date of retirement may vary anywhere between September 2011 and September 2013, dependent on birth date within the year. Some compromises were required in order to fit this data to the confines of the model. As can be seen from the table above, a median value was taken in order to give a retirement date that is correct for the largest possible proportion of individuals within the birth year.

5.8.2 Health Transitions

Within the model constructed in this study, health transitions will be initially based upon Self-Reported Health. Transitions will be specified based on the detailed longitudinal ELSA dataset. The covariates used within the model will include age, marital status, NS-SEC social group, highest educational attainment, housing tenure and lagged health status from ELSA wave 4. While the modelling will focus on those individuals of age 30 and above, results regarding health will only be considered for those aged 50 and above, in line with available health data. This will allow the stabilisation in a number of critical variables, as well as simplifying the modelling procedure from a full population. Initial placement of individual health states will be taken from the Census base dataset. Following this initial placement, transition probabilities will then be specified for transitions between states for subsequent iterations.

5.8.3 Mortality Timing

For the first and most simple run of the model, data from the ONS mortality data will be utilised covering relevant mortality rates by single year of age from 2001. This will provide accurate data leading up to the 2011 verification year. From here, the ONS prime projection of mortality rates into the future will be utilised. These rates were chosen to produce the most conceptually coherent scenario of mortality rates during the base scenario. Those who are defined to have died within the model will have year of death recorded and will be removed from the model. It must be noted here that as mortality rates into the future remain unknown, the model assumptions and subsequent results form only plausible scenarios of future trends. This will require careful analysis subsequent to the observed data from 2011 onwards to ensure correct model operation.

5.8.4 Feedback Between Employment and Health

The literature review contained in section 1.2.2 concluded that no single direction of influence could be found in the interaction between employment and health throughout the population. For this reason, the study opted to include a number of possible feedback effects between employment and health, assessing how the outcome varies, depending on assumption used. The first run of the model will assume no additional effects of economic activity, premature inactivity or retirement on the health of individuals. For further runs, the model facilitates both positive and negative assumptions of how employment, premature inactivity and retirement may affect an individual's health. Additionally, such effects can be specified by NS-SEC social group, allowing scenarios in which those in higher NS-SEC groups may benefit more from continued employment than those in lower groups, or vice versa.

5.8.5 Economic Activity States

Three economic activity states are available within the model are allowed. These are 1: Economically Active, 2: Retired, 3: Prematurely Inactive. Initially, all those who are defined as being 'of working age', which indicates being under SPA will be classified as 'Economically Active'. When an individual is below their SPA but health falls into the 'Poor' health category, this individual will be re-classified as 'Prematurely Inactive'. This category describes the state in which the individual is of working age, but may experience difficulty continuing in employment. This characterisation was made to assess the degree to which individuals may find themselves either experiencing difficulty or unable to continue working, while still being under the defined SPA. Once an individual has aged past the specified SPA, they will then be re-classified as 'retired'. As the primary topic of investigation is physical ability to remain in the workforce across society, it was decided that all individuals over SPA and therefore able to retire should be classified as retired.

5.9 Specification of Health Transition Probabilities – Self-Reported Health

Following the selection of socioeconomic status indicators for modelling, it was necessary to establish which measures were best able to explain the variation in health across different groups of the population. To do this, regression techniques were applied to the individual-level English Longitudinal Study of Ageing data. The aim of this modelling was to establish the importance of various socioeconomic status variables on individual level health. This modelling focused on those aged 50 and older, as this is the representative population available within ELSA.

A Multinomial Logistic Regression model was selected to characterise the health trajectories of male and female individuals within the study. This model type was chosen above a number of alternative methods. Firstly, this study opted to use an empirical base and health trajectory dataset with an outcome variable and a number of covariates. Due to the categorical nature of the primary self-reported health measure with more than two levels, a binary model was precluded. Due to the ordinal nature of the self-reported health variable, an Ordinal Regression model was also considered. This model type was not selected however as this assumes proportional odds, assuming that the distance between the categories is equal, which cannot be stated for a self-reported health measure. Additionally, the narrowing of variables through a stepwise multinomial regression was beneficial to the study, again precluding the use of an ordinal regression model. These assumptions are not required however when utilising a Multinomial Logistic Regression, lending this to be chosen for the analysis. Additionally a Multinomial Probit model was considered as an alternative to a logistic model, but was rejected due to the computational intensity of a probit model. Within the microsimulation model set out here, regression models are used to project the health of all modelled individuals for each year of the model run. A probit model was trialled but deemed too computationally intensive to facilitate analysis.

A series of Multinomial Logistic Regression analyses were undertaken to establish which variables provided suitable statistical significance when explaining variations in health across the population. A reverse stepwise procedure was utilised within the modelling to narrow down the range of potentially significant variables selected from the literature. This involved addition of all available variables to the model and subsequently removing variables at each step until a suitable selection of variables were accrued. The modelling process identified a number of discrepancies between expected relationships drawn from literature and those identified within the data. The final selection of variables utilised was based on a combination of the two elements, drawing from the modelling procedure, but also from the literature. Due to the use of a logistic regression model, the 'goodness of fit' was assessed through use of a number of different measures, building a picture of significance. This included: classification tables, -2 log likelihood (-2LL) values, statistical significance of variables and to some extent the Pseudo R-square values. The choice of last reference category was taken for conceptual simplicity when interpreting the results. While both first and last reference categories were trialled in order to assess variability in standard error and confidence interval width, no significant difference was found.

The final model included the variables:

- Lagged Health from Previous Wave
- Age
- Highest Educational Qualification
- Marital Status
- NS-SEC Social Group
- Housing Tenure

Additionally, in line with observed variations in data, as well as previously identified difference in health and SPA experience, separate models were specified for males and females. As categorical variables were used in the analysis, *k-1* dummy variables were set up and reference categories chosen. In this analysis, the lowest value of a categorical variable was chosen as the reference category. This was done to aid interpretation, giving the amount of benefit in health of each higher level of covariate. The overall reference category for the models was ‘good health

The results from the regression analyses are as follows:

Figure 5.15 – Multinomial Logistic Regression Results - Female Model, ELSA Wave 5

Pseudo R-Square	
Cox and Snell	0.326
Nagelkerke	0.42
McFadden	0.263

Parameter Estimates
Sample Size: 5,710

Wave 5 Female Self-reported Health		**B**	**Sig.**	**Exp(B)**	**95% Confidence Interval for Exp(B)**	
					Lower Bound	**Upper Bound**
Fair	Intercept	0.014	0.917			
	Age	0.021	0.000	1.021	1.019	1.024
	Marital Status					
	Single / Never Married	0.151	0.013	1.163	1.033	1.311
	Married/Civil Partnership	-0.185	0.000	0.831	0.777	0.888
	Separated / Divorced	-0.024	0.592	0.976	0.892	1.067
	Widowed / Surviving Partner	Reference				
	Highest Educational Qualification					
	Degree or Higher	-0.318	0.000	0.728	0.674	0.786
	Below Degree / A Level	-0.146	0.000	0.864	0.805	0.927
	O Level/NVQ1	-0.087	0.014	0.916	0.855	0.982
	Foreign Qualification	-0.134	0.010	0.875	0.790	0.968
	No Qualifications	Reference				
	NS-SEC					
	Managerial /Professional	-0.505	0.000	0.603	0.566	0.643
	Intermediate Occupations	-0.369	0.000	0.692	0.646	0.740
	Small Employers / Own Account Workers	-0.234	0.000	0.791	0.721	0.869
	Lower Supervisory / Technical	-0.02	0.690	0.98	0.887	1.083
	Semi-Routine / Routine	Reference				
	Housing Tenure					
	Outright Ownership	0.033	0.414	1.034	0.955	1.119
	Mortgage & Part Mortgage / Rent	0.147	0.002	1.159	1.056	1.272
	Private Rented / Rent Free	0.215	0.003	1.24	1.078	1.425
	Social Rented	Reference				
	Lagged Health State					
	Good Health	-3.122	0.000	0.044	0.039	0.050
	Fair Health	-0.811	0.000	0.445	0.391	0.505
	Poor Health	Reference				
Poor	Intercept	0.573	0.003			
	Age	0.025	0.000	1.025	1.020	1.029
	Marital Status					
	Single / Never Married	0.334	0.000	1.396	1.164	1.674
	Married/Civil Partnership	-0.289	0.000	0.749	0.675	0.831
	Separated / Divorced	0.038	0.575	1.039	0.909	1.188
	Widowed / Surviving Partner	Reference				

Highest Educational Qualification					
Degree or Higher	-0.054	0.375	0.947	0.841	1.068
Below Degree / A Level	-0.054	0.350	0.948	0.846	1.061
O Level/NVQ1	-0.035	0.546	0.966	0.863	1.081
Foreign Qualification	-0.469	0.000	0.626	0.525	0.746
No Qualifications	Reference				
NS-SEC					
Managerial /Professional	-0.699	0.000	0.497	0.447	0.553
Intermediate Occupations	-0.268	0.000	0.765	0.689	0.850
Small Employers / Own Account Workers	-0.339	0.000	0.713	0.607	0.836
Lower Supervisory / Technical	-0.251	0.002	0.778	0.665	0.911
Semi-Routine / Routine	Reference				
Housing Tenure					
Outright Ownership	-0.039	0.543	0.962	0.850	1.090
Mortgage & Part Mortgage / Rent	-0.197	0.010	0.821	0.707	0.953
Private Rented / Rent Free	-0.059	0.621	0.943	0.747	1.191
Social Rented	Reference				
Lagged Health State					
Good Health	-5.625	0.000	0.004	0.003	0.004
Fair Health	-2.672	0.000	0.069	0.061	0.079
Poor Health	Reference				

Notes: The reference category is: Good Health.

Source: Authors own analysis of ELSA wave 4 and 5 data.

Figure 5.16 - Multinomial Logistic Regression Results - Male Model, ELSA Wave 5

Pseudo R-Square	
Cox and Snell	0.312
Nagelkerke	0.406
McFadden	0.255

Parameter Estimates Sample Size: 4,524					
Wave 5 Male Self-reported Health		**B**	**Sig.**	**Exp(B)**	**95% Confidence Interval for Exp(B)**
					Lower Bound
Fair	Intercept	-0.553	0.000		
	Age	0.031	0.000	1.031	1.028
	Marital Status				
	Single / Never Married	-0.060	0.424	0.941	0.812
	Married/Civil Partnership	-0.153	0.003	0.858	0.777
	Separated / Divorced	0.218	0.001	1.243	1.091
	Widowed / Surviving Partner	Reference			
	Highest Educational Qualification				
	Degree or Higher	-0.236	0.000	0.789	0.723
	Below Degree / A Level	-0.241	0.000	0.786	0.724
	O Level/NVQ1	-0.244	0.000	0.784	0.723
	Foreign Qualification	-0.055	0.366	0.947	0.841
	No Qualifications	Reference			
	NS-SEC				
	Managerial /Professional	-0.514	0.000	0.598	0.556
	Intermediate Occupations	-0.169	0.013	0.845	0.739
	Small Employers / Own Account Workers	-0.037	0.403	0.963	0.882
	Lower Supervisory / Technical	-0.016	0.721	0.984	0.901
	Semi-Routine / Routine	Reference			
	Housing Tenure				
	Outright Ownership	-0.021	0.648	0.979	0.896
	Mortgage & Part Mortgage / Rent	-0.136	0.013	0.873	0.785
	Private Rented / Rent Free	-0.003	0.973	0.997	0.847
	Social Rented	Reference			
	Lagged Health State				
	Good Health	-3.274	0.000	0.038	0.034
	Fair Health	-0.879	0.000	0.415	0.366
	Poor Health	Reference			
Poor	Intercept	0.521	0.015		
	Age	0.022	0.000	1.022	1.017
	Marital Status				
	Single / Never Married	0.149	0.156	1.161	0.945

Married/Civil Partnership	-0.203	0.007	0.817	0.705
Separated / Divorced	0.437	0.000	1.549	1.291
Widowed / Surviving Partner	Reference			
Highest Educational Qualification				
Degree or Higher	0.213	0.001	1.237	1.092
Below Degree / A Level	-0.154	0.015	0.857	0.758
O Level/NVQ1	-0.271	0.000	0.763	0.675
Foreign Qualification	0.225	0.011	1.252	1.052
No Qualifications	Reference			
NS-SEC				
Managerial /Professional	-0.655	0.000	0.520	0.467
Intermediate Occupations	-0.762	0.000	0.467	0.377
Small Employers / Own Account Workers	-0.252	0.000	0.777	0.683
Lower Supervisory / Technical	-0.220	0.000	0.802	0.709
Semi-Routine / Routine	Reference			
Housing Tenure				
Outright Ownership	-0.167	0.011	0.846	0.744
Mortgage & Part Mortgage / Rent	-0.157	0.046	0.855	0.733
Private Rented / Rent Free	-0.291	0.027	0.747	0.577
Social Rented	Reference			
Lagged Health State				
Good Health	-5.096	0.000	0.006	0.005
Fair Health	-2.254	0.000	0.105	0.092
Poor Health	Reference			

Notes: The reference category is: Good Health.

Source: Authors own analysis of ELSA wave 4 and 5 data.

Summary of the salient points from the regression:

- Lagged health from the time t-1 is the most important variable when determining health at time t, especially for women.
- NS-SEC social group is increasingly important when health declines. This is likely to be due to the increased resources available to those in higher NS-SEC groups to mitigate the effects of poor health.
- The model fit is marginally better for women than men. This could be due to higher incidence of morbidity, rather than death among women.

- Highest educational qualification is more influential for men than for women, providing the greatest protective effect if the man is in poor health. However, highly educated women (degree or above) see more of a benefit than men when in fair health.
- Marital status again appears more influential for men in poor health than for women in poor health.

Some of these points will be picked up and discussed further in the context of the final results in the Discussion chapter (Chapter 9).

Specification of Health Transition Probabilities – Hand Grip Strength

Figure 5.17 – Linear Regression Results – Female Model, ELSA Wave 4

Model Summary			
R	**R Square**	**Adjusted R Square**	**Std. Error**
0.701	0.491	0.49	4.81589

Wave 4 Mean Grip Strength Coefficients	Unstandardized Coefficients		Standardized Coefficients		
Sample Size: 2882	B	Std. Error	Beta	t	Sig.
Intercept	19.182	1.16		16.53	0
Age	-0.171	0.013	-0.228	-13.304	0
Marital Status					
Single	-0.135	0.464	-0.004	-0.291	0.771
Married / Civil partnership	0.298	0.242	0.022	1.233	0.218
Separated / Divorced	0.363	0.334	0.018	1.088	0.277
Widowed / Surviving Partner	Reference				
Highest Educational Qualification					
Degree or Higher	0.3	0.357	0.014	0.839	0.401
Below Degree / A Level	0.224	0.288	0.013	0.776	0.438
O Level / NVQ1	-0.072	0.26	-0.004	-0.277	0.782
Foreign Qualification	-0.311	0.307	-0.015	-1.011	0.312
No Qualifications	Reference				
NS-SEC					
Managerial and Professional Occupations	0.555	0.273	0.036	2.03	0.042
Intermediate Occupations	0.413	0.255	0.025	1.618	0.106
Small Employers and Own Account Workers	0.191	0.335	0.008	0.571	0.568
Lower Supervisory and Technical Occupations	0.47	0.382	0.017	1.229	0.219
Semi-Routine / Routine	Reference				
Housing Tenure					
Owner Occupied	0.361	0.286	0.024	1.263	0.207
Mortgage / Part Mortgage and Part Rent	-0.028	0.378	-0.001	-0.073	0.942
Private Rented	0.429	0.536	0.012	0.8	0.424
Social Rented	Reference				
Lagged Health State	0.573	0.015	0.558	37.309	0

Source: Authors own analysis of ELSA wave 2 and 4 data.

Figure 5.18 – Linear Regression Results – Male Model, ELSA Wave 4

Model Summary			
R	**R Square**	**Adjusted R Square**	**Std. Error**
.757a	0.573	0.573	6.40103

Wave 4 Mean Grip Strength Coefficients	Unstandardized Coefficients		Standardized Coefficients		
Sample Size: 2278	B	Std. Error	Beta	t	Sig.
Intercept	29.406	2.182		13.474	0
Age	-0.263	0.02	-0.223	-13.305	0
Single	-0.153	0.66	-0.003	-0.232	0.817
Married / Civil partnership	0.373	0.201	0.003	1.243	0.112
Separated / Divorced	-0.28	0.363	-0.011	-0.772	0.44
Widowed / Surviving Partner	Reference				
Highest Educational Qualification					
Degree or Higher	0.554	0.472	0.024	1.174	0.241
Below Degree / A Level	0.502	0.424	0.023	1.186	0.236
O Level / NXVQ1	0.1	0.418	0.004	0.24	0.811
Foreign Qualifications	0.93	0.65	0.022	1.432	0.152
No Qualifications	Reference				
NS-SEC					
Managerial and professional occupations	0.789	0.407	0.04	1.94	0.052
Intermediate occupations	0.612	0.657	0.014	0.932	0.352
Small employers and own account workers	0.674	0.457	0.025	1.475	0.14
Lower supervisory and technical occupations	0.721	0.448	0.027	1.608	0.108
Semi-Routine / Routine	Reference				
Housing Tenure					
Owner Occupied	-0.459	1.225	-0.021	-0.375	0.708
Mortgage / Part Rent and Part Mortgage	-1.289	1.273	-0.047	-1.013	0.311
Private Rented	-1.409	1.277	-0.047	-1.103	0.27
Social Rented	Reference				
Lagged Health State	0.645	0.017	0.617	38.599	0

Source: Authors own analysis of ELSA wave 2 and 4 data.

Summary of the salient points from the regression:

- The male model was marginally more successful at explaining the variance in the dependent variable.

- Lagged health from the time t-1 is the most important variable when determining health at time t, especially for men.
- Age appears more influential for men than for women
- Housing tenure and highest educational qualification are significant for men but not for women
- Marital status is observed as being insignificant in the relationship, however was included due to the large body of literature suggesting the importance of the variable, particularly amongst men.

5.10 Technical Details

The PENHEALTH model is written in the R programming language (R Core Team, 2015). This language allows the simple integration of statistical procedures and database functions. The source code reads a series of .csv input files, prepared in IBM SPSS to form the base and transition data. Additionally, a series of Excel spreadsheets are utilised for the input of the model assumptions of mortality rates and retirement ages. Following each iteration, the model outputs and appends a .csv file of the results of the model run. This provides a full account of the individual transitions, facilitating longitudinal analysis. Additionally, areas of specific interest can be outputted individually in .csv format, ready for analysis in the programme of choice.

Health transitions utilise alignment within the model to match the outcomes of the model to the known data of the 2011 UK Census.

Due to the use of Monte Carlo simulation, an element of stochastic variability between model runs is likely to be encountered. This is likely to produce a source of error in the model results obtained. In order to quantify this, a run of 100 model iterations based on the 2001 base data was undertaken. This was done specifying a random seed to allow quantification of variability. It was found that mortality results varied by 7% between model runs. Health transitions were found to vary by 0.1% between model runs. Health transitions perform significantly better than mortality as each individual within the model always calculates a health transition. However, only a comparatively small proportion of individuals undertake a mortality transition (or die) each year. The greater sample size of the health transitions mitigates the variability of the random number generation, providing a more reliable result. However, the mortality variability of 7% was deemed acceptable to allow assessment of the research questions.

5.11 Validation and Verification of the Model

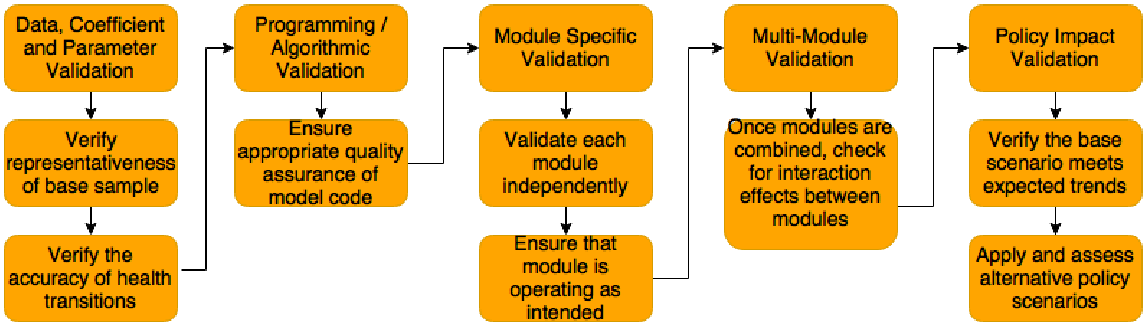
As discussed in section 4.10 above, this research will utilise the validation framework proposed by Morrison (2008). This framework intends to provide a comprehensive assessment of the suitability of both the model construction and operation. The steps involved are as follows:

- Data, coefficient and parameter validation;
- Programming / algorithmic validation;
- Module-specific validation;
- Multi-module validation;
- Policy impact validation.

(Morrison, 2008).

A flow diagram of the necessary validation steps is shown in Figure 5.19 below.

Figure 5.19 - Flow Diagram of Validation Steps



Source: Author's own analysis

5.11.1 Data, Coefficient and Parameter Validation

The base data for the PENHEALTH model is the UK Census individual sample of anonymised records (ONS, 2001). This represents a 3% sample of individuals for all countries within the United Kingdom, consisting of approximately 1.84 million records. The census is a high quality survey, in which a large amount of resources are utilised in order to achieve a complete sample of individuals within the UK. The census 3% sample is representative of the whole population of the UK. The large sample size additionally allows disaggregation by a number of contextualising variables while maintaining statistical strength.

Health transition probabilities were derived from the English Longitudinal Study of Ageing dataset. While it may have been ideal to utilise more than two consecutive waves when deriving these transitions, data consistency provided limitations. Transition probabilities were obtained through multinomial logistic regression modelling, which was shown to predict suitably accurately for the needs of the model, as described in section 5.9. The modelling parameters were selected following a review of health modelling literature and existing dynamic microsimulation models. The use of the ELSA data for health trajectory information also has the limitation of only including individuals from the population of England, compared to the census base data population covering the UK. The life expectancy of individuals in England is marginally higher than that of other UK countries

(ONS, 2015f;h;i). This is likely to lead to a slight inflation of those in better health states within the model population, over the true population. This was assessed as a necessary compromise to maintain sample size and ensure availability of data. As no geographical analyses are undertaken within the following analysis, focusing instead on a population level, it was assessed that the error introduced to the analysis will be small and to take account of this effect within the discussion of the results presented in chapter 9.

5.11.2 Programming / Algorithmic Validation

The PENHEALTH model was coded by the author in the R programming language. R is a high level language that allows the inclusion of statistical elements and database management functions, along with debugging operations. The model building process was undertaken with model validation in mind. For this reason, each model parameter was verified at the time of coding. This was undertaken on a reduced data sample to allow a large number of runs to be undertaken to check for inconsistencies or unintended effects of module coding.

5.11.3 Module-Specific Validation

Each module was specified independently and therefore needed to be checked for modelling inconsistencies on a separate basis. The modules of the PENHEALTH model include Mortality, Health Transition and the Employment/Health Feedback Module. The validation of individual modules took place by comparing figures with known totals. As a historical base population of 2001 was utilised, this allowed the 10-year period leading to 2011 to be used as a validation period. The 2011 data consisted of the subsequent UK census, as well as mortality data for all years in-between. This validation period allowed the identification of deviation from these benchmark figures. This was used for two purposes, first to check that the module itself was operating correctly and secondly if the module was operating correctly, to align these figures with the established benchmark.

The validation found that there was a very small amount of stochastic variation in projected health profiles between years, due to the large number of health transitions undergone on a specified year. A divergence was found between the health profiles projected from 2011 in the model and the observed health profile in the 2011 Census (as can be seen later in Figure 5.20). This divergence between projected trend and expected values was then removed through the model alignment mechanism. In doing so, the assumption that future health trends will follow the same trajectory as those observed between 2001 and 2011 is built in to the future iterations of the model. The operation of the mortality module was assessed by comparing model outputs with expected counts within the population by sex and single year of age. As the module-specific validation took place at each stage of the model construction, any new errors were likely to be due to new code and were therefore easy to identify and rectify.

5.11.4 Multi-Module Validation

The multi-module validation of the PENHEALTH model took place on a number of levels. First, the operation of individual parameters ensured that all variables were updating through the model as intended. Secondly, the plausibility of results both up to the validation year and beyond were checked. This was undertaken through cross-sectional and longitudinal data analysis, both with and without alignment. These longitudinal results were then compared against external projections of population totals. The outcome of this model validation stage is presented later in section 5.12.

5.11.5 Policy Impact Validation

Policy Impact validation is concerned with establishing whether the model provides an accurate representation of behaviour following a policy change. This is often the most challenging aspect of model validation as in the real world there may be outcomes that were unexpected by the model developers following a policy change. Policy impact validation within this thesis will focus on the distribution of those reporting premature economic activity, as well as health state at time of retirement, under a number of SPA assumptions. As this research is concerned with physical ability to continue working until SPA, the behavioural elements of a change in SPA are not accounted for. This may provide some variation between the model and the true distribution of those remaining in the workforce. However, the ability to continue working will remain unaffected by a change in SPA. Those who will be unable to continue working will experience this effect, regardless of SPA. Rather, it is the interaction between the two variables that remains pertinent to this study.

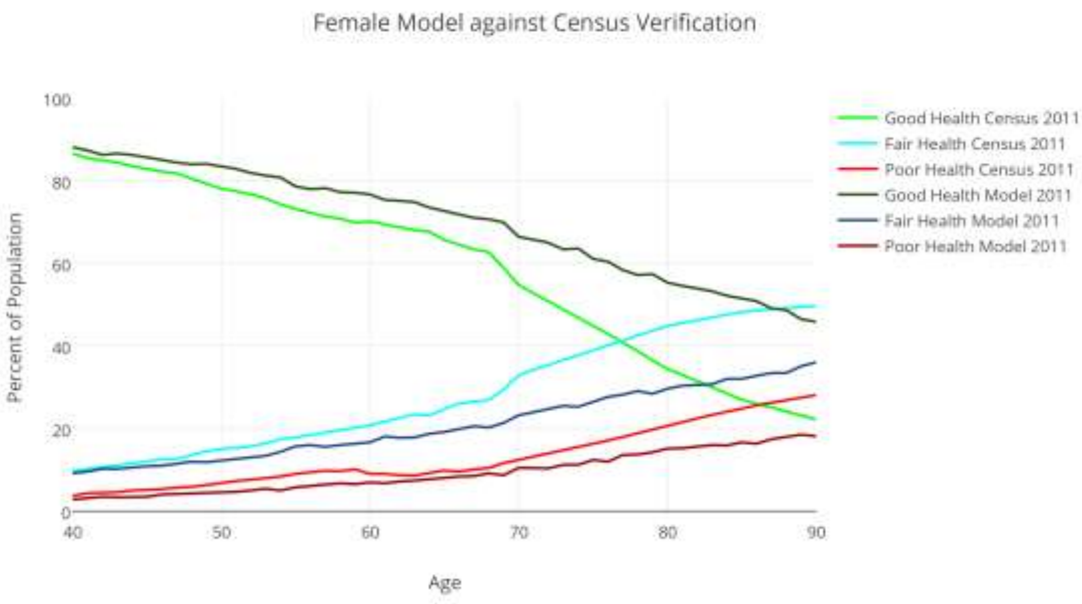
In the absence of behavioural responses to policy, the projected policy outcomes were validated through the plausibility of the results that they produced. A consistent base population and health modelling strategy was utilised between base and alternative scenarios, this allowed multiple alternative scenarios to be trialled under the same conditions. A base scenario was constructed first and was intended to model reality as closely as possible, using currently legislated policy. Initial health trajectories were validated and the plausibility of these figures was ensured through the use of the alignment mechanism discussed later in section 5.12. Alternative policies were then trialled on top of these plausible health paths and the impact of alternative policies were investigated for what impact they may have on health outcomes. A number of currently proposed alternative SPA policies were utilised from both government and literature were trialled and the impact was assessed. These outcomes will be discussed further in Chapter 8.

5.12 Verification / Alignment of the Model

The issue of alignment was discussed previously in section 4.10.2 above. The PENHEALTH model was intentionally estimated utilising a historical base dataset of the 2001 Census in order to allow verification and alignment in line with the more recent 2011 Census. Any discrepancy from observed trends, under or over prediction could therefore be calibrated to 2011 data. When deciding whether to align the model, a number of verification steps took place.

First the base model was advanced 10 years, subject to the health transitions specified within the model. The results were then plotted against the 2011 census data, and the result is shown in Figure 5.20 below.

Figure 5.20 - Female Model vs. 2011 Census Verification – Base Scenario



Source: Author's own analysis of PENHEALTH model data.

The lighter colours represent results projected by the PENHEALTH model, while the darker lines represent the 2011 Census results. As can be seen from Figure 5.20, in 2011 the model is increasingly optimistic in representing good health as individuals increase in age (light and dark green lines). This is shown as a divergence between the predicted and observed quantities of individuals in the 'Good Health' state.

Critically for this study, the model undertakes the projection of poor health more accurately (light and dark red lines). Again the model projects comparatively well at younger ages, with 2.8% of the population being in poor health at age 40, compared to 3.7% in the Census. Following this, the model is again optimistic, placing a smaller number of individuals into the poor health state than observed in the census. However, this analysis is hindered by the census verification file, in which the age variable is only available in categorical format at later ages. This limits the detail of analysis that can be made.

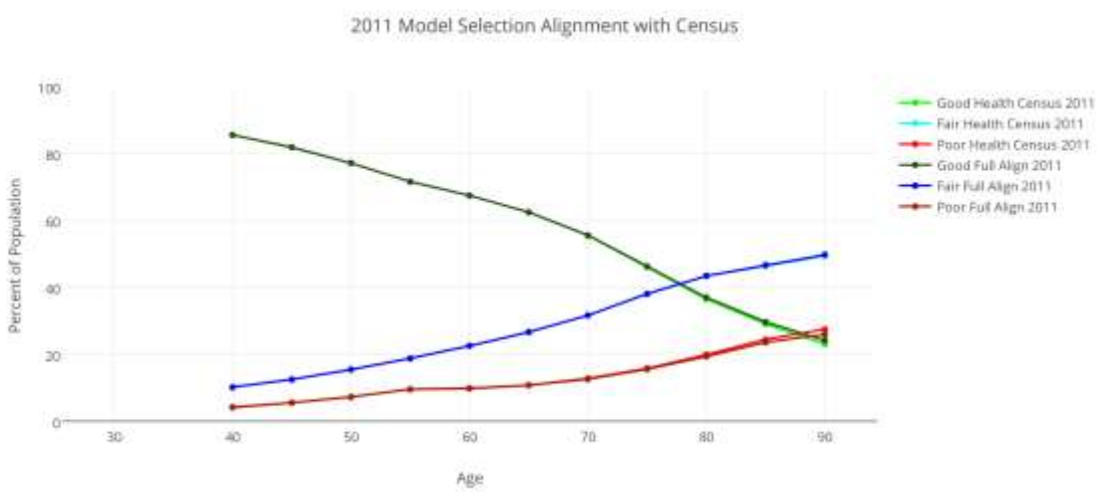
When deciding on type of alignment to be undertaken, it is useful to take into consideration both the benefits and drawbacks that model alignment can bring. It must be noted that no alignment method is perfect and inputting additional alignment parameters can manipulate the micro-macro link that is a fundamental component of microsimulation modelling (O'Donoghue, 2010). Additionally, the alignment procedure may serve to constrain model outputs, even if there has been an underlying behavioural or structural change (Bækgaard, 2002). There are similarly a number of alignment methods available to modellers, with little research analysing the operation and distributions change as a result of various alignment methods.

The input used for the health transitions was taken from a longitudinal study of those over 50 years of age (as discussed previously in section 5.4.1). This cohort of individuals represents a sub-set of the population for whom the experience of health may not adequately represent the population as a whole. The deviance in expected versus actual results can likely be attributed to model misspecification.

The earlier section 4.10.2 discussed the various types of alignment available and it was concluded that due to the variability in alignment outcomes across models, a number of alignment methods should be trialled and compared. This comprised the comparison of Sort by Predicted Probability (SBP), Sort by Difference (SBD), SBD manipulated with forced inclusion of 10% low probability individuals (SBDM) and SBD Logistic (SBDL) alignment strategies. These algorithms rely on the sorting of individuals by a range of factors and selecting the appropriate number of individuals upon whom to impose a state change to meet an externally derived target.

No significant difference was found in the ability of individual sorting-based algorithms to meet the intended population level totals per by year of age and health state in 2011. The results of the SBP alignment can be seen below in Figure 5.21, however these are indicative of the three other alignment methods trialled. The alignment methods do however vary significantly in the way in which the reweighting algorithms manipulate health transitions between groups. For this reason, the analysis of alignment method suitability will be made based on these group proportions

<u>Figure 5.21 - 2011 PENHEALTH Model Output with SBP Alignment</u>



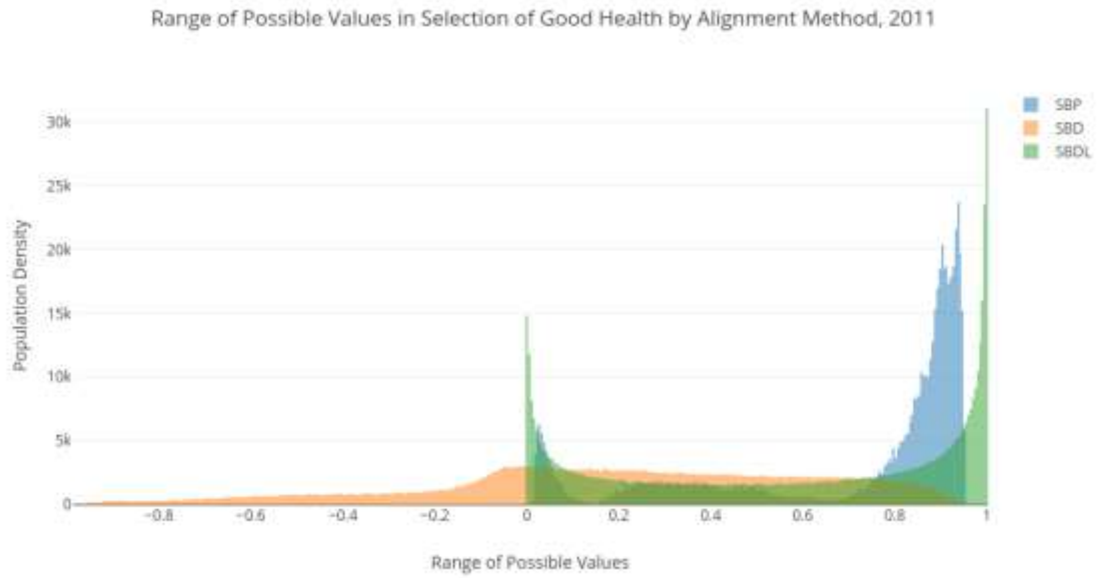
Source: Author's own analysis of PENHEALTH model data.

As can be seen from the above Figure 5.21 the population proportions in each health state are matched to within 1% throughout most of life, with only a small maximum diversion of 1.51% within good and poor health states at age 90. All four algorithms can therefore be said to achieve the target set by Li & O'Donoghue (2014, p6) of 'replicating as close as possible the external control totals for the alignment totals'. The choice between the alignment methods will therefore be made through investigating the impact of the alignment upon the sub-group proportions when we begin to disaggregate the model. The results of this analysis by disaggregation can be seen in Appendices C through G, showing the change in sub-group membership, depending on the alignment algorithm selected. The alignment method was enacted at an aggregate level. The method ensured that the proportion of the population, disaggregated at single year of age and sex, falls into each health state matched that of the 2011 Census. This is likely to influence the results as the alignment is enacted at a population level, rather than being able to explicitly align with the same individual in the future. This may influence the proportions of self-reported health when the data is disaggregated into various sub-groups.

First trialled was the SBP alignment. This alignment method simply ranks the modelled individuals by year of age and predicted probability of health state. Within this method, only those who report a very low probability of being in a health state but are allocated to that group nonetheless are selected. This may impact on the accuracy of the health state selection in a number of ways. Firstly, this may have the effect of minimising the false positives of the model by forcing these low probability individuals out of better health states. However SBP includes no random component, so is unlikely to replicate reality, in which an individual may have a high risk of health state transition but not undertake that transition. The impact of this alignment's disregard for selection distribution can be seen in Appendices C through G. The SBP alignment causes greatest impact amongst those with high risks of being in poorer health states, with comparatively smaller impact across those in lower risk sub-groups.

As would be expected, both SBD and SBDM alignment types produce similar results as both algorithms operate through a similar comparison, varying only those who are selected by 10%. SBDM and SBDL are shown to provide consistently more accurate results than the SBD algorithm, shown by lower levels of deviation from the expected totals. While accuracy is shown in aggregate results, no data is available to assess the accuracy of transitions on an individual level, as this result is likely to depend on innumerable other factors. This draws into question the accuracy through which individuals are selected to change health state, however this is a compromise made by the model to achieve the aims of the microsimulation. As can be seen from Appendices C through G, SBDM and SBDL provide more consistent results both within and across sub-groups, as opposed to stacking toward higher or lower risk groups. An index was created detailing the average health group deviation of aligned results from the 2011 Census results. When utilising this index, the SBDL algorithm is shown to provide overall the most accurate results. Additionally, the deviation from expected results is more evenly spread throughout the health risk categories than was observed in the SBP alignment. SBDL alignment was found to perform most accurately in retaining the shape of distributions in different subgroups.

Figure 5.22 – Range of Possible Values in Selection of Good Health by Alignment Method, 2011



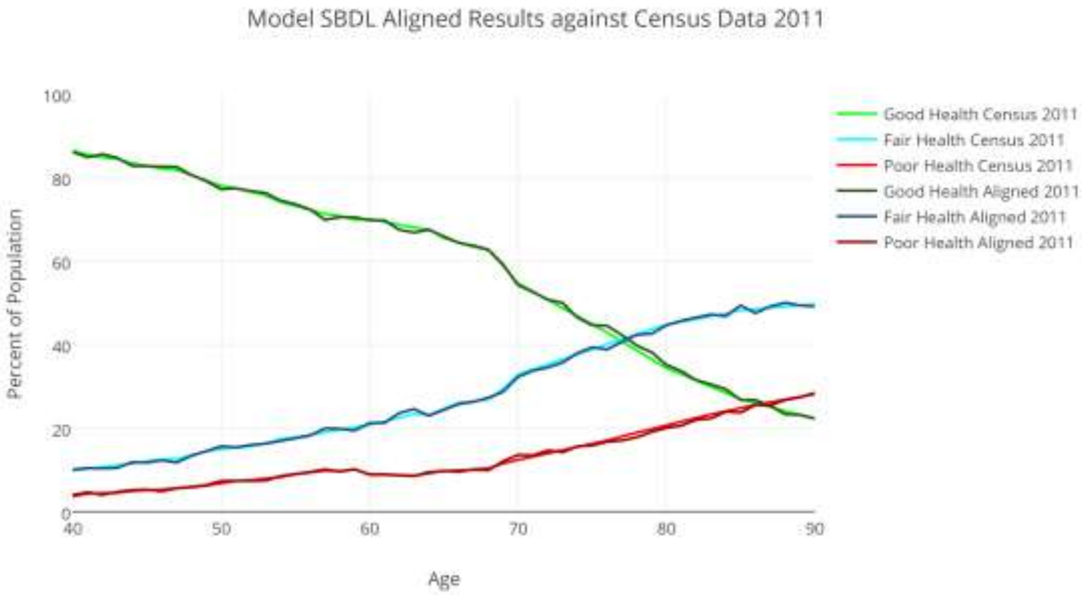
Source: Author's own analysis of PENHEALTH model data.

The difference in selection characteristics can be explained in part by Figure 5.22 above. Figure 5.22 shows the distribution of possible values, after various alignment algorithms have been applied. These are used to select individuals to undergo a change of health state. The SBP algorithm simply ranks the individuals and therefore the range of values utilised is the original probability distribution generated by the model. Within this distribution, the majority of individuals experience a high probability of remaining in the good health group, with a smaller but significant spike of those with a low probability of falling into the good health group. The range of possible values of the original model distribution is constrained to slightly less than 0-1 as a result of the regression model utilised. Conversely, due to the combination with a uniform random number, the SBD algorithm provides a much flatter overall range of possible values. The range of possible values utilised by the SBD algorithm is expanded to encompass -1 through +1. The SBDL algorithm shows a more stylised version of the SBP algorithm, utilising a 0-1 range of values with large peaks at the high and low probabilities and a flatter distribution between the peaks. The nature of these probability distributions will modify those that are selected for a state change by the alignment algorithm. The flatter profile of the SBD algorithm is likely to result in a more diverse selection of individuals falling into the range affected by the alignment. Conversely, due to the peaks of low probability individuals within both SBP and SBDL algorithms, the individuals selected are more likely to come from a cluster of high-risk characteristics for a health state change. The impact of this effect can be seen within the outcome proportions in Appendices C through G. The SBP, and to a lesser degree the SBDL, algorithms are likely to select the majority of individuals with characteristics that put them at risk of being in poor health, while leaving other groups comparatively unchanged. Meanwhile, with the flatter probability distribution, the SBD and SBDM algorithms select from a more even spread of individuals.

The final selection of alignment method should be made in relation to not only the overall performance of the alignment, but also to achieve the best level of accuracy for the study research questions. Were this study to be interested in those at least risk of undergoing a transition, an SBP alignment mechanism may be the correct selection. SBP alignment was shown to have a lower impact on the distributions of individuals throughout lower risk sub-groups, but a comparatively higher impact on high-risk groups. This however would not be optimal for this case as the high-risk groups of poor health in the lead up to state pension age are of critical importance. The ideal alignment method for this study therefore provides minimal deviation from expected census data within the key high-risk groups. For these reasons, this study will utilise the SBDL algorithm.

The results of the final SBDL alignment can be seen below in Figure 5.23.

__Figure 5.23 - 2011 Model Output with SBDL Alignment__



Source: Author's own analysis of PENHEALTH model data

As can be seen from the above Figure 5.23, the alignment procedure does well at replicating the desired totals by health state and single year of age, the variables upon which the alignment is specified.

5.13 Chapter Summary

This chapter has discussed the specification of the PENHEALTH model used within this study. In order to build this microsimulation model, a number of simplifying assumptions were made. These simplifications are required for the model to align to currently available data, computational requirements and feasibility. All attempts have been made to minimise the impact of these assumptions on the outcomes of the model. The following section (Chapter 5) will detail the preliminary results of the baseline scenario, followed by discussing the alternative scenarios that will be utilised within the following chapters. Finally, the limitations of the study will be discussed.

Chapter 6 Base Model Parameters

Following the construction of the model detailed in the previous chapter, the findings and data put forward in chapter 6 are those drawn from the base iteration of the PENHEALTH model. This model utilised the Census base sample and health data drawn from ELSA to project forward possible trends of the interaction between continued employment and health. While these results cannot be viewed as providing an exact picture of the future population, they can be seen as plausible scenarios from which to judge policy implications. It is necessary therefore to assess the results presented in this section in the context of the model and its own limitations. This chapter will focus on the key outcomes of direct relevance to the research questions, thereby assessing the ability to continue to work until a given SPA across society. The chapter will discuss the results and trends produced through the base scenario of the PENHEALTH model, covering the how the model operates and the potential impact of current legislation on the population.

As discussed in Chapter 5, the base scenario encompasses the simplest variant of the model. This scenario utilises the current legislation of SPA increases and base values of health transitions with minimal manipulation, in order to provide a base scenario of a most logically consistent outcome against which to compare alternative scenarios. This base scenario is built upon with a number of assumptions (as provided below in Table 6.1), which are inherent and which define the outputs of the model. These are the result of simplification measures from the real world that were required in order to achieve adequate scope and simplicity within the model.

Table 6.1 - Summary of the Scenarios Used in Chapter 6

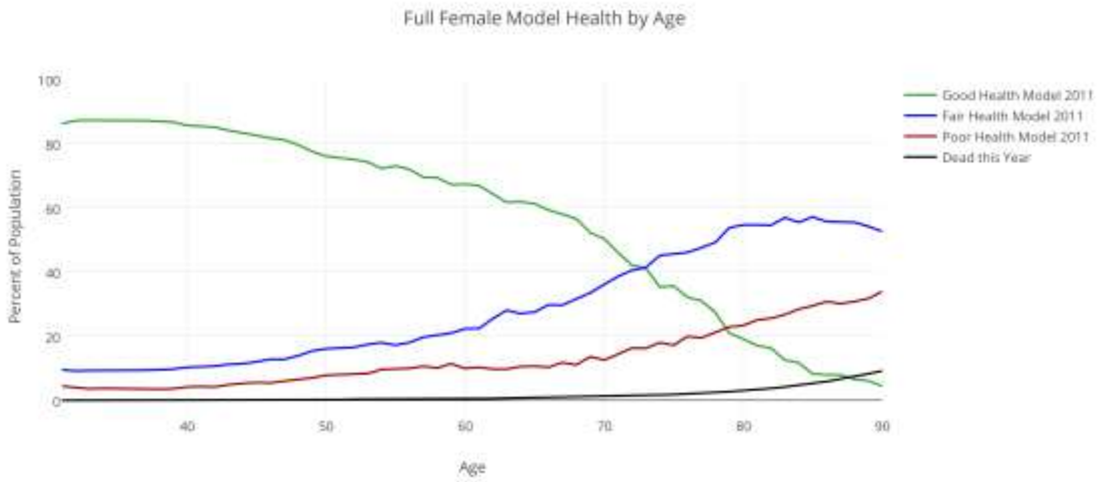
Scenario	Assumptions
Scenario A – Base Model Parameters	a) Self-reported health utilised b) ONS Prime Mortality Projection c) No additional longevity change effects d) No Health / Employment feedback e) Those falling into 'Poor' health defined 'Prematurely Economically Inactive' f) Male and Female SPA in line with current legislation

6.1 Base Scenario – Basic Trends

Scenario A, also referred to as the base scenario, investigates the impact of current legislation on individuals' ability to continue to work until an increasing SPA. The SPA is undergoing a period of increase, as discussed earlier in section 1.1. Meanwhile, the health of the population experiences a substantial social gradient of health, with greatly reduced health for those in less affluent social groups, as discussed in section 1.2.1. When combined, these measures have the potential to create an unequal impact of the change in SPA across society. The first scenario investigates this impact in the simplest terms, investigating the ability of a variety of groups to continue working to an increasing SPA.

First, a general discussion of model operation and population dynamics over the model run will take place. Figure 6.2 below shows the proportions of female individuals reporting good, fair and poor health within the model, subsequent to alignment. This is taken across the whole 50-year run of the model from 2001 to 2051. As can be seen in the figure, the proportion of individuals defined to be in 'Good Health' reduces throughout life. The critical element to the SPA argument is where the SPA line is placed along this graph. If policy were to place this line at age 65, a set number of individuals are likely to experience poor health before reaching SPA. However, the further to the right that policy pushes the SPA, the greater proportion of individuals are likely to be in poorer health states in the lead up to SPA.

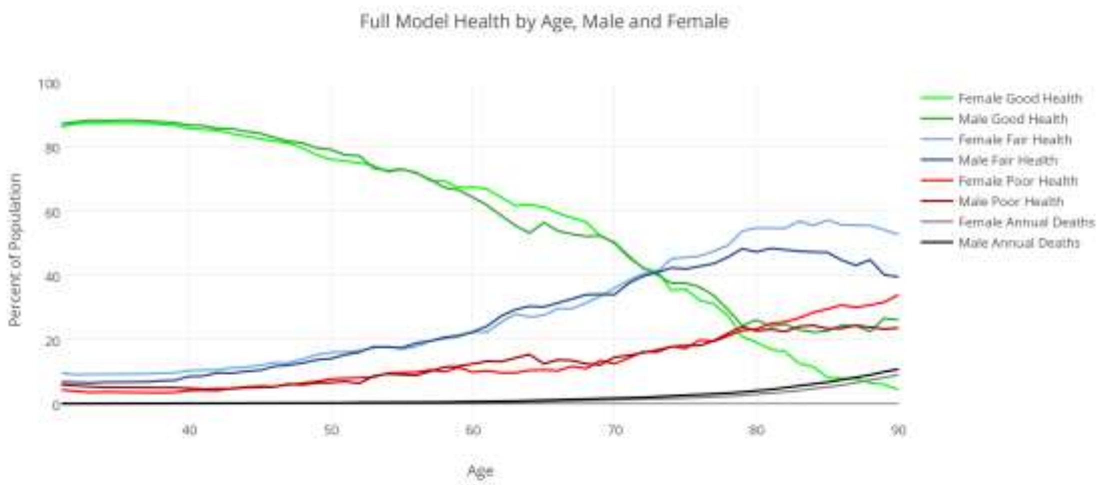
Figure 6.2 - Female Health by Age – Base Scenario



Source: Author's own analysis of PENHEALTH model data.

As noted earlier when specifying the health transition model in section 5.9, the health trajectories and retirement experience vary between men and women. Separate models were specified producing differing results. As can be seen in Figure 6.3 below, the female and male models operate similarly, but there are some notable differences. Males are more likely to report a 'Good' health state from age 69 onwards. This could be observed for a number of reasons, including the higher incidence of morbidity among females towards later ages, or that male respondents may have been more optimistic about their own health during the census of 2011, however this will be discussed more critically in Chapter 9. Such divergence at older ages however can again be seen in the 'Fair Health' category, in which females experience a significantly higher level of fair health from age 70 onward. Within the poor health category, males have an initially overall higher precedence of poor health within the population, up to the age of 80, from which point, female individuals experience greater incidence of poor health than men. This could again be due to higher levels of female morbidity, coupled with the higher life expectancy of women. Due to the linear implementation of the alignment mechanism, those above age 90 experience a heavy constraint to good and fair health states towards the later iterations of the model. As all individuals within the model have retired by age 90, this is not likely to pose a problem for the questions investigated here, however should be kept in mind for further analyses. Additionally, females experienced lower levels of mortality than males at older ages, as would be consistent with the higher life expectancy of females. This effect will be investigated further in the discussion provided in Chapter 9.

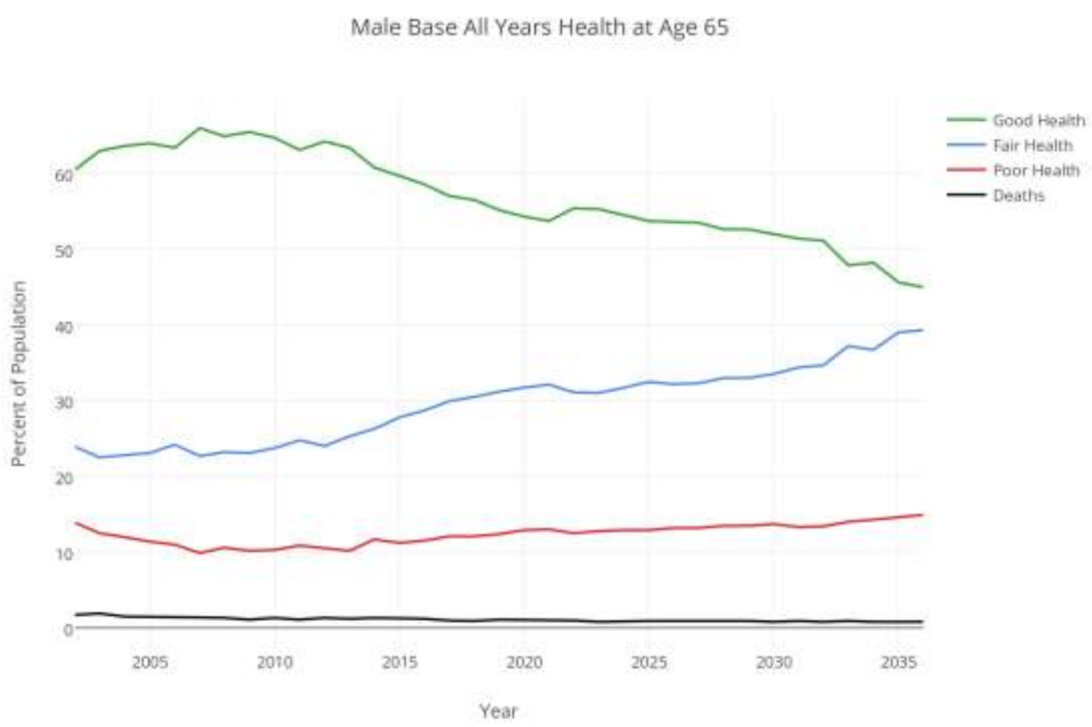
Figure 6.3 - Male and Female Health by Age – Base Scenario



Source: Author's own analysis of PENHEALTH model data.

The results of the model were then investigated longitudinally in order to assess the model's variability in prediction across time. The results can be seen in Figure 6.4 below, detailing the change in health state reporting of male individuals aged 65 from 2001 to 2035. As can be seen from the below figure, over time male individuals aged 65 are decreasingly likely to report good health and correspondingly more likely to report fair health. Such a decrease in good health reporting with time is likely to be a result of the alignment mechanism used within the model. In order to achieve a consistent result between the 2011 model projection and the 2011 UK Census, a linearly applied correction is applied which then continues for the remainder of the model run. The alignment serves to re-allocate individuals from the 'good' health category, down into the 'fair' health category. While such a trend is unlikely in the real population, this correction does provide a reliable estimate of the trajectory in health states between 2001 and 2011. Outside of further information regarding health trends in the future, it is conceptually reasonable to assume that the equal amount of correction will be needed on an on-going basis.

Figure 6.4 – Health of Male Individuals at Age 65 by Model Year – Base Scenario



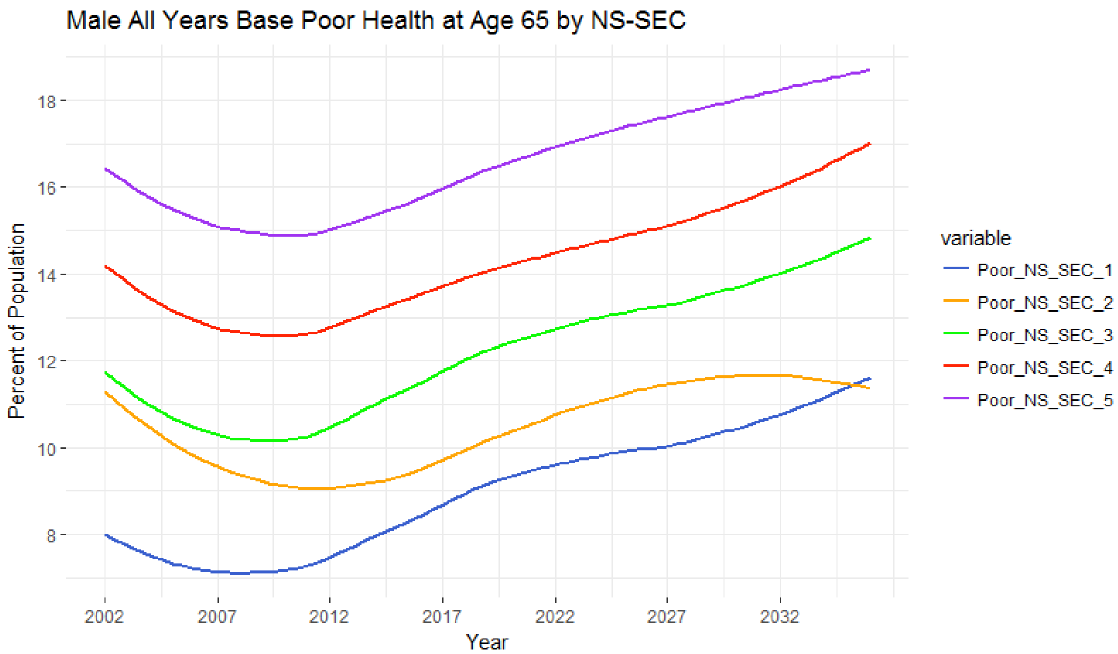
Source: Author's own analysis of PENHEALTH model data.

6.2 Variation of Health by NS-SEC Within the Model

While the figures presented above provide insight to the health states of all individuals within the base scenario of the model, this is not the full story. These average figures hide a large amount of the underlying variation, as the health of a variety of sub-groups of the population differs significantly from the mean figures presented here. It is these groups that experience significant variation from the mean that are likely to be disproportionately impacted by an increase in SPA. For this reason, the analysis then turned to investigate the distribution of health states across different NS-SEC social groups. As discussed previously in section 5.5.2, the NS-SEC social group can serve as a useful proxy for a number of variables that characterise the health of an individual, including employment conditions and social resources.

As can be seen from Figure 6.5 below, the proportion of individuals reporting 'poor' health varies significantly through time, depending on NS-SEC social group. As can be seen, while the overall trend of all groups is toward an increasing level of poor health within the population of individuals aged 65, a complex picture emerges. Those in NS-SEC group 5 (i.e. lowest occupational social class) report consistently the highest levels of poor health, throughout the model run. Similarly, those in NS-SEC group 1 predominantly report the best health across the model run. Between these two groups exists a very consistent gradient of health, dividing the experience proportionally between the highest and lowest NS-SEC groups.

Figure 6.5 – Health of Male Individuals at Age 65 by Model Year and NS-SEC – Base Scenario

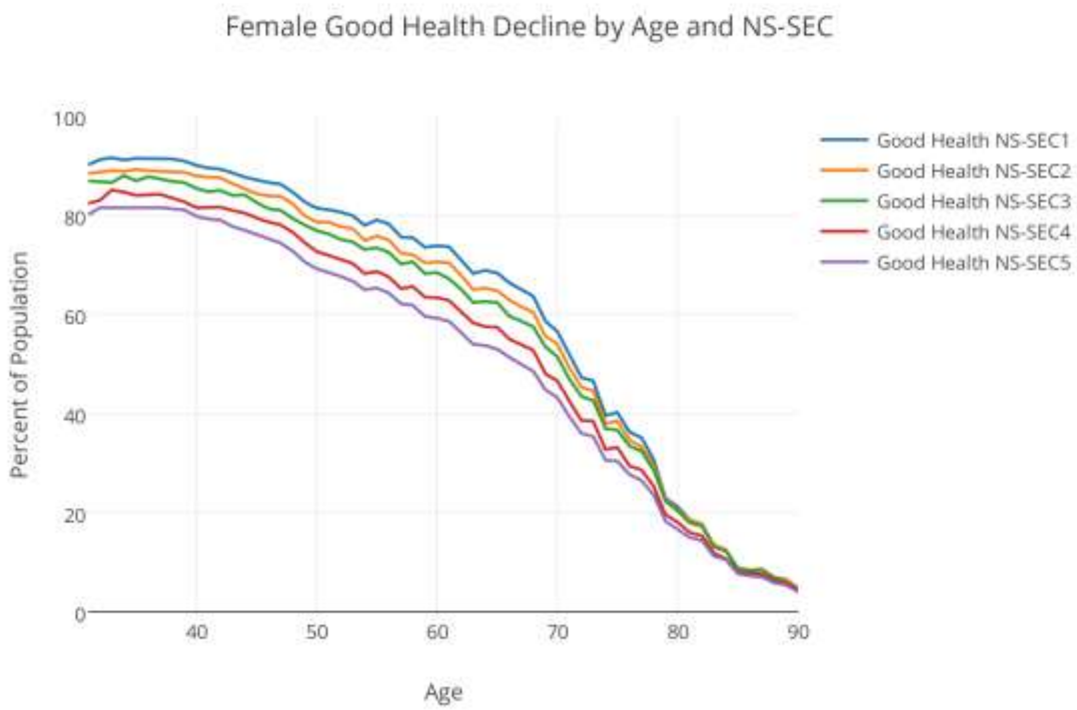


Source: Author's own analysis of PENHEALTH model data.

Notes: Pattern has been smoothed through 100 model iterations.

This trend is also observable at all ages within the model, as can be seen in Figure 6.6 below, showing the decline in those females reporting good health across life. The variation seen within the model, following from the ELSA base data, follows the social gradient of health hypothesis. Those in the highest NS-SEC social group, in this case those defined as NS-SEC 1 or Managerial and Professional Occupations exhibit the highest proportion reporting good health at all ages of the model. This peaks at 91.5% of the population reporting good health at age 35, and this pattern then continues down the NS-SEC groupings to group 5, defined as Semi-Routine and Routine Occupations, where 81.6% of the population of NS-SEC group 5 report good health at age 35. At age 35, individuals in NS-SEC group 5 experience a 9.9% lower proportion of good health than NS-SEC group 1. This trend is then observed to constrict, with the distance between the groups decreasing with age. This is a result of the alignment algorithm having an increasing influence toward the older ages, thereby constraining the results toward similarity, as alignment is not specified by NS-SEC.

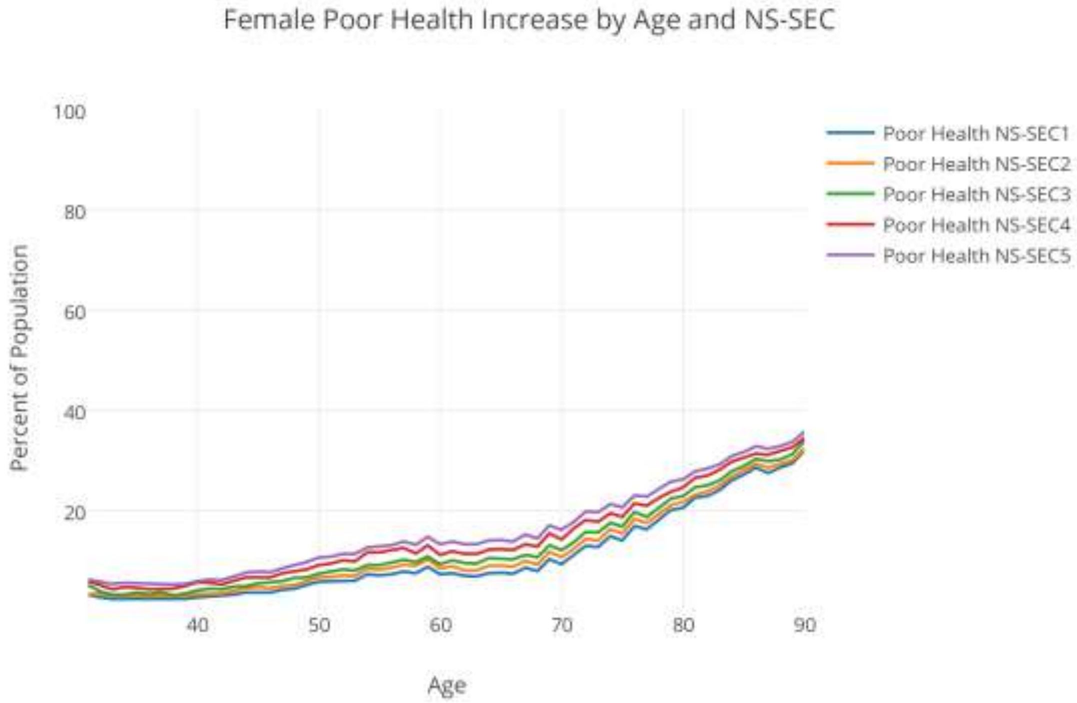
<u>Figure 6.6 - Decline in Female 'Good' Health by Age – Base Scenario</u>



Source: Author's own analysis of PENHEALTH model data.

The inverse can be seen among those reporting poor health, as shown in Figure 6.7 below. At age 35, those reporting poor health from the top and bottom NS-SEC groups represented 2.2% and 5.4% respectively, showing a difference of 3.2%. This difference then increases, resulting in diverging health outcomes throughout life. By age 65, this is found to represent 7.6% of the NS-SEC 1 population and 14.1% of the NS-SEC 5 population, a difference of 6.5%.

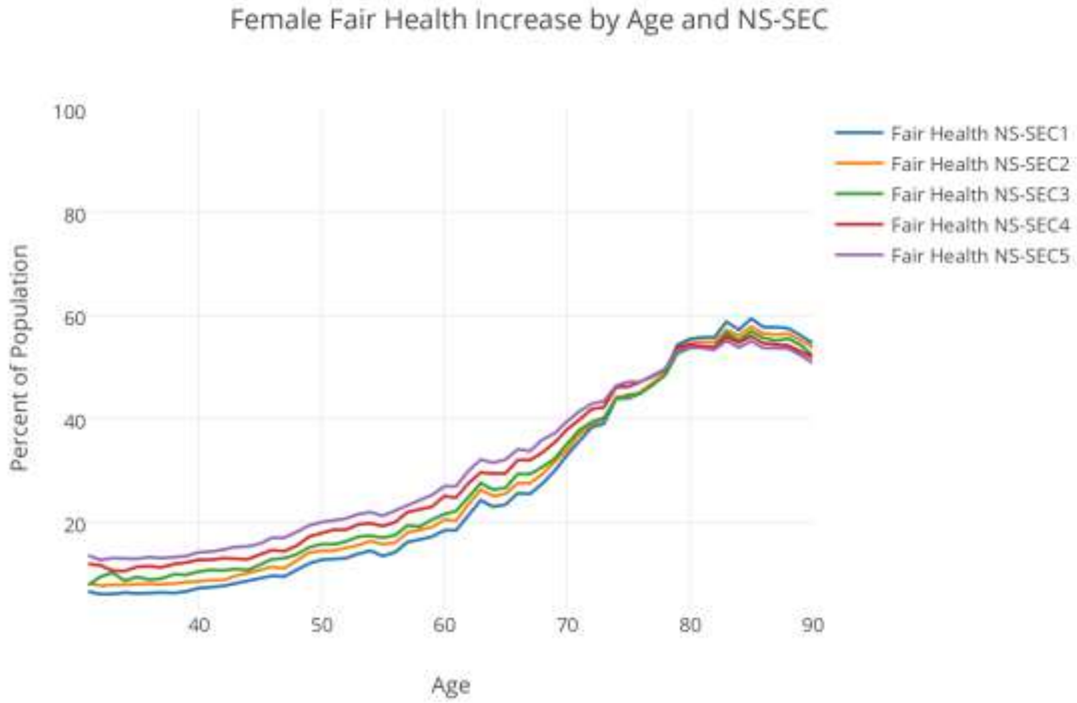
Figure 6.7 - Increase in Female 'Poor' Health by Age – Base Scenario



Source: Author's own analysis of PENHEALTH model data.

Similar to the increase of poor health experienced within the population, the increase and divergence can be seen in the increase of percentages reporting fair health, as shown in Figure 6.8 below. The increase of those in fair health should also be considered when assessing policy, as these individuals may likewise suffer difficulties continuing in employment, however this will be discussed further in Chapter 9.

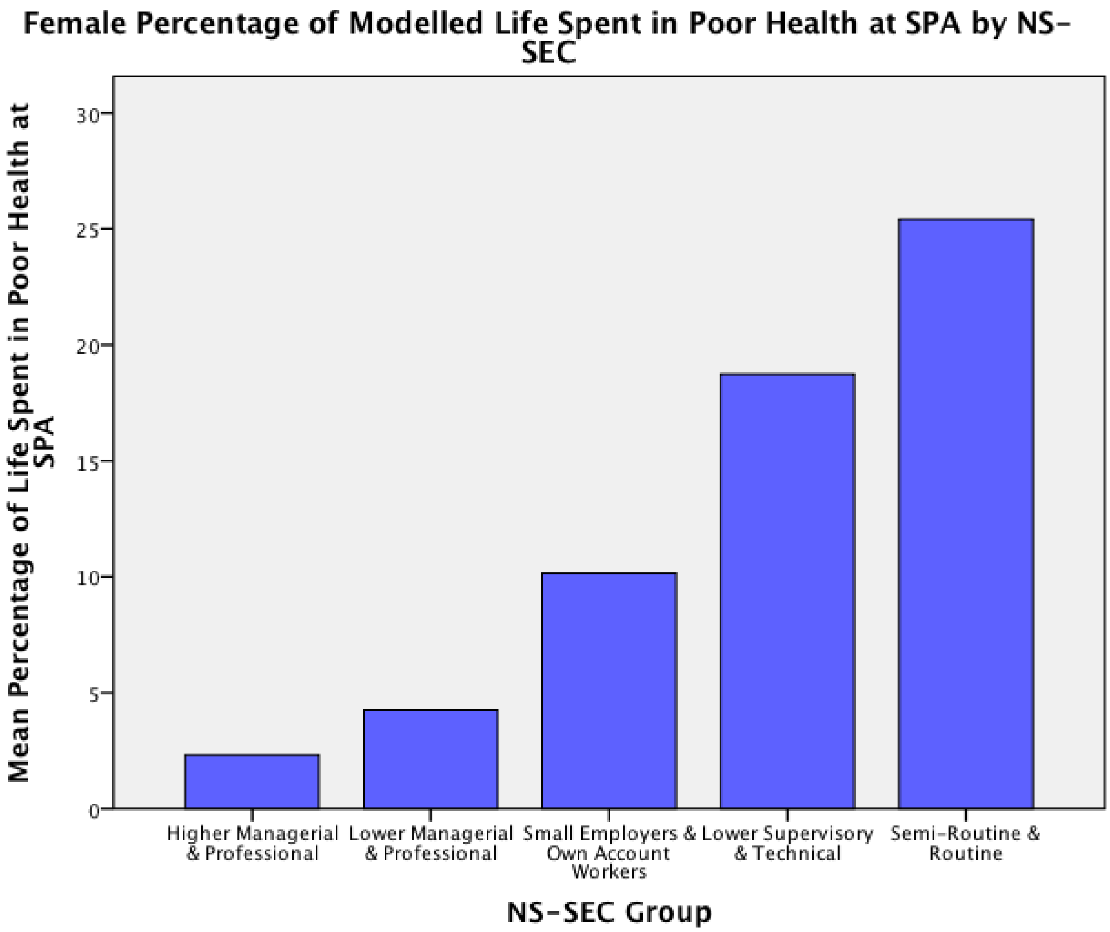
<u>Figure 6.8 - Increase in Female 'Fair' Health by Age – Base Scenario</u>



Source: Author's own analysis of PENHEALTH model data.

This increase in poor and fair health by NS-SEC translates into a greater proportion of life spent in poor health. This can be seen in Figure 6.9 below, detailing the percentage of modelled life spent in poor health when reaching SPA at age 65. Those in lower NS-SEC groups were found to spend a significantly greater average percentage of their pre-SPA life in poor health than those in higher groups. This suggests that those in lower NS-SEC groups experience poor health at significantly earlier ages, raising the possibility of difficulty when raising the SPA.

__Figure 6.9 – Female Percentage of Modelled Life Spent in Poor Health at SPA by NS-SEC__



Source: Author's own analysis of PENHEALTH model data.

Notes: SPA used is 65

The proportions falling into individual health states within the model can then be combined with the 2001 census totals by single year of age to produce absolute numbers of individuals within the population, as seen in Tables 6.10 and 6.11 below for the years surrounding the SPA. As can be seen from the figure, the number of women in the poor health category increases from 19,112 at age 60 to 27,024 at age 75. Under this assumption, while delaying the SPA will allow all those within the 'Good' and 'Fair' health states to continue working for an additional calendar year, it also requires all of those within the 'Poor' health state to continue working. Within the context of a welfare system, this may result in this population experiencing difficulty remaining at work, being forced into unemployment or being pushed onto another form of support, whether provided by the government or otherwise, as discussed in section 1.2.5. A move of the SPA from 65 to 66 within the base scenario of the model would result in 22,859 female individuals in the UK falling into poor health, while still being below SPA. Additionally, the same move would require 22,266 male individuals in poor health to remain within the workforce, thereby possibly requiring additional support.

Table 6.10 - Total Female Individuals Surrounding SPA by Health State

Total Number of Female Individuals in Health States Surrounding SPA				
Age	**Good**	**Fair**	**Poor**	**Annual Deaths**
60	217931	47066	19112	1141
61	227823	51230	21095	1205
62	224045	52417	21865	1498
63	219130	52568	22445	1477
64	211704	53143	22528	1444
65	204886	53056	22859	1693
66	196896	52926	22761	1645
67	187664	52408	22763	1853
68	186645	54050	23431	1864
69	186045	55224	24663	2145
70	185388	57376	25711	2436
71	178035	57848	25886	2377
72	169455	57166	26031	2552
73	160379	56072	25710	2693
74	158177	57630	26731	2943
75	153218	57909	27024	3137

Source: Author's own analysis of PENHEALTH model Data

__Table 6.11 - Total Male Individuals Surrounding SPA by Health State__

Total Number of Male Individuals in Health States Surrounding SPA				
Age	Good	Fair	Poor	Annual Deaths
60	213985	38682	20576	1097
61	224291	42653	22052	1161
62	219626	43008	22651	1147
63	215084	44265	22984	1419
64	206307	44503	22526	1374
65	197215	44267	22266	1590
66	188670	43775	22016	1536
67	177000	42733	21366	1700
68	173204	43361	21321	1677
69	170371	44259	21415	1904
70	165155	44725	21198	2096
71	155466	43753	20877	1999
72	145538	43029	20249	2109
73	135592	41552	19484	2187
74	130621	42180	19243	2333
75	122962	41358	18732	2411

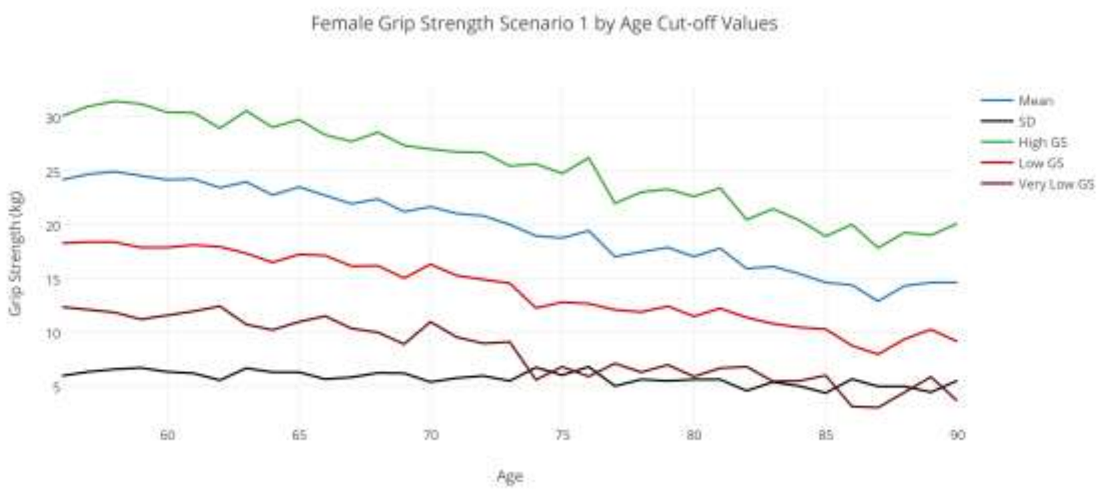
Source: Author's own analysis of PENHEALTH model Data

6.3 Alternative Measure of Health – Hand Grip Strength

As discussed previously in Section 5.4.3, in order to assess the variability of results by health measure used, an alternative conceptualisation of health should be utilised within the same framework as the base measure. The health measure selected for this was Hand-Grip Strength, intended to provide a more objective measure of health than the more subjective and individual Self-Reported Health. The discrepancy and difference between the two results have particular pertinence for policy makers, depending on the measure utilised within the study, significantly different results may be found. Additionally to this, the way in which the measure is used is likely to influence the outcome of the results; therefore this section will also investigate alternative modelling techniques. The decision to utilise hand-grip strength was taken both in line with literature surrounding grip strength as a predictor of musculoskeletal conditions, but also due to the continuous nature of the data. Continuous data within a health measure can be conceptualised in a number of different ways, each yielding different results when applied to policy. Grip strength in particular suffers from lack of agreement as to a 'cut off' value, defining normality or the incidence of poor health.

The first scenario investigated by this study can be seen in Figure 6.12 below. This scenario defines the risk of poor grip strength through standard deviations (SD) from the mean. A single SD from the mean was allocated as 'Low GS', while two SD's from the mean was allocated as 'Very Low GS'. Similarly, those with above one SD from the mean were allocated to the 'High GS' group. The results of these cut-off values, generated from the ELSA base data can be seen in Figure 6.12 below. As can be seen from the figure, there is a trend toward lower grip strength in older individuals. Interestingly however, little evidence for increased volatility in grip strength is found amongst older individuals.

Figure 6.12 - Female Grip Strength Scenario 1 by Age

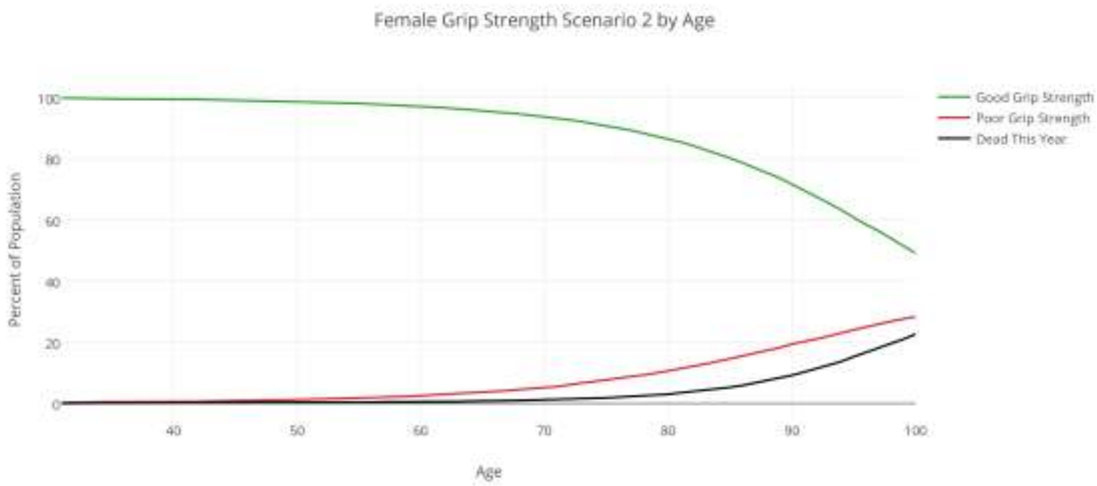


Source: Author's own analysis of ELSA Data

The second set of scenarios investigated, detailed below in Figures 6.13 and 6.14 utilised set cut off values to determine the number of individuals experiencing problems with a task or being at risk of musculoskeletal issues. The first scenario, detailed in Figure 6.13

below utilised the cut-off value of 9kg. This value as described in section 5.4.3 was suggested by Rice, Leonard & Carter (1998) and was proposed as a cut-off for men and women, indicative of the minimum grip strength required to complete most daily activities. As can be seen from the results, almost all individuals under the age of 50 achieve projected grip strength values over the threshold. From age 50 and more rapidly from age 70, the proportion of individuals falling under this threshold increases dramatically.

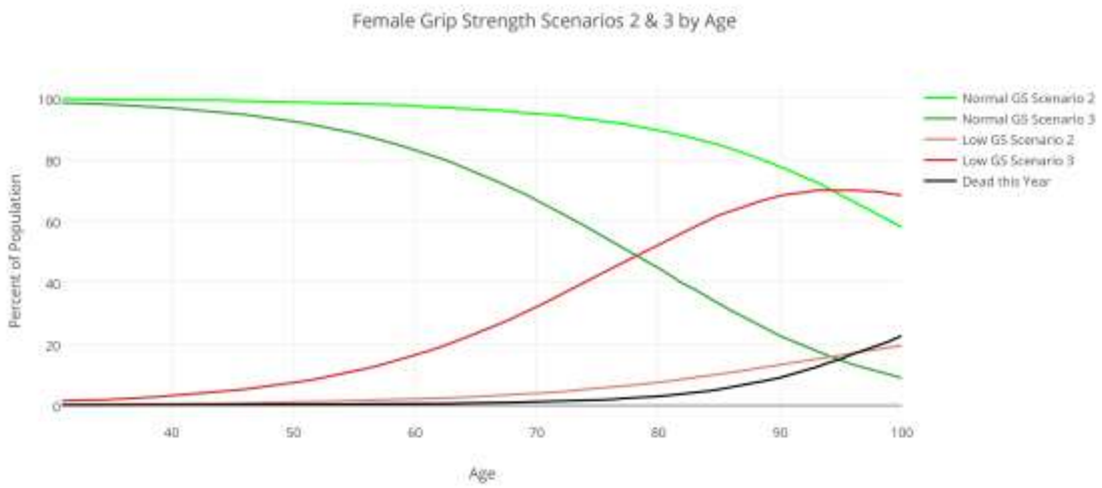
<u>Figure 6.13 - Female Grip Strength Scenario by Age</u>



Source: Author's own analysis of PENHEALTH model Data

Figure 6.14 below shows two possible alternative conceptualisations of grip strength as a measure of health. Scenario 2 utilises the same minimum threshold of 9kg as previously, while the second trajectory utilises the higher minimum grip strength threshold of 20kg for women as put forward by Lauretani *et al* (2003). The difference in proportion falling into ill health by age can be seen in the below figure. As can be seen, 9kg provides a significantly smaller cohort of individuals classed as in poor health at all ages. Meanwhile, within the 20kg scenario, a significantly larger number of individuals fall below the threshold value at significantly earlier ages. This leads to a widening discrepancy between the two definitions, with a greater number of individuals falling into poor health as they age, peaking towards the oldest old. An equal relationship can be seen in the proportion of those individuals in good health. Although the number of individuals reporting good health declines with age in both Scenarios 2 (9kg) and 3 (20kg), the reduction in good health is significantly more marked within the latter scenario. This graph highlights how crucial the definition of 'poor health' can be when assessing ability to work throughout life. Scenario 3 (20kg) is likely to provide a significantly greater population of individuals experiencing difficulty remaining in employment until SPA.

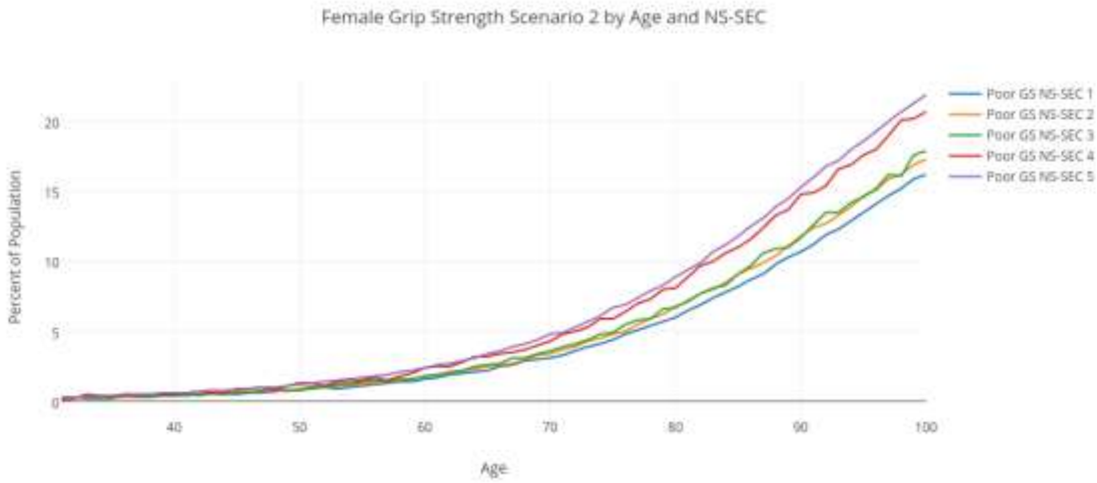
Figure 6.14 – Female Grip Strength Scenarios 2 and 3 by Age



Source: Author's own analysis of PENHEALTH model Data

The variability in poor grip strength reporting by NS-SEC group within the 9kg conceptualisation of model is shown in Figure 6.15 below. As can be seen, all individuals experience similar low levels of poor grip strength at younger ages. However, following age 40, the experience between those in high and low NS-SEC social status groups diverges significantly. Those in lower NS-SEC groups experience substantially higher levels of poor grip strength for each given year of age. These findings draw into question the ability of individuals, particularly those in jobs requiring manual labour and physical fitness to be able to continue in employment at older ages.

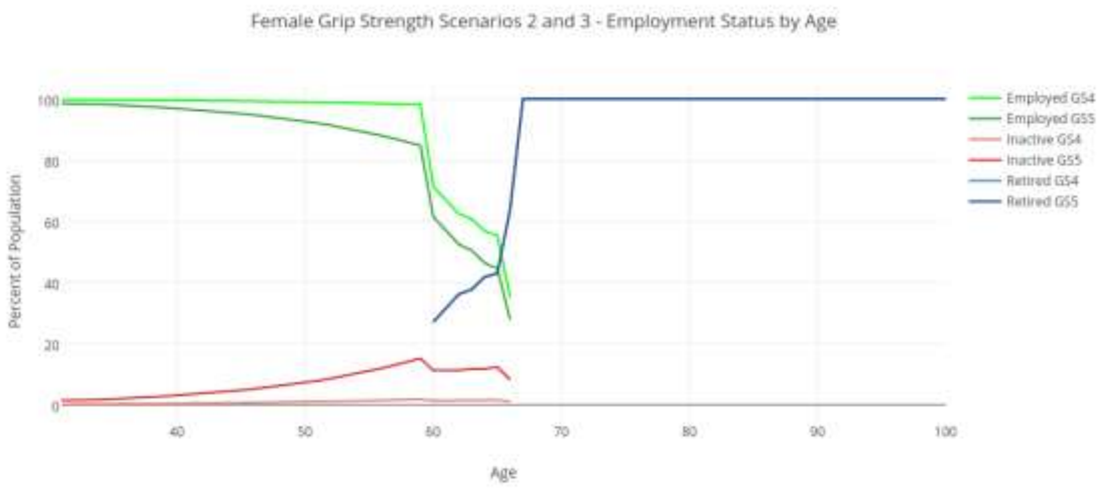
Figure 6.15 – Female Scenario 2 Poor Grip Strength by Age



Source: Author's own analysis of PENHEALTH model Data

The results of the two definitions of poor health on the employment status of individuals can be seen in Figure 6.16 below. Scenario 2, utilising the lower minimum grip strength value of 9kg results in a very small proportion of individuals falling into the definition of 'poor health' before SPA. Scenario 3 with the higher cut-off of 20kg however results in a significantly higher proportion of individuals in poor health before SPA. Similarly to the results for the base model, this value will increase significantly as the SPA is increased

Figure 6.16 – Female Grip Strength Scenario – Employment Status by Age



Source: Author's own analysis of PENHEALTH model Data

6.4 Chapter Summary

This chapter has investigated the results of the PENHEALTH model under the base scenario, which forms the simplest possible iteration of the model and is intended as a benchmark against which alternative scenarios can be compared. This section has shown that the health of individuals within the model deteriorates through life, with reducing proportions of those in 'Good' health and increasing proportions of those in 'Fair' or 'Poor' health states. Similarly, a social gradient of health element to the results is additionally identified surrounding this trend. Consistent with the input data, at all ages those with a higher social status report better health than those in lower groups. This effect is especially pertinent for this analysis when considering the proportion of individuals reporting 'Poor' health in the years nearing SPA. This scenario found that a significantly higher proportion of individuals in lower social groups were experiencing poor health in these critical later years. These results suggest a possible social gradient of premature economic inactivity in the years leading to SPA.

This result is especially important when considering an increasing SPA. Within this base scenario that assumes no interaction between employment and health, the number of individuals required to continue working while in poor health is likely to simply increase when increasing the SPA. The further the SPA increases, the more individuals are likely to experience poor health before reaching the age of retirement, however this will be discussed further in chapter 8. Without further measures to assist these individuals, this is likely to lead to a number of impacts for public policy and finances, as individuals experiencing premature economic inactivity are likely to be required to seek alternative means of support. This is especially true for the most vulnerable group, those in low NS-SEC groups, who are significantly less likely to have private pension income available (ONS, 2014e). This effect is likely to reduce the proposed savings expected through the policy of an increasing SPA, with an increase in expenditure from alternative forms of support such as Job Seekers Allowance, retraining costs and disability benefits. Similarly, the increase in SPA has the potential to act to the detriment of the future health of the population, with the largest impact on those with lower socioeconomic status. Increases in the number of individuals in poor health while they are still expected to continue working risks increasing the stress experienced during these pre and post retirement years. This has the potential to cause health 'shocks', negatively impacting the continued health of these individuals during their retirement years.

Chapter 7 Advanced Model Parameters –Feedback Effects between Employment and Health and Mortality Variants

The previous chapter put forward the base scenario of the model as the simplest iteration of the model in order to investigate the model operation and dynamics. Chapter 7 will elaborate this model, utilising and assessing more complex assumptions intended to bring the model closer to reality. The PENHEALTH model has capability to vary a number of assumptions in order to mimic reality or test policy alternatives. The model is capable of varying the SPA, mortality, feedback between employment and health, the measure of health utilised and the measure used to define health and difficulty remaining in the workforce. This chapter will focus on alternative assumptions of mortality and feedback between employment and health. The full details of the alternative assumptions utilised can be found below in Appendix B. Following this, Chapter 7 will investigate alternative SPA policy scenarios and alternative measures of health. Chapter 8 will then put forward likely combinations of assumptions that provide a similarity to observable trends.

The 4 scenarios considered in this chapter will include:

- Small Health Inversion Effect (Active Health Benefit, Inactive Health Detriment)
- Social Gradient of Health Effect (Impact Varied by NS-SEC Group)
- High/Low Alternative Mortality Assumptions

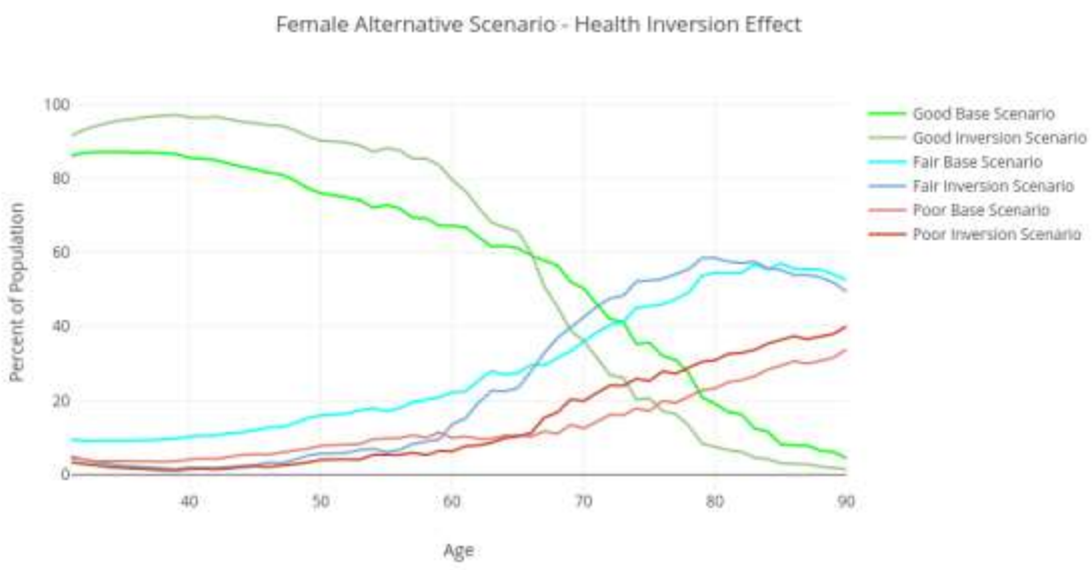
The first alternative scenario based analysis undertaken was differential conceptualisations of the feedback between employment and health. As discussed previously in Sections 1.2.2, 1.2.3 and 3.3, no consensus has been reached within the literature as to the direction, nor strength of feedback between employment and health. The relationship is likely to be dependent on a wide range of contextual variables, as well as individual and workplace characteristics. What is clear is that the existence of employment and the social status of that employment have a wide range of impacts, both directly and indirectly, positively and negatively on the lives of individuals.

It was decided to include an element of these effects within the model through the ability to manipulate the experience of health while in various employment states. The analysis took part in three stages; first the theoretical positive impact of either employment or inactivity was investigated. Secondly, a mixed effect was investigated, in which economic activity is assumed to impact health in one direction and the economic inactivity in the opposite direction. Finally, a social gradient of health assumption was investigated in which the impact of economic activity is variable dependent on NS-SEC social group. This was undertaken as the NS-SEC measure is intended to serve as an approximation of employment conditions. These conditions and context of employment are likely to serve as a large influence on whether continued employment will have a protective or diminishing impact on health. The scenario was enacted through the feedback mechanism included within the model, through which the health transition predicted probabilities are reweighted by a defined percentage to reflect the views of the modeller.

7.1 Scenario 2 – Economically Active Health Improvement, Economically Inactive Health Detriment

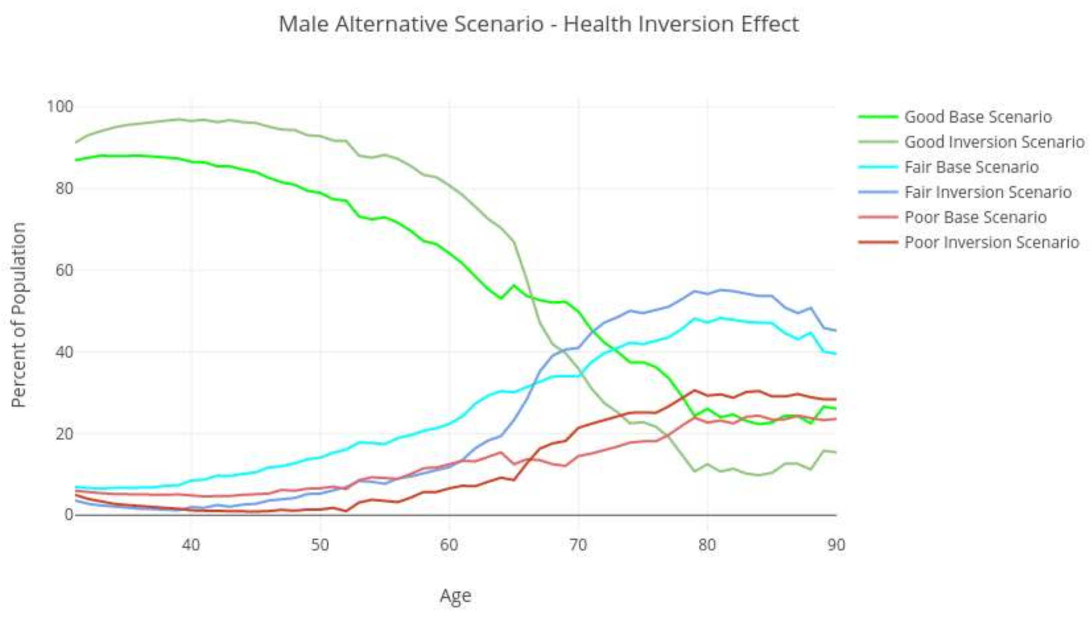
The second scenario investigates a possible health inversion between the years of employment and economic inactivity, as shown in Figures 7.1 and 7.2 below. Within these scenarios it is proposed that economic activity provides a positive impact on health through increased monetary and social resources, while economic inactivity has a negative impact on health. As can be seen in the figures, detailing a small health inversion effect, the feedback effect improves levels of good health during employment years and has a negative effect on health during inactive years. Conversely, the levels of fair and poor health are diminished during employment years and increased during the years of inactivity. This scenario is most plausible for those with limited economic means and minimal savings. The years of adequate employment may provide a health benefit, facilitating social interaction and activity. However, following retirement, the individual may experience a sharp reduction in means and therefore the degree to which they can interact with society and fulfil their goals. Under this circumstance, the individual may experience a sharp reduction in health following SPA. Critically for this study, such protective or diminishing health effects experienced manipulate the point at which SPA and health interact. Within a population level decline in health trajectory, if a protective effect of employment is experienced, additional years of work are likely to improve relative health at the age of retirement. Whereas if economic inactivity serves to the detriment of health during retirement years, these additional years will have a significant impact on one's health during pensionable ages. Additionally, the polarisation between the positive and negative health impact may lead to a health 'shock', in which the individual experiences rapidly diminished health, which can in turn stay with them for many years to come.

Figure 7.1 – Female Alternative Scenario – Small Health Inversion Feedback



Source: Author's own analysis of PENHEALTH model data.

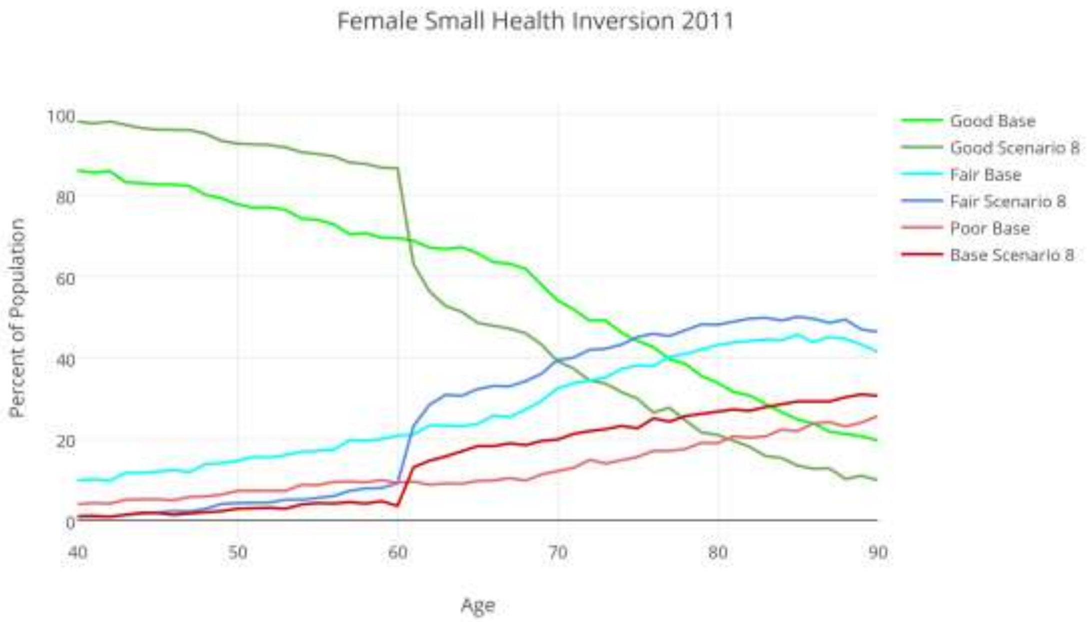
Figure 7.2 – Male Alternative Scenario – Small Health Inversion Feedback



Source: Author's own analysis of PENHEALTH model data.

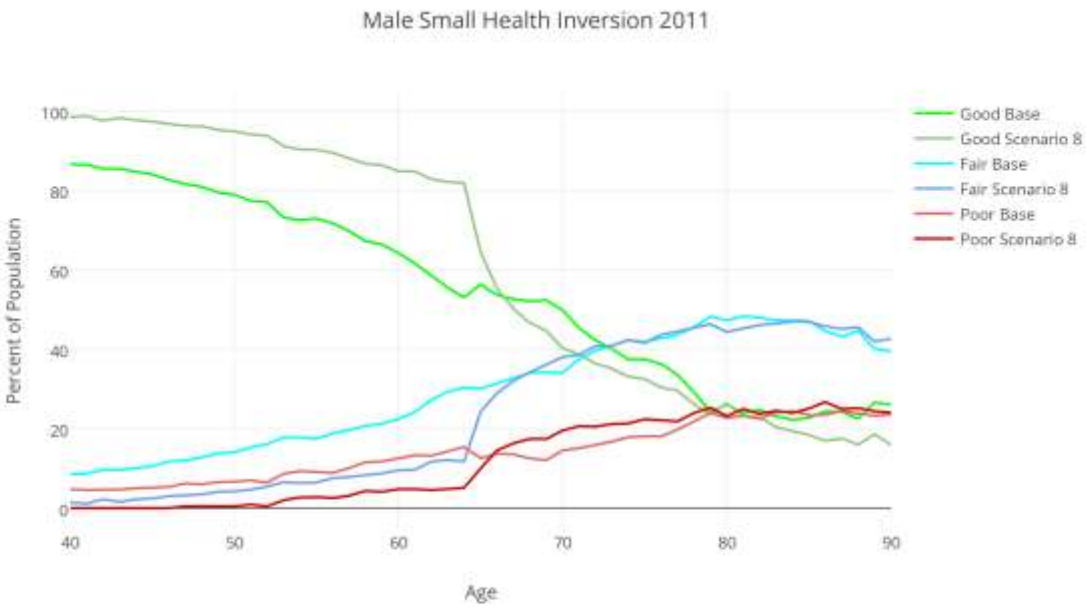
A closer focus on the individual year of 2011 is shown in Figures 7.3 and 7.4 below, highlighting the impact of SPA on this effect. The figures show the impact of male and female health inversion effects in 2011. As can be seen, female individuals experience a detriment to their health far earlier than male individuals, due to the lower SPA of women in 2011 of 60, compared to 65 for males. Following SPA, females proceed to experience a rapid decline in health, followed by a period of reduced health in comparison to the base data. Meanwhile however, male individuals experience a later health impact of retirement, providing a protective effect of employment on health until age 65. Following retirement, male individuals experience again a rapid decrease in the proportion reporting good health and an increase in the proportion reporting poor health. Unlike for female individuals however, minimal change in proportions is experienced in those reporting fair health. This could be a result of the reweighting algorithm, in which females with overall better health at older ages experience a full reweighting, whereas males with a greater spectrum of health states are pushed toward an increasing percentage of poor health individuals. This could provide a selection effect, in which those in good health remain in good health, whereas those that begin to deviate from good health rapidly find themselves in diminishing health states.

Figure 7.3 – Female Alternative Scenario Small Health Inversion 2011



Source: Author's own analysis of PENHEALTH model data.

Figure 7.4 – Male Alternative Scenario Small Health Inversion 2011



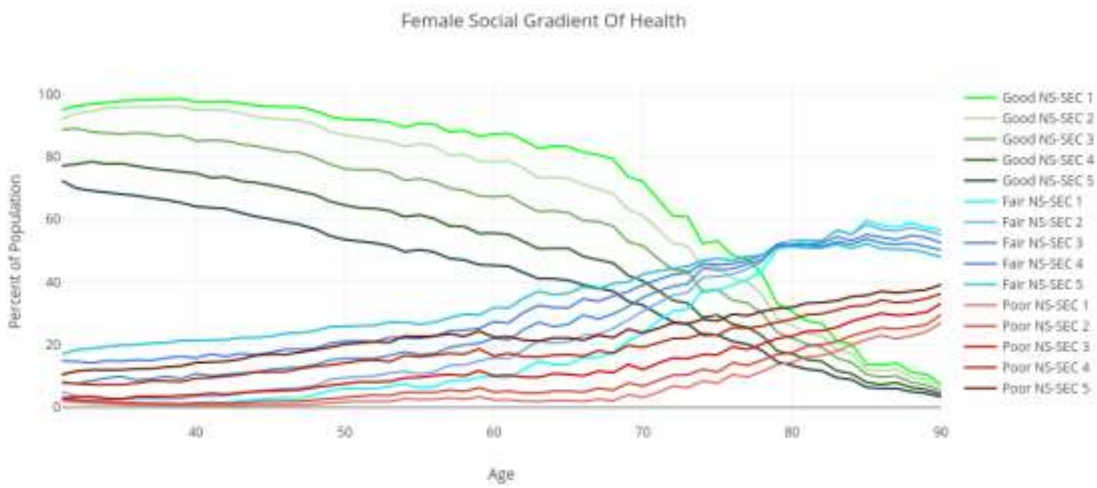
Source: Author's own analysis of PENHEALTH model data.

7.2 Scenario 3 – Social Gradient of Health Effect

Figures 7.5 and 7.6 below show the impact of a social gradient of health type effect within the population. Within Scenario 3, individuals in higher NS-SEC groups are assumed to benefit positively from both employment and retirement. This is based on the assumption that individuals in high NS-SEC groups are likely to experience better conditions of employment and means to engage in pleasurable activities outside of work during employment years. Additionally, these individuals are significantly more likely than lower NS-SEC groups to have additional private pension income, reducing the impact of change financial circumstances between employment and retirement years. Individuals in lower NS-SEC groups meanwhile are assumed to experience a negative health impact of continued employment. This is based on the assumption that those in lower NS-SEC groups often experience less secure forms of employment, reduced financial means and sometimes more physically demanding jobs than their high NS-SEC counterparts. Additionally, individuals in low NS-SEC groups are assumed to experience a negative health impact of retirement. This is based on the assumption of less financial means during retirement years due to a reduced likelihood of private pension income within this group. Within this scenario, probabilities of falling into good health for NS-SEC groups 1 to 5 are reweighted by 120%, 110%, 100%, 90% and 80% respectively for both employment and retirement years. The results of this can be seen in Figures 7.5 and 7.6 below.

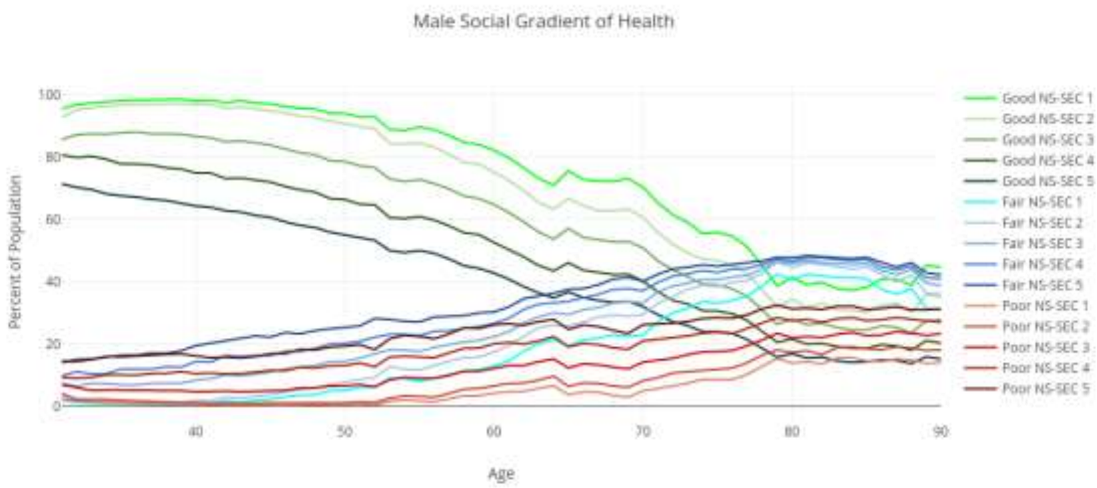
Within the social gradient of health scenario, the normal social gradient of health experienced within the base data is exacerbated through employment and retirement condition, leading to individuals in lower NS-SEC groups to experience consistently worse health than their high NS-SEC counterparts at all ages. The accuracy of the assumption of an increased social gradient of health over and above that in the base data depends on the impact of continued employment or retirement to the individual's health. Whether the full impact of continued engagement is captured within the base data or whether an additional lever is required to fill in for missing data accuracy remains under debate. As can be seen in the below figure, those in good health and in NS-SEC groups 1 and 2 are compressed towards the top of the health distribution, reporting similar experience of good health until age 63. Meanwhile, those in NS-SEC groups 3-5 show significantly reduced levels of good health at all ages, which translates into a significantly higher level of poor health for those nearing SPA. Within Male individuals in NS-SEC group 5 at age 65, 30.4% report poor health, compared to 3.6% of their counterparts in NS-SEC group 1.

<u>Figure 7.5 – Female Alternative Scenario – Social Gradient of Health</u>



Source: Author's own analysis of PENHEALTH model data.

__Figure 7.6 – Male Alternative Scenario – Social Gradient of Health__

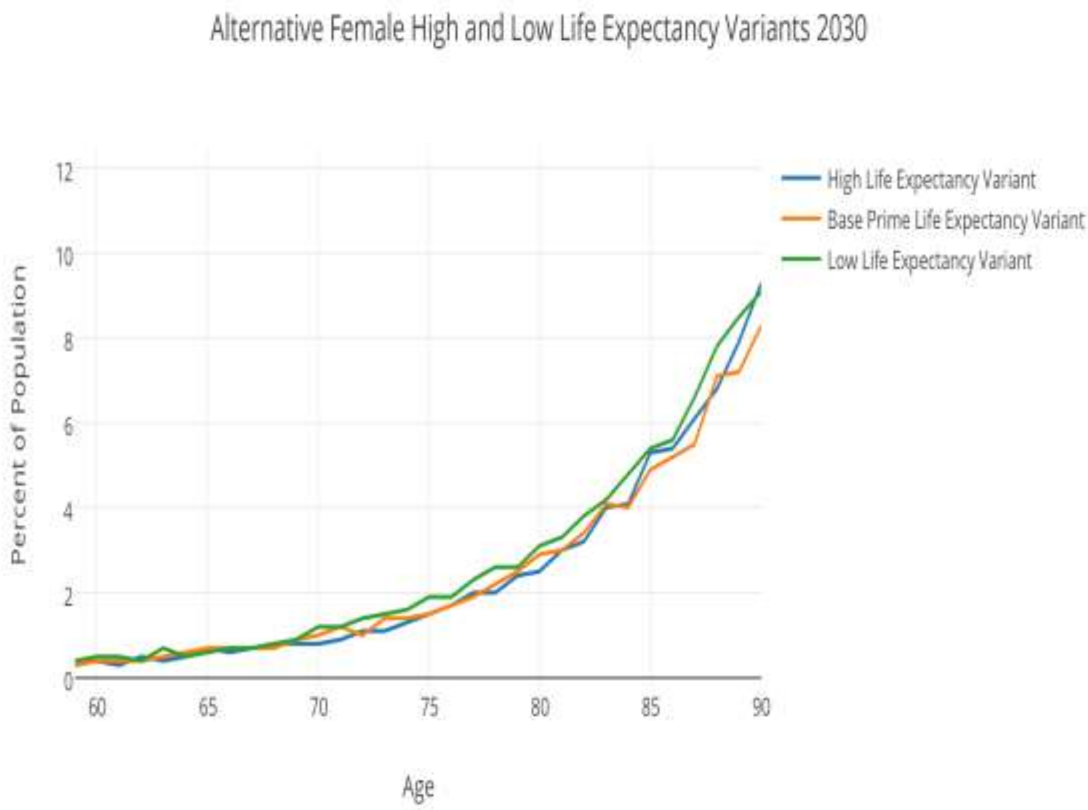


Source: Author's own analysis of PENHEALTH model data.

7.3 Scenario 4 – Alternative High & Low Mortality Variants

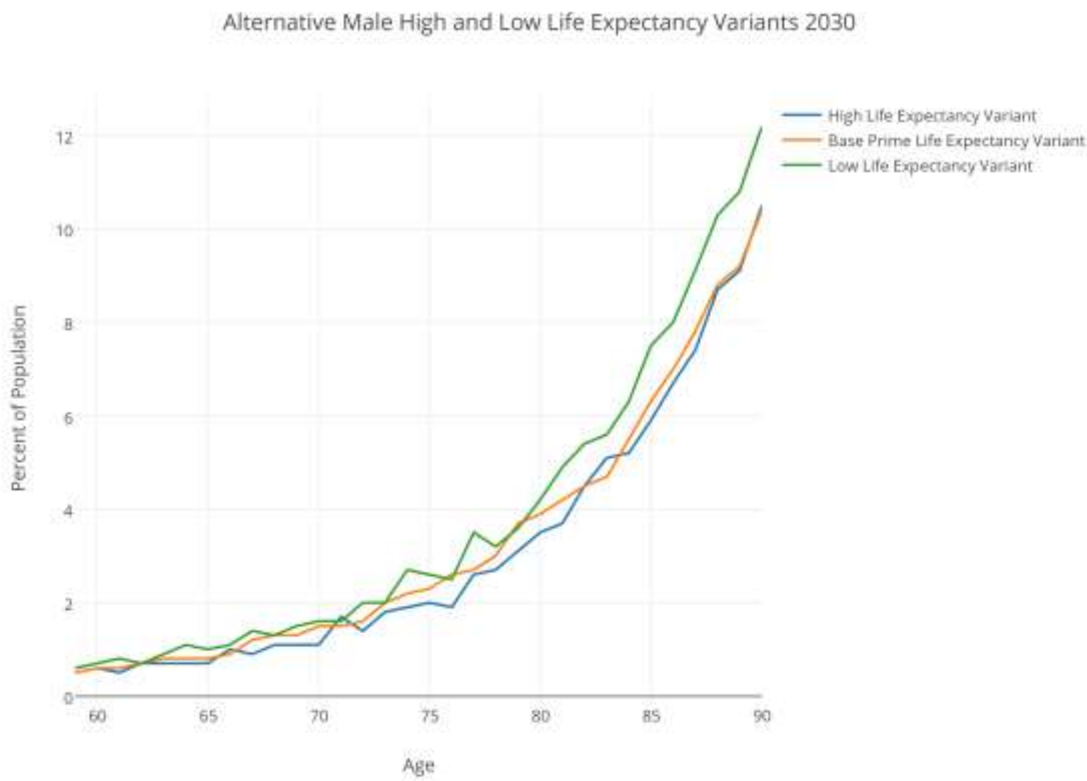
The second set of alternative scenarios investigates alternative assumptions of mortality within the model. The timing of death for an individual is critical when assessing the benefit they are likely to have received from the state pension system, as well as whether the individual is achieving the goal of 1/3 of life spent post state pensionable age. The measure of life expectancy utilised within the proposed formula provided by the DWP (2013a) is the same as that used within the base scenario of the PENHEALTH model, the ONS prime projection of mortality from 2001. This is intended to provide an indication of what the ONS currently expect to be the most likely scenario of mortality during this space. However, the prime projection gives no indication as to the possible variation and uncertainty in these figures if alternative assumptions were to prevail. For this reason, the ONS also provides high and low variants of mortality projections intended to give an indication of this uncertainty. The alternative scenarios of mortality utilised within the PENHEALTH model will utilise these high and low mortality variants to give an indication of possible variability in these results. As can be seen from the below Figures 7.7 and 7.8, high and low mortality rates, depending on the expectation of high or low life expectancy attained within the population. The figure shows data for 2030, however mortality data is specified annually for each model year. As can be seen from the figure, the variability between high and low life expectancy variants is small within a single year. This low variation is the result of a confidence of the ONS of the mortality rates in a single near-future year. As the distance into the future increases, the variability in possible mortality rates increases. There is a divergence towards the later ages, suggesting uncertainty on the part of the ONS at future health behaviour between these ages. This effect is particularly pronounced amongst male individuals who show a high divergence from the low life expectancy variant. Such a pattern may be due to male life expectancy improvements experienced recently not continuing into the future, resulting in a higher mortality rate than expected. The experience of the population and the quality of the projection of life expectancy over the coming years will form a critical component to the impact of the SPA changes. If a SPA linked with average life expectancy is enacted, the financial sustainability of the state pension system is likely to be heavily impacted by the quality of projections, an aspect that is discussed further in section 8.1.3 and chapter 9.

Figure 7.7 – Female Alternative Scenario Life Expectancy Variants 2030



Source: Author's own analysis of PENHEALTH model data.

Figure 7.8 – Male Alternative Scenario Life Expectancy Variants 2030



Source: Author's own analysis of PENHEALTH model data.

7.5 Chapter Summary

This chapter has investigated the more advanced scenarios available within the PENHEALTH model. The feedback effects between employment and health and mortality rates that we can expect in the coming years were found to be highly influential when characterising both the individual experience of SPA policy, as well as the potential gains that the government can expect to receive through increased National Insurance contributions. What is clear from the model results so far is that the direction of influence in feedback between employment and health is likely to form a critical component to this relationship. If individuals experience a protective effect from increased labour force involvement, then the SPA increase is likely to be beneficial for on-going health. If however, additional years of work are likely to impact the health of individuals negatively then this may exacerbate an already apparent decline in health towards the older ages. These results will be discussed further in Section 9.3

Mortality rates also form a critical component when assessing the proportional change in life spent in pensionable ages across society. If individuals experience low life expectancy, an additional year of labour force involvement was found to significantly reduce the proportion of years spent in pensionable ages. This element is increasingly important when assessing the impact of a possible link between SPA and average life expectancy, as will be discussed further in Chapter 8.

The following chapter will investigate possible SPA policy alternatives and identify policies that may reduce the impact of a change in SPA.

Chapter 8 Policy Assessment

This section will now cover the policy implications of a change in SPA. This will take place again through the base, and then more advanced scenarios of the model.

These include:

- Original, pre-reform SPA
- Post reform, currently legislated SPA
- SPA Linked with average life expectancy
- SPA reached upon 45 years of contributions.
- SPA reached upon 50 years of contributions

Within the base scenario presented first, all variables are utilised with minimal manipulation in order to provide a base figure against which to consider alternative scenarios. This section will first discuss the motivation and considerations behind a SPA. Secondly, results from the model for a variety of SPA assumptions will be put forward.

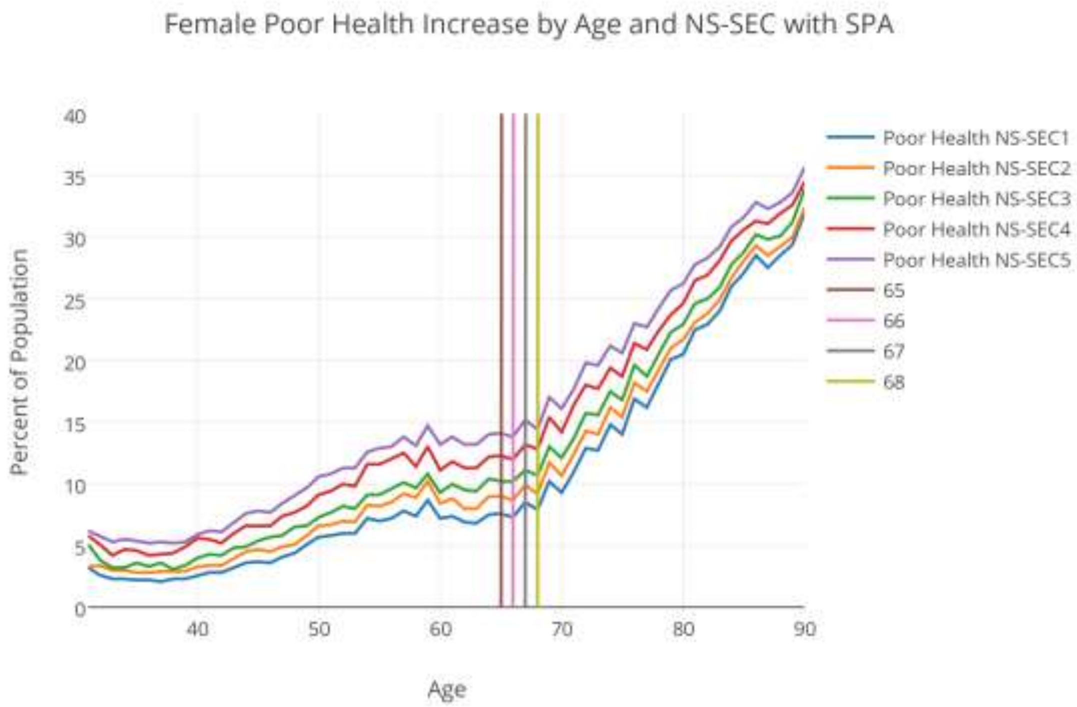
Within the base scenario, the only variable that is manipulated is the SPA. With no feedback between employment and health assumed within this first scenario of the model, the health trends generated by the model can be assumed to be constant across the duration of the model. Additionally, with no assumed impact between employment and longevity, nor additional longevity gains assumed within the population, the life-span of individuals remains constant. Within this scenario, the critical question therefore becomes at what point should the cut-off be placed, where remaining in the labour market could cause a greater number of individuals to fall into fair or poor health states while still under pensionable age. This therefore becomes an ideological standpoint, in which the government must decide what levels of poor health and subsequent potential difficulty continuing within the workforce are deemed acceptable or necessary.

A number of different of considerations must be made in the assessment of this variable. First, as discussed earlier in section 1.2.2, to what extent does falling into poor health impact the individuals' ability to continue working? While it is certainly possible to continue working while in poor health, the individual may encounter difficulty. Secondly, will poor health and subsequent potential inability to continue working push individuals out of the workforce and toward another type of economic support? This is likely to have implications of its own for the health of the individual. Indeed, it must also be considered whether in the current climate of a changing welfare state, whether such alternative support will be available, adequate or achievable for those falling out of the workforce, such as was discussed in section 1.2.5.

The ability to find an 'optimal' solution depends on the interaction of these and countless other variables, encompassing as values and beliefs of the current government, and those of the individuals affected by the policy. Consequently, the 'optimal' solution remains subjective and will not be provided here. Rather, discussion will focus on the possible impact of a variety of SPA assumptions.

As identified previously, the prevalence of 'poor' health within the model increases with age. Each year the SPA increases, and this adds an additional and expanding group to those at risk of being in poor health, while being required to remain in employment. As discussed previously, the critical question regarding policy impact under the base scenario therefore is where the line is drawn for SPA. A diagram of this can be seen below in Figure 8.1, showing the proportions of individuals per year of age falling into poor health for each year increase in the SPA. The vertical lines signify different state pension ages and therefore different 'cut-off' points for number of individuals falling into poor health before reaching state pension age. What must be considered is the dependence these individuals may have on the receipt of the state pension if they experience poor health before the SPA. As discussed previously in chapter 1, individuals with lower resources are simultaneously less likely to be able to contribute to an alternative private pension scheme, while having lower life expectancy and healthy life expectancy.

<u>Figure 8.1 - Variable SPA Assumption – Proportion Falling Into 'Poor' Health – Base Scenario</u>



Source: Author's own analysis of PENHEALTH model data.

8.1 Alternative SPA Policies

In addition to considering the current SPA legislation, the PENHEALTH model can also be utilised to test alternative policy assumptions, through which the relative impact of a variety of different policies can be assessed. This can assist in minimising the effect the policy shift may have to those groups most impacted by the policy.

The policies tested will comprise:

- Original, pre-reform SPA
- Post reform, currently legislated SPA
- SPA Linked with average life expectancy
- SPA reached upon 45 years of contributions.
- SPA reached upon 50 years of contributions

These four alternative SPA assumptions can be tested and subsequently disaggregated by a number of variables through comparing the impact across individuals and groups of individuals.

8.1.1 Original, pre-reform SPA

In line with pre-reform SPA (DWP, 2013b), under this scenario the SPA will be set at 60 for women and 65 for men. This scenario was included to give a figure that can be used to compare currently legislated SPA changes, as well as plausible alternative scenarios. Through doing this, we can compare the impact of the new legislated policy, versus the counterfactual scenario of either no policy change or alternatively suggested policies.

8.1.2 Post reform, currently legislated SPA

Formed from the base scenario and detailed in Tables 5.11, 5.12 and 5.13 above in section 5.8.1, this scenario utilises the currently legislated timetable of SPA changes (DWP, 2013b). This scenario allows the assessment of the impact of legislated reforms, versus a range of counterfactual scenarios.

8.1.3 SPA in line with average life expectancy

Following the period of set increases in SPA, the government has proposed regular revisions of policy and increasing SPA in line with average life expectancy (DWP, 2013a). This scenario will be considered as the most likely SPA policy direction to be taken, following the current period of set SPA increases. This will give the most likely scenario through which to assess future impact.

While the mechanism through which this will be enacted is still under debate, enough information has been provided to project one possible calculation of SPA policy. The mechanism proposed to calculate SPA in line with average life expectancy is:

$$\boldsymbol{Proportion\ of\ adult\ life\ spent\ in\ receipt\ of\ State\ Pension}\ =$$
$$(Life\ Expectancy\ at\ SPA)/(Life\ Expectancy\ at\ SPA\ +\ SPA - \ Adult\ Life\ Starting\ Age)$$

Source: (DWP, 2013a)

The DWP (2013a) additionally suggest that in line with OECD convention, the adult life starting age should be set at 20 years. The proposed measurement of life expectancy is the cohort principal projection provided by the ONS and that an average should be taken between male and female life expectancy, weighted for the sex ratio observed at the given age. Finally, the proportion of adult life expected to be spent in receipt of state pension is suggested to be up to 1/3. These factors combine to provide a moving average age of retirement, starting with the first iteration of the model and followed by an assessment of the impact of the policy, compared to original and the current SPA policy.

8.1.4 SPA reached upon 45 years of contributions

An alternative proposition of SPA was put forward by the Pensions Policy Institute (2016), linking SPA with the number of contributory years. Under the current SPA legislation, 30 years of contributions are required in order to obtain a full state pension, however one must wait until their defined SPA to be able to draw this. This number of years is set to increase to 35 years under the Single Tier Pension. However, a large number of individuals accrue more than 35 contributory years during their working lives (PPI, 2016). Those with the most physically demanding jobs may struggle to continue in employment and maintain the required level of fitness until an increasing SPA. Individuals with such characteristics are simultaneously the most likely to reach the required level of contributions early. By contrast, individuals in Semi-Routine or Routine occupations enter the workforce earlier, often resulting in obtaining more than the required number of years contributions. Figures obtained from the Department for Work and Pensions suggest that of the 660,000 people reaching SPA in 2013, 253,000 (38.3%) have more than 45 years contributions (PPI, 2016). It is argued that those in Routine or Semi-Routine occupations are more likely to have longer contributions records, having been more likely to start working straight out of school. It is therefore suggested that these additional years of work when other individuals pursue higher education should allow those with the contributions to retire earlier. Additionally, individuals most likely to be in poor health in the lead up to SPA are most likely to have a lower than average life expectancy, shortening the proportion of life spent post SPA. The PPI (2016) suggest allowing receipt of the pension following 45 years of contributions, through doing this it is argued that the discrepancy between life expectancy and retirement years can be reduced.

8.1.5 SPA reached upon 50 years of contributions

Similar to the above scenario, 50 years of contributions will additionally be trialled. Usage of 50 qualifying years was put forward by the Independent Review of the State Pension Age Interim Report (Cridland 2016), suggesting that those who had started work at 16 will be able to draw state pension at age 66. This represents a policy direction that may be under consideration by the government, following inclusion in the independent review.

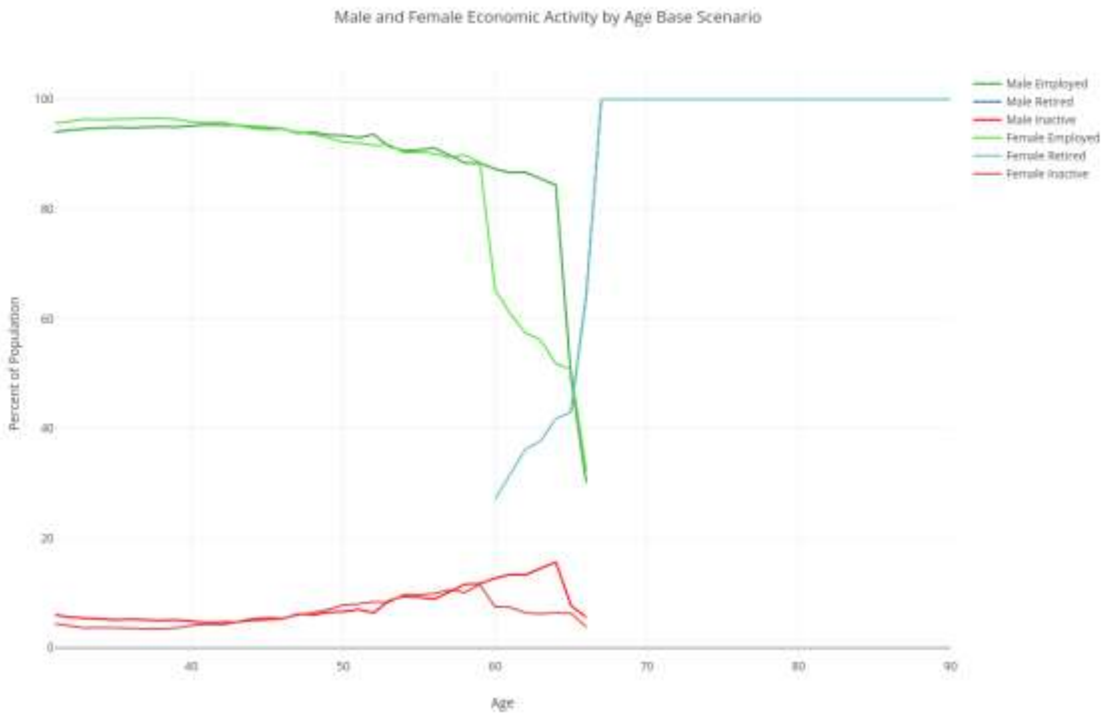
8.2 Base Scenario

The impact of SPA under the base scenario of the PENHEALTH model will have differing effects, depending on where the SPA is set. If SPA were to remain at 65 for women, the PENHEALTH model estimates that 6.2% of NS-SEC group 1 may experiencing poor health in the year preceding SPA. This compares with 12.9% of NS-SEC group 5 experiencing poor health. Under the base scenario and presuming no additional feedback effect between employment status and health, each additional year added to the SPA may add an additional group of individuals expected to be in poor health. For example if the SPA were to raise to 66, the model estimates that 6.4% of those aged 66 and in NS-SEC group 1 and 13.1% of those in group 5 may fall into poor health before SPA. Were the SPA to increase to 66, these proportions increase to 7.3% for NS-SEC 1 and 14.2% for NS-SEC 5. If the SPA rises to 68 as is set out in current legislation, these proportions are estimates to reach 7.9% and 14.4% respectively.

These trends can then be considered in the context of current SPA legislation, as displayed below in Figure 8.2. The figures show the population economic activity levels by year of age, showing the decreasing proportion of those defined as 'economically active' and increase of those 'inactive' individuals leading up to SPA, which begins at age 65. It is at this point where the SPA legislation sets in, with individuals being re-defined as 'Retired'. As discussed previously in section 5.8.1, the model assumes that those who reach SPA will take retirement at the earliest available opportunity. It must be noted that while individuals are redefined as retired, the poor health they experience persists past this point. The increased levels of poor health experienced before SPA will be carried forward into retirement, impacting the quality of on-going retirement years.

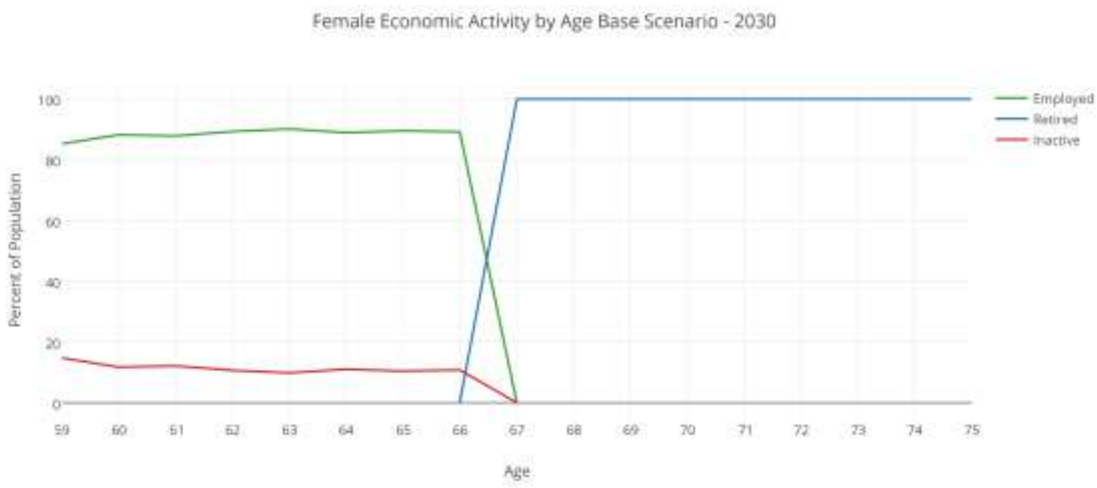
Within this scenario, retirement is 'staggered' within the population, with the variable SPA depending on one's birth year. This results in a decreasing proportion of individuals within 'Active' and 'Inactive' states between the ages of 65 and 67. Simultaneously, an increase in the proportion of individuals defined as retired takes place over the same period, resulting in 100% of the population defined as retired after age 67. Consequently, there is a population trend of increasing economic inactivity leading up to SPA. This trend is seen to be increasing rapidly, peaking at 15.6% of the population aged 64 for Males and 11.5% at age 59 for females. As the SPA increases, the trend of increasing economic inactivity is set to continue to increase, encompassing an increasingly large proportion of the population preceding the SPA. This is particularly true for women, who will experience the greatest increase in SPA, thereby allowing the trend in inactivity to continue. This increase is shown Figure 8.3 below, detailing female economic activity by age in 2030, by which time the SPA will have increased to 67. As can be seen from the figure, the additional years required to be in employment have allowed the trend of economic inactivity to continue into the later ages, culminating in an economic inactivity of those aged 66 of 10.8%. While the possibility to have a SPA of 68 is currently within legislation, the timetable for this is currently outside the scope of the model projection horizon. However the timetable is currently under review and may be brought forward, as was the case with previous changes in the SPA.

Figure 8.2 – Full Male and Female Model – Economic Activity by Age



Source: Author's own analysis of PENHEALTH model data.

Figure 8.3 – Female Economic Activity by Age Base Scenario - 2030

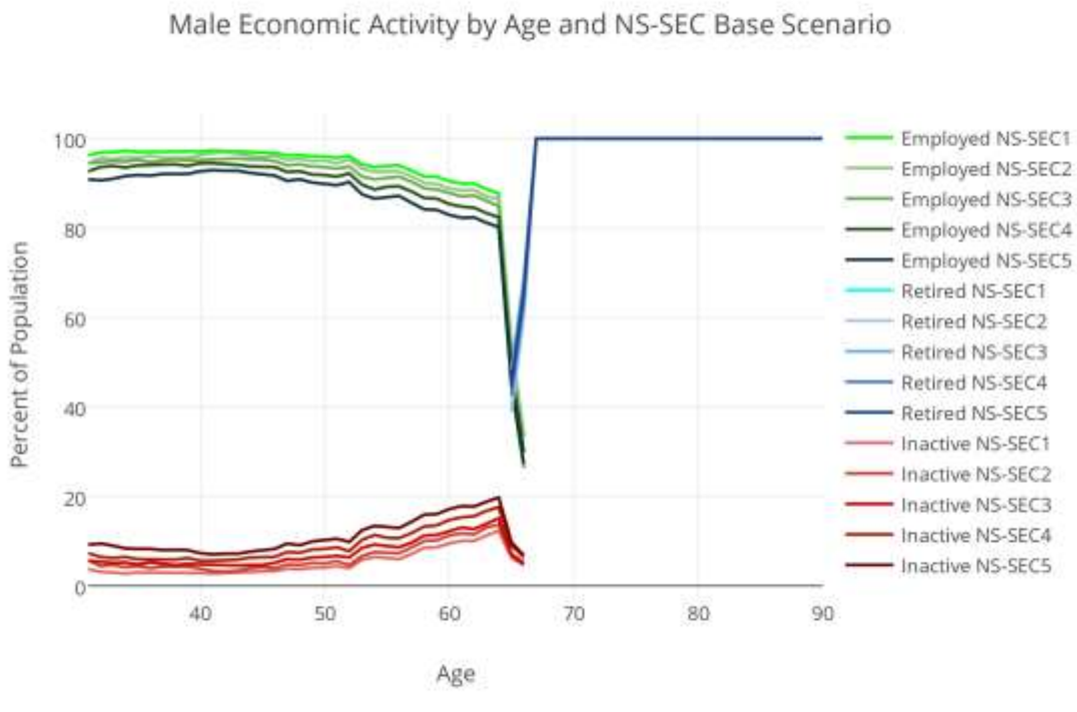


Source: Author's own analysis of PENHEALTH model data.

The above figures give average figures for the total population, hiding a large amount of variability. The following analysis will attempt to disaggregate this. Under the assumptions of the model, differences in health across the population will result in differing numbers of individuals falling into a 'Prematurely Economically Inactive' group before retirement. There are a number of ways to disaggregate this data, however a useful proxy for social standing, employment conditions and social resources is the NS-SEC measure, as discussed previously in section 5.5.2.

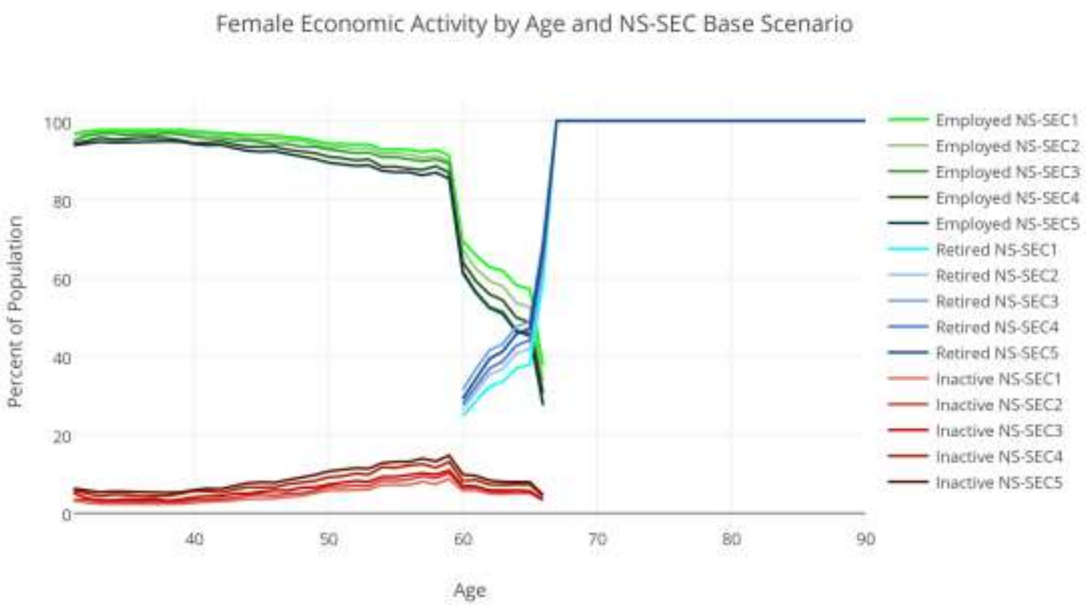
The impact of improved health of those in higher NS-SEC groups on economic activity can be seen in Figures 8.4 and 8.5 below. As can be seen in Figure 8.4, the inactivity level is diverging between the NS-SEC groups, with 5.8% of those in NS-SEC group 1 at age 60 being defined as inactive. This compares with 9.8% of those in NS-SEC group 5. The proportion of male individuals reporting inactivity increases significantly before retirement. Female individuals meanwhile experience a more constant level of inactivity overall between the ages of 60 and 68, but with a greater divergence between top and bottom NS-SEC groups. This is a result of males experiencing poorer health overall at earlier ages within the model population, and could also imply that male individuals may suffer a greater health impact of continued economic activity when nearing SPA. However, this will be discussed further in chapter 9. Additionally, the overall higher male SPA within current legislation gives a greater overall number of individuals falling into inactivity. The increase in the proportion of people reporting poor health when nearing SPA is experienced equally across all NS-SEC groups for both male and female individuals. This leads the level at which to define SPA to be crucial, as this will define the proportion of individuals that may encounter difficulties continuing in employment to SPA.

<u>Figure 8.4 – Full Male Model – Economic Activity by Age & NS-SEC</u>



Source: Author's own analysis of PENHEALTH model data.

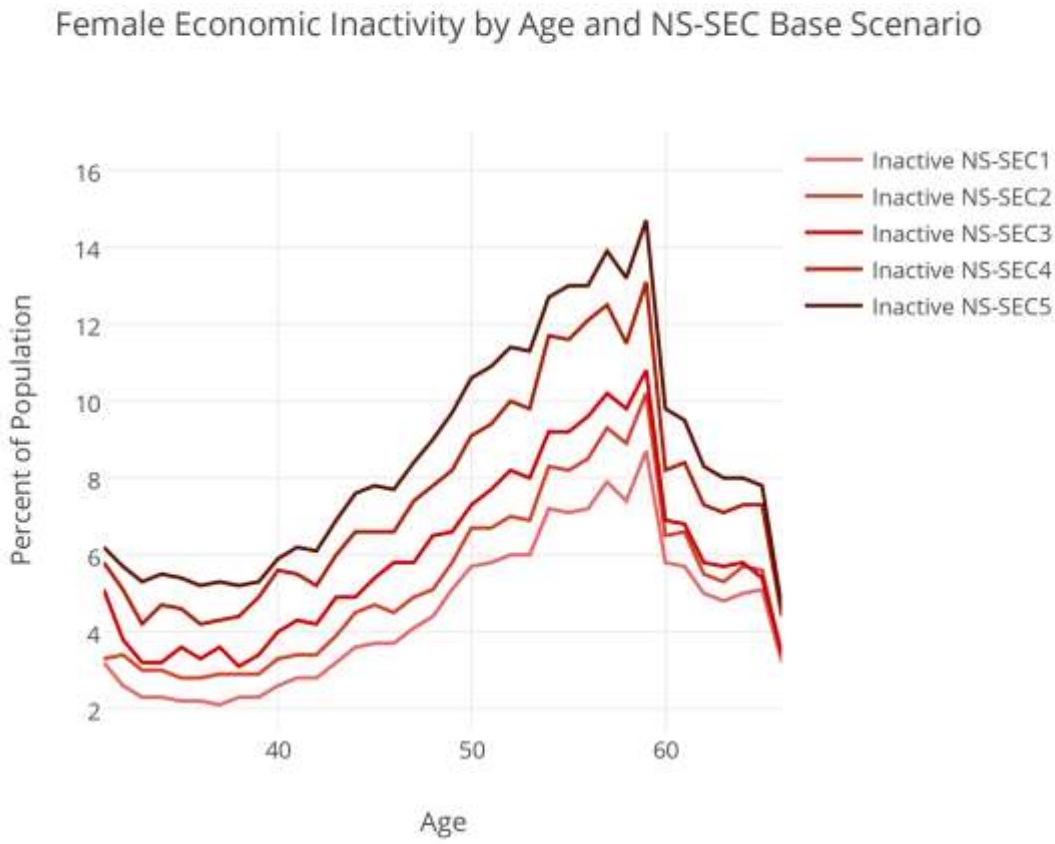
Figure 8.5 - Full Female Model – Economic Activity by Age & NS-SEC



Source: Author's own analysis of PENHEALTH model data.

Greater detail regarding the increase in economic inactivity across all ages amongst women can be seen below in Figure 8.6. The proportion of those falling into economic inactivity increases by age in the model, as the number of individuals reporting poor health increases. This is again diverging between the NS-SEC groups. The delaying of SPA will allow these trends to continue to increase, with an increasing number of individuals falling into economic inactivity. The proportion of individuals reporting poor health rises from a minimum level of 2.1% of those in NS-SEC 1 and 5.3% of those in NS-SEC 5 at age 37. This then continues throughout the remaining working lives of the individuals within the model. The trajectory peaks under the current SPA legislation with 8.7% and 14.7% reporting inactivity at age 59 for NS-SEC groups 1 and 5 respectively. As can be seen in the Base Scenario, a critical variable in the equity of the SPA becomes simply the age at which the SPA is set.

Figure 8.6 – Full Female Model - Economic Inactivity by Age

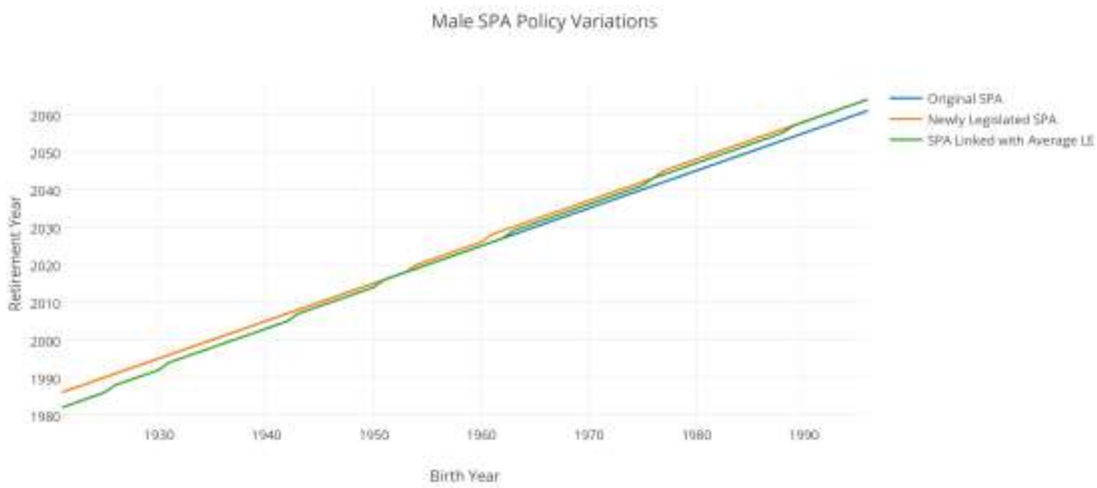


Source: Author's own analysis of PENHEALTH model data.

8.3 Alternative Scenarios

The trajectories of three different SPA assumptions are shown below in Figures 8.7 and 8.8, detailing male and female retirement year against birth year for different policy assumptions. As can be seen from Figure 8.7 for men, the SPA in line with average life expectancy would have historically resulted in a lower SPA for retirement years preceding 2016. However, this LE SPA then continues to increase in line with projected advances in SPA at retirement. This relationship tracks well with currently legislated increases in SPA to the model forecast horizon of 2060. Comparatively, the original SPA for men of 65 is shown to fall away from this advancing trend, leading to an increasing proportion of life spent post-SPA.

Figure 8.7 – Male State Pension Age Policy Variations



Source: Author's own analysis of PENHEALTH model data.

The female trajectories of SPA assumption are shown in Figure 8.8 below. As can be seen from the figure, the SPA in line with average life expectancy gives the highest age of retirement, diverging continuously from the original SPA legislation. Meanwhile, the original SPA provides the greatest proportion of life spent post pensionable age of the three SPA variations. As the SPA in line with average life expectancy maintains an approximately constant 1/3 of life spent in pensionable ages, the original SPA requires consistently less years of employment. Under the assumption of increasing life expectancy, provided by the ONS prime projection, under the original SPA legislation, women could be expected to spend an ever increasing proportion of their adult lives in pensionable ages. The newly legislated SPA bridges these gaps, with the trajectory following the original SPA legislation, followed by a jump to meet the SPA in line with average life expectancy. Interestingly for those women currently experiencing a sharp jump in age of pension availability, these lines converge for those reaching retirement in 1980. For this reason, SPA for women has been drifting away from the desired 1/3 figure since this time, resulting in the need for female SPA to 'catch up' this discrepancy, leading to a sharp jump in SPA. If the policy of matching SPA with average life expectancy had been brought in during the 1980's, this shift and the associated limited time to plan for the change could possibly have been avoided.

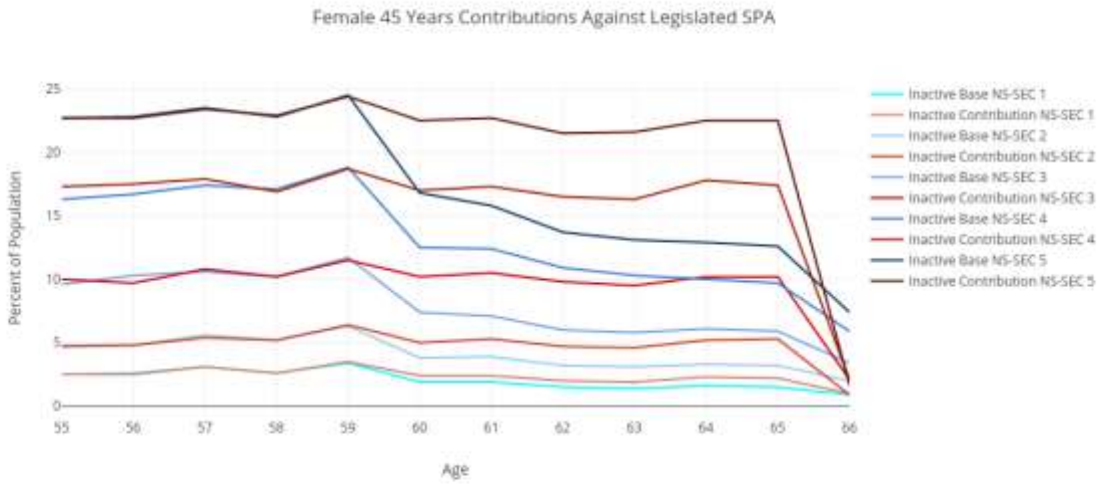
Additionally, the policy of a SPA linked with average life expectancy is based simply upon 1/3 of life, given an average life expectancy for both males and females, weighted for difference between male and female life expectancy. This measure does not account for a large amount of variability in life expectancies experienced across the population, depending on life-course conditions. As discussed previously in section 3.1, this provides a limited view of both individual life expectancy, as well not accounting for the quality of those years.

<u>Figure 8.8 – Female State Pension Age Policy Variations</u>

Source: Author's own analysis of PENHEALTH model data.

The PPI proposition of 45 years contributions was also tested within the PENHEALTH model to assess the possible impact of this assumption. Within the model, it was assumed that number of year's contributions could be approximated through highest educational attainment. Those obtaining A-level or degree level qualifications are likely to have lost these years' contributions at some point in their adult working lives. It was therefore assumed that individuals begin working directly following receipt of their qualifications and continued in employment until 45 years of contributions are reached. The results of this are shown in Figure 8.9 below, showing the level of premature economic inactivity by NS-SEC group in the years surrounding SPA. As can be seen, under current legislation a large number of individuals are required to continue in employment in the lead up to SPA. Again, a gradient is apparent, in which those with the least social resources are most likely to experience poor health before reaching SPA. However, under the assumption of 45 years contributions, this is shown to diminish rapidly. As can be seen from the figure, the number of individuals being required to continue in employment while in poor health rapidly falls from age 60. Within NS-SEC group 5, this results in a reduction from 22.2% at age 60, to 1.8% at age 61 of the population being required to work in poor health. Meanwhile, the proportions for those in NS-SEC group 1 remain comparatively unchanged. Following SPA, the proportion reduces from 2.4% at 60 to 1.4% at age 61 of those required to remain in employment. Under the assumptions put forward in this scenario, this policy has the potential to significantly reduce the gap in experience of working to SPA between those with the most and least social resources. It is possible that through this policy, individuals who are most likely to experience poor health in the years preceding SPA could access pension income during these years. This has the potential to avoid health 'shocks' brought about by continuation in the workforce while experiencing poor health. Additionally, those who find themselves able to continue working up to and even beyond the SPA have the opportunity to do so, allowing more time to plan and save for retirement.

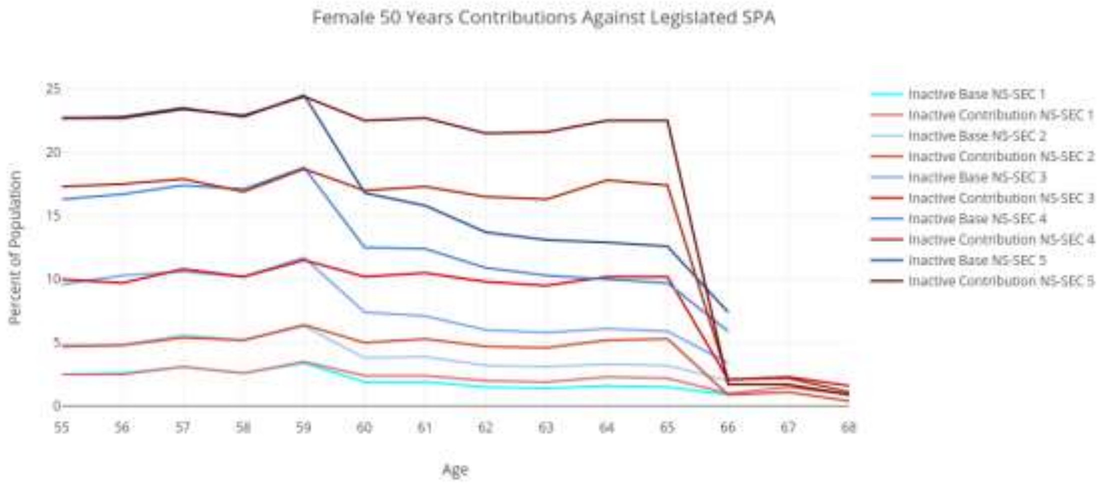
Figure 8.9 – Female 45 Years Contributions Against Current SPA Legislation



Source: Author's own analysis of PENHEALTH model data.

Comparatively, the proposition of the Cridland (2016) Independent Review of the State Pension Age report can be seen below. Based on 50 years of contributions, rather than the 45 suggested by the PPI, this assumes a minimum retirement age of 66, assuming that the individual worked constantly since leaving education at 16. This assumption provides vastly different effects, with no individuals defined in poor health within the model benefiting from this policy above currently legislated SPA policy. As can be seen from Figure 8.10 below, the largest impact under this scenario would be placed upon those in poor health and in semi-routine or routine occupations (NS-SEC 5). Within this scenario, those in higher NS-SEC groups, namely Higher Managerial & professional individuals (NS-SEC 1) experience the least difference in proportion of individuals in poor health before SPA.

Figure 8.10 – Female 50 Years Contributions Against Current SPA Legislation



Source: Author's own analysis of PENHEALTH model data.

8.4 Chapter Summary

The age at which SPA is set is likely to influence the equity of the state pension policy, not only within the lives of the individuals directly impacted, but also across society and between birth cohorts. Under current legislation, some cohorts may have to remain in employment for significantly longer than their predecessors. This not only impacts intergenerational equity, but also the impact these additional years of employment may have on the on-going health of individuals. Therefore the longitudinal assessment of SPA policy is critical in order to identify those groups that will be most impacted during each year of policy shift. The original pre-reform SPA policy allowed the proportion of life spent in pensionable ages to drift away from a policy based on average life expectancy. This was shown to be particularly true for women, whose trajectories have been diverging since the 1980's, thereby requiring a rapid 'jump' to re-gain the life expectancy link.

This chapter has assessed a number of different SPA policy options available to the UK government and assessed the impact, both at a population and stratified by NS-SEC groups.

It is clear that a trade-off must be made by the government when increasing the SPA, defining how many additional individuals may fall into poor health and be required to continue in employment, against required increases in economic activity. One policy trialled has shown the possibility to reduce the divergence in experience gradient between highest and lowest NS-SEC groups. A proposed link with years of National Insurance contributions may allow those with less educational attainment, who often experience poorer health to retire earlier, in line with starting their working life earlier. The analysis of such a policy within the model has shown the possibility to significantly narrow the experience gap between top and bottom NS-SEC groups for women in the levels of economic inactivity in the years preceding SPA.

Chapter 9 Discussion & Conclusions

9.1 Introduction

The life expectancy of individuals in the UK and across the world is increasing (ONS, 2015a). Although this has been heralded as one of the greatest achievements of modern technology and healthcare, such an effect presents equal challenges and opportunities for policy makers and governments. Increasing longevity without a similar level of health improvement at later ages is likely to lead to a greater number of years spent in ill health. Alongside this, the UK would be likely to experience increased cost to welfare, social care, pensions and healthcare providers. Meanwhile, the economic benefits of a workforce able to extend working years and continue contributing to taxation and pensions will facilitate a greater standard of living for individuals in older ages. To challenge to realise the opportunities of a workforce with greater life expectancy, while minimising the negative impacts of working longer is set to become one of the defining issues for the policy of ageing.

This chapter will investigate the impact of the study findings regarding the research questions. Results will be discussed more intimately, contextualising them within the debate of a change in SPA. The impact of the current SPA legislation will be assessed and alternative SPA assumptions that may mitigate some of these impacts will be put forward. Importantly, the quality and limitations of the results will be discussed alongside the variability of the model and avenues for future research. Following this, final conclusions will be drawn and key messages.

9.2 Research Question 1

How does the projected health of individuals interact with current State Pension Age legislation?

The results regarding interaction with and ability to continue working until SPA were in some ways predictable, and in other ways less so. The overall population figures show an increasing proportion of individuals in poor health towards the older ages, as may be suspected. However, the profile of individuals falling into poor health prior to SPA is heavily influenced by a large number of other factors.

First, we will consider the base scenario, giving the most theoretically simple assessment of the increase in SPA. Overall, the model projected a decline in the health of individuals, with a decreasing proportion of individuals reporting good health as they age. This result was consistent with the findings of ONS (2015e), which found a decline in good health and an increase in long standing illness as age increases. The relationship found within this study was particularly marked following age 60 for men and 65 for women, at which there is a sharp decrease in the proportion of individuals reporting good health. Between the ages of 60 and 69, male individuals within the model report a significantly reduced proportion in good health. This is a different finding from the study of Young *et al* (2010), who found a more steady increase in those reporting fair and poor health throughout adult life (ages 35 – 74), as compared a sharper decline at older ages seen within the PENHEALTH model. The gradient in health seen in Young *et* al (2010) was however present to a greater degree within males than with females, which was replicated within this study with a steeper fall in health of males prior to age 74. The difference in findings could have arisen for a number of reasons, including through the use of different base samples

This discrepancy between men and women could be due to a better overall health of women at younger ages. Following age 75, this relationship reverses with males experiencing a greater incidence of good health into older ages. These effects are mirrored by a relative increase in individuals reporting fair, and to a lesser extent poor health. This is an interesting effect and has the potential to be a result of a combination of a lower self perception of health among women at older ages (ONS, 2011), combined with a selection effect among men (West, 1991), in which only those in the better health states survive into the older ages. This result would be consistent with the findings of the ONS (2011), which found that although the overall life expectancy of males at age 65 is lower, they spend a greater proportion of those years in good or very good health. It must however be considered whether this effect is a true reduction in health amongst women at older ages, or conversely a gendered perception of the process of ageing (Barrett & Von Rohr, 2008), with male and female individuals experiencing different feelings regarding their health and abilities at older ages. Alternatively, a gendered perception of retirement could additionally be impacting the results, with the potential for men and women to experience the transition between employment and retirement differently. Loretto & Vickerstaff (2013, p.66) conceptualise retirement as 'a negotiation and trade-off in the domestic sphere', with Henretta, Angela & Chan (1993) adding that the retirement decision-making process is differentiated by work and family pathways. These alternate influences in the decision making process between men and women may impact the timing, expectations, and roles assumed during retirement, thereby varying the experience of the retirement process (Pienta & Hayward, 2002). Alternatively, a more general variability of satisfaction with ageing between men and women may influence the expectations and experience of older life, thereby impacting overall self-perception of health (Kleinspehn-Ammerlahn *et al*, 2008). This is backed up by a number of studies finding of difference in quality of life at older ages found between males and females in the English Longitudinal Study of Ageing (Netuveli *et al.*, 2006; Zaninotto, Falaschetti & Sacker, 2009). Additionally, well-being at older ages has also been found to be associated with frailty or pre-frailty within ELSA (Gale *et al.*, 2014). This potentially combines with differential frailty levels at older age between the sexes, leading to a differential self-perception of health and quality of life. Whether the result of an objective or subjective variation in health, the perception of ability to remain in employment is likely to form a crucial aspect in the behaviour of individuals surrounding SPA. This study takes the position that a wide range of influences are critical in defining the retirement experience. While study scope did not allow the modelling of each influence explicitly, these effects were to some extent proxied by an overall self-perception effect.

This decline in health throughout life is likely to impact the policy of increases to the SPA. Assuming no additional impact of continued employment or retirement on health (alternative assumptions will be considered later in Section 9.3), each year the SPA is delayed would result in an increasing proportion of the population falling into poor health. This is likely to consist of largely individuals who have experienced ill health for a number of years, as shown by the proportions of life spent in ill health. This group is then broadly augmented each year with a new cohort of individuals for each year that the SPA is increased. Health state during the previous year was found to be a strong predictor of current health within the regression analyses set out in section 5.9, resulting in health inertia. Allowing individuals to fall into poor health increases the probability that these individuals will remain in poor health, possibly incurring severe impacts on their continued health. Within the base scenario the poor health before SPA was found to peak at 15.6% of the male population aged 64 and 11.5% of the female population aged 59. These results show that through increasing the SPA, a greater proportion of individuals are likely to fall into poor health before reaching their SPA. As discussed earlier in the literature review, the SPA forms an important marker within the retirement expectations of individuals within the workforce (Cridland, 2016). Falling into poor health before reaching this age is likely to impact the experience of retirement for these individuals and may require alternative support mechanisms to be utilised while waiting for state pension income.

However, these overall figures for health leading to SPA hide a large amount of variation between individuals. Those categorised in lower NS-SEC social groups were found to suffer significantly higher incidence of ill health in the years preceding SPA. Similar gradients were found by a number of covariates, including educational attainment, housing tenure and marital status. These, along with other factors combine to produce a gradient in health, and more importantly for this study, a gradient of *ill health*. There is a clear and defined gradient of impact that a change in the SPA and the requirement to continue working may interact with. Those with multiple risk factors are likely to experience ill health at earlier ages and may therefore encounter difficulty remaining in employment to SPA. Simultaneously, those with high risk factors are also likely to be the same individuals with fewer economic and social resources, leading to a possibility of encountering greater difficulty if unable to remain in the workforce. This gradient was shown consistently for both men and women at all ages in the model, in line with the base health transition data taken from ELSA. The greater incidence of poor health and disability among those in semi-routine and routine occupations specifically has potential to lead to difficulties remaining in employment until SPA. As the SPA increases a year, this provides an additional cohort of individuals at risk of encountering difficulty continue in employment. The proportion of female individuals falling into poor health for each year of age between 60 and 75 undergoes a fairly linear increase. These additional individuals that are at risk of being unable to continue in the workforce may be required to seek alternative means to survive during the interim years.

This is likely to mean different things for individuals in different situations. Coping strategies to cover living expenses during these years of ill health preceding SPA can cover anything from alternative benefits, living on savings, a reduction in hours worked, forced continuation of work during ill health, friends and family members or other similar strategies. What these strategies have in common is that they are likely to negatively impact either the individuals through reduced savings or reduced health, or the government through greater social security payments. This result has the potential to reduce the monetary gains expected by the government through EWL, reorienting this cost onto social security and society more generally. These years are likely to be critical to the characterisation of the retirement experience, with an involuntary workforce exit being linked to a negative effect of retirement on health and well-being. The results combine with those found by Jagger (2015), who found a significant regional impact in both life expectancy and disability free life expectancy (DFLE). While this study did not allow the impact of regional variation in health and life expectancy within the model due to sample size, this may form an additional layer of detail in the true picture of health inequalities across the UK. Individuals that find themselves in the combined groups of low NS-SEC and an area of low LE/DFLE may experience a lower than SPA DFLE, posing a significant problem for extending working lives.

The research investigating question 1 found that at a population level, overall both men and women in the UK experience a decline in health throughout later life. The PENHEALTH model projected that men and women experience broadly similar levels of good health, until a divergence at age 73. Following this, men were found to experience significantly better health until the end of life. This decline was found to be subject to a social gradient, with those in high NS-SEC groups experiencing higher rates of good health and lower rates of poor health at all ages within the model. The overall decline in health was found to be of importance when increasing the SPA. Identifying those most likely to fall into poor health before reaching SPA is subject to a predictable social gradient in health. Individuals in low NS-SEC groups are simultaneously most likely to have poor health, but least likely to have access to private pension income in the event of needing to exit the workforce early. These effects are likely to increase the impact of the change in SPA on those with the least resources, while causing only a lesser impact on those with the most. Finally, due to the overall decline in health through life that was identified, each year the SPA is delayed was found to increase the percentage of the population falling into poor health before reaching SPA. This is likely to be critical when assessing the monetary and societal benefit of increasing the SPA.

9.3 Research Question 2

How might employment status influence the health of individuals during later life?

As identified within the literature review of this study, the potential feedback effects between employment and health are yet unknown and complex (section 1.2.2). While a number of studies have investigated the effect of health on employment state (Humphrey *et al.*, 2003), specific employment types on health (Benavides *et al.*, 2000) and retirement on health (Behncke, 2012), few studies have investigated the possible feedback effects between the elements. Employment is capable of being either beneficial or detrimental to overall health dependent on the context of the employment, as well as the overall social experience of the individual. This effect is increasingly important when considering employment into older ages, as divergences in overall health can either be exacerbated or reduced by continued workforce engagement (Ross & Mirowsky, 1995). The true direction in which EWL impacts health at an individual level is likely to be crucial in defining the effect additional working years have within the population. This study is unique in modelling the potential impacts of continued workforce engagement, allowing the outcome to take into account these feedback effects between employment state and health, when considering a change in SPA policy. This took the form of both positive and negative impacts of employment on health as well as positive and negative impacts of retirement on health. The first scenario block investigated a positive impact of continued workforce engagement, as detailed in section 7.1. This is in line with theories suggesting that continued social interaction, increased social standing and increases in purchasing power (Atchley, 1989) can lead to an improvement in health during employment years, as discussed in section 1.2.2. The scenarios trialled 10%, 20% and 50% improvements in health during employment years through a reweighting of health transition probabilities. What is clear from the scenarios is that although an increase in health is experienced, at younger ages this largely results in a very high proportion of individuals being defined as in 'good health'. This is as a result of an underlying high level of good health during these years, meaning that an additional feedback is only to the benefit of those with a higher chance to be in poor health. In reality, the experience of health is less defined, with no conceivable maximum or minimum health, however the premise of the reweighting rings true, with the greatest benefit of a positive feedback during working years being experienced by those in poorer health. As the overall health of the population begins to decline in the years nearing SPA, this relationship grows more complex. Following age 50 the health of all individuals is some extent protected from falling into poor health. It is in these years that a potential protective impact of employment would be most beneficial to the EWL agenda, with continued workforce engagement resulting in an overall improvement in health, as discussed in Section 1.2.2.

A series of combined effects were also investigated, assuming an inversion between the positive impact of employment and negative impact of retirement, or vice versa. These inversion effects found that under the negative impact of retirement, the rapid shift from employment to retirement years may cause a health shock. The main effect was a reduction of individuals within a 'good' health state, there being then re-weighted to 'fair' and 'poor' health categories. If this were to be the experience of an individual, the shock effect is likely to cause significant impact to the health of the individual and has the potential to be carried throughout the remainder of life. Finally, a social gradient of health impact was investigated, in which the experience of continued employment or retirement may be impacted by the NS-SEC social group of the individual. This scenario approximates social and monetary resource, as well as the ability of individuals to draw on these in order to alleviate the negative impacts of employment or retirement. This assumption models the work of Ekerdt *et al* (1983b) and Kim & Moen (2002), who posit that 'role strain', the continuation of physical or mentally stressful roles may be detrimental to health. Additionally, the social gradient in retirement experience models the work of Scherger *et al.* (2011) and Drentea (2002), who suggest that the experience of retirement is defined by the ability of the individual to afford and enjoy the retirement years, facilitating activities to replace those lost though discontinuing employment. This has the potential to form a social gradient in retirement experience, between those with most and least resources.

The analysis undertaken by this study found that under this assumption, the discrepancy in health between top and bottom NS-SEC groups was widest during the period of 60-70 years of age, those critical to the retirement age debate. This finding is in line with the ONS research regarding prevalence of disability through life, finding the largest gap between ages 60-64 (ONS, 2014d). Additionally, it was found that health of female individuals converged towards later life, despite the protective effect of a high NS-SEC group. Those in 'good' and 'fair' health reduced, increasing the proportion of individuals experiencing 'poor' health. Meanwhile, males continued to benefit from the protective effect of a high NS-SEC into later life. Finally alternative scenarios of mortality were investigated, based on the ONS projections of life expectancy. This was intended to explore the possible variability surrounding the ONS prime projection. A divergence in life expectancy projection was found particularly within the low life expectancy variant for male individuals. This suggests uncertainty on the part of the ONS regarding future health behaviours of this group, which is likely to be of increasing importance under the proposed link of SPA with average life expectancy. The projection of life expectancy trends will form a crucial component to maintaining the financial sustainability of the state pension system. If a life expectancy projection is exceeded, the proportion of life spent in pensionable ages will increase. Conversely, if the population does not meet the prime projection, individuals will receive less pension income than suggested. The manner in which this projection is made and the quality of this projection is likely to become a defining factor of the SPA in line with average LE, and should therefore be documented and scrutinised adequately.

As identified within the literature review, uncertainty regarding direction and influence of employment and retirement on health remains. This study found that the direction of influence of employment and retirement are likely to be crucial when defining the impact of an increase in SPA. It was found that modest improvements gained through a beneficial effect of employment served as a protective element to health, reducing the overall decline in health experienced over life. This scenario suggests that if employment is beneficial for health, an increase in SPA will have little detrimental health at a population level. However, if continued employment were to be detrimental to health, it was found that a rapid reduction in health may be experienced by individuals when nearing SPA. Under this assumption, an increase in SPA is likely to inflate the number of individuals experiencing difficulty remaining in employment until SPA, as well as having the potential for long-lasting effects on the health of individuals. Additionally, if an inversion effect is experienced, with a protective effect of employment and a detrimental impact of retirement, individuals were found to be liable to experience a health 'shock', rapidly moving from very good to very poor health states.

The research investigating question 2 found that the potential feedback effects between employment status and health are both complex and likely to play a significant role in the experience of individuals interacting with a change in SPA policy. The research identified that the gap in experience between those with most and least resources was also widest between the ages that a change in SPA is likely to impact. When alternative scenarios were trialled in the PENHEALTH model, it was found that socioeconomic status has the potential to be very influential in the way individuals experience retirement. However, the direction of this influence is critical. If a positive impact of continued employment is experienced, the impact of an increase in SPA is likely to be small. If however continued employment or premature economic inactivity causes a detriment in health, this is likely to have long term implications for the health and wellbeing of individuals under a change in SPA policy.

9.4 Research Question 3:

What alternative State Pension Age policies could assist individuals to remain in employment, compared to current State Pension Age change legislation?

The results of the investigation into alternative SPA policies drew a number of key findings. A number of the suggestions put forward by government, think tanks and other academic groups were simulated within the PENHEALTH model. This was done in order to identify any reductions of impact that could be generated, above that of the base model current SPA legislation.

Previous reforms to the SPA in the UK have been enacted as a series of one-off interventions, rather than a stand-alone and coherent policy programme alone (Cridland, 2016). The most recent reform and supporting documents, the topic of this study forms a strategy of SPA reforms both in the present and into the future. This change was required for two main reasons, increases in longevity within the population and as an incentive to extend the working lives of individuals. However, given the importance of the SPA in the planning of individuals and the number of unknowns surrounding future trends, particular care must be taken when enacting a policy that has such long-term impact. It is suggested that given the variations in health and longevity experienced within the UK, seeking to use an increasing single set pension age to encourage longer working is a crude tool to meet this end. It is additionally claimed that utilising a single measure in this way may risk increasing hardship among older people (TUC, 2016). The study goes further than this, claiming that the impact on individuals will additionally be systematic and in many ways predictable, given the trends in health across the population. Such a change may systematically disadvantage some of the least well off in society, while causing only a minimal impact to those better off individuals. For these reasons, this section investigated alternative policies that may be utilised by the government to reduce these inequalities in impact.

The first scenario investigated was the base scenario, exploring the impact of the currently legislated SPA. As was seen in section 8.1.2, the number of individuals classed as in poor health before reaching SPA increases through life for both men and women. Each year that the SPA is delayed is likely to result in an additional cohort of individuals experiencing difficulty remaining in employment. As can additionally be seen also in section 8.1.2, the same gradients found in health by alternative socioeconomic status variables are also apparent within economic activity. These results are in many ways predictable; given the discrepancy in health experienced across society, however do assist in identifying individuals who may be at risk. The study has found a clear gradient in health and therefore impact between those with the most and least social and economic resources. Those with lower educational attainment, less stable housing arrangements and marital status and those in less rewarding employment are those most likely to find themselves in poor health at earlier ages, and therefore most likely to be impacted by the proposed policy. Individuals most impacted by the reform are likely to be those that suffer from a combination of those risk factors described above. However, these represent only a small but indicative sample of risk factors or paths to ill health. Alternative risk factors to those described in this study such as lifestyle (Mokdad *et al*, 2003) or mental health (Blank *et* al, 2008) can additionally lead to poor health in earlier life, however all such factors may pose a difficulty for individuals to extend their working life.

One of the most surprising findings of the analysis was the divergence between the proportion of life spent in pensionable ages between the original, newly legislated and the proposed SPA linked with average life expectancy. The analysis found that the original SPA was resulting in an increasing proportion of life spent in pensionable ages. This divergence began with the cohort of those born in 1920, reaching SPA in 1980 and had been increasing since. The measure based on average life expectancy naturally kept pace with these changes. Meanwhile, women born in the 1950's, reaching SPA in the 2010's experienced a sharp increase in their SPA, as policy attempted to meet the dates for average life expectancy. Those women currently experiencing the sharp increase are amongst those most impacted by the change in SPA policy, experiencing a rapidly increasing SPA and reduced time to plan for changes. Critical to the policy analysis however, if a policy of increasing SPA in line with average LE had been brought in previously to the 1920 birth cohort reaching SPA, this jump could have been avoided. Male individuals meanwhile experienced a much less significant jump due to their higher SPA under original legislation. For this reason, male individuals will be impacted less by the policy change, but prior to the 1920 birth cohort will have spent a smaller proportion of their lives in retirement years than women.

The most encouraging results obtained through this analysis were for the adoption of the 45 years of contributions early exit policy. Given an individual entering employment following compulsory education at age 16 and maintaining a full contributions record would allow pension income to be accessible from age 61. In the eventuality the individual falls into poor health, this policy was found to be a significant benefit, given that a contribution record is maintained until the exit age. The maintenance of a full contributions record to this age is plausible, as the majority of poor health and disability incidence occurs toward later life and many individuals within the population currently achieve 45 years contributions before reaching SPA. In 2013, of the 660,000 individuals reaching SPA, 38.3% had gained more than 45 qualifying years, while around 13% had over 50 contributory years (PPI, 2016). The policy was found to be particularly beneficial in equalising the impact of the SPA change for those in lower NS-SEC groups, significantly reducing the number of individuals in these groups, in poor health that are required to remain in employment, compared to that of the current SPA legislation. Such a policy would be relatively simple to enact, given a single figure of contributory years would be used for all individuals. Difficulty may be encountered with this policy if career breaks are taken earlier in life, such as for child rearing, as these will reduce the number of contributory years and therefore not benefit these individuals. The group most likely to be impacted by this is women, who are projected by the PENSIM model to have a lower pension wealth and therefore 25% less income in the first year of retirement than their male counterparts (Cridland, 2016). Conversely however, if a break were to be required at the end of working life such as for caring for a parent or spouse, this policy may facilitate early exit for individuals that have reached the necessary contributions. This policy may also combine well with the current ability to pay 'top up' national insurance contributions, allowing individuals to offset missed contributory periods.

The 50 years contributions policy meanwhile does not serve as an early exit point for individuals in poor health before that of the SPA, and if this were to be the only SPA legislation, the model results this would lead to greatly increased levels of pre-SPA poor health. This impact may change for future cohorts if the value of 50 years contributions remains constant while SPA increases in line with average life expectancy. However, this is unlikely to be the case, as this would provide a route to SPA that grows more generous each year, going against the sustainable policies currently being investigated. Additionally, 50 years of contributions is set significantly above the 35 years of contributions currently required to obtain a full state pension, requiring a constant employment record from age 16 to achieve a retirement age of 66. In the current climate of increasingly variable employment histories noted by Macaulay (2003) and an increase in caring responsibilities with age found by Dahlberg, Demack & Bambra (2007), a full and complete 50-year contributions record is likely to become harder to obtain by age 66. Setting the requirement as high as 50 years contributions therefore has the potential to remove the benefits individuals may gain from the policy, above waiting until their standard pensionable age. The crucial factor in the relative benefit of this policy is likely to be how the years of contributions will change, if and when a SPA linked with average LE is enacted, however no statements have currently been made on this.

The analysis of research question 3 found that current legislation shows potential to increase the number of individuals falling into poor health before reaching SPA. Delaying the SPA is likely to add an additional cohort to this group for each years increase. This has the potential to increase economic inactivity within the population in the lead-up to SPA, possibly requiring these individuals to seek alternative support. This effect was found to again be subject to the social gradient of health and those in lower NS-SEC groups are likely to experience higher levels of economic inactivity in older ages than those in higher groups. The proposal to link future SPA increases with average life expectancy was found to work successfully at maintaining the proportion of life spent in retirement. However, average life expectancy hides a large amount of variation within the population. This may increasingly lead to some individuals having a higher SPA than healthy or disability free life expectancy, resulting in significant difficulty remaining in employment until this age. Policy makers should pay careful attention to the variations in health and disability across the population and the interaction this has with SPA. The policy analysis also found that the recent jump in SPA for women is the product of a divergence between a SPA in line with average LE and the legislated SPA, leading to an increasing proportion of life spent in pensionable ages. Had the link with average LE been brought in for the birth cohort of 1920, this jump could have been avoided. A proposed access to state pension following 45 years of national insurance contributions appears promising for reducing levels of ill-health in the years leading to SPA. The 50 years contributions proposed by the recent Independent Review of the State Pension Age however appears to nullify this benefit.

9.5 Research Question 4:

How do alternative measures of health influence the projected ability of individuals to remain in employment?

The fourth research outcome of this study identified significant variation in policy impact, dependent on health measure. As discussed in Section 3.3, the nature of health is multifaceted, no single measure of health is currently able to encompass '*a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity'* (WHO, 2006). It is therefore important when choosing indicators of health to acknowledge the elements that may or may not be recorded by the measure, as well as investigate the different conclusions that may be reached if a different health measure is utilised.

The analysis trialled hand-grip strength alongside the more common self-reported health. It was found that a general decline in grip strength was identified through later life, within both high and low grip strength groups. This finding was in line with the study undertaken by Dodds *et al.* (2014), which utilised twelve British studies to undertake a meta analysis of grip strength across life. The Dodds *et al.* study found that a general decline was experienced throughout later life, following a peak around age 30. The volatility of the grip strength values found by the PENHEALTH model increased only slightly towards the older ages. This finding however is different from the findings of the Dodds *et al.* study, which found a slight compression in volatility of grip strength values at older ages. This difference could have arisen through the use of specific older-age datasets, such as the N85 Newcastle 85+ survey within the Dodds *et al.* study. The use of such studies may input a selection effect for those at older ages, known as the *age-as-leveler* hypothesis, in which selective mortality, lack of further exposure to poor conditions and the influence of biological ageing combine to categorise the sample (Kröger, Fritzell & Hoffmann 2016; Hoffmann, 2011; Liang *et al*, 2002). In comparison to this, the PENHEALTH model uses only data from English Longitudinal Study of Ageing. This forms a closed population within the model with due to the nature of the modelling process, no explicit link between poor health and mortality. This has the potential to increase the number of individuals in poor health states surviving beyond what may be observed within the population, leading to greater volatility in results.

The consistent decline in grip strength throughout life suggests that the measure may form a useful part of health assessment, charting the decline in health and possible frailty towards later life. The most interesting element identified by the study was the impact that the level at which the cut-off is placed influences the results heavily. When utilising a comparatively low cut-off value of 9kg, intended to represent the ability to undertake standard household tasks, the level of low grip strength within the population remained low until the very oldest old. However, if this value is increased to 20kg, intended to represent the ability to conduct manual functions, such as the moving of a weighted box, this increases the proportion falling into the low grip strength category. This results in substantially higher levels of poor grip strength, particularly at early ages. Critically for this study, the level of low grip strength is seen to increase heavily during the period of 60-

70 years of age. This finding is again affirmed by the results of the Dodds *et al* (2014) study, that finds a steeper gradient in grip strength decline following age 60, particularly within male individuals. This large increase in individuals falling into low GS suggests a potential for increasing difficulty in conducting more manual occupational tasks following age 60. Under an increasing SPA, this could result in an increasing number of individuals either struggling to continue in employment or needing to change employment type during this period. When state pension income is not available until later ages, this may influence the retirement decisions of individuals, requiring re-training or influencing the pay out of final salary pensions. These different conceptualisations of grip strength lead to significantly differing employment statuses within the model. Section 6.3 shows that under a higher GS cut-off, a significantly lower proportion of the population are able to remain in employment to SPA, leading to a much higher pre-SPA inactivity rate.

Additionally, those in lower NS-SEC groups were found to experience lower grip strength, diverging from age 50 and widening towards later life. This result is similar to the findings of Kröger, Fritzell & Hoffmann (2016), who found that a mid-life exposure to low occupational position correlates with a decline in grip strength in men. Additionally, this divergence was most notable following age 80 in both the PENHEALTH model and the Kröger, Fritzell & Hoffmann analysis. These two results are in contrast to other studies that suggest the importance of low socioeconomic position is most influential in early life (Haas, 2008; Kuh *et al.,* 2002; Case, Fertig & Paxson, 2005). This variation is likely to result from the nature of the health measure used. It is possible that those in lower NS-SEC groups may undertake employment that provides a protective effect against declining grip strength. Lower NS-SEC occupations are routine or semi-routine occupations that are likely to require a greater level of activity than managerial or professional occupations. While being in a lower socioeconomic position may be detrimental for overall health during these years, grip strength may be protected be higher activity levels into later life.

Once an individual enters retirement and employment activity declines, the resultant decline in grip strength in line with health may occur.

The study found that the both the health measure used and the nature in which the measure is utilised significantly impacts the assessment of health in the lead up to SPA. Significantly different results, dependent on use of a subjective or objective measure. Additionally, the continuous nature of the objective gip strength measure allowed the manipulation of projected policy impact. Utilising a lower threshold value of grip strength, considering ability to complete basic activities of daily living as compared to a higher threshold to approximate the risk of more general mobility limitations resulted in significantly different results. A lower threshold resulted in a significantly smaller proportion of individuals experiencing poor grip strength before reaching SPA than was found under the higher threshold. It was identified that policy makers, government and citizens should scrutinise carefully the health measure selected to analyse health and the interaction with policy, in particular with SPA.

9.6 Limitations and Suggestions for Further Research

This study was undertaken subject to a number of limitations, this section will discuss the limitations and suggest ways these may be avoided in further research. The main limitations this study encountered were surrounding data availability and time constraints on the study. The majority of modelling decisions were made in line with the availability of data. An example of this is the modelling of retirement decisions, in which it was assumed that all individuals work until SPA, at which point they retire. However, we know this is not the case. Historically within the UK, there has been a tendency to retire before SPA (Cridland, 2016). This trend is reversing, with individuals retiring on average later, but with greater transitions to part time employment towards the end of working life. The reasons behind these transitions into retirement or reduced working hours are complex and significantly impacted by the situation, resources and finances of the individual. If substantial data and time had been available, this retirement decision process could have been modelled within the Pension Health framework, improving both the quality and the comprehensiveness of the analysis. Similarly, due to the limited availability of Census data that formed the base of the simulation model, only a limited number of individual characteristics were utilised. Were a greater depth of individual level data available to the research, further insight could be gained surrounding the profile of individuals most impacted. Additional data would have assisted in the reduction of simplifications employed by the model. However, the model utilised by this study attempted at each decision to strike a balance between data availability and simplification of the real world, in order to be able to answer the given research questions to an acceptable degree.

The manner in which health trends are projected within the model can also be considered a limitation. The model presented here assumes a linear discrepancy between the health transition data and the date provided by the census data. Through the addition of an expected health trends module, alternative assumptions of the modeller could be included and the impact of alternative health trends experienced in the future could be considered. It was not selected to include this module during this study as limited information is available regarding projected health trends into the future. The projection of elements such as Self Reported Health is linked to a wide range of influences within social, economic and cultural spheres. For the sake of simplicity, a linear trend was assumed here, but this is recognised as a weakness of the predictive ability of the model, and should therefore be investigated within further work. Additionally, the health transition data utilised in the final model was only representative of the population of England, while the census base data was representative of the whole of the UK. This decision was made to maintain sample size and data availability. However, due to the higher life expectancy of those within England, as compared to the UK, this may artificially inflate the number of individuals within better health states at older ages within the model. Additionally, the variability of stochastic processes between simulation runs was found to vary for mortality transitions by up to 7%. This is a result of the comparatively low number of individuals undergoing a mortality transition in any specified year. This effect could be reduced through the use of a larger base sample of individuals, however this was not used in the study due to computational requirements and data availability limitations.

The alignment of the model with the 2011 Census is also likely to heavily impact the results. As the alignment is enacted at an aggregate population level and only disaggregated by age and sex, this is likely to influence the proportions falling into specified health states when disaggregated by other variables. This impact was minimised through the use of an alignment mechanism that distributes the alignment re-allocation, allowing an element of stochasticity, however this effect is likely to persist and influence the final results of the study.

Data analysis could have additionally been expanded through the utilisation of an 'open' population structure within the microsimulation model. Such a model allows individuals to enter the model through births or migration. The study opted to utilise a 'closed' population structure. This decision was taken to maintain a consistent base population, taken from the empirical census data, as well as to maintain simplicity of the data modelling. While an 'open' population structure would have allowed for longer runs of the model and ability to maintain a consistent population structure, suitable base data was not available. Accurately characterising in particular migration or the inclusion of synthetic individuals as the model advances through time would increase data requirements and the computational complexity of the model significantly. Little data currently exists to accurately quantify the level of migration into the UK. Similarly, including synthetic individuals into the model through births would build in an implicit assumption regarding the expected characteristics of the future population of the UK, which would be impossible to verify. For these reasons, it was opted to use a 'closed' data structure within this model, however if sufficient data were available, model accuracy may improved through use of an 'open' structure.

Further work should seek to increase the number of interacting modules within the model, to further refine the accuracy of the projections. A module encompassing the economic situations of the modelled individuals would benefit the analysis of requirement to remain in employment until an advancing SPA, taking into account alternative coping mechanisms. Similarly, a module investigating the advent of familial disruption and caring responsibilities and availability would assist the analysis through further allowing for the experience of modelled individuals when nearing SPA.

9.7 Key Contributions of Thesis

Table 9.1 – Key Contributions

Number	Contribution
1	Development of a Dynamic Microsimulation to investigate the interaction between employment and health
2	At a population level, health was found to decline through life
3	For each year the State Pension Age increases, the number of individuals likely to find themselves having difficulty or being unable to remain in employment until SPA increases
4	Those in lower NS-SEC groups were found to experience greater levels of poor health, particularly during the ages surrounding SPA
5	The 'feedback' between employment and health is likely to be crucial in determining the impact of SPA policy
6	Allowing individuals to retire following 45 years of National Insurance contributions was found to have the potential to significantly reduce the number of individuals falling into poor health before reaching SPA
7	Conversely 50 years of NI contributions was not found to be beneficial over current policy
8	The health measure used in policy analysis was found to be very influential when determining the impact of SPA policy

The study found a decline in overall health within the population of the UK throughout life. Each year the SPA was delayed resulted in an increasing proportion of individuals projected to fall into poor health before reaching the SPA. This decline in health is likely to be crucial when determining the impact and sustainability of any current or future increases to SPA. The results indicate that there will be a significant patterning to the experience of an increasing SPA, with those in lower NS-SEC groups experiencing poor health at significantly earlier ages. This was found to be likely to lead to a much larger proportion of those in low NS-SEC groups experiencing difficulty remaining in employment before reaching SPA than their high NS-SEC group counterparts. The level of feedback between employment status and health was additionally found to be influential when defining the impact of a SPA change. It was found that if employment leads to even a slight improvement in health, the effect of additional working years protect individuals from the overall decline in health found. If however continued employment was detrimental to health, overall declines in health may be exacerbated, leading to a rapid reduction in health state when nearing SPA. The study additionally trialled a number of alternative SPA policy measures. It was identified that allowing individuals to retire following 45 years of contributions has the potential to significantly decrease the number of individuals falling into poorer health while being under SPA. Conversely, the 50 years of contributions suggested by the Cridland (2016) Independent Review of the State Pension Age was found to pose little benefit in this regard. The impact of health measure was also identified as influential when assessing the impact of policy. The study utilised the subjective Self-Reported Health measure, as well as an objective Hand-Grip Strength measure. Significantly different results were obtained, dependent on both the measure of health used and the manner in which conceptualisations of health were made.

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Appendix A Census Data Categorical Age Procedure

Age	Persons	Males	Females	Prop. of Total Pop.	Prop. of Male Pop.	Cumulative Male Pop.	Prop. of Female Pop.	Cumulative Female Pop.	Total Persons	% in Age Bracket	Cumulative % in Bracket	Total Males	Male % in Bracket	Male Cumulative %	Total Females	Female % in Bracket	Female Cumulative %
All ages	36,606,791	17,361,060	19,245,731						In group			In group			In group		
30	878,633	429,100	449,533	2.400191265	2.471623276	2.471623276	2.335754355	2.335754355	13,270,975	6.620711741	6.620711741	6,534,303	6.566882497	6.566882497	6,736,672	6.67292396	6.67292396
31	869,849	426,098	443,751	2.376195717	2.454331706	4.925954982	2.305711329	4.641465684		6.554522181	13.17523392		6.520940336	13.08782283		6.58709523	13.26001919
32	902,531	441,077	461,454	2.465474234	2.540611	7.466565982	2.397695364	7.039161048		6.80078894	19.97602286		6.750176721	19.83799955		6.849880772	20.10989996
33	908,253	444,492	463,761	2.481105214	2.560281457	10.02684744	2.409682438	9.448843486		6.843905591	26.81992845		6.802439373	26.64043893		6.884126168	26.99402613
34	934,319	459,107	475,212	2.552310581	2.644464105	12.67131154	2.469181347	11.91802483		7.040319193	33.86024765		7.026105156	33.66654408		7.054106241	34.04813237
35	930,987	457,028	473,959	2.543208445	2.63248903	15.30380057	2.462670813	14.38069565		7.015211769	40.87545941		6.994288453	40.66083253		7.035506553	41.08363892
36	942,077	463,452	478,625	2.57350337	2.669491379	17.97329195	2.48691515	16.8676108		7.098777595	47.97423701		7.092600389	47.75343292		7.104769239	48.18840816
37	933,667	459,412	474,255	2.550529491	2.64622091	20.61951286	2.464208816	19.33181961		7.035406215	55.00964323		7.030772831	54.78420575		7.039900414	55.22830858
38	920,581	453,903	466,678	2.514782025	2.614488977	23.23400184	2.424839046	21.75665866		6.936800047	61.94644327		6.946463915	61.73066967		6.92742648	62.15573506
39	898,498	444,004	454,494	2.454457152	2.557470569	25.79147241	2.3615315	24.11819016		6.770399311	68.71684258		6.794971093	68.52564076		6.746565663	68.90230072
40	874,182	432,141	442,041	2.388032319	2.489139488	28.2806119	2.296826242	26.4150164		6.587172382	75.30401496		6.613421508	75.13906227		6.561711777	75.4640125
41	840,271	416,459	423,812	2.295396502	2.398810902	30.6794228	2.202109133	28.61712553		6.331644811	81.63565978		6.373426515	81.51248878		6.291118226	81.75513072
42	828,071	410,266	417,805	2.262069352	2.363139117	33.04256192	2.170897016	30.78802255		6.239714866	87.87537464		6.278649766	87.79113855		6.201949568	87.95708029
43	818,896	406,161	412,735	2.237005697	2.339494247	35.38205616	2.144553512	32.93257606		6.170579027	94.04595367		6.215827457	94.00696601		6.126689855	94.08377015
44	790,160	391,603	398,557	2.158506601	2.255639921	37.63769609	2.070885226	35.00346129		5.95404633	100		5.993033993	100		5.916229854	100
45	762294	378146	384148	2.082384113	2.178127372	39.81582346	1.996016675	36.99947796		6.858083957	6.858083957		6.867758606	6.867758606		6.848587051	6.848587051
46	744666	368996	375670	2.034229113	2.125423217	41.94124668	1.951965348	38.95144331		6.699491204	13.55757516		6.701579429	13.56933803		6.697441345	13.5460284
47	753123	373083	380040	2.057331384	2.148964407	44.09021108	1.974671682	40.92611499		6.77557578	20.33315094		6.775806128	20.34514416		6.775349665	20.32137806
48	741433	367448	373985	2.025397419	2.116506711	46.20671779	1.943210159	42.86932515		6.670405071	27.00355601		6.673465181	27.01860934		6.66740118	26.98877924
49	734448	363791	370657	2.00631626	2.095442329	48.30216012	1.925918013	44.79524316		6.607563546	33.61111956		6.607047995	33.62565734		6.608069626	33.59684887
50	739798	366654	373144	2.020931034	2.111933258	50.41409338	1.938840359	46.73408352	11,115,262	6.655695565	40.26681512	5,506,105	6.659044824	40.28470216	5,609,157	6.652407846	40.24925671
51	765279	378580	386699	2.090538338	2.18062722	52.5947206	2.009271563	48.74335508		6.884938925	47.15175405		6.875640766	47.16034293		6.894066256	47.14332296
52	789112	391556	397556	2.155643744	2.2553692	54.8500898	2.065684073	50.80903916		7.099355823	54.25110987		7.11130645	54.27164938		7.087624754	54.23094772

53	852869	422732	430137	2.329810881	2.434943488	57.28503329	2.234973564	53.04401272	10	7.672954538	61.92406441		7.677514323	61.9491637		7.668478525	61.89942624
54	893379	443702	449677	2.440473408	2.555731044	59.84076433	2.336502573	55.38051529		8.037408385	69.96147279		8.058364307	70.00752801		8.016837468	69.91626371
55	689196	341514	347682	1.882699852	1.967126431	61.80789076	1.80654089	57.18705618		6.200447637	76.16192043		6.202460723	76.20998873		6.198471535	76.11473524
56	710966	351977	358989	1.942169692	2.027393489	63.83528425	1.865291581	59.05234776		6.396304469	82.5582249		6.392486159	82.60247489		6.400052628	82.51478787
57	689867	342107	347760	1.884532845	1.970542121	65.80582637	1.806946174	60.85929394		6.206484382	88.76470928		6.213230587	88.81570548		6.199862118	88.71464999
58	659506	325880	333626	1.801594682	1.877074326	67.6829007	1.733506511	62.59280045		5.933337424	94.6980467		5.91852135	94.73422683		5.947881295	94.66253129
59	589326	289939	299387	1.60988162	1.670053557	69.35295426	1.555602123	64.14840257		5.301953296	100		5.265773174	100		5.337468714	100
60	559,590	274,340	285250	1.528650791	1.580203052	70.93315731	1.482146872	65.63054944	2,879,948	19.43055916	19.43055916	**1,409,676**	19.46120953	19.46120953	**1470272**	19.40117203	19.40117203
61	591,509	290,156	301353	1.615844994	1.67130348	72.60446079	1.565817375	67.19636682		20.53887779	39.96943695		20.58316947	40.04437899		20.49641155	39.89758358
62	586,244	286,718	299526	1.601462417	1.651500542	74.25596133	1.556324361	68.75269118	5	20.35606198	60.32549893		20.33928364	60.38366263		20.37214883	60.2697324
63	579,076	283,752	295324	1.581881351	1.634416332	75.89037766	1.534490948	70.28718213		20.1071686	80.43266753		20.12888068	80.51254331		20.08635137	80.35608377
64	563,529	274,710	288,819	1.539411089	1.582334258	77.47271192	1.500691244	71.78787337		19.56733247	100		19.48745669	100		19.64391623	100
65	547,286	265,074	282,212	1.495039541	1.526830735	78.99954265	1.466361553	73.25423493	2,596,843	21.07505151	21.07505151	**1,241,382**	21.35313707	21.35313707	**1,355,461**	20.82037034	20.82037034
66	530,226	255,997	274,229	1.448436166	1.474547061	80.47408972	1.424882225	74.67911715		20.41809998	41.49315149		20.62193587	41.97507294		20.23141942	41.05178976
67	507,487	242,799	264,688	1.386319276	1.398526357	81.87261607	1.375307594	76.05442474		19.54245983	61.03561132		19.55876596	61.5338389		19.52752606	60.57931582
68	505,819	239,563	266,256	1.381762745	1.379886942	83.25250302	1.383454856	77.4378796		19.47822799	80.5138393		19.29808874	80.83192764		19.64320626	80.22252208
69	506,025	237,949	268,076	1.382325482	1.370590275	84.62309329	1.392911498	78.8307911	10	19.4861607	100		19.16807236	100		19.77747792	100
70	503,581	232,941	270,640	1.375649125	1.34174411	85.9648374	1.406233933	80.23702503	2,339,231	21.52763023	21.52763023	**1,059,151**	21.99318133	21.99318133	**1,280,080**	21.1424286	21.1424286
71	486,241	222,094	264,147	1.328280865	1.279265206	87.24410266	1.372496581	81.60952161		20.78636099	42.31399122		20.96905918	42.96224051		20.63519468	41.77762327
72	466,129	210,925	255,204	1.273340239	1.214931577	88.45903418	1.326029133	82.93555075		19.92659126	62.24058248		19.91453532	62.87677583		19.93656646	61.71418974
73	443,669	198,815	244,854	1.211985503	1.145177771	89.60421195	1.272250973	84.20780172		18.96644667	81.20702915		18.77116672	81.64794255		19.12802325	80.84221299
74	439,611	194,376	245,235	1.200900128	1.119609056	90.72382101	1.274230633	85.48203235		18.79297085	100		18.35205745	100		19.15778701	100
75	426,751	185,463	241,288	1.165770034	1.068270025	91.79209104	1.253722189	86.73575454	3,280,476	13.00881336	13.00881336	**1,300,408**	14.26190857	14.26190857	**1,980,068**	12.18584412	12.18584412
76	405,387	172,271	233,116	1.107409278	0.992283881	92.78437492	1.211260825	87.94701537		12.3575664	25.36637976		13.24745772	27.50936629		11.77313102	23.95897515
77	389,535	161,798	227,737	1.064105838	0.931959224	93.71633414	1.183311769	89.13032714		11.87434385	37.2407236		12.4420951	39.95146139		11.50147369	35.46044883
78	372,571	150,821	221,750	1.017764709	0.868731518	94.58506566	1.152203572	90.28253071		11.35722377	48.59794737		11.5979754	51.54943679		11.19911033	46.65955917
79	372,685	147,358	225,327	1.018076127	0.848784579	95.43385024	1.170789512	91.45332022	10	11.36069887	59.95864625		11.33167437	62.88111116		11.3797607	58.03931986
80	368,167	141,490	226,677	1.005734155	0.814984799	96.24883504	1.177804054	92.63112427		11.22297496	71.1816212		10.88043137	73.76154253		11.44794017	69.48726003

81	337,780	127,790	209,990	0.922724967	0.736072567	96.9849076	1.091099112	93.72222339		10.29667646	81.47829766		9.82691586	83.58845839		10.60519134	80.09245137
82	221,508	80,383	141,125	0.60510084	0.463007443	97.44791505	0.7332795	94.45550289		6.752312774	88.23061044		6.181367694	89.76982609		7.127280477	87.21973185
83	188,740	66,027	122,713	0.515587395	0.38031664	97.82823169	0.637611531	95.09311442		5.753433343	93.98404378		5.077406476	94.84723256		6.197413422	93.41714527
84	197,352	67,007	130,345	0.539113084	0.385961456	98.21419314	0.677267078	95.77038149		6.015956221	100		5.152767439	100		6.58285473	100
85	184,524	59,873	124,651	0.504070406	0.344869495	98.55906264	0.647681296	96.41806279	1,124,056	16.4159081	16.4159081	**310,035**	19.31169062	19.31169062	**814,021**	15.31299561	15.31299561
86	177,304	54,981	122,323	0.484347292	0.31669149	98.87575413	0.635585107	97.0536479		15.77359135	32.18949946		17.73380425	37.04549486		15.0270079	30.34000351
87	153,053	45,407	107,646	0.418100019	0.26154509	99.13729922	0.559324039	97.61297194		13.61613656	45.80563602		14.6457658	51.69126066		13.22398317	43.56398668
88	130,373	37,269	93,104	0.356144301	0.214670072	99.35196929	0.483764425	98.09673636	5?	11.59844349	57.40407951		12.02090087	63.71216153		11.43754277	55.00152944
90	107,533	29,303	78,230	0.293751506	0.168785777	99.52075507	0.406479754	98.50321612		9.566516259	66.97059577		9.451513539	73.16367507		9.610317179	64.61184662
90+	371,269	83,202	288,067	1	0.479244931	100	1.496783884	100		33.02940423	100		26.83632493	100		35.38815338	100
				100	100		100					**17,361,060**			**19,245,731**		

Population at Census Day 2001: Resident population by single year of age and sex

Source: Author's own analysis of 2001 Census data.

Appendix B List of Alternative Scenarios

Alternative Scenarios, Male & Female							
No.	**Feedback between work & Health**	**No.**	**Alternative Mortality**	**No.**	**SPA**	**No.**	**Measures of Health**
1	Base	4	High Variant	6	Pre-Reform SPA	1	Base - SRH
2	Inversion Small 1.1/0.9	5	Low Variant	7	Post-Reform SPA	2	Grip Strength - 9kg Cut Off
3	Social Gradient of Health			8	SPA 65	3	Grip Strength - 20kg Cut Off
				9	SPA 66		
				10	SPA 67		
				11	SPA 68		
				12	SPA in Line with Average Life Expectancy		
				13	SPA Following 45 Years Contributions SGOH Feedback		
				14	SPA Following 50 Years Contributions SGOH Feedback		

Appendix C Age Alignment Comparison

Age Comparison

2011 Base				2011 Sort by Predicted Probability Alignment				2011 Sort by Difference Alignment				2011 Sort by Difference with 10% Manipulation				2011 Sort by Difference Logistic			
	Good	Fair	Poor		Good	Fair	Poor		Good	Fair	Poor		Good	Fair	Poor		Good	Fair	Poor
40	87.20%	9.40%	3.30%	40	86.00%	10.10%	3.90%	40	85.70%	10.10%	4.20%	40	85.90%	10.10%	4.10%	40	86.10%	10.00%	3.90%
41	87.10%	9.60%	3.30%	41	84.70%	10.80%	4.40%	41	84.70%	10.90%	4.50%	41	85.10%	10.60%	4.30%	41	84.80%	10.90%	4.30%
42	87.10%	9.50%	3.40%	42	83.70%	11.50%	4.70%	42	83.90%	11.30%	4.80%	42	83.20%	12.00%	4.80%	42	83.50%	11.80%	4.70%
43	85.80%	10.70%	3.50%	43	84.20%	10.70%	5.10%	43	84.40%	10.60%	4.90%	43	84.00%	11.00%	5.00%	43	84.10%	11.00%	5.00%
44	85.70%	10.60%	3.80%	44	83.30%	11.80%	4.90%	44	83.00%	12.00%	4.90%	44	82.90%	11.60%	5.40%	44	82.90%	11.60%	5.50%
45	85.50%	10.70%	3.80%	45	82.30%	12.30%	5.40%	45	82.00%	12.30%	5.70%	45	82.20%	12.30%	5.50%	45	82.20%	12.20%	5.50%
46	85.10%	11.00%	3.90%	46	81.10%	13.00%	5.80%	46	80.80%	13.20%	6.00%	46	80.90%	13.40%	5.70%	46	81.20%	13.10%	5.70%
47	84.60%	11.40%	3.90%	47	80.10%	13.60%	6.20%	47	80.00%	13.40%	6.60%	47	79.90%	13.80%	6.20%	47	80.10%	13.70%	6.20%
48	84.10%	11.50%	4.40%	48	79.20%	14.50%	6.30%	48	79.10%	14.50%	6.50%	48	79.40%	14.30%	6.30%	48	79.00%	14.70%	6.30%
49	83.90%	11.70%	4.40%	49	78.40%	14.90%	6.70%	49	77.80%	15.30%	6.90%	49	78.20%	15.00%	6.80%	49	78.20%	14.80%	7.00%
50	83.60%	11.80%	4.60%	50	77.00%	15.80%	7.20%	50	77.10%	15.60%	7.20%	50	77.20%	15.60%	7.20%	50	77.10%	15.70%	7.20%
51	83.10%	12.20%	4.60%	51	75.40%	16.90%	7.80%	51	76.60%	15.60%	7.70%	51	75.60%	16.60%	7.80%	51	75.60%	16.50%	7.90%
52	83.10%	12.10%	4.90%	52	73.70%	18.00%	8.30%	52	74.60%	17.30%	8.20%	52	74.40%	17.60%	8.10%	52	74.10%	17.80%	8.20%
53	81.90%	13.00%	5.10%	53	74.00%	17.70%	8.30%	53	73.90%	17.80%	8.30%	53	73.70%	17.70%	8.60%	53	74.00%	17.40%	8.60%
54	81.10%	13.90%	5.00%	54	73.10%	17.80%	9.10%	54	72.60%	18.20%	9.20%	54	72.40%	18.10%	9.50%	54	72.30%	18.30%	9.40%
55	78.70%	15.40%	6.00%	55	72.20%	18.10%	9.70%	55	71.60%	19.10%	9.30%	55	72.60%	18.30%	9.10%	55	72.00%	18.20%	9.80%
56	79.40%	15.00%	5.70%	56	69.30%	20.00%	10.70%	56	69.60%	20.10%	10.30%	56	70.30%	20.00%	9.70%	56	71.00%	19.20%	9.80%
57	77.90%	15.90%	6.20%	57	70.10%	20.50%	9.50%	57	70.20%	19.90%	9.90%	57	69.80%	20.40%	9.70%	57	70.10%	20.20%	9.60%
58	77.00%	16.60%	6.40%	58	69.50%	20.90%	9.60%	58	69.50%	20.60%	9.90%	58	69.30%	20.70%	10.00%	58	68.90%	21.00%	10.10%
59	77.30%	16.40%	6.20%	59	68.00%	21.70%	10.30%	59	67.50%	21.80%	10.70%	59	68.10%	21.90%	10.10%	59	67.90%	22.00%	10.10%
60	76.50%	16.40%	7.00%	60	67.20%	23.30%	9.50%	60	67.30%	23.10%	9.60%	60	67.80%	22.60%	9.60%	60	67.30%	23.30%	9.40%
61	75.20%	17.40%	7.40%	61	67.90%	22.70%	9.40%	61	67.30%	23.20%	9.50%	61	66.40%	23.60%	10.00%	61	67.10%	23.20%	9.70%
62	74.90%	17.40%	7.70%	62	65.30%	25.20%	9.50%	62	65.70%	24.40%	9.80%	62	65.00%	25.10%	9.90%	62	65.40%	24.80%	9.80%
63	74.40%	17.90%	7.70%	63	63.60%	26.10%	10.30%	63	63.40%	25.50%	11.10%	63	64.30%	25.60%	10.10%	63	64.50%	25.20%	10.20%
64	73.20%	19.00%	7.80%	64	63.90%	25.40%	10.70%	64	62.90%	26.40%	10.70%	64	64.40%	25.20%	10.40%	64	63.70%	25.50%	10.80%
65	73.20%	19.30%	7.50%	65	62.40%	26.60%	11.10%	65	62.10%	26.20%	11.60%	65	60.50%	27.70%	11.80%	65	61.30%	27.10%	11.70%
66	71.80%	20.30%	7.90%	66	61.60%	27.00%	11.40%	66	61.70%	27.00%	11.20%	66	61.40%	27.00%	11.60%	66	61.60%	26.80%	11.60%
67	71.40%	20.10%	8.60%	67	59.40%	28.80%	11.80%	67	60.10%	28.60%	11.30%	67	59.40%	29.00%	11.60%	67	59.20%	29.40%	11.40%
68	70.70%	20.30%	9.00%	68	58.80%	30.00%	11.20%	68	58.10%	30.20%	11.70%	68	59.00%	30.10%	10.80%	68	58.40%	29.90%	11.60%
69	69.20%	21.40%	9.40%	69	56.80%	30.40%	12.80%	69	56.90%	30.30%	12.70%	69	56.90%	30.50%	12.60%	69	57.10%	31.00%	11.90%

70	66.60%	22.90%	10.40%
71	65.60%	23.90%	10.60%
72	65.00%	24.70%	10.30%
73	63.60%	25.10%	11.30%
74	62.70%	25.60%	11.70%
75	61.10%	26.60%	12.30%
76	60.30%	27.20%	12.40%
77	59.20%	28.00%	12.80%
78	60.20%	27.10%	12.70%
79	58.20%	28.80%	13.00%
80	55.00%	30.20%	14.70%
81	55.30%	30.10%	14.60%
82	53.60%	30.70%	15.70%
83	52.10%	31.90%	16.00%
84	52.90%	32.20%	15.00%
85	52.40%	31.50%	16.10%
86	50.60%	32.60%	16.80%
87	49.30%	33.10%	17.50%
88	48.50%	34.20%	17.30%
89	47.30%	34.90%	17.80%
90	46.20%	34.90%	19.00%

70	56.70%	31.80%	11.50%
71	53.30%	33.30%	13.30%
72	52.10%	33.40%	14.60%
73	50.20%	35.60%	14.20%
74	49.20%	36.20%	14.50%
75	45.50%	39.10%	15.40%
76	44.60%	38.70%	16.70%
77	42.10%	40.40%	17.60%
78	39.60%	42.30%	18.10%
79	39.00%	41.70%	19.40%
80	37.70%	44.00%	18.30%
81	35.10%	44.50%	20.30%
82	34.70%	45.10%	20.30%
83	33.70%	44.50%	21.80%
84	29.80%	46.10%	24.10%
85	27.70%	47.90%	24.40%
86	28.70%	47.90%	23.50%
87	28.00%	47.90%	24.10%
88	26.10%	47.80%	26.10%
89	25.20%	48.70%	26.00%
90	23.60%	50.00%	26.40%

70	55.40%	32.50%	12.20%
71	54.10%	33.00%	12.90%
72	52.30%	33.50%	14.20%
73	50.20%	36.10%	13.70%
74	48.10%	36.90%	14.90%
75	46.60%	37.90%	15.50%
76	44.90%	39.10%	16.00%
77	43.30%	39.60%	17.10%
78	39.30%	41.80%	18.90%
79	38.70%	42.40%	18.90%
80	38.70%	42.40%	18.80%
81	34.60%	44.70%	20.70%
82	34.10%	45.00%	20.90%
83	33.20%	44.80%	22.00%
84	29.90%	46.10%	24.00%
85	28.20%	48.10%	23.70%
86	29.10%	47.00%	23.90%
87	27.40%	48.00%	24.60%
88	26.60%	48.70%	24.70%
89	25.40%	48.30%	26.30%
90	23.10%	51.70%	25.20%

70	55.50%	31.80%	12.60%
71	53.60%	32.60%	13.90%
72	51.20%	34.50%	14.20%
73	50.30%	35.60%	14.10%
74	48.30%	37.00%	14.80%
75	47.30%	37.00%	15.60%
76	45.10%	38.00%	16.90%
77	42.40%	40.50%	17.10%
78	39.40%	42.10%	18.50%
79	39.00%	42.00%	19.00%
80	37.40%	43.20%	19.40%
81	35.00%	44.40%	20.60%
82	36.40%	43.30%	20.30%
83	34.60%	44.00%	21.40%
84	30.80%	45.70%	23.50%
85	29.30%	47.00%	23.70%
86	28.10%	47.60%	24.30%
87	27.70%	47.90%	24.40%
88	25.60%	48.70%	25.80%
89	25.80%	48.30%	25.90%
90	23.70%	50.40%	25.90%

70	55.40%	32.70%	11.90%
71	53.80%	33.20%	13.10%
72	51.20%	34.00%	14.90%
73	50.60%	35.00%	14.40%
74	48.40%	36.40%	15.20%
75	46.00%	38.60%	15.50%
76	44.30%	39.10%	16.60%
77	44.10%	39.40%	16.50%
78	40.00%	42.30%	17.70%
79	38.30%	41.70%	19.90%
80	37.00%	43.60%	19.40%
81	34.70%	44.40%	20.90%
82	34.00%	45.20%	20.80%
83	33.80%	45.60%	20.60%
84	29.40%	47.30%	23.30%
85	28.80%	47.80%	23.50%
86	28.80%	47.70%	23.50%
87	27.00%	48.20%	24.90%
88	26.70%	48.30%	25.00%
89	25.30%	48.90%	25.80%
90	23.90%	50.30%	25.80%

Source: Author’s own analysis of PENHEALTH model Data

Appendix D NS-SEC Alignment Comparison

NS-SEC Comparison

NS-SEC 2011 Base			
NS-SEC	Good	Fair	Poor
1	82.10%	12.70%	5.20%
2	76.50%	16.60%	7.00%
3	71.20%	19.90%	8.90%
4	66.00%	23.50%	10.50%
5	60.10%	27.10%	12.90%

2011 Sort by Predicted Probability Alignment			
NS-SEC	Good	Fair	Poor
1	77.90%	10.90%	11.20%
2	70.80%	16.90%	12.40%
3	64.90%	22.20%	12.90%
4	58.60%	28.10%	13.30%
5	44.90%	40.40%	14.70%

2011 Sort by Difference Alignment			
NS-SEC	Good	Fair	Poor
1	75.60%	15.90%	8.50%
2	68.00%	21.30%	10.70%
3	61.50%	25.30%	13.20%
4	56.10%	29.30%	14.60%
5	48.90%	33.60%	17.50%

2011 Sort by Difference with 10% Manipulation			
	Good	Fair	Poor
1	74.30%	17.50%	8.20%
2	67.70%	21.80%	10.50%
3	61.90%	25.40%	12.80%
4	56.70%	28.50%	14.80%
5	50.00%	32.30%	17.80%

2011 Sort by Difference Logistic Alignment			
	Good	Fair	Poor
1	72.70%	18.50%	8.80%
2	66.60%	22.50%	10.80%
3	61.20%	25.90%	12.90%
4	57.40%	27.90%	14.70%
5	51.60%	31.40%	17.10%

NS-SEC 2011 Sort by Predicted Probability Alignment Difference from Base			
	Good	Fair	Poor
1	-4.20%	-1.80%	6.00%
2	-5.70%	0.30%	5.40%
3	-6.30%	2.30%	4.00%
4	-7.40%	4.60%	2.80%
5	-15.20%	13.30%	1.80%

NS-SEC 2011 Sort by Difference Alignment Difference from Base			
	Good	Fair	Poor
1	-6.50%	3.20%	3.30%
2	-8.50%	4.70%	3.70%
3	-9.70%	5.40%	4.30%
4	-9.90%	5.80%	4.10%
5	-11.20%	6.50%	4.60%

NS-SEC 2011 Sort by Difference with Forced 10% Difference from Base			
	Good	Fair	Poor
1	-7.80%	4.80%	3.00%
2	-8.80%	5.20%	3.50%
3	-9.30%	5.50%	3.90%
4	-9.30%	5.00%	4.30%
5	-10.10%	5.20%	4.90%

NS-SEC 2011 Sort by Difference Logistic Alignment Difference from Base			
	Good	Fair	Poor
1	-9.40%	5.80%	3.60%
2	-9.90%	5.90%	3.80%
3	-10.00%	6.00%	4.00%
4	-8.60%	4.40%	4.20%
5	-8.50%	4.30%	4.20%

2011 Census Data			
NS-SEC	Good	Fair	Poor
1	79.40%	15.30%	5.30%
2	71.60%	20.80%	7.60%
3	71.00%	20.70%	8.40%
4	62.50%	25.30%	12.20%
5	55.80%	29.10%	15.10%

2011 Sort by Difference Alignment Difference from Census			
NS-SEC	Good	Fair	Poor
1	-1.50%	-4.40%	5.90%
2	-0.80%	-3.90%	4.80%
3	-6.10%	1.50%	4.50%
4	-3.90%	2.80%	1.10%
5	-10.90%	11.30%	-0.40%
Avg. Census Group Deviation	-4.64%	1.46%	3.18%

2011 Sort by Difference Alignment Difference from Census			
NS-SEC	Good	Fair	Poor
1	-3.80%	0.60%	3.20%
2	-3.60%	0.50%	3.10%
3	-9.50%	4.60%	4.80%
4	-6.40%	4.00%	2.40%
5	-6.90%	4.50%	2.40%
Avg. Census Group Deviation	-6.04%	2.84%	3.18%

2011 Sort by Difference with 10% Manipulation Difference from Census			
NS-SEC	Good	Fair	Poor
1	-5.10%	2.20%	2.90%
2	-3.90%	1.00%	2.90%
3	-9.10%	4.70%	4.40%
4	-5.80%	3.20%	2.60%
5	-5.80%	3.20%	2.70%
Avg. Census Group Deviation	-5.94%	2.86%	3.10%

2011 Sort by Difference Logistic Alignment Difference from Census			
NS-SEC	Good	Fair	Poor
1	-6.70%	3.20%	3.50%
2	-5.00%	1.70%	3.20%
3	-9.80%	5.20%	4.50%
4	-5.10%	2.60%	2.50%
5	-4.20%	2.30%	2.00%
Avg. Census Group Deviation	-6.16%	3.00%	3.14%

Source: Author's own analysis of PENHEALTH model Data

Appendix E Housing Tenure Alignment Comparison

Hotenu1 - Housing Tenure Comparison

2011 Base			
	Good	Fair	Poor
Own Outright	64.30%	24.10%	11.60%
Mortgage	79.30%	14.80%	6.00%
Private Rented & Rent Free	70.80%	20.00%	9.30%
Social Rented	63.20%	25.30%	11.50%

2011 Sort by Predicted Probability Alignment			
	Good	Fair	Poor
Own Outright	54.10%	28.60%	17.30%
Mortgage	72.90%	18.00%	9.10%
Private Rented & Rent Free	62.40%	24.80%	12.90%
Social Rented	48.80%	36.70%	14.50%

2011 Sort by Difference Alignment			
	Good	Fair	Poor
Own Outright	52.20%	31.10%	16.80%
Mortgage	72.30%	18.80%	8.90%
Private Rented & Rent Free	63.00%	23.90%	13.10%
Social Rented	53.10%	30.50%	16.40%

2011 Sort by Difference with 10% Manipulation			
	Good	Fair	Poor
Own Outright	51.90%	31.40%	16.70%
Mortgage	72.20%	19.00%	8.80%
Private Rented & Rent Free	63.50%	23.50%	13.00%
Social Rented	53.90%	29.50%	16.50%

2011 Sort by Difference Logistic Alignment			
	Good	Fair	Poor
Own Outright	51.60%	31.60%	16.80%
Mortgage	71.90%	19.20%	8.90%
Private Rented & Rent Free	63.10%	23.70%	13.20%
Social Rented	55.00%	29.00%	16.00%

2011 Sort by Predicted Probability Alignment Difference from Base			
	Good	Fair	Poor
Own Outright	-10.20%	4.50%	5.70%
Mortgage	-6.40%	3.20%	3.10%
Private Rented & Rent Free	-8.40%	4.80%	3.60%
Social Rented	-14.40%	11.40%	3.00%

2011 Sort by Difference Alignment Difference from Base			
	Good	Fair	Poor
Own Outright	-12.10%	7.00%	5.20%
Mortgage	-7.00%	4.00%	2.90%
Private Rented & Rent Free	-7.80%	3.90%	3.80%
Social Rented	-10.10%	5.20%	4.90%

2011 Sort by Difference with 10% Manipulation Difference Alignment Difference from Base			
	Good	Fair	Poor
Own Outright	-12.40%	7.30%	5.10%
Mortgage	-7.10%	4.20%	2.80%
Private Rented & Rent Free	-7.30%	3.50%	3.70%
Social Rented	-9.30%	4.20%	5.00%

2011 Sort by Difference Logistic Alignment Difference from Base			
	Good	Fair	Poor
Own Outright	-12.70%	7.50%	5.20%
Mortgage	-7.40%	4.40%	2.90%
Private Rented & Rent Free	-7.70%	3.70%	3.90%
Social Rented	-8.20%	3.70%	4.50%

Source: Author’s own analysis of PENHEALTH model Data

Appendix F Highest Educational Qualification Alignment Comparison

Highqual1 - Highest Educational Qualification Comparison

2011 Base	Good	Fair	Poor
Degree or Above	82.20%	12.10%	5.70%
A Level	80.10%	13.90%	6.00%
O Level	77.30%	15.80%	6.80%
Foreign Qualification	68.40%	21.80%	9.80%
No Qualification	59.40%	27.90%	12.80%

2011 Sort by Predicted Probability Alignment	Good	Fair	Poor
Degree or Above	77.90%	11.00%	11.10%
A Level	75.40%	13.90%	10.70%
O Level	71.70%	18.00%	10.30%
Foreign Qualification	60.20%	25.50%	14.30%
No Qualification	44.20%	39.50%	16.30%

2011 Sort by Difference Alignment	Good	Fair	Poor
Degree or Above	76.00%	15.20%	8.80%
A Level	73.60%	17.30%	9.10%
O Level	70.00%	20.00%	10.00%
Foreign Qualification	57.80%	28.10%	14.10%
No Qualification	46.80%	35.00%	18.10%

2011 Sort by Difference with 10% Manipulation	Good	Fair	Poor
Degree or Above	74.60%	16.80%	8.50%
A Level	73.40%	17.80%	8.80%
O Level	69.90%	20.20%	9.90%
Foreign Qualification	58.20%	27.80%	14.00%
No Qualification	47.70%	34.00%	18.30%

2011 Sort by Difference Logistic Alignment	Good	Fair	Poor
Degree or Above	73.10%	17.90%	9.00%
A Level	72.20%	18.40%	9.40%
O Level	69.70%	20.30%	10.00%
Foreign Qualification	58.10%	28.20%	13.80%
No Qualification	48.60%	33.50%	17.80%

2011 Sort by Predicted Probability Alignment Difference from Base	Good	Fair	Poor
Degree or Above	-4.30%	-1.10%	5.40%
A Level	-4.70%	0.00%	4.70%
O Level	-5.60%	2.20%	3.50%
Foreign Qualification	-8.20%	3.70%	4.50%
No Qualification	-15.20%	11.60%	3.50%

2011 Sort by Difference Alignment Difference from Base	Good	Fair	Poor
Degree or Above	-6.20%	3.10%	3.10%
A Level	-6.50%	3.40%	3.10%
O Level	-7.30%	4.20%	3.20%
Foreign Qualification	-10.60%	6.30%	4.30%
No Qualification	-12.60%	7.10%	5.30%

2011 Sort by Difference with 10% Manipulation Difference	Good	Fair	Poor
Degree or Above	-7.60%	4.70%	2.80%
A Level	-6.70%	3.90%	2.80%
O Level	-7.40%	4.40%	3.10%
Foreign Qualification	-10.20%	6.00%	4.20%
No Qualification	-11.70%	6.10%	5.50%

2011 Sort by Difference Logistic Alignment Difference from Base	Good	Fair	Poor
Degree or Above	-9.10%	5.80%	3.30%
A Level	-7.90%	4.50%	3.40%
O Level	-7.60%	4.50%	3.20%
Foreign Qualification	-10.30%	6.40%	4.00%
No Qualification	-10.80%	5.60%	5.00%

2011 Census	Good	Fair	Poor
Degree or Above	87.80%	9.30%	2.90%
A Level	84.80%	11.40%	3.80%
O Level	83.50%	12.20%	4.30%
Foreign Qualification	75.80%	17.40%	6.80%
No Qualification	53.10%	30.50%	16.40%

2011 Sort by Predicted Probability Alignment Difference from Census	Good	Fair	Poor
Degree or Above	-9.90%	1.70%	8.20%
A Level	-9.40%	2.50%	6.90%
O Level	-11.80%	5.80%	6.00%
Foreign Qualification	-15.60%	8.10%	7.50%
No Qualification	-8.90%	9.00%	-0.10%
Average Census Group Deviation	-11.12%	5.42%	5.70%

2011 Sort by Difference Alignment Difference from Census	Good	Fair	Poor
Degree or Above	-11.80%	5.90%	5.90%
A Level	-11.20%	5.90%	5.30%
O Level	-13.50%	7.80%	5.70%
Foreign Qualification	-18.00%	10.70%	7.30%
No Qualification	-6.30%	4.50%	1.70%
Average Census Group Deviation	-12.16%	6.96%	5.18%

2011 Sort by Difference with 10% Manipulation Difference from Census	Good	Fair	Poor
Degree or Above	-13.20%	7.50%	5.60%
A Level	-11.40%	6.40%	5.00%
O Level	-13.60%	8.00%	5.60%
Foreign Qualification	-17.60%	10.40%	7.20%
No Qualification	-5.40%	3.50%	1.90%
Average Census Group Deviation	-12.24%	7.16%	5.06%

2011 Sort by Difference Logistic Alignment Difference from Census	Good	Fair	Poor
Degree or Above	-14.70%	8.60%	6.10%
A Level	-12.60%	7.00%	5.60%
O Level	-13.80%	8.10%	5.70%
Foreign Qualification	-17.70%	10.80%	7.00%
No Qualification	-4.50%	3.00%	1.40%
Average Census Group Deviation	-12.66%	7.50%	5.16%

Source: Author's own analysis of PENHEALTH model Data

Appendix G Marital Status Alignment Comparison

Marstat1 - Marital Status Comparison

2011 Base

	Good	Fair	Poor
Single & Never Married	79.60%	14.70%	5.80%
Married	74.10%	18.20%	7.70%
Separated & Divorced	74.30%	18.00%	7.70%
Widowed	48.20%	33.70%	18.10%

2011 Sort by Predicted Probability Alignment

	Good	Fair	Poor
Single & Never Married	75.50%	15.20%	9.40%
Married	66.20%	22.60%	11.20%
Separated & Divorced	62.90%	26.80%	10.30%
Widowed	25.40%	46.20%	28.40%

2011 Sort by Difference Alignment

	Good	Fair	Poor
Single & Never Married	73.80%	17.40%	8.80%
Married	64.60%	24.30%	11.10%
Separated & Divorced	65.20%	24.00%	10.80%
Widowed	31.50%	39.00%	29.40%

2011 Sort by Difference with 10% Manipulation

	Good	Fair	Poor
Single & Never Married	73.40%	18.00%	8.60%
Married	64.60%	24.40%	11.00%
Separated & Divorced	65.20%	23.80%	10.90%
Widowed	32.50%	37.90%	29.60%

Sort by Difference Logistic Alignment

	Good	Fair	Poor
Single & Never Married	72.80%	18.40%	8.80%
Married	64.40%	24.50%	11.10%
Separated & Divorced	65.60%	23.60%	10.80%
Widowed	32.80%	38.20%	29.00%

Sort by Predicted Probability Alignment Difference from Base

	Good	Fair	Poor
Single & Never Married	-4.10%	0.50%	3.60%
Married	-7.90%	4.40%	3.50%
Separated & Divorced	-11.40%	8.80%	2.60%
Widowed	-22.80%	12.50%	10.30%

Sort by Difference Alignment Difference from Base

	Good	Fair	Poor
Single & Never Married	-5.80%	2.70%	3.00%
Married	-9.50%	6.10%	3.40%
Separated & Divorced	-9.10%	6.00%	3.10%
Widowed	-16.70%	5.30%	11.30%

Sort by Difference with 10% Manipulation Alignment Difference from Base

	Good	Fair	Poor
Single & Never Married	-6.20%	3.30%	2.80%
Married	-9.50%	6.20%	3.30%
Separated & Divorced	-9.10%	5.80%	3.20%
Widowed	-15.70%	4.20%	11.50%

Sort by Difference Logistic Alignment Difference from Base

	Good	Fair	Poor
Single & Never Married	-6.80%	3.70%	3.00%
Married	-9.70%	6.30%	3.40%
Separated & Divorced	-8.70%	5.60%	3.10%
Widowed	-15.40%	4.50%	10.90%

2011 Census

	Good	Fair	Poor
Single & Never Married	88.90%	6.20%	2.40%
Married	77.60%	16.20%	6.20%
Separated & Divorced	69.10%	20.00%	10.80%
Widowed	42.60%	38.90%	18.60%

Sort by Predicted Probability Alignment Difference from Census

	Good	Fair	Poor
Single & Never Married	-13.40%	9.00%	7.00%
Married	-11.40%	6.40%	5.00%
Separated & Divorced	-6.20%	6.80%	-0.50%
Widowed	-17.20%	7.30%	9.80%
Avg. Census Group Deviation	-12.05%	7.38%	5.33%

Sort by Difference Alignment Difference from Census

	Good	Fair	Poor
Single & Never Married	-15.10%	11.20%	6.40%
Married	-13.00%	8.10%	4.90%
Separated & Divorced	-3.90%	4.00%	0.00%
Widowed	-11.10%	0.10%	10.80%
Avg. Census Group Deviation	-10.78%	5.85%	5.53%

Sort by Difference with 10% Manipulation Alignment Difference from Census

	Good	Fair	Poor
Single & Never Married	-15.50%	11.80%	6.20%
Married	-13.00%	8.20%	4.80%
Separated & Divorced	-3.90%	3.80%	0.10%
Widowed	-10.10%	-1.00%	11.00%
Avg. Census Group Deviation	-10.63%	5.70%	5.53%

Sort by Difference Logistic Alignment Difference from Census

	Good	Fair	Poor
Single & Never Married	-16.10%	12.20%	6.40%
Married	-13.20%	8.30%	4.90%
Separated & Divorced	-3.50%	3.60%	0.00%
Widowed	-9.80%	-0.70%	10.40%
Avg. Census Group Deviation	-10.65%	5.85%	5.43%

Source: Author's own analysis of PENHEALTH model Data

Appendix H Lessons from Previous Microsimulation Experience

A number of different microsimulation models have been built to investigate similar questions to those posed within this study. This review will focuses on those models that include a health projection module, but also includes other models with approaches of interest. This includes eight models including DYNASIM, CORSIM, DYNAMOD, DYNACAN, SAGE, MOSART, PENSIM and EUROMOD. The development of these models have produced insights and past experience, each of these is considered for what lessons and good practice can be utilised in the development of the study.

Model	Key Features
SESIM(2,3)	Modelling of health transitions. Uses logistic regression and ordered probit models, calibrates with an external long-range population forecasts.
DYNASIM(2,3)	Use of a modular approach to improve model development, computational speed and model validation
CORSIM	Use of a historical base dataset to allow for model alignment period
DYNACAN	Modelling of base and alternative scenarios within same framework to allow comparability between results.
DYNAMOD (2)	Uses Pseudo-continuous time, lending greater accuracy to results than can be achieved with discrete time modelling.
MOSART	Modelling of health trajectories through the life course. The model shows the capability of a model when rich data is available.
EUROMOD	End-user approach, no manipulation of code is required on the part of the user and the code remains unchanged by the simulations

SESIM(2,3)

The original SESIM model was developed by the Swedish Ministry of Finance in 1997 to investigate Swedish higher education funding. The second SESIM model sought to take this further, developing the model into a general microsimulation model, changing the focus of the model to pensions. The third generation of the model, SESIM 3 focused again on pensions, including the influence of health, regional mobility and health within the analyses (Flood, 2008). A large number of events are simulated within the SESIM model, with the base population of around 100,000 individuals simulating events such as education, marriage, fertility, employment, retirement and health declines (Flood, 2008). Crucial to this study are the modelling of health transitions and mortality throughout life.

Mortality risk is modelled through three separate age groups, those between 0-29 years, 30-64 years and greater than 64 years of age. Due to low mortality at younger ages, mortality risks are initially constructed based on observed risks amongst the total population in this age group and applied across the group. Secondly, a logistic regression model is applied to those between 30-64 years of age including the covariates of sex, age, an indicator for early retirement due to the correlation between this and poor health, pensionable income and marital status. Finally, the oldest group within the population aged over 65 is again modelled using a logistic regression, with the addition of highest level of education as an additional covariate. These results are then calibrated with external long-range population forecasts (Klevmarken & Lindgren, 2008). This approach allows realistic mortality modelling through dividing risks into three primary age categories.

The modelling of health transitions is crucial within the SESIM model to calculate the care needs of an ageing population. Similarly, the modelling of health will assist the model developed within this study to assess the impact of increased working years under state pension age reform. The SESIM health module assesses health based on a health index comprising of self-assessed health, mobility, long-standing illness and working capacity. Data for these variables is included within the base data of the model and thereafter simulated by the model. During the simulation run of the model, self-rated health is first simulated into four categories: full health, good health, bad health and severe health problems. These events are estimated using an Ordered Probit model, based on the covariates of region, marital status, property tenure, nationality, age group, gross income, education, number of children and gender. Secondly, ADLs are simulated within the model using a scale, dividing the population into non-disabled, slightly disabled, moderately disabled and severely disabled. Due to the nature of the simulation investigating elderly care requirements, these events are only simulated after age 65, based on an Ordered Logit model using the health index, age group and sex as covariates. Additionally number of days in patient care and elderly assistance requirements are simulated to aid analysis.

Due to differences in research topic, slight modifications are needed to utilise the approach used in the SESIM model. In line with the SESIM model, initial values are taken from observed data, thereafter being estimated within the model.

DYNASIM (2,3)

Beginning work in 1969, the Dynamic Simulation of Income Model (DYNASIM) developed by Guy Orcutt and colleagues was among the first models to adopt the microanalytic simulation approach (Zaidi & Rake, 2001). The first model, completed in the mid 1970's attempted to include a representation of all major demographic and economic events in the modelling process (Zedlewski, 1990), modelling the economic and social behaviours of households in the United States. The second iteration of the model developed in the early 1980's, DYNASIM2, improved upon the operating characteristics and other features of the model by updating and re-specifying most modules. While the first iteration of the model included all modules in a single model, executing for each person every year, DYNASIM2 subdivided these processes into three smaller interacting models, the Family and Earnings History (FEH) model, the Job and Benefit History (JBH) model and the Cross-Sectional Imputation Model (CSIM). The FEH processed as the original model, processing the whole sample once each year. The FEH formed a model of demographic and labour market behaviour, being further subdivided into fourteen modules, corresponding to events or characteristics simulated (Spielauer, 2007). The FEH output then serves as the input for the JBH model. This allowed the base sample to be processed only once for the whole period of simulation (Zaidi & Rake, 2001). The CSIM model is an additional static model that is used to impute additional information to the annual output files generated by the other two models. These variables include health status, institutionalisation for those aged over 60, financial assets, home ownership and supplemental security income (Spielauer, 2007). Health status is not dynamically modelled, but rather imputed for any given year. Health status is measured by number of (instrumental) limitations on activities of daily life (I)ADLs). Subdivision of the model into smaller components can be beneficial as it allows systematic working of the model and facilitates troubleshooting at different stages of model development. DYNASIM 3 utilises a base population of 100,000 individuals from the 1990-1993 Survey of Income and Program Participation (SIPP) panels.

This study utilises the modular approach to development used within DYNASIM models. Development of specific modules facilitates model development through improved computation speed and ease of model validation. The model utilised in this study takes on a modular format. The modules are subdivided into a health trajectory module, a retirement timing module, a mortality module and finally bring these elements together in an overall pensions microsimulation. This allows systematic troubleshooting and verification of the model, however care needs to be taken that all module interactions are accounted for and no undesired effects are implemented.

CORSIM

Some of the ideas/experiences of DYNASIM were brought forward to CORSIM. The CORSIM project began in 1987 in the United States at Cornell University. The model built upon much of the initial ideas and experiences of the DYNASIM and DYNASIM2 models, utilising similar core components to the original models. CORSIM is built upon a base of the 1960

Public Use Microdata Survey, drawn from the 1960 US census. This consists of around 180,000 person records, contained within 70,000 families living throughout the US. The model covers both individuals and families, projecting basic demographic variables including emigration and immigration, as well as education, employment status and earnings, economic variables including assets and debts, as well as pension contributions. This model sought to support research of fundamental socioeconomic processes, provide a platform for a wide range of policy analyses and as an object of study of the application of microsimulation methods. The CORSIM model sought to include approximately 26 behavioural modules, utilising a diverse sample of datasets including longitudinal micro-data, as well as several rile-based routines (Spielauer, 2007). Externally to the main model, three additional modules were computed including a voting module, a consumption-expenditure model and a dental module. One of the most distinctive features of CORSIM is the utilisation of a historical base dataset. This allowed the modellers to evaluate the accuracy of the model and make heavy use of alignment procedures to adjust results in relation to known figures. The modelling of health was done through the inclusion of four influential risk factors to the model; smoking, alcohol consumption, sugar consumption and diabetes, as well as modelling institutionalisation. In order to save costs in implementing a model, the CORSIM framework went on to form the template used for the development of the Canadian model DYNACAN and the Swedish model SVERIGE.

This study utilises the ideas developed in CORSIM through consideration of a historical base dataset. This benefits the study in two ways. Firstly utilising a historical base data allows easier model alignment, through projection toward current observations, as in CORSIM. Secondly and additionally, this allows for a period of alignment of health trajectory information to be implemented before the final running of the model.

DYNACAN

DYNACAN is one component used by the Canadian government in assessing the impact of proposed changes to the Canada Pension Plan (CPP). This microsimulation works alongside the cell-based actuarial valuation model known as ACTUCAN. The model is a stochastic, open, longitudinal dynamic microsimulation (Morrison & Dussault, 2000). DYNACAN begins analysis with a heavily modified version of the 1971 census, providing a representative base of the Canadian population close to the beginning of the CPP totalling over 212,000. Demographic factors are then simulated, together with labour force entry, exit, work and earnings. Alongside this, the model calculates the CPP contributions and benefits the individual would accrue in their lifetime. DYNACAN is built on a population basis, allowing the number of individuals in the model to vary between years, in line with population projections. Meanwhile, individuals are always treated in the context of the families in which they reside in order to align with policy. This approach provides a full 'synthetic' dataset including individual employment and social histories back to the beginning of the CPP scheme, and up to the ultimate forecast horizon of some variables of 2130. Events are simulated stochastically (Monte Carlo) through the use of random numbers to control the generation of events including births, deaths, marriages and retirement (Morrison & Dussault, 2000). Critically, DYNACAN is able to simultaneously simulate in parallel both a base and alternative policy scenario. This approach allows direct comparison of the policy outcomes of both approaches while utilising the same projected population. The model operates over several decades, projecting from the past, into the future to facilitate alignment of data, full synthetic histories and forward projection in the same model. Typically, DYNACAN's primary objective was to project the CPP as it stood into the future to assess the consequences of proposed changes. The model additionally provides a java-based 'front end', allowing easy analysis of results and generation of graphs and tables.

This study takes influence from the DYNACAN model through use of simultaneous base and alternative scenario modelling and the use of a model 'front end' to facilitate analysis. Firstly, the inclusion of simultaneous modelling under stochastic processes allows the same population to be used throughout comparisons. This allows model results to be directly comparable before running Monte-Carlo processes, as well as allowing the full scope of variation in the model to be explored. Secondly, the use of a model 'front end' allows the model to be manipulated by those without expertise in the model construction. Finally the review process developed within the DYNACAN project is often regarded as one of the most comprehensive and well-documented schemes available (Kelly & Percival, 2009) (as discussed further in section 4.10 and implemented in section 5.11).

DYNAMOD (2)

DYNAMOD and the subsequent DYNAMOD-2 are early dynamic MSMs of the Australian population. The project was first undertaken to investigate income-contingent student loans. However, more recently the model has expanded to project characteristics of the Australian population over a period of up to 50 years (Abello, King & Kelly, 2002). DYNAMOD utilises a 0.1% base sample taken from the Australian 1986 census, totalling 150,000 individuals. It was elected to follow early examples such as DYNASIM2, opting to split the modelling between two modules; a population simulator known as PopSim and an analysis module. PopSim generated detailed population projections through modelling demographic processes, education and labour market processes. The outputs generated by the population projections were then intended to be utilised by the analysis module, covering areas such as health services, social security, taxation, student loans and household wealth (Antcliff, 1993). For the purposes of this study, DYNAMOD2 critically varied from the original conception through its attempt to model in pseudo-continuous time, rather than discrete intervals.

Microsimulations are often defined by the time interval utilised. The majority of models opt to utilise an annual time period as an approximation of reality. This is as a result of the demands on the data inputs used for parameter estimation, usually taking place on an annual basis. Additionally, any attempt to move towards a more continuous measure of time adds greatly to computational requirements, through increasing the number of periods to be simulated. However, DYNAMOD argued that the shorter the time interval utilised, the more realistic the model could be (King, Robinson & Bækgaard, 1999). The DYNAMOD project sought to draw a trade-off between period length and computing requirements through utilising a month as the basic time period of the model, giving twelve times the detail in projections over an annual approach.

The modelling sought to reduce computational cost through making maximum use of survival functions over transition probabilities (Antcliff, 1993). Survival functions do not need to be evaluated at each period of the model, only being updated when there is a shift in characteristics included in the survival function (King, Robinson & Bækgaard, 1999). For example, month of death is calculated at time of birth and stored, pending update from change in status through continuous time competing risk modelling (King, Robinson & Bækgaard, 1999; Spielauer, 2007). While the majority of processes are modelled on a monthly basis, depending on data availability, each element was assessed for its suitability for a monthly time unit. Education and earnings were deemed unsuitable for the pseudo-continuous time and are therefore modelled annually.

Had sufficient data been available, the pseudo-continuous time utilised in DYNAMOD could have been used in the PENHEALTH model. Pseudo-continuous time would lend greater accuracy to the results generated by the model than an annual time period would allow, while maintaining the discrete time period modelling approach. However, modelling time on a monthly basis, computational time is increased twelve times, while additionally requiring data for each transition. However, as such data is not readily available on a representative scale within the UK, this study opts to use a discrete annual conceptualisation of time.

MOSART

The MOSART model is a dynamic microsimulation model developed by Statistics Norway to explore policy alternatives and financing within the Norwegian population. Primary projections included demographic behaviour, education and labour force participation. A second version of the model included the modelling of pensions. Finally, the third iteration of the model included behavioural modules to improve the calculation of household formation and disability (Spielauer, 2007). The model utilises a detailed 12% base sample of the population administrative records from 1993, totalling around 480,000 individuals. Due to the detail available from administrative records in Norway, rich longitudinal data was available for a wide range of variables back to 1985 and to 1967 for labour income and pension entitlement variables. The MOSART model incorporates a set of health behaviours including movement in and out of care, disability and rehabilitation and disability related benefits including pensions. MOSART has become a trusted tool for policy analysis within Norway, primarily due to the access to rich administrative data. Through utilisation of observed data, the modelling process is greatly simplified, the model is therefore much easier to understand and more trusted by policy developers. The MOSART model does make attempts to model the health of individuals within the model. The approach taken relies on detailed information from administrative records. Such data is not available for the target population of this study, the UK. Additional steps will need to be taken to infer trajectories of health, based on available data to adequately model individuals through life.

EUROMOD

EUROMOD is the tax-benefit microsimulation model of the European Union, modelling individual and household tax liabilities and benefit entitlements (Sutherland & Figari, 2013). This model covers all European Union (EU) countries within the same framework, taking into account differences in policy rules between member-states. The model is able to examine effects of actual policy change over time, pose hypothetical policy modifications or explore alternative demographic or economic scenarios. The model was developed to utilise a single model across nations, allowing the potential to evaluate the impact of 'borrowing' policies from other nations. The modelling framework is open source, intended for academic and non-commercial policy analysis. EUROMOD was developed with multiple users throughout the EU, allowing results to be analysed at household, national or EU level. Results of the model are generated at a micro-level and can be analysed by any statistical software. As a result of the ease of use vs. flexibility trade off, EUROMOD is a static model. Socio-demographic population characteristics are assumed to be fixed over time and tax/benefit simulation is abstracted from behavioural responses to the policy. Additionally, by maintaining a consistent model framework across countries flexibility in analysis and comparability of results between countries is facilitated. National micro-data is prepared and supplied individually by each constituent nation. This opens the possibility of differential methods of data collection across nations, possibly hindering analysis of trends over time. Additionally, heterogeneity of conditions across constituent nations may impact the applicability of policy analysis. EUROMOD is programmed within C++ and compiled, meaning users have access to an executable file.

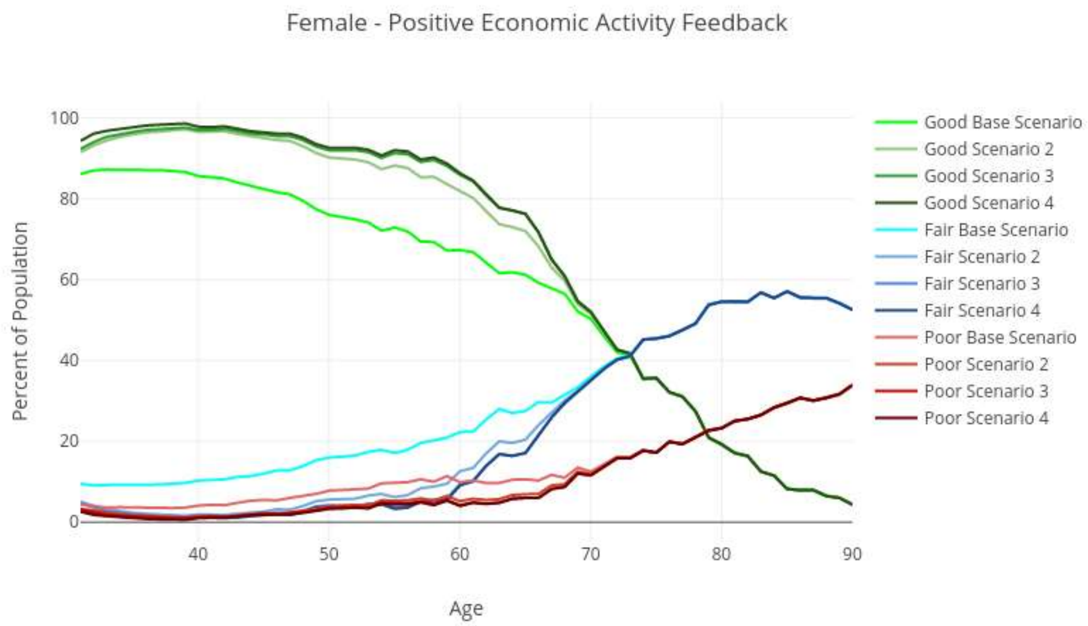
This study adopts an end-user approach in line with that of EUROMOD, in that no manipulation of the code is required on the part of the users and the code remains unchanged by simulations. The EUROMOD framework is the result of the input of a large team of experts, utilising large quantities of data and combining knowledge across countries. While the resulting model is very flexible in its outlook, the costs required to achieve this were very high.

Appendix I

Additional Alternative Scenario - Small, Medium & Large Economically Active Health Improvement

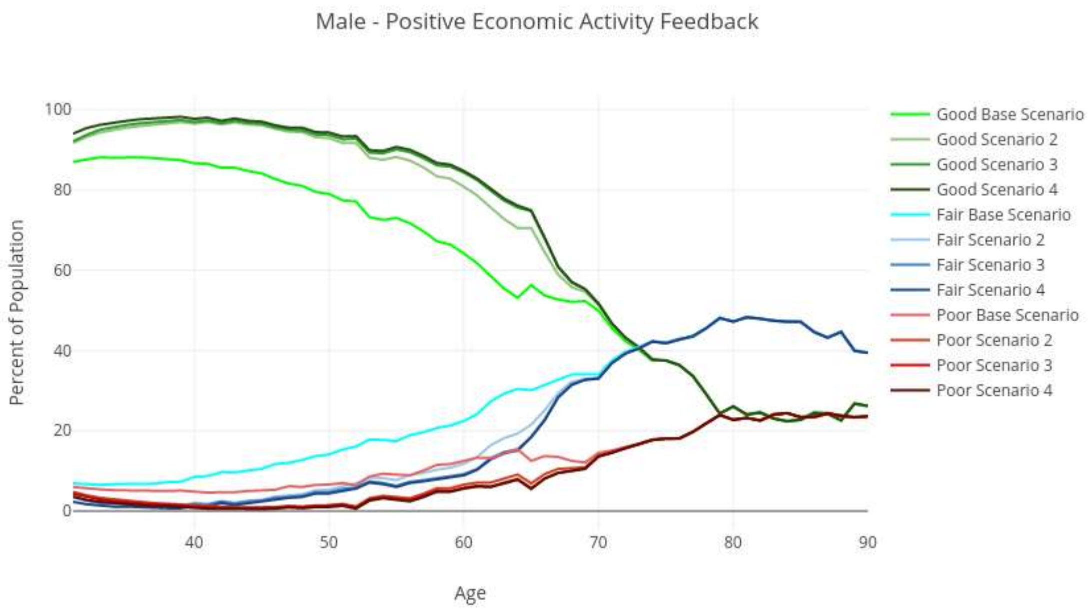
The additional alternative scenarios investigated a small, medium and large improvement to the health of those defined within the model as economically active. This was enacted through a proportional 10%, 20% and 50% improved probability of being in a good health state respectively. The effect of such manipulation on female individuals can be seen in Figure A1 and male individuals in Figure A2 below. As can be seen in the graphs, the reweighting of the predicted probabilities increases the likelihood of individuals within employment years remaining in good health. For females at age 60, the reweighting algorithm has manipulated the proportion of individuals falling into good health from a population average of 67.3% to 81.8% for Scenario 2, 85.9% for Scenario 3 and 86.3% for Scenario 4. Following the economically active years, the impact of this assumption remains similar. This shows the assumption of a 'protective' effect of employment on health, while assuming no effect of retirement or inactivity years. Additionally, the figure below shows a corresponding decrease in the probability of being in fair and to a lesser degree poor health states as a result of the reweighting algorithm. For female individuals, this has reduced the proportion of individuals in fair health at age 60 from 22.3% to 12.6%, 9.4% and 9.1% for scenarios 2, 3 and 4 respectively. Male individuals under the positive feedback scenarios experience a longer duration of the protective health effect of employment due to their overall later retirement age across the model. It should be noted however that health improvement experienced within the alternate scenarios at an aggregate level does not vary as much as may be expected between the alternate scenarios. This is a result of applying the reweighting to those individuals that are broadly in good health during early working years. With no improvement in these individuals health state possible, the model becomes deterministic, forcing them into the good health category and reducing the probability of other health states to zero. This impact was identified during initial testing of the model, however was found to have the greatest effect amongst those already very likely to be in good health. On an individual level, those less likely to be in good health will experience the protective effect of employment, which is likely to be crucial in determining the impact of a change in SPA. As can be seen from the results, even a small 10% improvement in health through employment can lead to a significantly better health throughout the population. However, it is possible that some employment types may lead to health improvement while others may lead to health detriment.

<u>Figure A1 – Female Additional Alternative Scenario – Positive Economic Activity Feedback</u>



Source: Author's own analysis of PENHEALTH model data.

<u>Figure A2 – Male Additional Alternative Scenario – Positive Economic Activity Feedback</u>



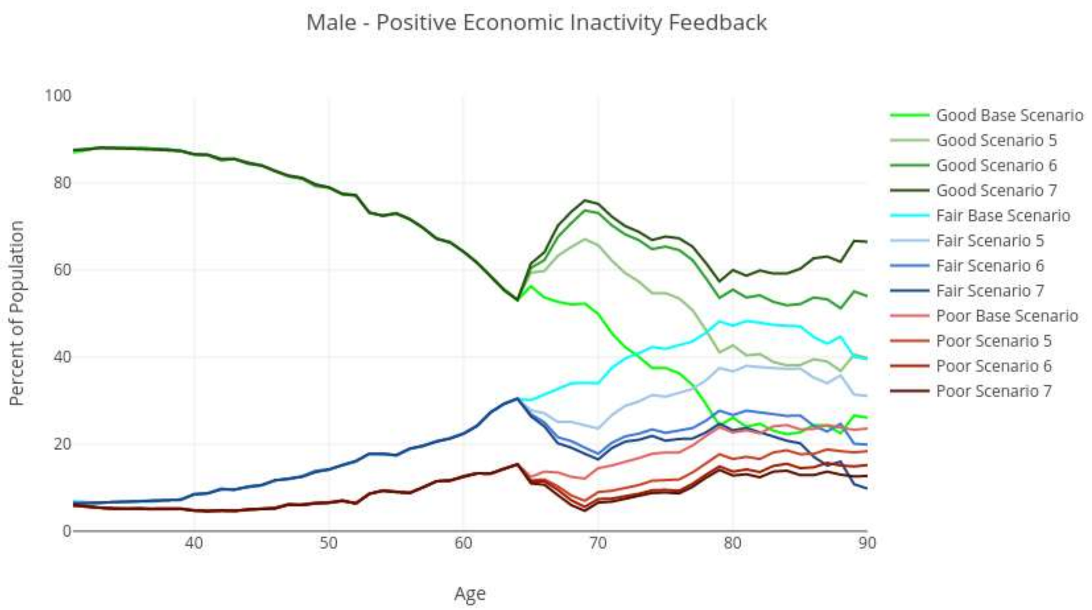
Source: Author's own analysis of PENHEALTH model data.

Additional Alternative Scenario - Small, Medium & Large Economically Inactive Health Improvement

Following on from a possible positive impact of economic activity, the second group of alternative scenarios investigates a possible health benefit to retirement only, while other economic activity states maintain the base scenario. The grounding for this was put forward in Section 1.2.3, with discussion that dependent on the context, individuals may experience a positive benefit of retirement, with a reduced time cost of healthy activities and visits to a doctor. Additionally, the ability to engage in meaningful relationships with friends and family and time for pleasurable pursuits may improve the health of individuals.

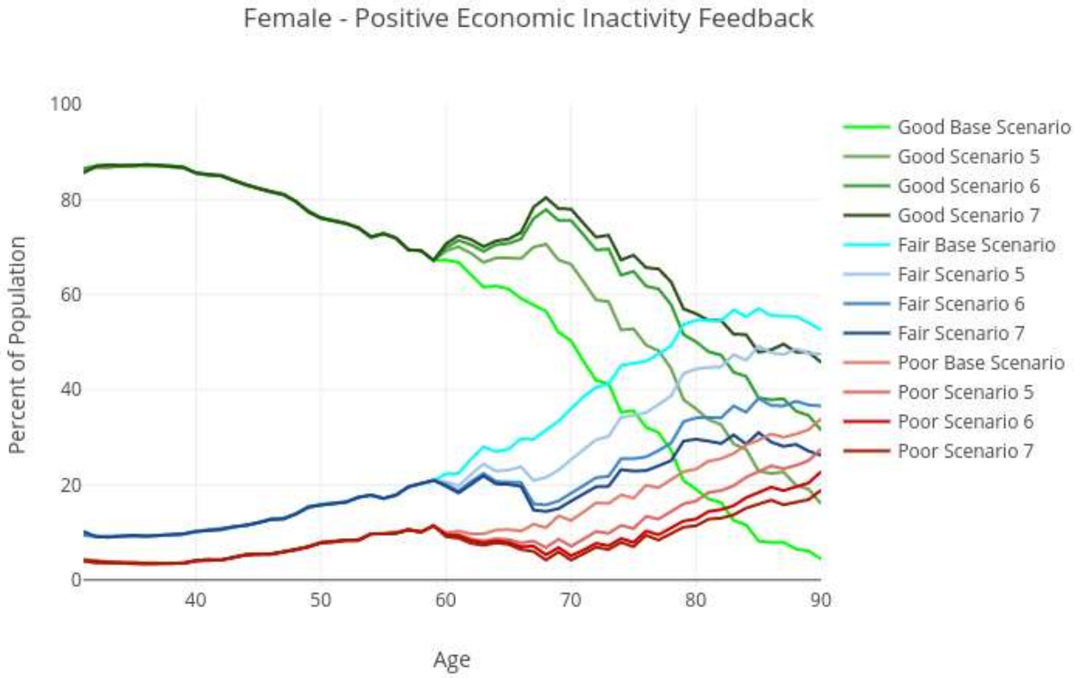
Figures A3 and A4 below show the impact of a positive feedback between of economic inactivity on health for male and female individuals. As can be seen from the figure, a strong initial benefit is experienced following exit from the workforce, with health significantly improving. Following this initial improvement after age 68, the positive impact of economic inactivity can be seen to provide a protective effect on health, slowing the decline of health into older ages. The degree to which this protective effect is observed increases with the strength of the feedback effect, with again a 10%, 20% and 50% improvement for scenario 5, 6 and 7 respectively. For female individuals aged 70, the health improvement of inactivity has increased the proportion experiencing good health from 50.3% to 66.4%, 75.6% and 78% respectively. Additionally, a corresponding fall in the number of individuals reporting fair and poor health can be seen following the introduction of the positive health impact of inactivity as individuals are protected from falling into these health states. Again for females aged 70, this has reduced the incidence of poor health from 12.5% to 7.1%, 5.1% and 4.2% for scenarios 4, 5 and 6. From a policy point of view, the direction of such positive or negative health impacts within the population is crucial, as these will heavily influence the health of the population experiencing a change in SPA. Additionally, it is possible that there is a socioeconomic component to the outcome of such scenarios. If an individual with adequate resources to retire is experiencing a health detriment of continued employment, this individual is more likely to forego continued economic activity. If, however an individual does not have economic means to retire before their SPA, they may have to accept the detriment to their health, thereby impacting their later life.

Figure A3 – Male Additional Alternative Scenario – Positive Economic Inactivity Feedback



Source: Author's own analysis of PENHEALTH model data.

Figure A4 – Female Additional Alternative Scenario – Positive Economic Inactivity Feedback



Source: Author's own analysis of PENHEALTH model data.