Determinants of Labour Supply at Older Ages: A Theoretical and Empirical Approach.

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Abstract

An ageing population is a common feature shared amongst developed economies. Increasing longevity has significant implications for fiscal expenditure, pensions and the welfare state. Therefore, research investigating the determinants of labour supply at older ages is of paramount importance.

To understand labour supply behaviour from a theoretical perspective, in chapter one we turn to a lifecycle framework, in which not only labour supply but saving and consumption behaviour are also modelled. By analytically solving the model, we are able to understand its general properties and what implications these have for optimal within period decisions. In chapter two we show how state pension deferral can be modelled within a general lifecycle framework and the effect it may have on labour supply. We demonstrate the size of this effect using a numerical simulation and also compare the generosity of the two deferral options available under UK legislation.

To investigate the determinants of labour supply from an empirical perspective, we use a duration approach to model a variety of standard and non-standard retirement paths. In chapter three we pay attention to the way in which an individual's labour force history may affect their retirement decision. In chapter four we determine which factors are more likely to lead to an individual returning to work conditional on having retired, and the typical characteristics of an 'unretirement job'. In both chapters we show that; age, pension wealth, education and spousal employment characteristics are important factors in determining labour force transitions at older ages.

The final two chapters are concerned with survey methodology. Chapter five shows the importance of longitudinal survey weights in appropriately controlling for attrition in the UK Labour Force Survey (UKLFS). We demonstrate this by comparing estimated labour market flows under existing and revised weights. Chapter six highlights the extent of seasonality in UKLFS flows and shows that adjusting for seasonality provides an improved understanding of the underlying dynamics in the UK labour market.

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Introduction

An ageing population has become a prominent characteristic amongst many advanced economies which have simultaneously witnessed a decline in their fertility rate (OECD, 2011a). Average life expectancy has increased by 6 years in the OECD area between 1983 and 2008. A recent report (OECD, 2011b) indicated 20% of all individuals in OECD countries were aged 65 and over in 2010. As of 2011, 1 in 6 individuals in the UK population is aged 65 and over (ONS, 2013b). Population ageing has serious fiscal implications, State Pension (SP) payments alone made up 48% of total benefit expenditure in the UK between 2012-2013 (DWP, 2013). These statistics highlight important questions for researchers to investigate: for example is one able to capture and understand which factors influences major lifecycle decisions such as when to retire? Or when should an individual choose to take up their pension conditional on being eligible to receive it? In order to formally answer these questions one can turn to a theoretical lifecycle framework in which major economic decisions such as retirement can be analysed (Friedman, 1957; Ben-Porath, 1967). Important contributions have shown that the classic lifecycle framework can be extended to allow for non-standard retirement paths and can also be tested using empirical data (Rust, 1989; Berkoven and Stern, 1991 and Gustman and Steinmeier, 2002). However, by their very nature these latter models tend to be complex and as such it is often difficult to understand the way in which particular economic and sociodemographic characteristics affect economic decision making.

An alternative approach to understand the determinants of labour supply at older ages is to use a combination of secondary data and econometric methodology. Increasing longevity raises important questions regarding how governments will manage to support an increasing number of individuals in retirement for longer. What kinds of policies does government need to have in place to help stem or reverse the trend in early retirement? How can policymakers keep individuals in work past state pension age? Which factors influence the decision for a retired individual to return to paid work? During the past few decades researchers have attempted to answer these questions, to help policymakers understand the significant changes in labour supply behaviour at older ages. The emergence of early retirement (Quinn, 1977; Bazzoli, 1985; Kohli, 1991; Meghir and Whitehouse, 1997; Blundell et al., 2002), partial retirement (Gustman and Steinmeier, 1984a) and unretirement (Maestas, 2010) has led to new ideas about the precise definition of retirement over the past half century (Costa, 1998). In light of this, more recent studies often define retirement based on hours worked in addition to self reported status (Maestas, 2010). Developments in econometric methodology and an emphasis on developing longitudinal household panel surveys means methods now exist to shed light on these questions.

Non-response is one particular aspect of longitudinal household panel surveys which affect analysis and interpretation (Wooldridge 2002; Solon, Haider and Wooldridge, 2013). Attrition is inherent in any survey attempting to follow the same individual or household over time. The decision to leave a survey is complex and likely to be related to a variety of sociodemographic and economic characteristics such as employment status, age or tenure (van den Berg and Lindeboom 1998; Nicoletti and Perrachi 2005; Jones et al., 2012). Therefore how does one control for attrition in longitudinal weights used to estimate labour market flows such as those from employment into retirement? One method by which to do so is to use raking methods which provide a method to adjust a survey sample for factors such as attrition or sample design in order to improve the relation between the sample and population (Battaglia et al., 2004). Subsequent estimated flows of population statistics then account for the fact that particular respondents are more likely to respond than others.

Another important factor to consider in the context of a longitudinal household survey is seasonality. To what extent do seasonal factors affect labour market flows? How can one appropriately control for this when analysing an economic time series? By simply analysing an unadjusted series researchers may not truly understand the underlying behaviour of the time series. Seasonal and calendar effects may include cultural and religious events, weather patterns, trading days and administrative events such as school holidays (ONS, 2007). All of these can potentially affect an economic time series (Findley et al., 1998). One solution is to seasonally adjust data and determine it's constituent components; by doing so it is possible to estimate the underlying trend component.

This thesis answers the questions posed above. It is comprised of three sections: theory, empirics and data; each of which contains two chapters. The next section highlights the contribution of each chapter.

0.1 Theory

0.1.1 Chapter One: Work and Play Pave the Way: The Importance of Part Time Work in a Lifecycle Model

In order to capture and understand important decisions over the lifecycle one must turn to a structural model. Chapter one presents such a framework in which major economic decisions such as; labour supply, consumption and savings are analysed and makes use of a commonly assumed functional form for the utility function (Gustman and Steinmeier, 2002).

Under the assumption of perfect foresight we first ask whether it is possible to solve such a model analytically. This is important if one is to understand the general properties of the model and how these influence economic decision making over the lifecycle. Whilst richer models incorporate more features akin to the real world such as the social security system or uncertainty (Rust, 1989; Gustman and Steinmeier, 2002), these models require numerical methods to solve the optimisation problem.

Given our particular interest in modelling the labour supply decision for a particular period, we pay particular attention to the way in which future decisions regarding labour supply, consumption and savings (do not) affect within period decisions. By way of an application we investigate this in the context of the retirement decision, to determine whether the heterogeneity in retirement paths such as partial retirement (a gradual reduction in working hours) and unretirement (a transition from retirement back into paid employment) can be accommodated within our framework.

0.1.2 Chapter Two: To Defer or Not Defer: State Pension in a Lifecycle Model

Lifecycle models capture important economic decisions over the lifecycle. One such decision is whether to defer receipt of State Pension (SP). In Chapter two we investigate the SP deferral decision in the context of a lifecycle model and how it may affect labour supply, consumption and savings.

Legislation regarding SP deferral is particularly simple. It only require that an individual has reached State Pension Age (SPA) and has made a sufficient number of National Insurance (NI) contributions. Therefore the first question we pose in the context of a lifecycle model is under what conditions is SP deferral optimal? With little research in this area our contribution is important if one is to fully understand the implications of such a policy, and why it should motivate individuals to defer receipt of their SP further; SP by definition is deferred income from an earlier period.

The second question we pose is whether pension deferral affects labour supply behaviour. A recent Department of Work and Pensions report (DWP, 2008) showed that despite current legislation implying that the deferral and labour supply decision are independent, in practice those who deferred tended to remain in the labour market. Understanding whether deferral has an impact on labour supply behaviour in the context of a lifecycle may help to shed some light on why this is the case.

Related to the first aim, assuming deferral is optimal we ask which of the two options (deferred income or lump sum) available under current legislation is preferred? Understanding what conditions must hold for a particular choice to be desired helps policymakers grasp the full fiscal implications of deferral policy. This is important when factors such as an individual's life expectancy and rate of return affect the optimal choice particularly in the face of increasing longevity. In line with existing literature we show in most simulations the deferred income option is more lucrative.

0.2 Empirics

0.2.1 Chapter Three: Lifetime Labour Market Activity and Retirement Decisions: Evidence from ELSA

The age at which to retire is arguably the most important labour supply decision to be made. In the first of two empirical chapters, we focus on modelling the retirement and early retirement decision. Both Chapters three and four make use of the English Longitudinal Study of Ageing (ELSA) dataset which contains a representative sample of individuals aged 50 and over in England.

Using the duration approach of Jenkins (1997) the aim of Chapter three is to understand which factors affect the hazard of retirement and early retirement of English men and women as they approach SPA. This is important given that over the past few decades England like many countries has witnessed a rapid increase in the proportion of individuals aged 65 and over in the population (ONS, 2013b).

The exact timing of retirement behaviour depends on a variety of factors. Maes (2013) and Nicholls (2010) highlight the importance of lifetime labour market experiences such as periods of unemployment and inactivity and how these raise the likelihood of pensioner poverty. Using retrospective employment history information available from the ELSA wave 3 life history survey we investigate how lifetime labour market experiences affect the hazard of retirement.

Alongside employment history, income is an important factor in the retirement decision. This is likely to be correlated with other lifetime sociodemographic factors such as education and pension wealth. In Chapter three we investigate the effect of income on retirement behaviour, and how it may differ depending on position in the income distribution. Our results suggest the information set has a differential impact on the hazard of retirement depending on the quintile position in the income distribution.

The UK has witnessed a rise in the heterogeneity of retirement paths over the past three decades particularly towards early retirement (Meghir & Whitehouse, 1997; Blundell, 2002). Such behaviour has a wide range of effects on current and future fiscal revenues and the welfare state, particularly given the recent raft of changes to UK welfare programmes and complete overhaul of the

SP system. These major changes in welfare and retirement policy are likely to affect labour supply behaviour, especially for those individuals approaching SPA. Understanding the dynamics of retirement behaviour is important for informing current and future policies in this area.

0.2.2 Chapter Four: Unretirement in England: An Empirical Perspective

Chapter four models the unretirement decision for a group of retired English men using the ELSA dataset. Unretirement is defined as a transition from retirement to paid employment. We model the unretirement decision using the duration approach of Jenkins (1997), to investigate the link between how an individual's economic and sociodemographic characteristics are related to the likelihood of returning to work.

In particular, previous research into modelling the retirement decision highlights the importance of savings facilitated by occupational and state pension (Banks and Smith, 2006). In light of this we use detailed financial information available in ELSA to control for pension wealth, our results suggest it is an important factor in determining whether unretirement takes place. This has important policy implications and highlights the need for policymakers to understand the affect preretirement savings has on labour supply behaviour post retirement. We also control for initial labour supply of the spouse, which may affect labour supply behaviour due to factors such as complementarities in leisure (Cribb et al., 2013).

In order to profile the economic characteristics of unretirees we estimate the preretirement annual salary for this group of individuals using the ELSA retrospective employment history data. Following Maestas (2010) we also document information relating to the unretirement job in terms of the average annual salary, weekly hours and job occupation. In doing so we are able to establish which preretirement characteristics are associated with unretirees. This is important in formulating and understanding how potential policies may affect older workers in this group.

To the best of our knowledge there has been no previous research investigating the determinants of unretirement in England. With 1 in 6 individuals aged

65 or over (ONS, 2013b) this pool of individuals (in addition to those who have retired early) represent a source of potentially underutilised economic capacity.

0.3 Data

0.3.1 Chapter Five: Accounting for Attrition in the two-quarter UK Labour Force Survey

The first part of chapter five investigates the sociodemographic and economic characteristics correlated with attrition, and whether it is appropriately controlled for in existing longitudinal weights estimated for the two-quarter UK Labour Force Survey (UKLFS). Using sample data covering the period 2001-2010 we derive longitudinal weights for the two-quarter longitudinal survey, following the initial work by Clarke and Tate (1999). Since their study survey response rates for the UKLFS have declined by around 25% (ONS, 2012a). Therefore understanding which factors affect the non-response decision and whether they are identical to those in Clarke and Tate (1999) is crucial to ensuring revised longitudinal weights appropriately capture survey attrition.

The second part of Chapter five is a feasibility study to determine whether it is possible to estimate longitudinal weights in an alternative raking engine: Generalised Estimation System (GES), used more widely within the ONS and Government Statistical Service (GSS). We formally investigate the quality of the revised weights and compare them with those currently produced using a Calibration on Margins (CALMAR) raking engine, following the work of Clarke and Tate (1999).

The UKLFS is an important longitudinal household survey in the UK and has an important role to play in providing a static and dynamic description of UK labour force dynamics. It is therefore important for longitudinal weights to appropriately control for attrition to ensure subsequent analysis reflects the true population.

0.3.2 Chapter Six: Approaches to the Seasonal Adjustment of Labour Market Flows

All time series are subject to seasonality that is to say part of the series is attributable to calendar effects. Chapter 6 investigates the extent of seasonality in the UKLFS and conditional on its presence adjusts labour force flows appropriately. Prior to this piece of research the ONS only released UKLFS gross flows, which do not take into account calendar effects.

In order to uncover the underlying trend component of UKLFS flows and thus determine the extent and direction of seasonality we make use of X-12-ARIMA (AutoRegressive Integrated Moving Average) software. The second part of chapter six compares whether it is optimal to adjust the series directly at the aggregate level for a given labour market flow at each quarter, or alternatively adjust each sub-series individually. These are known as direct and indirect adjustment respectively.

As the national statistical agency for the UK the ONS has a duty to provide estimates of labour force flows with each quarterly release of the UKLFS. Part of the work undertaken in chapter six involved designing a file system whereby deriving seasonally adjusted labour force flows became a largely automated process.

0.4 Summary

The first four chapters of this thesis investigate the determinants of labour supply at older ages in England. The first two from a theoretical perspective and the latter two from an empirical perspective. This is an important area of research given the increase in life expectancy observed over the past fifty years and is forecast to rise further (ONS, 2011a; ONS, 2013c). To alleviate the potential fiscal implications of an ageing population requires state intervention through well designed policies to ensure a sufficiently flexible labour market. Policy responses to date have included bringing forwarded the planned rise in the SPA and also the introduction of a single tier SP. Supply side initiatives include reducing barriers to work for older workers such as abolition of legislation allowing employers to retire individuals once they reach SPA. Research which focuses on understanding the determinants of labour supply behaviour at older ages helps inform current and future policy aimed at this group of individuals.

The final section of the thesis examines two particular aspects of the UKLFS, attrition and seasonality. Chapter five illustrates how attrition may affect estimates of labour force flows including those into retirement. Chapter six shows that the UKLFS exhibits seasonality, and hence the importance of being able to estimate the trend component of a labour force series. As the main statistics agency in the UK the ONS has a responsibility to ensure it releases high quality data, so any subsequent analysis which is used to inform policymakers accurately reflects the population of interest. This is achieved by ensuring the use of appropriate survey methods.

Chapter 1

Work and Play Pave the Way: The Importance of Part Time Work in a Lifecycle Model.

1.1 Introduction

In a lifecycle context individuals must determine their intertemporal labour supply, consumption and savings. In any period an individual can choose to have zero hours of work, full time hours or, with suitable assumptions on labour demand, anything in between. Changes in participation pattern between periods can correspond to major life events like leaving education to enter employment, or retiring from the labour force. But there may also be shorter term, repeated switches over time in participation, e.g. entering part time work after the birth of a child. From the Panel Survey of Income Dynamics (PSID) there is strong evidence of lifecycle effects in labour force participation, hours worked, and in assets. This is so for females but also for males, even though they are less affected by fertility issues.

Analysing intertemporal choices is difficult because of the curse of dimensionality which prevents closed form solution of many or even most examples. If decision variables are subject to inequality constraints then it is even more complex. A prime example is intertemporal labour supply where participation can be at corners. Faced with this difficulty many researchers use numerical solution/simulation methods to try to characterise the lifecycle profile of labour participation and associated decisions. For example Gustman & Steinmeier (2002) and Blau (2012) use a lifecycle model with time additive discounted preferences in which utility per period depends on a single consumption good and leisure. The per period utility function is isoelastic in consumption and quasilinear in leisure. Each period there is a time endowment which can be allocated between paid work and leisure. There is a single one period financial asset in which the individual may borrow or save to any extent desired, a wage rate per unit of work and perfect foresight.[1] A crucial aspect is that in a lifecycle context the optimal participation state now depends on current assets and market conditions and also on all planned future participation states, which in turn are determined by future market conditions and preferences. The decision tree becomes formidable. For this reason there is a tendency to use simulation methods, which can represent complicated problems but at the cost of being dependent on numerical details of preferences, wage rates, etc.

The main contribution of this chapter is to derive the closed form solution of this widely used model under the assumption of perfect foresight, which is also commonly made in this literature. We show that the value function at t has branches which are isoelastic in assets and other branches which are linear in assets. Which branch is optimal at t (and hence period t optimal decisions) depends in general on which branch is optimal at $t + 1$ and hence on the entire future. If in any period of time t it is optimal to work part time then at all earlier periods the value function is linear in assets. This then implies that in any period prior to the last period in which part time work is optimal, the labour participation decision depends only on the wage rates, marginal utility of leisure and the elasticity of marginal utility of adjacent periods. On the other hand in any period subsequent to the latest period of part time work, labour supply is either zero or full time work and the decision depends on the whole remaining future. Given the value function, the consumption and savings functions follow. The combination of constant elasticity of consumption and quasilinearity of leisure of current period utility leads to a consumption function which is independent of wealth in periods for which the future value function is linear in wealth, or a consumption function which is linear in wealth when the future value function is isoelastic. Theoretically this

[1] The framework developed by Blau (2012) accounts for uncertainty.

is quite intuitive but it also suggests a useful empirical strategy for estimating parameters in a lifecycle framework jointly studying the consumption function and intertemporal labour participation.

A useful device is to think of the optimal lifetime plan as being the union of a succession of epochs (Beveridge, 1923). Within an epoch the individual has a common participation state (full time, part time or zero work hours) and moving from one epoch to another corresponds to a change in participation status over time. We analyse the behaviour within and between epochs.

In this model we find that the presence of an epoch of part-time work is critical in breaking the curse of dimensionality. The role of part time work has strong implications for the form of the value function, the labour force participation decision and the marginal utility of leisure and wealth. These in turn impact on values of optimal consumption and savings. In fact prior to the final epoch of part time work, only preference and market conditions in adjacent periods matter in determining the participation decision, and so prior to this final part time epoch there is no curse of dimensionality. We also find that in any period of part time work (except if it occurs at periods characterising a change in the labour force regime or the final period), hours of work and savings are indeterminate. The individual is indifferent between lower current savings and higher leisure or higher current savings and lower current leisure.

Within our model part time work has a different economic significance to corner labour participations of full time or zero work. If part time work is optimal in a period the current period marginal utility of income (as defined by the ratio of the current marginal utility of consumption to the current wage) is equal to the expected marginal value of future wealth. Moreover if there are two adjacent periods of optimal part time work then the change in the current marginal utility of leisure and wage matches the change in the marginal value of future wealth but the former is much easier to observe and model than the latter. By contrast the corner solutions generate inequalities between the current and future marginal values of income/wealth which are harder to use empirically and less informative on how future values impact on current values and decisions.

More generally the empirical importance of flexible working practices, such as part time hours of work in recent decades has increased, particularly with the steady rise of the female labour force participation rate (Fernandez, 2011). Part time work (<35 hours per week) has become common practice in the majority of labour markets, approximately one in five workers in the US in 1999 were engaged in part time work, whilst in the Netherlands 38% (and 69% of women) in the workforce are engaged in part time work (Houseman and Osawa, 2003; Kalleberg, 2000). Part time work has also become increasingly popular in smoothing the transition from full time work to full retirement, via partial retirement or a bridge job and also in terms of unretirement jobs defined as a transition from retirement back into paid employment (Gustman and Steinmeier, 1984a; 1986). Gustman and Steinmeier (2002) and Blau (2012) investigate the labour participation of individuals, especially elderly individuals in a lifecycle setting. The questions they investigate concern the response to private and public pension provisions and also the return to work decision of previously retired individuals.[2]

The plan of this chapter is as follows: Section 1.2 presents a static illustration of key economic variables using the 2007 wave of the Panel Survey of Income Dynamics (PSID). Sections 1.3 and 1.4 state the general and terminal period form of the value function coming from choice of optimal labour participation, consumption and savings at each period. Section 1.5 characterises the labour market participation conditions which must hold within an epoch, and the nature of optimal consumption, savings and hours of work. In Section 1.5 we show that prior to the final epoch of part-time work (if there are any) the value function is linear in assets whereas in the remaining later epochs it is isoelastic in assets. Depending on how the utility of leisure and economic variables like interest rates, wage rates and non-labour income vary over time, the patterns and lengths of epochs through time may vary widely. In Section 1.6 we summarise the nature of the optimal path. In Section 1.7 we show what our framework implies for a variety of non standard retirement paths, including partial retirement and unretirement. Section 1.8 considers future work. Section 1.9 concludes.

[2]For earlier studies which document unretirement or reverse flows see Rust (1989) and Gustman and Steinmeier (1984, 1986).

1.2 US Male lifecycle Labour Participation

Over the lifecycle individuals usually spend a period of time in education before subsequently entering the labour market, the amount of education consumed is likely to affect the potential wage, length of time spent in the labour market, and also the amount of income which can be saved or invested in the form of assets generating future non-labour income. In addition to education, heterogeneity in labour market behaviour may stem from a variety of sociodemographic, economic and institutional factors, causing individuals to differ in lifecycle labour market participation. We document the lifecycle and cross section characteristics of key economic variables such as labour supply, wages, non-labour income and family assets for all head of household (HOH) males by their highest education level using information from the 2007 PSID cross year index.[3]

The PSID is a representative longitudinal survey of the US population administered by the University of Michigan. The sample began in 1968 and contained 30,000 households (McGonagle et al., 2012), the long sample period lends itself to analysing key economic characteristics over the lifecycle. In order to do this Figures 1.1-1.3 cross tabulate key variables of interest against weekly hours spent in paid work. Therefore the patterns of labour supply consider only those in work.[4] Specifically we consider how the stock of household asset holding varies over the lifecycle. Assets are defined as the value of all car(s) in the residence + value of all family members AMT balances + value of all bonds/insurance but not including housing wealth.[5] Another variable of interest which is non-labour income which is defined as the flow of income the HOH receives (per year) from dividend income + interest income and rental income. For further details of sample construction and variable definitions see Appendix 8.1.1.[6]

By analysing behaviour over the entire lifecycle we are ignoring potentially

[3]We include all family members who have subsequently left home. We do not present results for females however they are very similar to that of males, with the exception of a short dip in the hours profile due to maternity leave, results are available upon request.

[4]It is therefore likely we are ignoring strong selection effects in operation over the lifecycle.

[5]We do not include individuals who report constituent asset component values in excess of 2006 US $1 million.

[6]Note that these may not be identical samples. In each case we keep only men and create age groups for each variable of interest, we then plot the mean value for each group.

strong cohort effects. Therefore some of the patterns described in Figures 1.1-1.3 may well be magnified due to such effects, for example the lifecycle earnings and stock of assets of a 75 year old college educated white male interviewed in 2006 are likely to be quite different to his 25 year old counterpart. It is important to bear this in mind when interpreting Figures 1.1-1.3.

Figure 1.1 compares the hours spent in paid work per week versus family assets. Similar to Erosa et al. (2010) we find a hump shaped curve in the hours worked over the lifecycle, college students tend to work lower hours initially whilst they combine work and study at younger ages, and then engage in career occupations which require higher average weekly hours in work compared to their lesser educated counterparts. Interestingly, our findings indicate a kink in the hours worked (for those in work) in later life. Such heterogeneity in the number of hours worked in later life, and more generally the fact that non standard retirement paths have become commonplace in the US since the 1970's (Gustman and Steinmeier,1984a, 1984b; Rust, 1989; Maestas, 2010), suggests individual responses and the precise definition of retirement which traditionally involved leisure or perhaps voluntary work, should be adjusted to include paid work post retirement. So called unretirement could be due to preference factors (Maestas, 2010), in our model ceteris paribus a drop in assets or fall in the marginal value of leisure would serve to the increase the number of hours in work.

Figure 1.1 indicates for individuals with a college level of education that as assets increase over the lifecycle, perhaps due to accumulation of savings from labour income, the average number of hours spent in work declines. However it is worth noting that the same does not hold true for individuals with below college level education. Hours worked is conditional on being in the labour market. Therefore Figure 1.1 highlights the difference in work intensity conditional on being in work at older ages by educational attainment. Lower educated males work more than their college educated counterparts perhaps due to credit constraints. Figure 1.1 also highlights the average difference in family assets by educational group, at younger ages families where the male HOH has a college education are slightly more wealthy than their high school or below high school counterparts, and this difference increases substantially over the lifecycle.

Figure 1.1: Family assets versus weekly hours in paid work 2006.

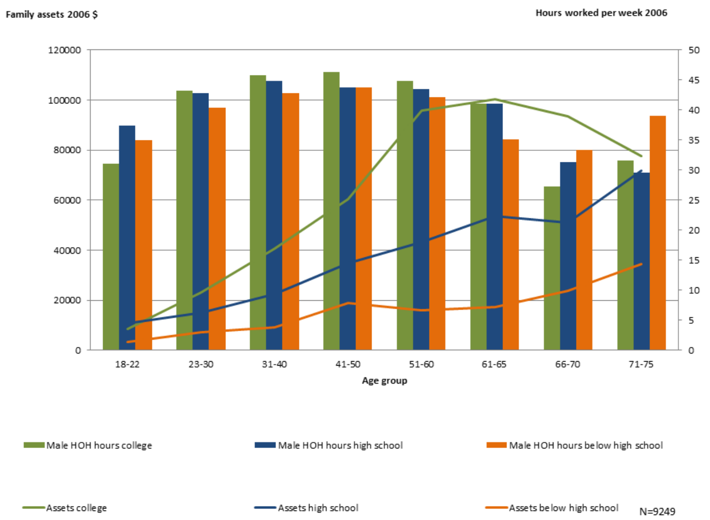
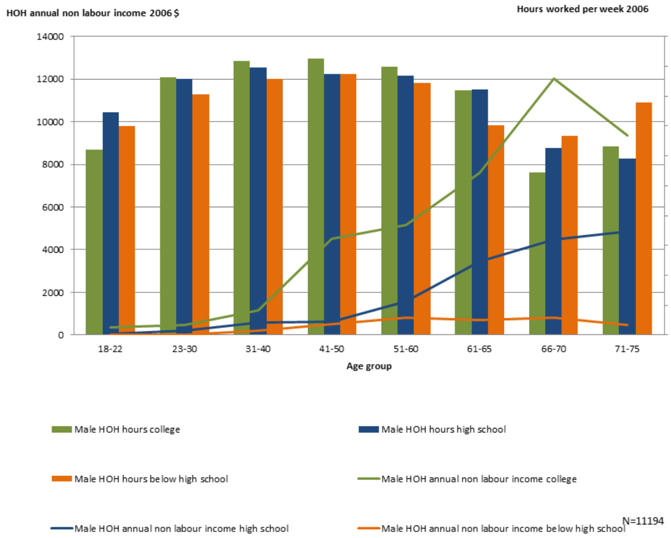


Figure 1.2 documents the hours spent in work for the HOH versus the HOH annual non-labour income, by education level. We find that on average more educated individuals tend to start life with slightly higher annual non-labour income which then increases substantially over the lifecycle, particularly between the ages of 30 and 65. Those who are less educated tend to have a flatter growth in their non-labour income over the lifecycle, particularly those with a low level of education. Our model predicts that ceteris paribus as annual non-labour income increases, individuals are more likely to increase the amount of leisure they consume. Indeed the shape of the curve representing the average non-labour income for the 2007 cross section indicates that aside from the career periods, hours and non-labour income tend to move in opposite directions as the model predicts, particularly in later life where those with below high school education tend, on average, to work more hours than their more educated counterparts.

Figure 1.3 compares weekly hours spent in the labour force versus the average hourly wage rate, by education level. We find that at younger ages there is little difference between the average reported hourly wage, irrespective of education level. However at each age the wage differential increases, particularly for those with a college education, and peaks when individuals are in their mid

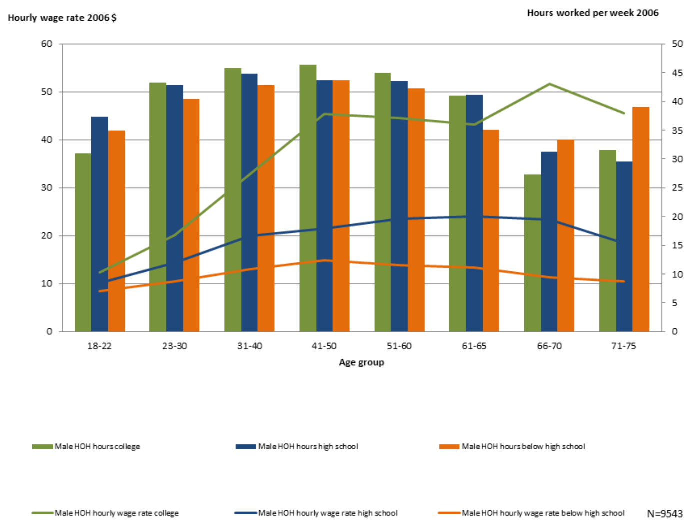
Figure 1.2: HOH annual non labour income versus weekly hours 2006.



forties after which point it remains relatively flat. Those with the lowest wages tend to work more hours, especially given their asset and non-labour income is relatively low. It is interesting to note even for the college educated, in later life as the average wage declines for those in work, average reported hours in work increases. Economic theory suggests there are income and substitution effects which arise from say a rise in the wage rate, but here this couples with intertemporal effects. Within our model labour force participation level depends either on a comparison of the current and future wage or an expression denoting the contribution of the current wage to future value through raising savings and assets available next period (depending on the initial asset level). Therefore the relationship between participation and hours depends on the individual leisure preferences and wage rate they can obtain.

In this section we have described a cross section snapshot of the key economic variables, and also taken a lifecycle view on respondents average behaviour by education group. As one would expect, those with the highest education level tend to fare better in life. We have abstracted from various individual characteristics. For example individuals may be constrained in the number of hours they can supply to the market if they have care responsibilities, or health conditions. These types of effects may affect certain groups

Figure 1.3: Hourly wage versus weekly hours in paid work 2006.



more than others. Nor have we plotted the debt characteristics by education level which may well differ. Indeed it could be the case that those with a higher earnings potential are less credit constrained, and more willing to carry more debt today safe in the knowledge they will not default due to higher earnings in later life. Regardless, it is clear there are marked differences in the economic characteristics of male workers by their educational group, and in their lifecycle behaviour.[7] So a model which is consistent with theory and can yield explicit predictions of the lifecycle pattern of labour supply will be empirically valuable. We develop this framework next.

1.3 The Framework and Value Function

A decision maker with known finite life T has a per period utility function which is isoelastic in consumption and quasilinear in leisure so the lifecycle

[7] Given the main contribution of this paper is theoretical, and the purpose of the data is to motivate the general pattern of lifecycle behaviour we do not construct a panel and observe the characteristics of the same individuals through time. Also the long time horizon means attrition has a large cumulative effect in providing accurate measures of our key variables of interest.

preferences are given by

$$U = \Sigma_t^T \delta^t [\frac{c_t^\alpha}{\alpha} + h_t L_t] \tag{1.1}$$

where c_t, L_t, h_t are respectively consumption, leisure of period t and the marginal value of leisure of period t.[8] T is the foreseen life and δ is the discount factor on preferences. There is a time endowment per period of 1 which can be allocated to work or leisure each period. Thus $0 \leq L_t \leq 1$. There is a perfect capital market with a single one period financial asset, the individual can borrow or save but cannot die in debt. The budget constraint each period is

$$A_{t+1} + c_t = a_t A_t + y_t + w_t(1 - L_t) \tag{1.2}$$

where A_t is the stock of financial assets at the start of the period, w_t is the wage rate per unit of work, a_t is the interest factor (1+ the interest rate) and y_t is non-labour income. The decision of the individual is then to choose a time path of consumption, net savings and leisure so as to

$$\max \Sigma_t \delta^t [\frac{c_t^\alpha}{\alpha} + h_t L_t] \tag{1.3}$$

$$\text{st } A_{t+1} + c_t = a_t A_t + y_t + w_t(1 - L_t)$$

$$0 \leq L_t \leq 1$$

$$A_0 \text{ given and } A_T = 0 \tag{1.4}$$

We start by finding the analytical value function for this problem, from which we can then deduce the consumption function, the labour participation status at each date and hours worked when these are determinate (see below). A main result is that at any time period t the value function characterising the maximum payoff for the individual is the higher of an isoelastic and a linear function:

[8] The utility function specified in equation 1.1 is isoelastic in consumption, this implies there is constant relative risk aversion. That is to say an individual's risk aversion is independent of his level of income. Leisure on the other hand is quasilinear because it is enters in a multiplicative fashion and is not independent of income. In terms of the theory, such a specification implies all income effects operate via leisure.

Proposition 1.1 *The value function $v_t(A_t)$ at period t has the form*

$$v_t(A_t) = \max[P_t^i + M_t(N_t^i + Q_tA_t)^\alpha/\alpha, R_t^i + S_t^iA_t] \quad (1.5)$$

where the functions $P_t^i, N_t^i, R_t^i, S_t^i$ have alternative definitions according to current and future values of the discount rate, wage rate, non-labour income and value of leisure which are denoted by the variables δ, w, y, h respectively. In particular there are two alternative forms for P_t^i, N_t^i , $i = 0, 1$ and three alternative forms for $R_t^i, S_t^i, i = 0, I, 1$. We denote the accumulation of future interest factors by Q_t and denote the effects of future interest rates and time preference rates by M_t.[9]

$$Q_t = r_tQ_{t+1} = \Pi_t^T r_s \text{ with } Q_{T+1} = 1, Q_t = r^{T+1-t} \text{ if } r \text{ is constant} \quad (1.6)$$

$$M_{T-t} = (\Sigma_{s=0}^t \delta^{(t-s)/(1-\alpha)} Q_{T-s+1}^{\alpha/(1-\alpha)}) \text{ with } Q_{T+1} = 1 \quad (1.7)$$

This bears a family resemblance to Merton's (1971) seminal result that within the HARA class, the value function has the same functional form as the within period utility function. However it is more general given that within our framework an individual has two decision variables per period (c_t, L_t), one of which is inequality constrained, and the within period utility combines features of isoelasticity and quasilinearity. The linear branch of the value function is intimately connected with periods or phases of part time work, and involves different intertemporal tradeoffs to periods in which the value function is isoelastic.

There is a strong interpretation to the components of the value function. In the isoelastic case, N_t reflects the discounted value of future non-asset resources (non-labour income plus value of the time endowment for periods of work), discounted at the successive one period interest rates. P_t reflects the discounted value of the stream of future leisure value in future periods of zero work. In the linear case R_t is a combination of $(y_t + w_t)'s$ and discounted future marginal rates of substitution (MRS) between leisure and consumption, S_t measures the discounted utility of leisure relative to the wage of one period t.

[9] We formally derive M in appendix 8.1.2

The key interest is in the optimal labour participation states over life and the associated consumption and savings paths. We describe these by piecing together different labour participation states, and note the forms of the value function to derive an overall optimal path of consumption, savings and leisure. We first show some fundamental links between the branches of the value function, and the optimal labour participation in any period.

Proposition 1.2 *(i) If part time work is optimal at t then whatever the form of the future value $v_{t+1,}$ the current value v_t is linear in current wealth*

(ii) If the future value v_{t+1} is linear in A_{t+1} then the current value v_t is also linear in A_t whatever the nature of current labour participation

(iii) If the future value is isoelastic and optimal current participation is at a corner then the current value is also isoelastic

To explain *(i)* the intuition is as follows. If at time t part time work is optimal and the future value function v_{t+1} is linear in future assets then the marginal utility of leisure at t,h_t, must equate to the marginal value of the wage w_t in raising future value S_{t+1}. Hence $\frac{h_t}{w_t}$ must equate to the marginal value of future wealth. This means that when part time work is optimal at t and the future value function is linear in assets, future market conditions and leisure preferences do not affect the current marginal value of assets at t. In this sense once the value function for any period $t+1$ is linear in assets, then all earlier periods will also have a linear value function. For all these earlier periods the choice of participation status will only depend on adjacent time period variables.

An important fact is that even if future value v_{t+1} is isoelastic in future assets A_{t+1}, if optimal current participation involves part time work, then the current value is linear in current assets A_t.This stems from the quasilinearity of utility in leisure. If part time work is optimal when v_{t+1} is isoelastic, the constant current marginal utility of leisure is equated to the future marginal value of wealth multiplied by the current wage. So the future marginal value of wealth is equated to $\frac{h_t}{w_t}$. Since $A_{t+1} = r_t A_t + y_t + w_t(1 - L_t)$ and the future marginal value of wealth is a power function of A_{t+1}, when part time work is optimal at t, current optimal leisure is a linear function of A_t. Optimal consumption equates the current marginal utility of consumption to the appropriately discounted marginal value of future wealth and so is independent of current wealth. Combining the leisure demand linear in wealth with consumption and savings being independent of current wealth yields a linear current value function. Hence starting from a future value which is isoelastic, if optimal current participation involves part time work, then the current value becomes linear in A_t.[10]

To explain *(ii)* if participation at period t is at a corner then within period consumption c_t is the only unknown affecting next periods assets, A_{t+1}. If we know the future value is linear in A_{t+1} then equating the current marginal utility of c_t to the discounted marginal value of wealth A_{t+1} gives an optimal level of c_t which is independent of current assets. Hence current assets A_t enter current value v_t only through their effect on the future value v_{t+1} which is linear in A_t it follows that v_t is linear in A_t.

The intuition behind *(iii)* is as follows, suppose that at t the future value v_{t+1} is isoelastic and optimal participation is at a corner, the current marginal utility of consumption is equated to the marginal future value of savings, both of which are isoelastic, in which case optimal consumption and savings conditional on participation are linear in current assets. Since current utility and the future value function are isoelastic respectively in consumption and assets carried forward, given that A_{t+1} is linear in current savings, this then implies that the current value function is isoelastic in the starting assets A_t. Thus if future value is isoelastic and current participation is at a corner, then current value is isoelastic. The marginal value of wealth then varies with assets and so depends on the entire future profile of optimal decisions, preferences and market variables.[11]

There is a close connection between the branches of the value function and the labour participation status. It is helpful to think of an epoch as a sequence of adjacent time periods with the same choice of labour participation. Within an epoch the value function, consumption and savings functions will have the same form, but between epochs these shift between the branches of the value

[10] If the value function at $t+1$ is isoelastic and linear at t because at t part time work is optimal, then at t leisure and savings are determinate (for example in the last period), but if part time work is optimal at t and there is a linear value at $t+1$ then leisure and savings are indeterminate.

[11] Proposition (i) and (ii) are derived in the text. We prove (iii) in Appendix 8.1.3.

function. This device helps us piece together the different forms of lifetime behaviour that may be optimal, starting from the terminal period.

1.4 The terminal period

In order to solve the individual's problem we start with the terminal period and use backward induction. We assume there is no bequest motive in the model, thus $A_{T+1} = 0$. Terminal period utility is given by:

$$u_T = \frac{(rA_T + y_T + w_T(1 - L_T))^{\alpha}}{\alpha} + h_T L_T \tag{1.8}$$

Optimal leisure in the terminal period can be at a corner or interior. The individual will consume zero leisure (i.e. work 24 hours) if the marginal utility of leisure is below the wage rate multiplied by the marginal utility of consumption. Alternatively the individual will spend all their time in leisure if the marginal utility of leisure is above the wage rate multiplied by the marginal utility of consumption. If marginal utility of leisure lies between these two extremes then the individual is at an interior solution.

The saving decision at $T - 1$, is a choice variable and this in turn governs the optimal choice of leisure at T. The critical opening asset positions which govern the labour supply at T are:

$$A_T^0 = \frac{[(\frac{h_T}{w_T})^{1/(\alpha-1)} - w_T - y_T]}{r} \tag{1.9}$$

$$A_T^1 = \frac{\left[(\frac{h_T}{w_T})^{1/(\alpha-1)} - y_T\right]}{r} \tag{1.10}$$

If saving at $T - 1$ results in $A_T < A_T^0$ at T the individual works full time whereas if $A_T > A_T^1$ the individual is retired at T. Notice that the only difference is the wage rate entering negatively in A_T^0 thus $A_T^0 < A_T^1$.[12] Substituting in optimal leisure the terminal period value functions can be described as follows:

[12] Derivations for terminal period assets and labour supply can be found in the appendix 8.1.4.

Proposition 1.3 *In the final period T*

(1) Optimally $L_T = 0$ *and the value function has the form*

$$v_T^0 = \frac{(y_T + w_T + r_T A_T)^\alpha}{\alpha} \text{ if } \frac{h_T}{w_T} \leq (y_T + w_T + r_T A_T)^{\alpha - 1} \tag{1.11}$$

(2) Optimally $0 < L_T < 1$ *and the value function has the form*

$$\begin{aligned} v_T^I &= (\frac{1}{\alpha} - 1)(\frac{h_T}{w_T})^{1/(\alpha-1)} + (\frac{h_T}{w_T})(y_T + r_T A_T + w_T) \\ &\text{if } w_T + y_T + r_T A_T > (\frac{h_T}{w_T})^{1/(\alpha-1)} > y_T + r_T A_T \end{aligned} \tag{1.12}$$

(3) Optimally $L_T = 1$ *and the value function has the form*

$$v_T^1 = \frac{(y_T + r_T A_T)^\alpha}{\alpha} + h_T \text{ if } (\frac{h_T}{w_T})^{1/(\alpha-1)} \leq y_T + r_T A_T \tag{1.13}$$

In each of the three cases note the importance of the critical level of assets carried forward relative to the marginal rate of substitution between leisure and the wage rate in the current decision period. The intuition is that in the final period labour supply choices use just the one period comparison of the real wage with the $MRS_{h,w}$, since there is no future . From equations 1.11-1.13 it is clear assets enter the value function in either a power or linear form depending on whether it is optimal for the individual to be at a corner or interior respectively. The general form of the value function at period T is given by:

$$v_T = \max \frac{[P_T^i + M_T(N_T^i + Q_T A_{Tt})^\alpha}{\alpha}, R_T + S_T A_T],\ i = 0, I, 1 \tag{1.14}$$

where

$$\begin{aligned} P_T^1 &= h_T, N_T^1 = y_T, \\ P_T^0 &= 0, N_T^2 = y_T + w_T \\ Q_T &= r_T, M_T = 1 \\ R_T &= h_T(1 + \frac{y_T}{w_T}) + (\frac{1}{\alpha} - 1)(\frac{h_T}{w_T})^{\alpha/(\alpha-1)}, S_T = r_T \frac{h_T}{w_T} \end{aligned}$$

Here the superscript i refers to the two cases $L_T = 0$ and $L_T = 1$. This

Proposition gives us the final position of the individual, working backwards we can then analyse behaviour within the final epoch terminating in v_T^i. In the next section we show the form and components of the value function for particular types of epochs which can arise, depending on which one of the two possible forms the value function takes in the future adjacent epoch.[13]

1.5 Epochs

We can find the optimal lifetime path by piecing together the optimal sequence of epochs. Within an epoch, for each period assets at the start of the period must be at a level which makes continuing the current labour participation status optimal, and, between epochs, assets at the start of the first period of the subsequent epoch determine the optimal change in participation behaviour in that period and in the new epoch.

1.5.1 Epochs Preceding an Epoch with a Power Function Value Function

Suppose the epoch stretches from periods t_2 to t_1-1 so that t_1-1 is the last period within the epoch and the value function at t_1 is $v_{t_1} = \frac{P_{t_1}^i + M_{t_1}(N_{t_1}^i + Q_{t_1}A_{t_1})^\alpha}{\alpha}, i = 0, I, 1$. The function $P_{t_1}^i$ measures the value arising from discounted future leisure time, whilst the function N_t^i measure the appropriately discounted values of future non-financial income.[14]

(i) Full Time Work t_2 to $t_1 - 1$

In this case during the epoch there is no leisure to cumulate in to values within the epoch, so the only impact of leisure on the value function within the epoch is through the discounted value of leisure which arises in future epochs. This gives the term P_s^0 at each period $s = t_2..t_1 - 1$ prior to the last in the epoch. On the other hand with full time work at every period within the epoch,

[13] We derive the value functions for each labour force state in the terminal period in Appendix 8.1.4.

[14] We derive the expressions for value functions preceeding a power value function in Appendix 8.1.5.

nonfinancial income within the epoch is $w_t + y_t$ each period and the function N_s^0 cumulates this effect through the epoch.

$$\begin{aligned} N_s^0 &= \Sigma_{\tau=s}^{t_1} Q_{\tau+1}(w_\tau + y_\tau) + N_{t_1}^i, s = t_2..t_1 - 1 \quad (1.15) \\ P_s^0 &= \delta^{t_1-s} P_{t_1}^i, s = t_2..t_1 - 1 \quad (1.16) \end{aligned}$$

Period to period within this epoch, full time work must be optimal. That is the marginal value of current leisure must be no greater than the contribution of the current wage to future value through raising savings and assets available next period.

$$\begin{aligned} (\frac{h_s}{w_s})^{1/(\alpha-1)} &\geq B_s[y_s + w_s + r_s A_s + N_{s+1}^0], s = t_2 + 1...t_{1-2} \quad (1.17) \\ \text{where } B_s &= \frac{(\delta Q_{s+1} M_{s+1})^{1/(\alpha-1)}}{1 + Q_{s+1}(\delta Q_{s+1} M_{s+1})^{1/(\alpha-1)}} \end{aligned}$$

The term B_s shows the combined effect of the discount and interest rate. In the final period of this epoch similarly it must be the case that

$$(\frac{h_{t_1-1}}{w_{t_1-1}})^{1/(\alpha-1)} \geq B_{t_1-1}[y_{t_1-1} + w_{t_1-1} + r_{t_1-1} A_{t_1-1} + N_{t_1}^i], i = 1, I \quad (1.18)$$

where the subsequent epoch must display one of $L_{t_1} = 1$ or L_{t_1} interior.

(ii) Zero Work t_2 to $t_1 - 1$

In this case at every period within the epoch the individual is in full time leisure, therefore the term P_s^1 cumulates the impacts of these leisures through the epoch, discounting them at the rate of time preference. On the other hand with zero work at every period within the epoch, nonfinancial income within the epoch is just non-labour income each period and the function N_s^1 cumulates this through the epoch.

$$\begin{aligned} N_s^1 &= \Sigma_{\tau=s}^{t_1} Q_{\tau+1} y_\tau + N_{t_1}^i, s = t_2..t_1 - 1 \\ P_s^1 &= \Sigma_{\tau=s}^{t_1-1} \delta^{t_1-s} h_\tau, s = t_2..t_1 - 1 \end{aligned}$$

The marginal utility of leisure at any period within the epoch must exceed the contribution of the wage to the future value both within and importantly beyond the epoch:

$$(\frac{h_s}{w_s})^{1/(\alpha-1)} \leq B_s[y_s + w_s + r_s A_s + N^0_{s+1}], s = t_2 + 1...t_1 - 2 \tag{1.19}$$

and in the final period of this epoch similarly it must be the case that

$$(\frac{h_{t_1-1}}{w_{t_1-1}})^{1/(\alpha-1)} \leq B_{t_1-1}[y_{t_1-1} + w_{t_1-1} + r_{t_1-1}A_{t_1-1} + N^i_{t_1}], i = I, 0 \tag{1.20}$$

(iii) Part time Work t_2 to $t_1 - 1$

The value function at $t_1 - 1$ becomes linear in assets:

$$v_{t_1-1} = R^I_{t_1-1} + S^I_{t_1-1}A_{t_1-1} \tag{1.21}$$

with

$$\begin{aligned} S^I_{t_1-1} &= \frac{h_{t_1-1}}{w_{t_1-1}} \\ R^I_{t_1-1} &= \frac{h_{t_1-1}}{w_{t_1-1}}(y_{t_1-1} + w_{t_1-1}) + \frac{h_{t_1-1}}{Q_{t_1}w_{t_1-1}}N^i_{t_1} + [\delta M_{t_1}\left(\frac{h_{t_1-1}}{\delta M_{t_1}Q_{t_1}w_{t_1-1}}\right)^{\alpha/(\alpha-1)} \\ &\quad -\frac{h_{t_1-1}}{Q_{t_1}w_{t_1-1}}\left(\frac{h_{t_1-1}}{\delta M_{t_1}Q_{t_1}w_{t_1-1}}\right)^{1/(\alpha-1)}](1 + Q_{t_1}(\delta M_{t_1}Q_{t1})^{1/(\alpha-1)} \end{aligned}$$

Coming backwards in time, if part time work is optimal in all periods back to t_2 then future market conditions and leisure preferences do not affect the current marginal value of assets at any period s within the epoch. The value function is linear in assets at any $t_2 \leq s \leq t_1 - 1, v_s = R^I_s + S^I_s A_s$ with

$$\begin{aligned} S^I_s &= \frac{h_s}{w_s}r_s \\ R^I_s &= \frac{h_s}{w_s}(w_s + y_s) + \delta R^I_{s+1}, s = t_2..t_1 - 2 \\ &= \Sigma^{t_1-2}_{\tau=s}\delta^{t_1-1-\tau}(y_\tau + w_\tau) + \delta^{t_1-1-s}R^I_{t_1-1} \end{aligned} \tag{1.22}$$

Here S_s is an optimally set constant marginal value of future wealth, equated to the ratio of the marginal value of leisure to the discounted wage. With optimal part time work, the period s marginal utility of labour income equates to the present value of the marginal value of future wealth. The term

R_s evaluates the contribution to value of the stream of future full incomes, discounting them at the time preference rate.

Given that the value function at t_1 is a power function, for part time work to be optimal at $t_1 - 1$, the ratio of the marginal utility of leisure to the wage w_{t_1-1} at $t_1 - 1$ (which is the marginal utility of current income in $t_1 - 1$), must exceed the marginal value of wealth at t_1 evaluated at $L_{t_1-1} = 0$:

$$\frac{B_{t_1-1}\left[(y_{t_1} + w_{t_1} + r_{t_1}A_{t_1}) + N^1_{t_1+1}\right]}{(\delta M_{t_1})^{1/(\alpha-1)}Q_{t_1}} > (\frac{h_{t_1}}{w_{t_1}})^{1/(\alpha-1))} \tag{1.23}$$

and conversely the current marginal utility of income must be lower than the marginal value of wealth evaluated at zero hours of work, $L_{t_1-1} = 1$:

$$\frac{B_{t_1-1}\left[(y_{t_1} + w_{t_1} + r_{t_1}A_{t_1}) + N^1_{t_1+1}\right]}{(\delta M_{t_1})^{1/(\alpha-1)}Q_{t_1}} < (\frac{h_{t_1}}{w_{t_1}})^{1/(\alpha-1))}, i = 0, 1 \tag{1.24}$$

Within the epoch at each period s the value function becomes linear as stated in Proposition 1 , and then for part time work to be optimal at each period s within the epoch requires

$$S^I_{s+1} = \delta r_{s+1} w_s \frac{h_{s+1}}{w_{s+1}}, s = t_2..t_1 - 2 \tag{1.25}$$

From equation (1.22) within each period in the epoch the current marginal utility of income is exactly equal to the marginal value of wealth which, in this epoch, is independent of assets A_{s+1}. We next characterise epochs prior to an epoch with a linear value function.

1.5.2 Epochs Preceding an Epoch with a Linear Value Function

This epoch lasts from periods t_2 to $t_1 - 1$, the next adjacent epoch starts at t_1 and has a linear value function:

$$v_{t_1} = R_{t_1} + S_{t_1}A_{t_1} \tag{1.26}$$

The epoch t_2 to $t_1 - 1$ could for example be either the first period of part time work or any period which is followed at some point by an epoch of part time work.[15] As noted the special feature of epochs which precede an epoch with a linear value function, is the particularly simple expressions which govern the critical levels of starting assets which determine current optimal labour participation. They involve comparing the marginal utility of current income as defined by the ratio of the marginal utility of current leisure to the wage with the discounted value of the marginal value of future wealth. If the current marginal utility of income is higher then it is optimal to work full time, if lower then it is optimal not work at all, and if it is just equal part time work is optimal. Since the marginal value of future wealth is independent of assets and future income, the optimal labour participation depends only on values of exogenous variables and is independent of current hours worked or consumption. The value functions for the three possible states of labour force participation and the critical asset condition can be summarised as follows:

(i) Full Time Work t_2 to $t_1 - 1$

In this case the value function at $t_1 - 1$ is

$$\begin{aligned} v_{t_1-1} &= \delta S_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1}) + \delta R_{t_1} + \delta^{\alpha/(\alpha-1)} S_{t_1}^{\alpha/(\alpha-1)}[\frac{1}{\alpha} - 1] \\ &= S^0_{t_1-1}A_{t_1-1} + R^0_{t_1-1} \end{aligned} \quad (1.27)$$

where the term $S^0_{t_1-1}$ captures the discounted utility of leisure relative to the wage of one period and $R^0_{t_1-1}$ is a combination of discounted future $MRS_{h,w}$ between leisure and consumption.

with

$$\begin{aligned} S^0_{t_1-1} &= \delta S_{t_1} r_{t_1-1} \\ R^0_{t_1-1} &= \delta S_{t_1}(y_{t_1-1} + w_{t_1-1}) + \delta R_{t_1} + \delta^{\alpha/(\alpha-1)} S_{t_1}^{\alpha/(\alpha-1)}[\frac{1}{\alpha} - 1] \end{aligned}$$

The critical asset condition which governs full time work to be optimal is

[15] We derive the expressions for value functions preceding a linear value function in appendix 8.1.5.

particularly simple

$$S_{t_1-1} < \delta S_{t_1}$$

For full time work to be optimal for each period s within the epoch, the marginal value of leisure must exceed the discounted marginal value of future wealth multiplied by the wage, formally $S_s < \delta S^0_{s+1}, s = t_2..t_1 - 2$. Optimal within period consumption is independent of wealth, $c_s = \delta^{1/(\alpha-1)} S_s^{1/(\alpha-1)}$. The period s value function for a full time work epoch is:

$$\begin{aligned} v_s &= (r_s A_s + y_s + w_s - A_{s+1})^\alpha/\alpha + \delta[S^0_{s+1}A_{s+1} + R^0_{s+1}], s = t_2..t_1 - 2 \\ &= S^0_s A_s + R^0_s \end{aligned}$$

with

$$\begin{aligned} R^0_s &= \Sigma_{\tau=s}^{t_1-2}\left((\frac{h_s}{w_s})^{\alpha/\alpha-1)}(1/\alpha - 1) + h_s + \frac{h_s}{w_s}y_s\right) + \delta R_{s+1} \\ S^0_s &= \Sigma_{\tau=s}^{t_1-2}\frac{h_s}{w_s}r_s \end{aligned} \quad (1.28)$$

The terms S^0_s and R^0_s denote the cumulative effect of the combination of future discounted utility of leisure relative to the wage, and discounted future $MRS_{h,w}$ between leisure and consumption.

(ii) Zero Work t_2 to $t_1 - 1$

The value function at $t_1 - 1$ is derived as

$$\begin{aligned} v_{t_1-1} &= h_{t_1-1} + \delta S_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1}) + \delta R_{t_1} + \delta^{\alpha/(\alpha-1)}S_{t_1}^{\alpha/(\alpha-1)}[\frac{1}{\alpha} - 1] \\ &= S^1_{t_1-1}A_{t_1-1} + R^1_{t_1-1} \end{aligned} \quad (1.29)$$

with

$$\begin{aligned} S^1_{t_1-1} &= \delta S_{t_1} r_{t_1-1} \\ R^1_{t_{1-1}} &= h_{t_1-1} + \delta S_{t_1} y_{t_1-1} + \delta R_{t_1} + \delta^{\alpha/(\alpha-1)}S_{t_1}^{\alpha/(\alpha-1)}[\frac{1}{\alpha} - 1] \end{aligned}$$

Notice that in this case $R^1_{t_{1-1}}$ contains the marginal value of leisure h_{t_1-1}, whilst in $R^0_{t_1-1}$ the contribution of working in period $t_1 - 1$ was $\delta S_{t_1} w_{t_1-1}$. The critical asset condition governing whether full time leisure is optimal is given by:

$$S_{t_1-1} > \delta S_{t_1}$$

For each period s within the epoch the individual solves

$$\max c_s^{\alpha}/\alpha + h_s L_s + \delta(R^1_{s+1} + S^1_{s+1}A_{s+1}) \qquad (1.30)$$
$$c_s + A_{s+1} = rA_s + y_s$$

For full time leisure to be optimal for each period s within the epoch, the marginal value of leisure must exceed the discounted marginal value of future wealth multiplied by the wage, formally $S_s > \delta S^1_{s+1}, s = t_2..t_1 - 2$. Optimal within period consumption is then a constant independent of assets or current income: $c_s = \delta^{1/(\alpha-1)} S_s^{1/(\alpha-1)}$. The period s value function for a linear zero work epoch is defined as:

$$v_s = h_s + (r_s A_s + y_s - A_{s+1})^{\alpha}/\alpha + \delta[S^1_{s+1}A_{s+1} + R^1_{s+1}], s = t_2..t_1 - 2 \quad (1.31)$$
$$= S^1_s A_s + R^1_s$$

with

$$R^1_s = \Sigma_{\tau=s}^{t_1-2}\left((\frac{h_s}{w_s})^{\alpha/\alpha-1)}(\frac{1}{\alpha} - 1) + h_s + \frac{h_s}{w_s} y_s \right) + \delta R_{s+1}$$
$$S^1_s = \Sigma_{\tau=s}^{t_1-2} \frac{h_s}{w_s} r_s \qquad (1.32)$$

The interpretation of S^1_s and R^1_s is analogous to definition noted in the previous subsubsection, but for the case of zero work.

(iii) Part time Work t_2 to $t_1 - 1$

The value function for a switch into part time work at $t_1 - 1$ is

$$
\begin{aligned}
v_{t_1-1} &= \delta S_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1}) + \delta R_{t_1} + \delta^{\alpha/(\alpha-1)} S_{t_1}^{\alpha/(\alpha-1)}[\frac{1}{\alpha} - 1] \\
&= S^I_{t-1}A_{t-1} + R^I_{t-1} \qquad (1.33)
\end{aligned}
$$

with

$$
\begin{aligned}
S^I_{t_1-1} &= \delta S_{t_1} \qquad (1.34) \\
R^I_{t_1-1} &= \delta S_{t_1}(y_{t_1-1} + w_{t_1-1}) + \delta R_{t_1}
\end{aligned}
$$

The critical asset condition which must hold for part time work to be optimal is given by

$$
S_{t_1-1} = \delta S_{t_1}
$$

That is, it must the case that the marginal value of income at $t_1 - 1$ must grow at the exogenous discount rate delta multiplied by the t_1 marginal utility of income, as defined by the marginal rate of substitution of leisure to the wage rate. Then for part time work to be optimal for each period s within the epoch, this condition must hold $S_s = \delta S^I_{s+1}, s = t_2..t_1 - 2$. Optimal within period consumption is again independent of wealth and is given by $c_s = \delta^{1/(\alpha-1)} S_s^{1/(\alpha-1)}$. The period s value function for a linear part time work epoch is:

$$
v_s = S^I_s A_s + R^I_s, s = t_2..t_1 - 2
$$

with

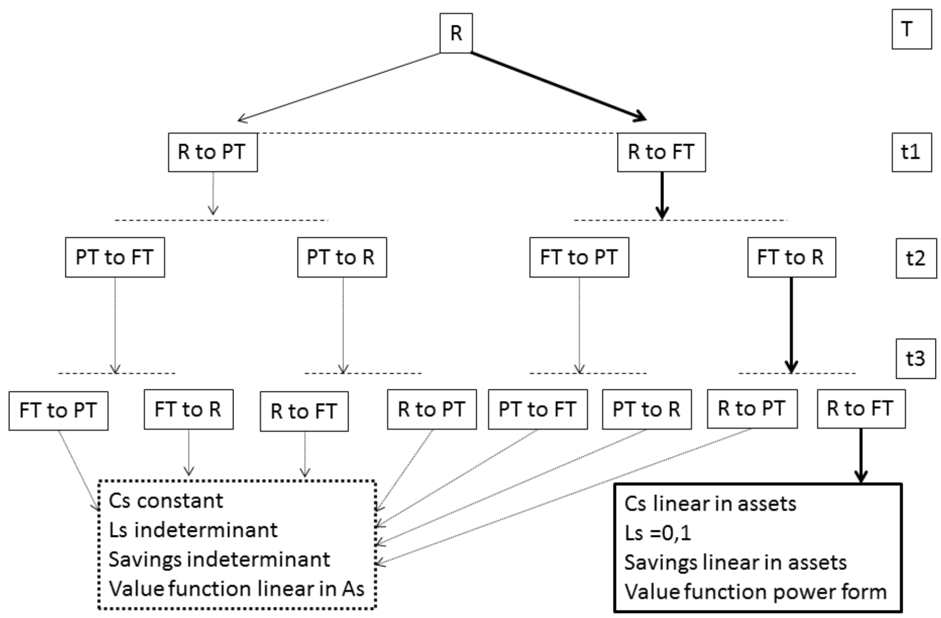
$$
\begin{aligned}
S_s &= \delta S^I_{s+1} \\
R^1_s &= \frac{h_s}{w_s}(w_s + y_s) + \delta R^1_{s+1}, s = t_2..t_1 - 2 \\
&= \Sigma_{\tau=s}^{t_1-2} \delta^{t_1-1-\tau}(y_\tau + w_\tau) + \delta^{t_1-1-s} R^1_{t_1-1}
\end{aligned}
$$

The term S^i_s $i = 0, I, 1$ measures the marginal value of wealth at period s. Starting from a linear value function at the end of the epoch, this is a constant at each period within the epoch, and grows or falls at the rate r/δ. That is, in all cases of labour participation which are determined by comparing the current and future marginal utility of income, labour supply and savings adjusts optimally whilst consumption is independent of wealth. In this case it is only at the end of the epoch when switching into the next epoch that labour supply and savings are determinate. At all periods within the epoch labour and savings are indeterminate. The terms R_s^i $i = 0, I, 1$ reflect the impacts of nonfinancial income on value during the epoch, this can vary with optimal participation status and is cumulated at the marginal value of wealth discounted by the time preference rate.

1.6 The Nature of the Optimal Path

We have derived the conditions on market variables and on preferences which determine the optimal participation status. From this it is possible to derive the form of consumption, savings and labour supply. This is seen more clearly in the Figure 1.4.

Figure 1.4: Potential labour supply paths conditional on retiring in terminal period.



In Figure 1.4 the dashed lines represent periods within an epoch where consumption is independent of wealth and the value function is linear in assets. Whilst the solid lines represent periods where consumption and savings are linear functions of assets and the value function is a power function. The dashed lines consist of periods within epochs which precede (or in the limit coincide with) the final period of part time work. We can divide the dashed lines into two subgroups: those with part time work where hours worked and savings are indeterminate and those with full time or retirement where hours worked is determinate and savings is a residual. The dashed periods have the properties in the dashed box, the solid periods have the properties in the solid box.

We know that prior to any epoch of part time employment, the value function is linear, consumption is always independent of wealth and in epochs of full time or zero work labour supply is of course constant. It is clear from the diagram the majority of the paths do in fact involve a linear value function. Savings in each period of epochs of full time or zero work before an epoch of part time work is hence a residual which fluctuates with the wage and non-labour income. After the final period (or equivalently epoch) of part time work, consumption and savings are linear functions of current assets and the value function is always a power function, the optimal labour participation can involve either full time or zero work. An example of such a path is shown on the furthermost right hand side of the diagram. Figure 1.4 highlights that lifecycle paths such as these (characterised by the properties in the solid box) are quite rare within our model.

1.7 Application of model to retirement paths

Mandatory retirement has historically marked the cessation of paid work (Lazear, 1986, 1979; Banks and Smith, 2006), which usually occurred when an individual reached the State Pension Age (SPA). In more recent times early retirement has also been observed, whereby individuals retire before SPA for example because they can afford to do so, or their private pension scheme allows them to draw their pension earlier than SPA. Another phenomenon which has occurred since the 1960s/1970s is that of partial retirement (Gustman and Steinmeier, 1984a, 1984b). This can be thought of as an individual either reducing the number of hours working in their career job, or if this was not possible then changing job when they reach SPA.[16] Partial retirement can be viewed as a mechanism by which individuals can move gradually into full retirement and adjust their lifestyle and habits more smoothly.

More recently non standard retirement paths have been investigated by Maestas (2010); Petersson (2011); Larsen and Pederson (2013) and Schlosser et al. (2012) in the form of unretirement, which is defined as a transition from retirement to partial retirement, or even back in to full time work.[17] Various reasons have been noted in the literature which may explain this: unexpected income or preference shocks, in particular it may turn out that the anticipated utility of leisure is actually lower than was expected, once it is actually experienced. Maestas (2010) finds that unretirement is an anticipated event, using expectations data, she finds that the majority of unretirees anticipated unretiring prior to initial retirement.

Another possibility concerns the impact of pension schemes. Many pension schemes even of the funded variety (which involve purchase of an annuity from a personal pension fund) yield a stream of non-labour income y_t that is fixed in nominal terms but not in real terms. An individual may choose to retire at t having previously been in full or part time work because y_t jumps upwards when retirement coincides with eligibility for receipt of an income stream from a pension. But if the income flow is not indexed fully, in real terms the income stream starts falling. Then at some date $s > t$ it could be optimal to return to work since the fall in present and future non-labour income reduces the marginal value of future wealth. Our framework can account for the heterogeneity in retirement paths reported in the literature for example (with $t_1 > t_2$):

(1) Full time$_{t_1}$ $\longrightarrow$Retired$_{t_2}$

(2) Full time$_{t_1}$ $\longrightarrow$Part time$_{t_2}$ $\longrightarrow$Retired$_{t_3}$

(3) Full time$_{t_1}$ $\longrightarrow$Retired$_{t_2}$ $\longrightarrow$Full time$_{t_3}$

[16] This is due to the labour market regulation in the US.

[17] The exact definition of retirement is difficult to pin down precisely, given that it could be based on a self reported definition or on the number of hours reported in paid work. Unretirement is not a new phenomenon, it was observed in the US during the 1980's and was coined as 'reverse flow'. See Gustman and Steinmeier (1984) and Rust (1989,1990).

(4) Full time$_{t_1}$ $\longrightarrow$Retired$_{t2}$ $\longrightarrow$Part time$_{t_3}$.

After the last period of part time work (if any such exists) participation decisions depend on the whole future evolution of the h, w, y (as in cases (1)-(3) above). But in case (4) for any t before the final part time epoch the participation decision at t depends only on comparing variables at t with variables at $t+1$. Retirement paths (1) and (2) have been studied extensively (Gustman and Steinmeier, 1984b 1986), within our framework these paths and also path (3) will involve future market conditions and preferences. Only path (4) has a simple structure and does not involve the future. We show the implications of our general framework for each category.

1.7.1 Periods for which the whole future matters

Retirement paths in which the whole future matters involve full time work or full retirement, due to the role of future non financial wealth, N, in the critical asset conditions. The critical level of assets in these cases have the general form

$$\frac{h}{w} \gtrless B(M,Q)(N^i + Q(rA + (w) + y)^{\alpha-1} \tag{1.35}$$

Thus the more value an individual places on the marginal value of leisure ceterus paribus, the less likely they are to work now. Higher opening and current financial wealth and future nonfinancial wealth, serve to reduce the desire to work. However future non financial wealth can increase if either future w or y increase or if the balance of r, δ changes. Note that the future marginal value of leisure does not affect current participation but does affect the current value of the future.

To demonstrate the importance of the marginal value of leisure, suppose an individual follows a retirement path defined by (1) above with complete withdrawal from the labour market forever from that point on. Take two individuals with identical w, y streams and starting assets but different h paths.

Then to retire at $T-2$ needs:

$$\begin{aligned}\frac{h_T}{w_T} &> (y_T + rA_T)^{\alpha-1} \\ \frac{h_{T-1}}{w_{T-1}} &> (Q_{T-1}(y_{T-1} + rA_{T-1}) + y_T)^{\alpha-1} \\ \frac{h_{T-2}}{w_{T-2}} &> (Q_{T-2}(y_{T-2} + rA_{T-2}) + Q_{T-1}Q_{T-2}y_{T-1} + y_T)^{\alpha-1}\end{aligned} \tag{1.36}$$

Therefore whilst the right hand side is the same for the 2 individuals, one may retire at $T-2$ but the other may not only if h_{T-2} is suitably different, and then subsequent assets may be different between them. A chronic health shock, retirement of spouse or existence of grandchildren can all raise h permanently into the future and lead to retirement.

Whilst retirement paths (1) and (2) have been investigated in some detail, the retirement path in (3) features full unretirement. That is to say an individual may find it optimal to fully retire at t and then subsequently return to full time work at $t+1$. For this unretirement to be optimal we must have

$$\frac{h_t}{w_t} > B_t(M_t, Q_t)(N^0_{t+1} + Q_t(rA_t + y_t))^{\alpha-1} \tag{1.37}$$

$$\frac{h_{t+1}}{w_{t+1}} < B_t(M_{t+1}, Q_{t+1})(N^i_{t+2} + Q_{t+1}(rA_{t+1} + w_{t+1} + y_{t+1}))^{\alpha-1} \tag{1.38}$$

$$\frac{h_t}{w_t} > B_t(M_t, Q_t)(N^i_{t+2} + Q_t y_t + Q_t(rA_t + y_t))^{\alpha-1} \tag{1.39}$$

$$\text{where } N^0_{t+1} = N^i_{t+2} + Q_t y_t$$

It is clear that the future plays an important role for non standard retirement paths of this type. Indeed Maestas (2010) suggests that unretirement is a planned event, individuals anticipate retiring and subsequently returning to the labour force, and it is not due to an unexpected shock to income or wealth.[18] Recent work demonstrating the empirical importance of unretirement in the case of the US and England can be found in Gustman and Steinmeier (2002),

[18] Maestas (2010) also notes that retirees preretirement leisure expectations do not coincide with the actual retirement experience, and this difference may induce individuals to return to the labour force.

Maestas and Li (2007), Maestas (2010) and Kanabar (2013).[19] It is important to note that in the majority of these studies (with the exception of Gustman and Steinmeier, 2002) unretirement flows are defined such that they include a transition from retirement to part time work, that is to say they follow a retirement path defined by (4) above.[20] As Gustman and Steinmeier (2002) show 'full unretirement', i.e. retirement path (3) does occur, but is relatively uncommon. In the US for example both Maestas (2010) and Gustman and Steinmeier (2002) use HRS data and find unretirement rates of 26% and 15% respectively.[21] The main reason for this difference is due to the majority of the flows going from retirement into part time work (retirement path (4)), which the former paper includes in their definition of unretirement whilst the latter does not.[22]

Our framework has clear implications for retirement policy. Take for example paths (2), (3) and (4), despite the latter two of these retirement paths featuring unretirement, the properties of the value function in each case are quite different. In retirement path (3) optimal participation changes can only be from corner to corner, if for example in the retirement phase t_2 a policy was announced which affected future non-labour income equations (1.17) and (19) show this would affect participation at t_2 by altering the size of N. An identical policy would not affect an individual following retirement path (2) or (4) prior to the final period of part time work, equations (1.28) and (1.32) show that the conditions which determine the optimal labour force regime are not affected by current or future non-labour income. However equations (1.17), (1.19) , (1.28) and (1.32) show any policy which affected future wages, w, would impact on current optimal labour supply decision irrespective of which retirement path the individual was on.

[19] Recent papers include Schlosser et al. (2012) who consider unretirement in Canada. Whilst Larsen and Pederson (2013) and Petersson (2011) consider the case of Denmark and Sweden respectively.

[20] Note that a fraction of the individuals who follow a retirement path defined by (4), subsequently go on to enter full time work.

[21] Gustman and Steinmeier (2002) pp.21 and pp.37. In their model they only consider two labour force states, namely full time work and full time retirement.

[22] There are key differences in the way these authors construct their samples, for example Maestas (2010) uses the first six waves of HRS whilst Gustman and Steinmeier (2002) use the first five waves.

1.7.2 Periods for which only adjacent periods matter

An example of a retirement path where the participation decision depends only on adjacent period variables is highlighted in path (4) Full time$_{t_1}$ $\longrightarrow$ Retired$_{t2}$ $\longrightarrow$ Part time$_{t_3}$. Appendix 8.1.5 derives the particularly simple conditions governing optimal labour supply, prior to an epoch with a linear value function. If we make the additional assumption that the $MRS_{h,w}$ is constant at every period and grows at the (exogenous) discount rate δ, in this case the conditions governing labour force participation are

$$\begin{aligned} L_t &= 1 \text{ if } \frac{h_t}{w_t} > \delta\frac{h_{t+1}}{w_{t+1}} \\ 0 &< L_t < 1 \text{ if } \frac{h_t}{w_t} = \delta\frac{h_{t+1}}{w_{t+1}} \\ L_t &= 0 \text{ if } \frac{h_t}{w_t} < \delta\frac{h_{t+1}}{w_{t+1}} \end{aligned} \tag{1.40}$$

Therefore within our framework not only can we model a variety of non standard retirement paths, in those cases where only adjacent periods matter (1.40) shows the optimal conditions governing labour supply depend on only the $MRS_{h,w}$, in this case a constant and the discount rate. An individuals tastes and preferences may display a marginal value of leisure that increases at older ages, for example to spend more time with family or phase into full retirement gradually and the optimal labour supply response would be to be (gradually) transition into full retirement. Alternatively there are a variety of reasons which may make it optimal for an individual to remain engaged in the labour force permanently or even unretire, for example due to changes in their leisure preferences (Maestas, 2010).

1.8 Future work

A central finding of chapter one is that a switch into part time work has important implications for the form of the value function and consumption. Calibrating our model with empirical data would allow one to test these theoretical predictions, and assess the models validity in explaining major economic decisions over the lifecycle.

The current framework in chapter one does not allow for uncertainty. Richer models which allow for such a feature usually require numerical methods to solve a more complicated problem (Gustman and Steinmeier, 2002). Future work to extend the current framework and incorporate uncertainty would be feasible however this would be at the cost of losing analytical solutions and a complete understanding of the model.

1.9 Conclusion

In this chapter we have taken a common form of the utility function used in the lifecycle literature, and found a number of its general properties. In particular, we have shown that whilst previous papers have used computational methods to find a tractable solution, we are able to break the curse of dimensionality through emphasising the role of part time work. After deriving the nature of lifecycle epochs of consumption, savings and labour participation, we apply our model to the increasing prevalence of non standard retirement paths. In doing so we note (1) the increasing importance of flexible working regulations in order to ensure individual's can supply an optimal level of labour over the lifecycle and (2) the framework captures several features of the 2007 cross section PSID data.

To show this we derive the explicit functional form of the value function, which switches as different forms of labour participation become optimal. These switches occur at critical values of current assets in relation to future market and preference parameters. At such a switch generally the consumption function switches between being a linear function of assets and being independent of assets. Similarly savings switches between being a linear function of assets and being jointly indeterminate with hours worked. Knowing the value function, we are able to characterise the entire lifecycle of an individual through the use of epochs, in particular we show the way in which the future can play an important role in the participation decision. This has implications on the forces which govern the within and intertemporal marginal rate of substitution between leisure and work, and also the marginal utility of wealth.

The framework excludes various potentially important effects. We have taken the individual as the decision making unit but most individuals live in families where the family decision rules, and also externalities in the preferences of different family members are important. For example partners may coordinate retirement decisions due to a preference for shared leisure, or the need for labour income from one family member may depend on the participation status of other family members. Even in a one period world the analysis of family labour market participation decisions is not straightforward (Donni & Moreau, 2007; Blundell et al., 2007). In a multiperiod world it is obviously more complicated. We have neglected preference or budget constraint uncertainty and all employment decisions are voluntary, anyone wanting to work can find a job and wages, non-labour income and interest rates are perfectly foreseen. This is in common with many papers in the literature, although its justification has to be on grounds of imposing sufficient simplicity to be able to derive analytical solutions which will be valid in any data set. The alternative would be to numerically determine the optimal lifetime path in the context of a specific random process for preferences or elements of the budget constraint. If the purpose is to determine qualitative properties of the optimal path, analytical solution is much more useful.

Chapter 2

To Defer or Not Defer: State Pension in a Lifecycle Model.

2.1 Introduction

Aging populations and longevity raise issues regarding labour force participation rates, savings and pensions especially amongst the elderly. These are also important issues for government fiscal balance since tax receipts, state pensions and work conditional benefits obviously vary with labour and capital incomes.

The aim of state pension systems is to alleviate poverty in old age (Beveridge, 1942) and in this sense it is a long term government commitment. Governments respond by encouraging later retirement and/or raising the age of eligibility for receipt of a state pension. Eligibility for receipt of a UK state pension only depends on age, although the amount received depends on lifetime work and tax (national insurance contribution) history, and is independent of current employment status.

The UK defines a statutory State Retirement Age (SRA) which serves two purposes: working individuals must pay National Insurance (NI) contributions at a percentage rate of their earnings until this age; it is also the age at which an individual first becomes eligible for receipt of a weekly state pension. The amount of the pension depends generally on past national insurance contributions (and so past earnings) although there is a guaranteed minimum state pension. As of April 2010 any individual who reaches SRA on or after 6^{th}

April 2010, is eligible to receive a full state pension if they have made 30 years of NI contributions, which replaces around 15% of the average labour income in 2008 (Coleman at al, 2008).

The 2013 White Paper introduced an entire overhaul of social security in the UK through the introduction of a flat rate pension from 2017, and for new retirees (post 2017) requires individuals to make 35 years of NI contributions. As with the existing rules, individuals who make less contributions will see an equivalent reduction in their state pension, whilst those individuals who make less than 10 years contributions will not receive any state pension.[1] The first date of eligibility for receipt of state pension will still only depend on age and will be independent of current or future employment status. Until recently the SRA had been 60 years for women and 65 for men but since 2012 there have been plans to align them, by 2018 the female retirement age will be 65, equal to that of males and by 2020 the SRA for both men and women will be 66.

Since its inception in 1948 individuals who are eligible to claim have had the option to defer receipt of state pension, in exchange for an increased weekly pension when they do subsequently decide to claim. [2] [3] Initially upon ending deferral individuals could claim a higher weekly income for their retirement period, however since 2005 individuals also have the option to claim a lump sum on their missed weekly payments (which earns interest above the Bank of England base rate) and then continue to receive their usual weekly payment. Since April 2010 the government has committed the State Pension (SP) to a triple lock indexing policy, in doing so State Pensions are uprated in line with whichever is highest of: (1) September-September Consumer Price Index (2) average earnings or (3) 2.5%. For those who defer their pension, at the date of undeferral the rate of return earned in the lump sum option means that past indexed increases are accumulated in the lump sum. In addition all additional flows of the basic weekly SP are uprated each year. On the other hand under

[1] Bozio et al. (2010) pp 13. For men born before April 1945 and females born before 1950, UK State Pension legislation requires these individuals to make the equivalent of 44 years and 39 years of full contributions respectively, in order to be eligible for the maximum State Weekly Pension. For these individuals men must make at least 11 years of contributions and females 10 years, in order to be eligible for any state pension at all.

[2] This is a one shot choice and an individual can only defer their pension once. The length of defer initially had an upper bound however since 2005 this has been removed.

[3] The exposition of the history of the UK state pension presented here draws heavily on Bozio et al. (2010).

the deferred income option at the undeferral date, indexing only applies to the initial amount of the SP the individual was due to receive before deferring. The additional income earned per week has not been uprated since April 2010 (Thurley, 2010).[4]

The possibility of State Pension deferral has implications for the planned savings and work pattern of individuals through changing their lifetime pattern of non-labour income.[5] What implications will deferral have for their work and savings patterns? Can deferral induce individuals to stay on longer in paid work? Disney and Smith (2002) formally analyse the effect of the abolition of the Earnings Rule (which effectively placed a very high marginal tax rate on individuals who wanted to claim their pension and continue working), and as a side issue also consider pension deferral. Their findings suggest that after abolition, male weekly hours (above SPA) rose by approximately 4 hours, whilst for women it rose by 2 hours. Disney and Smith (2002) do not explicitly consider the effects of pension deferral on labour supply. Farrar et al (2012) compare the two deferral options available under current State Pension legislation and conclude under most simulations that the incremental option (additional weekly state pension) generally tended to more lucrative.

Here we formally analyse the joint deferral and intertemporal labour supply and participation decisions in a lifecycle setting. We find the deferral decision is independent of preferences, wage rates or wealth. It is a purely financial decision: choose to defer if it raises the present value of non-labour income. However the effect of deferral on intertemporal labour supply does depend on preferences, wage rates and wealth. In a general model we sketch the qualitative effects but to get analytical and empirically applicable results, we then specify preferences. After deriving the analytical expression for the effects on reservation wages for different intertemporal labour participation patterns, we calibrate these to compute the size of the impacts. The present deferral scheme gives about a 2% increase in the reservation wage for full time work for 12 months of deferral. If an individual does defer, under the present system he can take the later rewards as either a lump sum or as an increase in the

[4]This holds true since April 2010, prior to this, the additional income earned in the deferred income option was also uprated annually under the same rules as the BSP.

[5]Strictly speaking state pension income is employment income deferred from an earlier period.

weekly payment. We analyse which option is optimal in the context of life expectancy, length of deferral and interest rates.

In Section 2.2 we lay out a general framework which encompasses the effects of pension deferral on optimal labour supply through the role of the present value of non-labour income. In Section 2.3 we show the effects of regime switches on the optimal labour supply, using a form of preferences used widely in the literature. Section 2.4 compares the two deferral options available under current UK State Pension legislation. Section 2.5 considers future work. Section 2.6 concludes.

2.2 The model

With perfect capital markets and in a world of certainty, financial wealth can be transferred intertemporally by the consumer. So one would expect that the benefits of deferring a state pension will depend only on a comparison between the implicit interest rate used in the government set terms of deferral and the market interest rate. This is because individuals will only defer if it raises their disposable wealth at the date of deferral, through raising the present value of non-labour income in the form of pension receipts.[6] For individuals who defer we would expect optimal adjustment in consumption c, and leisure L as they intertemporally smooth the marginal utility of consumption. There will be wealth effects on present and future labour supply and consumption. Disney and Smith (2002) point out that there may be labour participation effects of changes in the pension rules, or more specifically in the implicit wage income an individual can earn in the absence of an earnings rule. If we add uncertainty about other future income sources and especially about the remaining length of life, the decision to defer or not is much less clear. Similarly individuals who face borrowing constraints are less likely to defer when they have the opportunity.

[6] One could instead focus the analysis on the NPV value, which could be argued to be more realistic given that for an individual to defer their pension then by construction they are not in receipt of it. Therefore in theory one could replace PV with NPV in the paper. It is worth noting that formally this doesn't change the findings of the paper with the exception of some small changes in notation. All the findings hold and the policy implications of state pension deferral remain the same.

To see how a decision to defer impacts on current and future labour supply as individual leisure preferences and wage rates vary needs a formal framework. We present this next. Individuals maximise a per period time additive concave utility function which depends on a single consumption good, c, and leisure L subject to their lifetime budget constraint:

$$\max_{c_{T-1},c_T,L_{T-1},L_T} u(c_{T-1},L_{T-1}) + \delta u(c_T, L_T) \tag{2.1}$$

$$\text{st } rc_{T-1} + c_T = rA_{T-1} + ry_{T-1} + y_T + rw_{T-1}(1 - L_{T-1}) + w_T(1 - L_T) = x \tag{2.2}$$

$$0 \leq L_t \leq 1$$

Here r is the real interest factor, A_{T-1} is financial assets at the start of the penultimate period, y_{T-1}, y_T, w_{T-1},w_T, L_{T-1} and L_T denote non-labour income, wages and leisure respectively in periods $T-1$ and T.[7] There is a fixed time endowment each period of one unit of time which can be used either for leisure or work. Non-labour income includes any pension that is actually received in that period and so depends on the deferral decision.

Should an individual defer their pension from $T-1$ to T? This depends on the present value of the stream of pension payments over the two periods with and without deferral. The individual will choose the option which has the higher present value. The pension flow available at $T-1$ is p per period. Thus if the individual has non-pension,non-labour income of y^0_{T-1}, y^0_T then without deferral they receive $y_{T-1} = y^0_{T-1} + p, y_T = y^0_T + p$. With deferral they receive $y_{T-1} = y^0_{T-1}, y_T = y^0_T + r_g p$ where r_g is the implicit interest rate set by the government in the terms of deferral.

If there is no uncertainty and no restrictions on borrowing or lending except that individuals cannot die in debt, only the present value of non-labour

[7] The deferral decision is generally considered a decision an individual makes when they first become eligible for state pension. The framework considered here models this at the individual level. However recent studies have shown evidence of co-ordination behaviour between couples in terms of the date of retirement and their labour supply behaviour due to factors such as joint complementarities in leisure (Schirle; 2008, Cribb et al. 2014). The existing framework does not consider spousal preferences or a household budget constraint. Given the empirical evidence suggesting the importance of these factors, future work should consider extending the framework to incorporate these.

income affects the maximum value of lifecycle utility, and optimal labour market decisions depend only on non-labour income through its present value. The implicit interest rate factor r_g is common to all individuals so variation amongst individuals in the decision to defer must be due to variation in the market interest rate available to individuals, and more generally to variation in borrowing constraints or other capital market imperfections, or to omitted issues like uncertainty over the length of life. The deferral decision only impacts achievable lifecycle utility through affecting the present value of wealth, x, available from $T-1$ onwards. This is total of non-labour income at each period t-1 and t. For simplicity we assume non-labour income at each period has two subcomponents: non-pension income (y) and pension income p. Non-labour income in t-1 earns a rate of return, r. Whether pension income is received in t-1 depends on whether an individual chooses to defer their pension or not. Deferral will be chosen iff it raises $x = ry_{T-1} + y_T$. Without deferral $x = r(y^0_{T-1}+p)+y^0_T+p$ while with deferral $x = ry^0_{T-1}+y^0_T+r_g p$. The individual is better off deferring iff $(1+r) < r_g$.

For an individual who does decide to defer, his lifecycle wealth increases from the date of deferral. To explore the effects of this on intertemporal labour supply and consumption we have to go further with solving the maximisation problem. Consumption each period must be interior:[8]

$$\frac{\partial u_{T-1}}{\partial c_{T-1}} = r\delta \frac{\partial u_T}{\partial c_T} \tag{2.3}$$

$$rc_{T-1} + c_T = x$$

For fixed values of L_{T-1}, L_T this gives a semi-indirect utility $v(L_{T-1}, L_T, x)$ which is increasing in all its arguments and also concave in the leisures of each period (see Appendix 8.2.1). The remaining problem for the individual is to choose optimal labour supply in each period:

$$\max_{L_T, L_{T-1}} v(L_{T-1}, L_T, x) \text{ st } 0 \leq L_i \leq 1$$

Our main focus is on the interaction between labour participation deci-

[8] Assuming that the marginal utility of consumption in any period becomes arbitrarily high as consumption in that period becomes very small

sions, saving and pension deferral so we focus on just full time and zero work options for each time period.[9] There are four possible configurations of labour participation over the final two periods of life: full time work in both periods, zero work in both periods or full time work in one period and zero work in the other.

Define the lifecycle full incomes at the start of $T-1$ corresponding to each lifetime pattern of labour participation (the subscripts refer to the amount of leisure in each period so e.g. 01 corresponds to full time work at $T-1$ but zero work at T):

$$\begin{aligned} X_{11} &= rA_{T-1} + ry_{T-1} + y_T = Z \\ X_{00} &= rA_{T-1} + ry_{T-1} + y_T + rw_{T-1} + w_T = Z + rw_{T-1} + w_T \\ X_{01} &= rA_{T-1} + ry_{T-1} + y_T + rw_{T-1} = Z + rw_{T-1} \\ X_{10} &= rA_{T-1} + ry_{T-1} + y_T + w_T = Z + w_T \end{aligned}$$

We have a ranking of the full incomes $X_{00} > X_{01} > X_{11}, X_{00} > X_{10} > X_{11}$.

The possible payoffs corresponding to these labour participation patterns are then $v(1,1,X_{11}), v(0,1,X_{01})$, $v(1,0,X_{10})$ and $v(0,0,X_{00})$. Where $V_{x,x}$ describes the value function corresponding to working the labour force regime x,x where $x,x \in \{0,0;0,1;1,1;1,0\}$. The value function depicts the maximal utilities i.e. it is the utility function which has been solved for optimal consumption, savings and labour supply. An individual chooses the value function which gives them the highest level of utility and in this sense they can rank alternative labour supply regimes.

Note that if $v(1,1,X_{11}) > v(0,1,X_{01})$, $v(1,0,X_{10})$ then $v(1,1,X_{11}) > v(0,0,X_{00})$ from the monotonicity of $v()$ in all its arguments.

The only differences in the full incomes between participation patterns are in the value of the time endowment which arises in periods of work and depends on the wages of those periods. A suitable idea of the time profile of reservation

[9] If we included interior solutions for labour participation there would be 9 configurations. The way of getting the "reservation wages" above would be similar eg suppose $0 < L_{T-1} < 1$ and $L_T = 0$. Let L^*_{T-1} solve

$$\frac{dv(L^*_{T-1},0,x)}{dL_{T-1}} = 0 \text{ and then require } \frac{dv(L^*_{T-1},0,x)}{dL_T} < 0$$

wages between any two alternative profiles of labour participation is a pair w_{T-1}, w_T giving indifference between the two patterns of labour participation. So with $Z = rA_{T-1} + ry_{T-1} + y_T$, we can define:

$$\begin{aligned}
V_{11} &= v(1,1,Z) = v(1,0,Z + w_T^{11,10}) = V_{10} \\
V_{01} &= v(0,1,Z + w_{T-1}^{01,10}) = v(1,0,Z + w_T^{01,10}) = V_{10} \\
V_{11} &= v(1,1,Z) = v(0,0,Z + rw_{T-1}^{00,10} + w_T^{00,10}) = V_{00} \\
V_{11} &= v(1,1,Z) = v(1,0,Z + w_{T-1}^{11,01}) = V_{01} \\
&\Rightarrow v(0,0,Z + rw_{T-1} + w_{10}^{11}) < v(1,0,Z + w_{10}^{11})
\end{aligned}$$

In general there may not exist finite positive wages ensuring these indifferences. But the general pattern of how lifecycle labour participation is determined is clear. For the pattern ij to be optimal (i.e. participation state i in period $T-1$ and j in T) we require that $V_{ij} > V_{kl}$ for each other possible participation profile kl. How the optimal participation profile varies with Z and current wages depends on the form of the utility. There are some basic results just from monotonicity of $v()$ in its arguments. Thus if $V_{11} = V_{10}$ then $V_{00} < V_{10}$. In general for a given Z and utility function, there will be a region of high wages in both periods where it is optimal to work full time in both periods (corresponding to $V_{00} > V_{10}, V_{01}, V_{11}$). Similarly there will be a region of low wages in both periods where it is not optimal to work in either period (corresponding to $V_{11} > V_{10}, V_{01}, V_{00}$). Finally there will be two regions: one with high wages in $T-1$ but low wages in T (corresponding to $V_{01} > V_{10}, V_{00}, V_{11}$), where it is optimal to work full time in $T-1$ but not work at all at T, and conversely a region of high wages at T but low wages at $T-1$ where it is optimal to stay out of the labour market at $T-1$ but work full time at T (corresponding to $V_{10} > V_{00}, V_{01}, V_{11}$). With given preferences, Z and wage rates of each period, the optimal profile of labour participation over the two periods is determined.

How will introduction of the deferral option affect the optimal participation profile? Deferral is only taken up if it raises the present value of non-labour income including the pension stream. This change in wealth changes the demand for leisure in each period. If leisure is a normal good, an increase in wealth increases the demand for leisure in each period. So we would generally expect a drop in work hours in each period when an individual prefers to defer. If an individual was planning full time work in each period in the absence of deferral but chooses to defer, then if their wage rates were close to the reservation wage in one of the periods (as computed above), with deferral his optimal profile may switch into zero work in that period. Disney and Smith (2002) consider the effects of relaxation of the earnings rule on labour supply participation of older workers in the UK. Their empirical results indicate that increasing generosity of work incentives, such as reducing the marginal tax rate on earnings for older workers increases the number of hours worked. This suggests strong income effects are at work, whereas in our model deferral has a direct wealth effect and under standard assumptions would act to increase the amount of leisure consumed.

To see the impact of pension deferral on lifecycle labour force participation we need to know more about the wage regions corresponding to different labour participation patterns and how these vary with Z. To determine this we have to resort to a specification of preferences which allows us to explicitly compute the labour participation areas and the ways in which they vary with Z. From this we can predict which parts of the intertemporal wage rate distribution will lead to a switch to zero hours of work in either or both of periods $T-1, T$ on introduction of the pension deferral option . We can then also see how deferral will impact on consumption and savings in different parts of the wage rate distribution.

2.3 Quasilinear utility

In this section we take a commonly used specification for the utility function (Gustman and Steinmeier, 2010; Blau, 2012), in which consumption, c, is isoelastic and labour, L, is quasilinear.[10] We derive optimal saving and labour supply regimes in each case. We find the channels through which pension deferral affects optimal labour supply. In this specification, remaining lifetime preferences are given by:

[10] Implying all income effects operate through leisure.

$$u(c_{T-1,}L_{T-1}) + \delta u(c_T, L_T) = \frac{C_{T-1}^{\alpha}}{\alpha} + h_{T-1}L_{T-1} + \delta(\frac{C_T^{\alpha}}{\alpha} + h_T L_T) \tag{2.4}$$

Where δ is the per period discount rate. In Appendix 8.2.2 we derive the savings function A_T as

$$A_T = \frac{x_{T-1} - (\delta r)^{1/(\alpha-1)}(y_T + w_T(1 - L_T)}{1 + r(\delta r)^{1/(\alpha-1)}}$$

where $x_{T-1} = rA_{T-1} + y_{T-1} + w_{T-1}(1 - L_{T-1})$.

The resulting value function is

$$v(K, w_{T-1}, w_T) = \frac{(K + rw_{T-1}(1 - L_{T-1})) + w_T(1 - L_T))^{\alpha}}{\alpha} D + h_{T-1}L_{T-1} + \delta h_T L_T$$

where

$$K = r(rA_{T-1} + y_{T-1}) + y_T, D = ((\delta r)^{\alpha/(\alpha-1)} + \delta)$$

The value function v, is isoelastic in disposable wealth at $T - 1$ and linear in present and future leisures. Quasilinearity in leisure given the wealth effect of pension deferral, means that the income effects fall solely on participation.

The maximal utilities obtained from the lifecycle labour force regime (define by the subscript notation) are defined as

$$V_{00}(K, w_{T-1}, w_T) = \frac{(K + rw_{T-1} + w_T)^{\alpha}}{\alpha} D$$

$$V_{01}(K, w_{T-1}) = \frac{(K + rw_{T-1})^{\alpha}}{\alpha} D + \delta h_T$$

$$V_{10}(K, w_T) = \frac{(K + w_T)^{\alpha}}{\alpha} D + h_{T-1}$$

$$V_{11}(K) = \frac{K^{\alpha}}{\alpha} D + h_{T-1} + \delta h_T$$

This allows us to define six combinations of wages w_{T-1}^i, w_T^i $i = 1..6$ which give indifference between pairs of maximal utility levels. Conditions (1)-(6) are derived from the (immediately) preceding value functions in the text. The way this is done is a follows: For each $V_{x,x}$, where V is the value function and x, x represents the optimal labour supply configuration there is a wage combination (or a single wage depending on the comparison in question) which makes an individual just indifferent between the two labour supply configurations. The way to solve for these wage combinations is to equate each value function with every other (in a piecewise manner) and in each case solve for the wage. This is done in Appendix 8.2.3 and 8.2.4.

$$
\begin{aligned}
(1) V_{00}(K, w_{T-1}^1, w_T) &= V_{01}(K, w_{T-1}^1) \\
(2) V_{00}(K, w_{T-1}^2, w_T^2) &= V_{10}(K, w_T^2) \\
(3) V_{00}(K, w_{T-1}^3, w_T^3) &= V_{11}(K) \\
(4) \qquad V_{01}(K, w_{T-1}^4) &= V_{10}(K, w_T^4) \\
(5) \qquad V_{01}(K, w_{T-1}^5) &= V_{11}(K) \\
(6) \qquad V_{10}(K, w_T^6) &= V_{11}(K)
\end{aligned}
$$

Appendix 8.2.3 and 8.2.4 show that the critical wage combinations are related as depicted in Figure 2.1, and that all the intersections of regions exist at finite positive wages. Figure 2.1 correspond to the reservation wages w_{T-1}^i, w_T^i $i = 1..6$ giving indifference between pairs of maximal utility levels. i.e. value functions. The various pairwise comparisons are those given by expressions (1)-(6). Appendix 8.2.3 and 8.2.4 show that in order to derive the indifference curves, one must equate a pair of value functions and solve for the wage (or wages) in each case. These are then implicitly plotted in Figure 2.10 in order to show how the indifference curves behave over a defined wage region. Next, by making direct comparisons between the different curves (in terms of which offers the highest utility results) the optimal labour supply region is defined as per Figure 2.2.

Using monotonicity of the value function expressions in the wage rates, we can deduce regions of the wage space in which different intertemporal labour participation patterns are optimal as shown in Figure 2.2. The boundaries between the regions in Figure 2.2 correspond to the relevant parts of the lines in Figure 2.1: $(1), (2)$ giving lower bounds on full time work, $(5), (6)$ giving upper bounds on the zero work region and 4 giving the division between working either just in $T-1$ or in T.

Figure 2.1: Reservation wages which give indifference between pairs of maximal utility levels.

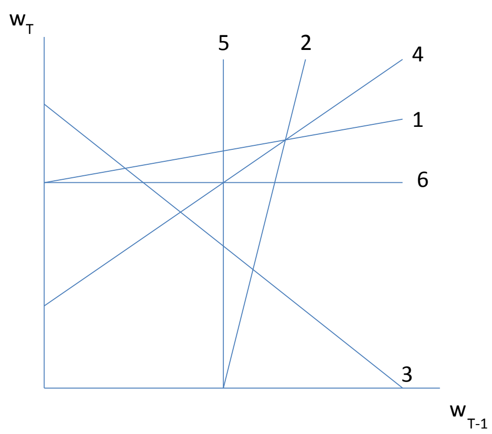
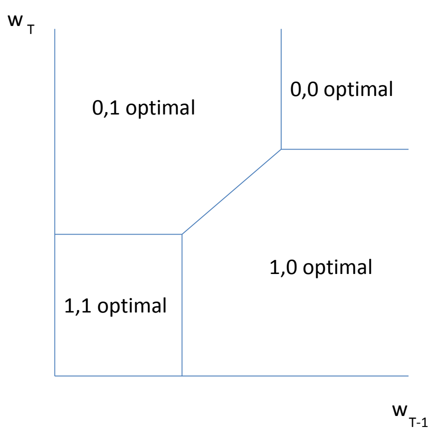


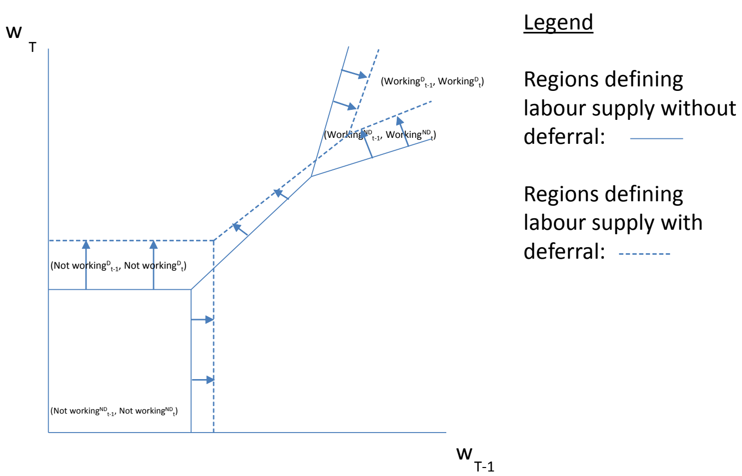
Figure 2.2: Optimal lifecycle participation profiles.



2.3.1 The effect of pension deferral on labour force participation.

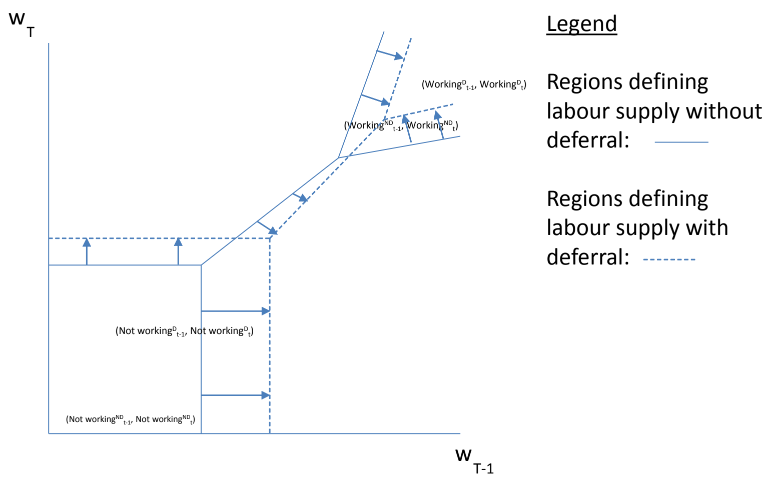
To examine the impact of pension deferral which raises the present value of non-labour income on lifecycle labour participation, we show how Figure 2.2 changes with K. Appendix 8.2.5 shows that the effect on the optimal labour participation profile of an increase in K depends on whether the utility value of leisure is higher in $T-1$ or T. In both cases the wage region with zero work in both periods expands and that with full time work in both periods contracts. But if the value of leisure is higher in period T than $T-1$, the wage region with full time work only at $T-1$ expands at the expense of the wage region with full time work only in T (as in Figure 2.3). Conversely if the value of leisure is higher in $T-1$ than T, the wage region with full time work at T expands at the expense of the wage region with full time work only in $T-1$ (as in Figure 2.4).

Figure 2.3: Increase in non labour income $h_{T-1} < \delta h_T$.



If the option to defer is suddenly introduced or taken up, or is made more generous, the present value of non-labour income increases. We can deduce the likely effects on lifecycle participation profiles. If leisure is more valuable in period $T-1$, the increase in K will tend to reduce full time work in $T-1$. A proportion of those individuals who were working full time in both periods may switch to only working in period T and some of those who previously only

Figure 2.4: Increase in non labour income $h_{T-1} > \delta h_T$.



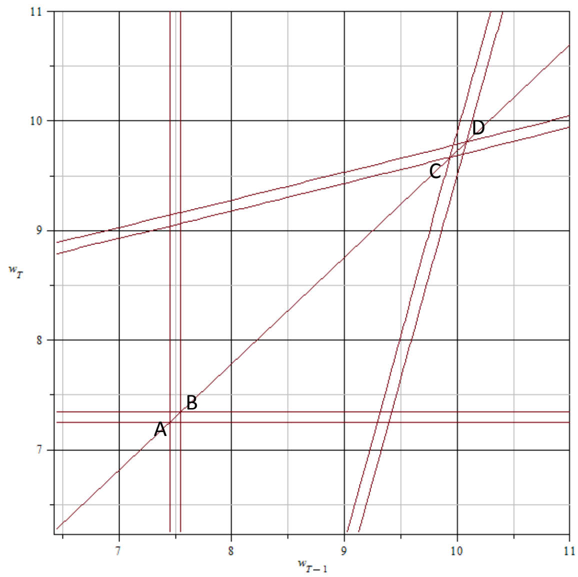
worked in $T-1$ may switch to only working in T. But some who previously only worked in T may switch into inactivity in both periods. Thus with leisure more valuable in $T-1$, the increase in the value of the deferred pension unambiguously reduces the number of full time workers in $T-1$, but may raise or lower it in period T. If the value of leisure is higher in period T, the opposite effects occur: the number of full time workers in T unambiguously falls while the number of full time workers in $T-1$ may fall or rise depending on the distribution of the lifecycle wages w_{T-1}, w_t in the population.

The wealth change caused by deferral has participation effects on individuals close to the reservation wage in one period at least. However labour force participation is unaffected by the presence of pension deferral for those who earn sufficiently above the relevant critical wage defining full time work. In the next subsection we simulate the effect of pension deferral implied by our framework.

Stylised simulation: defer or not defer?

Having considered the theoretical effects of pension deferral within our framework, we turn to a numerical simulation. In order to calibrate our model we use a mixture of assumed parameters available in the literature and those inferred from secondary data. Following the work of Attanasio et al. (2008) we set the relative risk parameter α to -0.5, we assume annual (non housing) wealth holding of £1500, weekly total non-labour income (for example the total of private and state pension) of £350 under no deferral and £365 under deferral.[11] [12] We assume individuals work 40 hours per week, can earn an annual rate of return of 3% in the free market and have a discount rate of 0.95. We set the marginal value of leisure in the penultimate period and terminal period of 0.006 and 0.00630 respectively (an increase of 5%).[13] In doing so we replicate the effects of Figure 2.3 more clearly i.e. assuming $h_{T-1} < \delta h_T$ as shown Figure 2.5.

Figure 2.5: Wage co-ordinates defining zero and full time work.



By deferring one period the required wages to be in a given labour supply regime increase in each period. In the case of zero work this is shown by the curves shifting from point A to point B, whereas for full time work the corresponding loci shifts from point C to point D. Under the no deferral option the

[11] Isoelastic utility implies constant relative risk aversion.

[12] The lack of secondary data providing average weekly pension payments meant we had to assume figures for weekly non labour income. Administrative data from the Annual Survey of Hours and Earnings (ASHE) show median gross earnings for employed individuals in April 2013 was £517 per week (ONS, 2013). Hence under no deferral we assumed non labour income (including employer and state pension) replaced 67% of weekly preretirement gross labour income.

[13] This value generates an optimal labour income/asset ratio of about 30%, reservation wages for zero work at a little above the UK minimum wage and for switching from part-time to full time of about one and a half times the minimum wage.

wage rate required to be in zero work at $(T-1, T)$ is $(£7.25_{T-1}, £7.45_{T})$ respectively, whilst under deferral it rises to $(£7.34_{T-1}, £7.54_{T})$. Similarly for full time work at $(T-1, T)$ the corresponding wage rates are $(£11.75_{T-1}, £10.95_{T})$, under deferral these increase to $(£12.02_{T-1}, £11.21_{T})$. The effect of pension deferral therefore raises the full time reservation wage by around 1.5% assuming the above parameters. In various simulations the average rise in the full time reservation wage for a 12 month deferral is around 2%, the particular example given has a zero work reservation wage close to the National Minimum Wage (NMW). Implicitly in the calibration the change in reservation wage on deferral is for deferral lasting one year. As the period of deferral increases beyond this, the reservation wage difference will rise. The relative slopes of the participation regime boundaries and their shifts principally depends on the difference between the value of non-labour income by deferring and the difference in the marginal value of leisure in each period.

Empirical relevance of pension deferral The stylised simulation showed that deferral is financially beneficial for all full time workers who earn more than approximately £11 per hour. We pool four waves of data from the UKLFS between the years 2008 and 2013 to determine the wage distributions (conditional on being in work) for women aged between 60 and 65, and men aged between 65 and 70.[14] We restrict our sample to these age ranges as they cover the state retirement age and hence the period when an individuals usually makes the decision to defer their pension. It is important to note that the decision to work and the deferral decision are independent (except for the implications on income tax). Our final sample consists of 483 individuals. Figures 2.6 and 2.7 depict their wages.

[14] We ensure there is no overlap in the surveys to ensure our sample does not contain any repeated observations. We include individuals working below full time hours to boost sample size, noting that the mean wage for full time and part time workers in this age category are roughly equal.

Figure 2.6: Female Wage Distribution: Ages 60-65 (2008-2013).

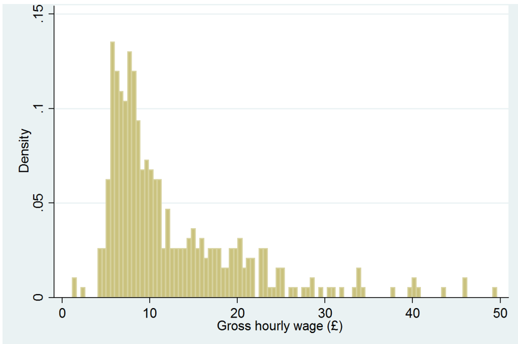
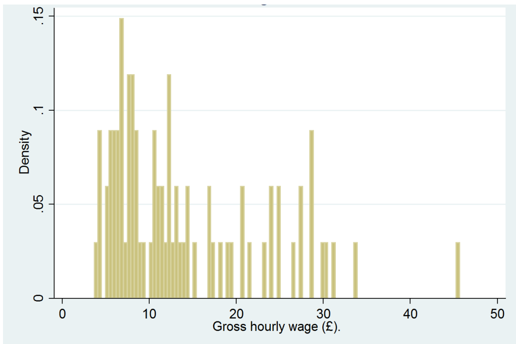


Figure 2.7: Male Wage Distribution: Ages 65-70 (2008-2013).



It is clear that a significant proportion, around 40% of females and more than 50% males in our sample earn more than £11 per hour, therefore deferral policy is an important component of the labour supply decision for a large proportion of older workers. Indeed a recent DWP report (2008) suggested that individuals tend to coordinate their labour supply and deferral decision. They found 79% of deliberate deferrers were in paid work and tended to maintain their preretirement hours, primarily full time, after deferral.[15] Family decisions were important so a partner continuing in work or uncertainty of life expectation made deferral more likely, as did the desire to avoid liability for a higher income tax rate. Given that state pension deferral is likely to become increasingly important in the face of population ageing and longevity, then it is of equal importance to analyse the choice between an increment in weekly

[15]In terms of our UKLFS sample, whilst we do not observe the deferral decision we do observe hours worked. The median male individual worked 34.5 hours per week whilst for females the figure is 24. The minimum and maximum weekly hours worked ranged from 3 to 68 for males and from 6.5 to 55 for females.

state pension or a lump sum payment, we turn to this in the next section.

2.4 UK State Pension & Deferral

2.4.1 Which Deferral Option is Best?

In a multiperiod setting the decision becomes one of choosing both if to defer and, if so, for how many periods. In this section we simulate the present value of an individuals state pension pot at the date of undeferral, under both the incremental and lump sum option for deferral over a varying number of years.

On reaching SRA an individual can choose whether to take up the state pension or defer it from that date. They do not have to precommit to a length of deferral but at any future date can ask for their pension to start from then on.[16] If an individual chooses to defer their pension, then current rules mean that for every five weeks an individual defers, their weekly State Pension increases by 1%, this is equivalent to a 10.4% rate of return for each full year of deferral. Alternatively an individual may also defer their State Pension and receive a lump sum payment.[17] [18] If an individual chooses to take the latter option, the lump sum they receive is the value of their past deferred weekly pension payments accumulated at an interest rate of at least 2% above the Bank of England base rate.[19] Depending on the life expectancy of the individual there is no clear answer as to which option is more lucrative, however given the increasing life expectancy observed in the past 30 years, it is generally considered that the incremental option offers a higher rate of return (Farrar et al., 2012).

[16]This not true for the lump sum option, in which case the individual must defer for at least 52 weeks.

[17]Extra State Pension and lump sum payment are both taxed. In addition if you choose to defer then this will impact means tested benefits, whereas if you choose to recieve a lump sum, this will not affect certain means tested benefits.

[18]Since it's inception there has been various changes to legilsation regarding how the rate of return on the deferral option is formulated, and the introduction of the lump sum option in 2006. For a more detailed description of these changes see Bozio et al (2010).

[19]In terms of pension deferral one of the biggest changes of the move to a single tier pension is that the lump sum option will be scrapped and only the incremental option will be available to those who defer (White Paper 2013). At the time of writing the actual generosity of the incremental option is yet to be decided, however is believed to be in the region of half its current generosity (FT, September 2013).

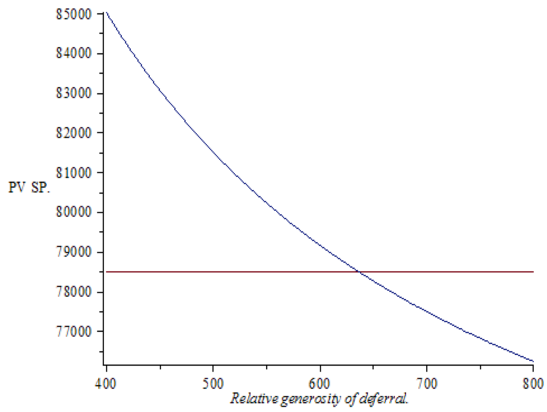
At the point of reinstatement of a deferred pension S, the present value of the extra weekly payment coming from the deferral is $x(1 + 1.01 + 1.01^2 + ..1.01^\tau)(1 + (1 + r)^{-1} + ..(1 + r)^{T-S})$ where τ is the number of months for which the pension has been deferred between SRA and age at S, x is the original weekly pension payable at SRA, r is a constant market interest rate and T is the date of death. On the other hand the lump sum payable at S is $x(1 + 1 + \rho + (1 + \rho)^2 + ..(1 + \rho)^\tau)$ where ρ is at least 2% above bank base rate.

We plot the present value under each option in Figures 2.8 and 2.9. In Figure 2.8 we vary the generosity of the incremental option, i.e. the length of time it takes to earn a 1% increase in an individuals weekly state pension. Whilst in Figure 2.9 we vary the length of the period from the date of undeferral to death. It is these two factors which to a large extent dictate the Present Value (PV) of the deferred pension. To show this we set all other parameter values as follows: initial weekly state pension of £100, weekly interest rate on lump sum option equal to $\frac{0.05}{52}$, post undeferral weekly net rate of return equal to $\frac{0.02}{52}$ and deferral period equal to two years.

(i) Varying rate of return on incremental option Figure 2.8 shows the effect of changing the rate of return or relative generosity, assuming an individual lives for 15 years following the date of undeferral. The sloping curve represents the deferred income option whilst the flat curve corresponds to the lump sum option.

The break even of point for the PV of the pension is at a rate of return of about 1% for every 6.25 weeks deferred. Under existing rules the current rate of return is a 1% increment for every 5 weeks deferred, and therefore in this example it is worth approximately £3000 to the individual to choose the deferred income option. However if the individual was credit constrained then it could be the case that they require the lump sum to clear some debt, e.g. an outstanding mortgage. Putting this into context, during the 1970s when the contribution rate was approximately 1% for every 7-8 weeks deferred, and individuals had a shorter life span (see Figure 2.10), the lump sum option would have been more lucrative had it been available. A recent government announcement to scrap the lump sum option and reduce the generosity of the incremental option by half would leave individuals worse off, however the proposed rate of return on the incremental option is still in excess of the free market rate.

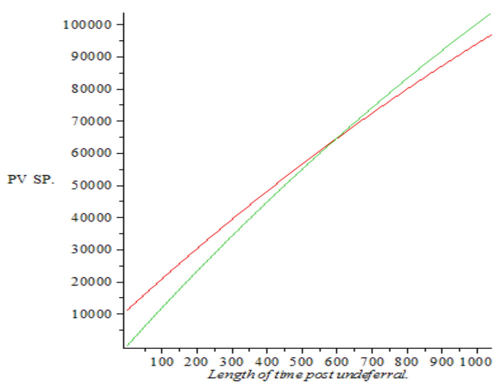
Figure 2.8: Varying the contribution factor.



Notes: The X-axis measures the number of weeks (multiplied by 100) required for an individual to defer their state pension in order for them to receive an additional £1 extra a week upon undeferral.

(ii) Varying life span from undeferral date Figure 2.9 shows the effect of increasing longevity under the incremental option (green) and lump sum option (red), assuming parameters of the current legislation.

Figure 2.9: Varying individuals life expectancy.



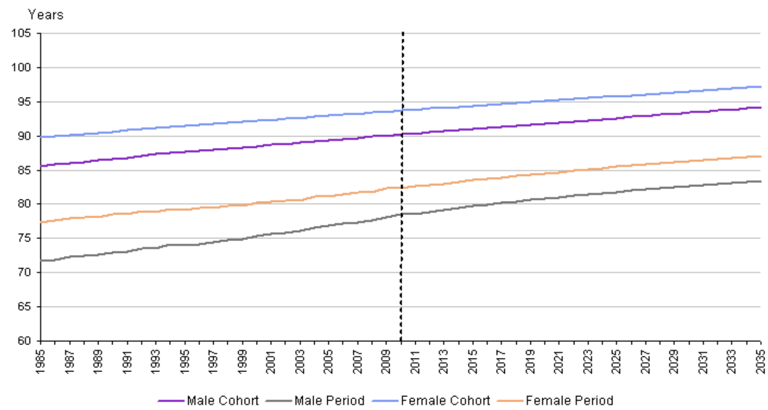
Notes: X-axis refers the duration (in weeks) of the deferral period.

Intuitively, the PV for those who only live a short period after they undefer are much better off choosing the lump sum option. However it is clear that the deferred income option is more lucrative provided an individual lives for approximately 12 years or more after they undefer.

The Office for National Statistics (2011) published current and projected life expectancy tables by gender in the UK covering the period 1985 to 2035. Over this period it is quite clear life expectancy has increased substantially, for both cohort and period groups. Period life expectancy refers to the life expectancy for those individuals in a given calendar year (ONS, 2011a). Hence in 2013 females are expected to live until 83 years of age on average. In contrast, cohort life expectancy at birth is calculated using age-specific mortality rates which allow for known or projected changes in mortality throughout a person's life (ONS, 2011b). Which implies a female born in 2013 is expected to live until 94 years of age.

Supposing an individual reaches their life expectancy, Figure 2.10 implies the deferred income option is more lucrative for both current and future retirees, so long as the relative generosity of this option is not changed.[20]

Figure 2.10: Cohort and period life expectancy men and women.



Source: ONS (2011a).

Farrar et al. (2012) compare the two undeferral options relative to not deferring and investing at the market rate, in most policy simulations deferral

[20] Along with the introduction of the single tier pension, the White Paper (2013) also notes potential changes to the relative generosity of the incremental income option. The Financial Times reported the implied interest rate is likely to be half the current annual rate of 10.4% (FT, September 2013).

of any kind is preferred over non deferral.[21] Similar to Disney and Smith (2002) and our own model, Farrar et al. (2012) assume individuals face no borrowing constraints. Deferral would not be optimal if individuals could not borrow against their future income. Assuming individuals reach their life expectancy, then the incremental option tended to offer a higher rate of return in most simulated examples, the post-tax deferral state pension income stream. Ferrar et al. (2012) show the 10.4% interest payment substantially exceeded the break even interest rate required for the incremental and lump sum option to be of equal PV.

Coleman et al (2008) analyse the characteristics of deferrers versus those who claim state pension at SPA. Their results suggest deferrers are mainly high earners who had good financial knowledge of the deferral option (hence the majority of them chose the deferred income option), and either they or their partner tended to continue engaging with paid work post SPA. These individuals reported they were financially comfortable during the deferral period. This suggests the employment and deferral decision may well be jointly determined, and it is unlikely deferrers are from credit constrained households. More recent data from waves four and five from the English Longitudinal Study of Ageing (ELSA), spanning the years 2008-2013 also contain information on state pension deferral, despite small sample sizes those who do defer tend to have worked in professional, managerial or skilled non manual occupations. These individuals are more likely to choose the deferred income option, and tend to defer their state pension for between 1 and 5 years.[22]

2.4.2 Prevalence of pension deferral

A recent Freedom of Information Request released by the DWP showed between September 2009-2010 approximately $66,300$ individuals deferred their pension.[23] Of this total roughly just over one third took the increment option, whilst nearly half took the lump sum option, the remainder took a mixture of

[21] In their paper the authors worked in continous time and do not consider a formal model of labour force participation.

[22] Occupation data is fed forward to wave one of ELSA from the Health Survey for England data, from which the original ELSA sample is derived.

[23] Freedom of Information request catalogue number (2773/2011).

the two.[24] Of the total number of individuals eligible to claim their state pension, roughly 1 in 10 chose to defer their pension. Coleman et al (2008) using administrative data surveyed individuals who were approaching or had reached SPA, and found only a low level of respondents, 65%, knew of the option to defer. This proportion only increased slightly after SPA. The main reasons cited were due time constraints and it being the 'spouses responsibility', lack of interest or confidence in financial matters. Therefore despite roughly 1 in 10 individuals deferring it is likely with increased awareness (one of the central aims of the 2013 White Paper) this proportion will rise.[25]

2.5 Future work

Chapter two modelled the State Pension deferral decision. The current framework is set within a two period model, to reflect the decision process at SPA. Whilst extending the framework to a multiperiod setting may seem appealing and is certainly feasible, the elegance the current framework is that it is able to capture the effects of SP deferral with only two periods.

We considered the deferral decision and its impact on labour supply restricting attention to corner solutions. The reason for this is to determine whether there is a significant change in labour force regimes in the presence of the deferral option. It would be possible to allow for a greater variety of potential labour market combinations, such as considering interior solutions which may give a more true reflection of the type of labour force behaviour around this particular phase in the lifecycle, however this would not alter our main results.[26] Indeed the Department for Business Innovation and Skills (June 2014) have announced legislation to make it compulsory for individuals to be

[24] FOI DWP (2011) pp.2 notes: New rules for deferral came into effect in April 2005 and lump payments became available from April 2006. A person who deferred their State Pension before April 2005 would qualify for increments for the period up to April 2005 and may have a choice of either a lump sum payment or an increment for the period of deferral from April 2005. This means some people may have both an increment and a lump sum payment. The lump sum option is only available to those who have deferred continuously for at least 12 months. The numbers do not include those who deferred for less than 12 months and opted for simple arrears instead of increments.

[25] Options to allow increased flexibility of defering and undefering multiple times are also being considered by the DWP (White Paper 2013).

[26] Banks and Smith (2006) note that partial retirement is not particularly common in the UK relative to the US.

allowed to request flexible working hours which is likely to facilitate phased retirement.

We have assumed older households do not face credit constraints, however this may not strictly be true for all older households (Le Blanc et al., 2014). The current framework assumes there are no credit constraints and capital markets work efficiently. Future research considers whether credit constraints affect the labour supply and/or deferral decision.

The fact we have considered corner solutions means there is the possibility for individuals to move from retirement back into paid work, so called unretirement (Maestas, 2010). We assume this is cost free, however it may be the case for those out of the labour market it is more costly in terms of retraining due to depreciation of human capital. In ongoing work we formally account for this by introducing a switching cost for those individuals for whom it is optimal to unretire.

As in chapter one we assume individuals have perfect foresight. It may be possible to incorporate particular forms of uncertainty in our model which may better reflect the true decision making process.

2.6 Conclusion and policy implications

In this chapter we develop a lifecycle model to analyse the joint decision of pension deferral and intertemporal labour supply. Contrary to the policy aim of pension deferral which is to extend working lives, our theoretical model indicates pension deferral acts to raise the reservation wage and reduce the likelihood of labour force participation. This is conditional on assuming leisure is a normal good. Economic theory would imply a rise in the PV of wealth would cause the individual to consume more leisure all else equal. The exact direction in which labour force changes in a two period framework depends on the marginal value of leisure in each period and its change over time. There are clear qualitative effects, depending on wage profile, non-labour wealth and preferences, introduction of a pension deferral scheme can tilt labour participation towards the present or future.

Our numerical simulation and empirical evidence suggest that the deferral policy affects a large proportion of the older working population. As a ballpark figure the option changes the reservation wages by about 2.5%. Similar to Farrar et al. (2012) our results indicate (1) Pension deferral is optimal in the absence of credit constraints and (2) Of the deferral options available, the incremental income option is more lucrative. Combined with the results of Coleman et al. (2008) the existing body of evidence suggests deferral take up is concentrated amongst higher income groups and those who are more financially literate, both of which are likely to be positively correlated. Empirical evidence suggests deferral and labour supply is treated as a joint decision, despite legislation implying they are independent.

The recent UK announcement of a move to a single tier pension system will have a number of financial implications for those approaching retirement and future generations (Crawford et al., 2013). This includes changes to the rules governing pension deferral, the most significant of which relate to the abolition of the lump sum option and reduction in the generosity of the incremental option (the implied annual interest rate on deferrals will halve from 10.4% to 5.2%). Nonetheless at present one in ten retirees chooses to defer their state pension; the institutional focus to extend working lives in the face of increasing longevity means research into understanding the effects of pension deferral from a theoretical and policy viewpoint are of paramount importance.

Chapter 3

Lifetime Labour Market Activity and Retirement Decisions: Evidence from ELSA.

3.1 Introduction

A long line of research has attempted to address the determinants of retirement (Quinn, 1977; Fields & Mitchell, 1982; Dwyer and Mitchell, 1999; Gustman and Steinmeier, 2004).[1] However relatively little attention has been paid to the role of lifetime labour market experiences in relation to time spent in employment, unemployment and inactivity, and how it may affect the retirement decision.[2] Lifetime labour market experiences have important implications for retirement behaviour given that retirement income tends to be a function of labour market income deferred from an earlier period.

The primary aim of this chapter is to understand the role of work life his-

[1] For a comprehensive review of modelling the retirement decision see Lazear (1986).

[2] The work of Nicholls (2010) and Miniciani et al. (1998) is closest to ours; however the main focus of his paper is to determine the effect of work life histories on pensioner poverty i.e. for those already in retirement. Nicholls (2010) uses a multinomial framework and therefore cannot ascertain any effects of duration dependence, nor does he account for unobserved heterogeneity. Miniciani et al. (1998) explicitly focus on the effects of lifetime unemployment and retirement using British Household Panel Survey (BHPS).

A non-exhaustive list of closely related work includes: Bardasi & Jenkins, (2002); Bozio, Emmerson, O'Dea & Tetlow, (2010); Bozio, Emmerson, O'Dea & Tetlow, (2011); Bozio, Emmerson & Tetlow, (2011); DeWilde, (2012).

tories on the retirement and early retirement decision. We use panel data from the English Longitudinal Study of Ageing (ELSA), which collects information on a representative sample of English private households aged 50 and over to estimate discrete time hazard models of retirement and early retirement. We control for a range of sociodemographic and economic characteristics, including data on pension wealth. In line with previous research we also control for unobserved heterogeneity which may be present given the lifestage of our sample members and may affect our estimation results (Meghir and Whitehouse, 1997; Nicolleti, 2006; Emmanouilidi and Kyriazidou, 2012). We investigate differences by income quintile and gender to show the differential impact these factors have in relation to (early) retirement.

Our results suggest episodes of unemployment and economic inactivity play an important role in the retirement and early retirement decision. In most specifications experiencing episodes out of the labour market tends to significantly lower the hazard of (early) retirement. Conditional on controlling for incidents out of the labour market spending lower proportions of potential labour market experience in employment tends to raise the hazard of retirement, particularly for men. The way in which lifetime labour market history affects retirement tends to differ across the income distribution. In addition to labour market history, the level of pension wealth an individual and their spouse has is also an important factor in the retirement decision. However, the relationship is not symmetric; our results indicate that the husbands pension wealth seems to play a more significant role in the wives retirement decision, whilst the same is not true vice versa. Alongside pension wealth the type of pension held is also important, we find the hazard of retirement is lower for those contributing to an employer or private pension. Finally, episodes of poor lifetime and baseline health tend to raise the hazard of (early) retirement, particularly for men.

The rest of this chapter is set out as follows: Section 3.2 provides an overview of the policy context; Section 3.3 reviews existing literature; Section 3.4 describes our methods; Section 3.5 describes our data and provides summary information regarding our sample; estimation results are presented and discussed in Section 3.6, by gender and income position and then for the specific case of early retirement; Section 3.7 considers policy implications of our results; Section 3.8 considers future work and Section 3.9 concludes.

3.2 Policy Context

Population ageing is an issue for the UK. The 2011 Census highlighted that 1 in 6 individuals in the UK is now aged above 65 (ONS, 2013b). Between 2002 and 2010 the number of additional years a male aged 65 should expect to live increased from 16 to 18.03 years and similarly for women from 19.08 to 20.62 years (ONS, 2011b). One consequence of ageing (which can be primarily attributable to advances in health technology and nutrition) is that individuals can spend more time in retirement assuming they have sufficient wealth to sustain their preferred level of consumption. However, adverse effects of ageing do exist and have been exacerbated by lower fertility rates. In the UK, the fertility rate has fallen from 2.71 children per female in 1960 to 1.64 in 2002, since which it has subsequently rose to 1.98 in 2010 (ONS, 2013c).[3] This is reflected in the dependency ratio, defined as the number of working age individuals divided by the number of those aged over State Pension Age (SPA). In the UK this fraction is projected to rise from approximately $\frac{10}{3}$ in 2010 to $\frac{10}{3.5}$ by 2031 (ONS, 2010). These statistics show ageing is and will have a significant impact on individual's lives. Understanding the determinants of (early) retirement in the UK is therefore of vital importance for central government if they are to alleviate the fiscal implications of population ageing in the future.

Retirement in the United Kingdom (UK) has traditionally been considered as a discrete transition from a career job to full retirement at or before SPA (Meghir and Whitehouse, 1997; Banks and Smith, 2006). Kohli (1991) suggests the social norm for retirement in the UK is the cessation of paid work, nonetheless much controversy surrounds the precise definition (Gustman and Steinmeier, 2000; Smith, 2006). In part this is due to the fact that labour market behaviour around 'retirement' has changed. Starting in the United States (US) during the 1960s and 1970s, individuals began to gradually reduce the number of hours they worked in the labour market before retiring fully. This gradual reduction (which required a job change at the time due to social security rules) gave rise to the so called 'bridge job' or partial retire-

[3] Where total fertility rate is defined as: the average number of live children that a group of women would bear if they experienced the age specific fertility rates of the calendar year in question throughout their childbearing lifespan.

ment. Population ageing and longevity are factors which are likely to alter the labour market behaviour at older ages, and this has led to a change in the way academics and policymakers view retirement.

In the UK, the 2010 British Conservative-Liberal Democrat coalition government bought forward plans (outlined in the Pension Act 2011) to align the SPA of women to that of men by November 2018. Government have also legislated to bring forward plans to increase the SPA for all individuals to 67 years of age between 2026-2028, which had initially been timetabled to be introduced between 2034-2036.[4] The reason for such drastic measures is highlighted by recent ONS (2010) forecasts, which indicate the dependency ratio (as defined earlier) is predicted to nearly double to $\frac{10}{5}$ by 2051 if the SPA is left unchanged. Whilst the eligibility age at which SP receipt is being increased, the age at which individuals may begin to draw down an occupational or private pension remains substantially below the SPA. Until April 2010 individuals were eligible to claim their private pension at the age of 50, since which it has been raised to 55 which still remains 10 years below SPA for males.

In an effort to simultaneously reduce pensioner poverty and the fiscal burden of ageing population, the 2010 British Conservative-Liberal Democrat coalition government legislated an entire overhaul of the state pension system to a single tier system set to come into force in 2017. One of the main changes relates to an increase in the number of 'qualifying years' (from 30 to 35) of national insurance contributions, in order for an individual to be eligible for a full state pension. Depending on how episodes out of the labour market impact the hazard of retirement will mean the forthcoming changes in retirement legislation may potentially have adverse consequences. If time spent out of the labour market due to unemployment and inactivity raises the hazard of (early) retirement, then ceteris paribus the forthcoming changes to the state pension system will have a detrimental effect on retirement income and lead to an increase welfare dependence and pensioner poverty in old age.[5,6]

[4] Information accessed via: https://www.gov.uk/changes-state-pension (04/06/2013).

[5] Maes (2013) shows that the absence of effective active labour market policies in Belgium (implying time out of the labour market lead to increased worklessness) increased the likelihood of being in old age poverty. The UK spends a significantly smaller amount on active labour market policies (as a proportion of GDP) relative to continental countries such as Germany or the Netherlands (OECD, 2013).

[6] The 2010 UK coalition government has overhauled a range of existing active labour

3.3 Literature review

As noted at the outset, relatively little research effort has been focused on understanding the affects of lifetime labour market experience on labour supply behaviour at older ages. The focus of previous research has tended to concentrate on the determinants of financial position, namely poverty, in retirement (Nicholls, 2010; Bozio et al. 2010, 2011). Banks and Smith (2006) show that one method to reduce poverty at older ages is to increase coverage of occupational pensions. However, until recently these have been traditionally concentrated amongst professional occupations, which have in part led to the increasing incidence of early retirement (Tanner, 1998; Blundell, Meghir & Smith, 2002).[7] The 2008 and 2010 Pension Acts aim to mitigate the effect of pensioner poverty by ensuring all employees have access to a workplace pension. This is unlikely to curtail the incentive to retire early given individuals are eligible to claim workplace pensions at 55 years of age, well below the current state retirement age.[8]

An alternative reason for an individual to experience poverty in retirement is if they were forced to retire early. Dorn & Sousa-Poza (2010) find one third of UK early retirement episodes are involuntary, due to factors such as economic recessions and strict employment protection legislation. The Equality Act 2010 includes legislation to ensure age based discrimination is not present in the workplace, in order to reduce the extent of involuntary retirement.[9] Whilst this will help empower older people and reduce the fiscal burden of retirement on the state, it may have detrimental consequences such as preventing younger people enter or progress in the labour market, although empirical evidence suggests this effect is weak (Banks et al., 2010; Banks et al., 2010; European Parliament, 2013). Indeed the Conservative British government of the 1980s allowed older workers to retire early and receive benefits under the Job Release Scheme (JRS), in exchange for a guarantee that their job was filled by an

market policies, however early evidence of the new programmes is currently unavailable.

[7] An early investigation on the role of social security and early retirement in the US can be found in Quinn (1977).

[8] Moreover given The Pension Act has only recently been introduced it is unlikely to affect the retirement behaviour of current cohorts approaching retirement.

[9] Evaluation on its effectiveness is unavailable at the time of writing.

unemployed individual who was commonly younger (Kohli et al., 1991).[10]

In the context of labour market experience of older workers and early retirement, the recession of the 1980s was concentrated in particular primary sectors such as manufacturing and mining.[11] Nickell (1997) argues that over this period labour market policies pushed individuals onto incapacity, long term unemployment or sickness benefits, particularly older workers in the manufacturing sector which through worklessness and schemes such as the JRS led to increased levels of early retirement. This clearly affects how attached individuals would have felt to the labour market and by raising the likelihood of early retirement, increases the chances of having inadequate financial resources in retirement. Blundell et al. (2002) find evidence to support an increasing trend in early retirement amongst British men in the UK; the proportion of males employed aged 60-64 halved from 80% in 1968 to less than 40% by the end of the 1990s.

Lower levels of labour force attachment during one's working life is also likely to be related to financial position in retirement. Maes (2013) using Belgium administrative data finds working life poverty associated with being on unemployment benefits impacts future poverty in retirement. Additionally early retirement incentives and a lack of active labour market policies for unemployed older workers tended to increase the likelihood of experiencing poverty at older ages. García-Pérez (2013) argues economic incentives including the role of unemployment and pension incentives play an important role in determining the retirement decision. His findings suggest these factors should be accounted for whilst controlling for unobserved heterogeneity. Meghir and Whitehouse (1997) model early retirement transitions for British men using non-parametric and parametric models, allowing for state and duration dependence whilst also accounting for unobserved heterogeneity. Their work also controls for labour market history using measures of pension con-

[10] The JRS scheme initially targeted 'Assisted Areas' defined as specific areas where unemployment was more prevalent. Its expansion during the 1980s was partially in response to macro factors such as the economic recession which led to structural changes in the British labour market.

[11] Dorn & Sousa-Poza (2010) argue countries with a relatively inflexible labour market such as Northern European (and was true for the UK in the 1980s), tend to fare worse off in economic recessions. It could be argued that there was a reduction in labour market regulation and employment protection due to the relative fall in power of trade unions under the Thatcher government (Nickell, 1997).

tributions from linked administrative data. Our approach differs in that we consider early retirement and retirement past SPA separately for both men and women. The labour force attachment of women has grown significantly in the past thirty years and warrants attention. Moreover our sample size is more than double that of Meghir and Whitehouse (1997) and makes use of five waves of longitudinal data whereas they restrict attention to one cross section of the Retirement and Retirement Plans data. Nonetheless, a common theme in all these papers is that employment history is likely to play a crucial role in the retirement decision.

3.4 Methods

We model the retirement decision using the duration approach of Jenkins (1995) analogous to the strategy used in Jones et al. (2010). The ELSA dataset provides information on respondents age, calendar month and year of interview and calendar month and year of retirement. From this information it is possible to derive accurate measures of the total time at 'risk' until first retirement. Data has been reorganised to account for period at risk of event in this case the age at which retirement takes place. This leads to an unbalanced panel setup and permits a complicated likelihood to be reduced to an estimation for a binary outcome (Jones et al., 2010).

We specify a piecewise constant baseline hazard which is a step function of the age of our stock sample of men and women.[12] The reason the baseline hazard is a step function of age is to account for the period at risk, i.e. we assume individuals become at risk when they reach age 50. The baseline hazard is assumed to be zero prior to this age. By defining the risk set in terms of age it is also possible to account for the heterogeneity in age of exit from the labour market, for example the incidence of early retirement has been well documented in the UK (see for example Banks et al. 2006; Jones et al. 2010).

This leads to semi-parametric specification of the discrete time hazard

[12] We restrict attention to individuals who are in a certain age range and economic status in their first wave of observation. The reason for this is because in the context of the discrete time model information prior to this initial age and economic status is not included in the model (i.e. makes no contribution to the likelihood). In this sense we are imposing a degree of homogeneity on the initial sample.

model. Stephen Jenkins (1997) estimation routine pgmhaz8 facilitates estimation of the Prentice-Gloeckler (1978) model, the discrete time counterpart to a continuous proportional hazards model and its extension to account for individual level unobserved heterogeneity summarised by a gamma mixture distribution (Meyer, 1990). We partially mitigate the extent of unobserved heterogeneity by controlling for a stock sample of individuals who are in (self) employment at wave 1.[13] Jones et al. (2012), Nicoletti and Rondinelli (2006) and Jenkins (1995) note that ignoring unobserved heterogeneity leads to (a) Over estimation of negative duration dependence, and (b) Under estimation of the true effects of positive relationships between regressor and duration. Nicolleti and Rondinelli (2010) present Monte Carlo evidence which suggests discrete time hazard models are robust to misspecification of the form of unobserved heterogeneity in terms of estimates of duration dependence.[14]

Formally we are interested in the effect of age and the set of covariates on the instantaneous hazard of retirement, which is modelled as a proportional hazard i.e. the effect of a unit increase of a covariate effects the hazard of retirement independent of time. The presentation of the model presented below draws heavily on Jenkins (1995).

The instantaneous proportional hazard of retirement for individual i at time t is

$$\lambda_{i,t} = \lambda_0(t)e^{[X'_{i,t}\beta]} \tag{3.1}$$

Where $\lambda_0(t)$ is the baseline hazard and $X'_{i,t}$ are our set of covariates with associated coefficient estimates β. The discrete time hazard in the j^{th} interval is given by:

$$h_j\left(X_{i,j}\right) = 1 - e\{-e^{[X'_{i,j}\beta+\tau_j]}\} \tag{3.2}$$

Where τ_j:

[13] We cross check individuals self-reported status with weekly earnings and number of hours worked per week.

[14] We test for alternative forms of unobserved heterogeneity assuming parametric distributed errors (Prentice and Gloeckler 1978, Meyer 1990), and also a non-parametric distribution (Heckman and Singer, 1984).

$$\tau_j = \log \int_{f_{j-1}}^{f_j} \lambda_0(\tau) d\tau \qquad (3.3)$$

Is the logarithm of the interval of interest in our specification. In the case of the extension assuming a gamma mixture distribution the proportional hazard of retirement in the j^{th} interval is given by:

$$\lambda_{i,t} = \lambda_0(t) e^{[X'_{i,t}\beta + \log(\epsilon_i)]} \qquad (3.4)$$

Where ϵ_i is a is a Gamma distributed random variable with unit mean and variance σ^2. The discrete time hazard in the j^{th} interval is given by:

$$h_j\left(X_{i,j}\right) = 1 - e\{-e^{[X'_{i,j}\beta + \tau_j + \log(\epsilon_i)]}\} \qquad (3.5)$$

Where the hazard now directly incorporates the unobserved heterogeneity term.

Sample attrition is a cause for concern and may be related to labour market activity and health (Zabel, 1998; Ziliak & Knieser,1998).[15] A relationship between labour force participation and attrition will lead to estimate bias. We find no evidence of attrition bias using a variable addition test proposed by Nijman and Verbeek (1992) which tests for any relationship between (early) retirement and the pattern of survey response. There may also be potential endogeneity between self reported health and retirement (Jones et al., 2010). To minimise the potential for such bias it is possible to use alternative composite measures of health to predict health status.[16] Given our interest is the effect of lifetime variables on the retirement, and not the effect of health shocks we do not follow this approach, but instead control for baseline health using self-reported measures and for lifetime measures of health from the age of 16 onwards available in the life history survey.

We also separately weight our data using the Inverse Probability Weighting (IPW) method of Wooldridge (2002), to account for individuals pattern of sur-

[15] For an overview of potential sources of non response see Nicoletti and Peracchi (2005).

[16] Jones et al. (2009) estimate an ordered probit and regress health limitations on self-reported health, the predictions from the ordered probit are used in the model of retirement.

vey response.[17] [18] In estimating non-response weights we use a combination of sociodemographic, economic and interview characteristics available in ELSA, which are deliberately excluded in the covariate set used for modelling (early) retirement. The strategy used in this Chapter (and Chapter 4) relies on assuming individuals are missing at random conditional on controlling for factors which are likely to correlated to non-response i.e. selection on observables and unobservables. Fitzgerald et al. (1998) note that for this approach to work there exist variables which are available in the dataset which are deliberately excluded from the information set used to predict the outcome of interest. This is commonly referred to as the conditional independence assumption. By assuming conditional independence then consistent estimates can be derived using the inverse of the probability of observation. This is true even when the excluded covariates (instruments) are not included in the model for the outcome of interest, even if they are endogenous (Jones et al. 2010).

We assume non-response is a function of: accuracy of interviewee response to work and pension questions; accuracy of interviewee response to income and asset questions; household net financial wealth; calendar quarter and year of interview; whether has a long-standing illness and whether health will affects ability to work. We estimate a misspecification test (to detect omitted variable bias), suitable for single equation non linear models, results suggest no evidence of this form of misspecification [19]

Definition of retirement We define retirement as a self reported transition from any labour force state to full retirement for which we have information

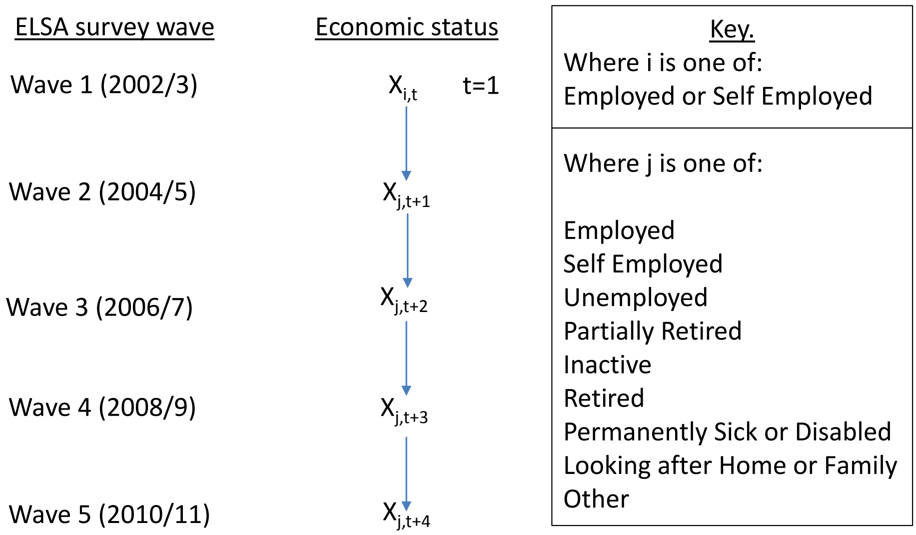
[17] Random effects models cannot account for IPW, however in absence of any significant evidence of unobserved heterogeneity, we present results assuming a (preferred) complentary log-log specification. Whilst this was possible for certain subsamples controlling for position in the income distribution, it was not possible for the full samples.

[18] For the purposes of estimation we exclude individuals who have an IPW >20 due to the sensitiveness of the hazard duration coefficients of including these individuals. This only drops 23 men and 12 women, or less than 2.5 percent of our total sample. Moreover, keeping these individuals in our sample does not affect the size and direction of the quantitative estimates (with the exception of age coefficients) significantly.

[19] There was some evidence to suggest that for the case of men the model lacked predictive power; this is due to the lack of appropriate variables available in ELSA which could be convincingly excluded from our retirement equation and were suitable for the non response equation. Net household financial wealth was not statistically significant in our preferred retirement regression specification which included various measures of a household's financial position such as pension wealth and income.

regarding the month and year of retirement, conditional on being in employment at wave 1. We do not include transitions to partial retirement as we are interested in complete detachment from the labour market. Similar to Jones et al. (2010) we assume individuals make a single exit from the labour market and do not allow for the possibility of unretirement. Figure 3.1 describes the initial and potential economic status an individual can report themselves to be in at each wave of ELSA. As noted above our stock sample in wave 1 is explicitly comprised of individuals who are in (self) employment.

Figure 3.1: Initial and potential economic status.



The most common transition an individual makes is from (self) employment directly into retirement. For the male sample which comprises of 767 individuals (614 in employment and 153 in self employment) this route corresponds to 316 out of a total 347 (91%) retirement episodes recorded. For our female sample which contains 567 individuals (525 are in employment and 42 in self employment in wave 1) 265 out of a total 308 (86%) retirement episodes were reported in a similar way.

3.5 Data

The sample used in this study is drawn from the English Longitudinal Study of Ageing (ELSA). ELSA is a biennial longitudinal study aimed at investigating changes in socioeconomic and demographic characteristics of individuals aged 50 and over in England. The survey is a joint collaboration between the Institute for Fiscal Studies (IFS), University College London (UCL), National Centre for Social Research (NCSR) and The University of Manchester. The survey sample is drawn from the Health Survey for England (HSE), with individuals and their spouses being eligible to take part in the survey if they live in private households in England, and were aged 50 and above on 1^{st} March 2002. The initial sample consisted of 11,391 core members, for a detailed description of the data used in this chapter see Appendix 8.3.1.

We make use of waves 1-5 which cover the period 2001-2012.[20] Our wave 1 stock sample consists of all (self) employed men aged between 50 and 64 (N=1818) and all (self) employed women aged between 50 and 59 (N=1,677).[21] These numbers reflect the number of observations in the core 1 dataset. These are then merged with the wave 1 net financial wealth variables dataset, pension wealth dataset. This final wave 1 dataset is then merged with the same information at waves 2-5. At each stage there is potential attrition, for example when the wave 1 dataset is merged with the wave 2 core data only 2,315 individuals (1,556 males and 1,264 females) are present in both waves of data. With each additional merge more individuals drop out of the sample, this could be due to factors such as health or death. The sample is unbalanced in that individuals are retained so long as they responded in at least waves 1 and 2. After the 5 datasets were merged and data was cleaned there were 787 eligible males and 567 females in the estimation sample. Appendix 8.3.2 contains summary statistics of our estimation sample.

3.5.1 Wave 3 life history data

In order to derive detailed information regarding periods of employment, unemployment and inactivity we make extensive use of the ELSA wave 3 life

[20] Despite there existing an additional wave of data known as wave 0, from which the original ELSA sample were constructed this wave of data contains little socioeconomic data compared to wave 1 onwards.

[21] We exclude those individuals who are in paid employment beyond SPA, as they may be considered systematically different from our stock sample in terms of their labour market behaviour which is likely due to unobservable characteristics.

history survey.[22] This module uses a 'life history calendar' to aid individuals in accurately recalling a retrospective account of their labour market history since leaving full time education. This includes the entry date to the labour market and subsequently the job start and end date for each job which lasted for a period of 6 months or more.[23]

The wave 3 life history data distinguishes between jobs that were full time, part time or a mixture of the two and our measure of time spent in employment accounts for this.[24] Using the life history survey we are able to construct measures related to lifetime labour market activity. The first measure is the potential number of years in the labour force for a given individual this is defined as: the calendar year an individual exited the labour market minus the calendar year (s)he entered the labour market after leaving full time education. The second measure is the actual number of years in paid employment, defined as the sum of the duration of each individual paid job. From these two measures it is possible to derive the proportion of the potential working life spent in employment, defined as:

$$\frac{\text{Actual number of years spent in paid employment}}{\text{Potential number of years in paid employment}} \tag{3.6}$$

It is this proportion which is used in the modelling framework to summarise the effect of individuals lifetime employment history on (early) retirement. Nicholls (2010) uses a similar method controlling for lifetime employment and highlights issues related to the accuracy of such a measure due to survey design and recall bias. Table 3.1 documents the proportion of potential working life spent in employment by gender.

[22] The information pertaining to the lifetime labour market history was collected in a one-off module in October 2007 immediately following fieldwork of the mainstage wave 3 survey. Therefore individuals had to appear at least (in addition to wave 1) in wave 2 and the wave 3 life history questionnaire. In practice this meant we had a balanced panel between wave 1, 2, 3 and the life history survey. Therefore potential attrition occurs at wave 4 and 5, where 66 (44 men and 22 women) and 108 (65 men and 43 women) individuals non-respond. We control for this in various ways described in Section 3.4.

[23] Short term jobs defined as lasting at least three months were also recorded and accounted for in analysis.

[24] If individuals respond a particular job was part time then we accounted for this as 0.5 FTE. If instead individuals responded that the job was a mixture of full time and part time and did not give exact details when this was the case then we assume an equal split i.e. 0.75 FTE. Finally if individuals did give the dates for which they worked full time and part time in a particular job, then these were recorded appropriately.

Table 3.1: ELSA Wave 3 Life History Data: Proportion of working life spent in employment.

Proportion of time spent in employment	Men (N)	Women (N)
30-39.99	N/A	6
40-49.99	N/A	14
50-59.99	2	40
60-69.99	1	76
70-79.99	5	117
80-89.99	26	145
90-99.99	143	79
100	609	84
Total	787	567

Two features emerge from Table 3.1. The first is that the majority of men in our sample spent their entire potential labour market experience in employment. Second, it is clear the same does not hold true for females. For the particular cohort under consideration male labour market attachment is characterised as being in continuous full time employment (Bozio, Emmerson, O'Dea and Tetlow, 2010, 2011; Nicholls, 2010; DeWilde, 2012). Whereas female labour attachment is observed to be more intermittent consistent with periods spent out of the labour market possibly due to child bearing and home production (Rosenweig and Wolpin,1980; Joshi,1998; Lundberg and Rose, 2000).

The life history file also contains information on an individual's circumstance between leaving school and entering their first job, and also their economic status between jobs.[25] These potential circumstances are recorded in Table 3.2.

We use this information in order to derive the number of counts an individual has experienced out of the labour market in 2002 (baseline). Given the design of the ELSA lifetime history file, we are only able to identify periods of employment, unemployment or inactivity which are a minimum of 3 months in length. ELSA contains only the start and end calendar year of each job, therefore it is not possible to determine the length of job which is less than one year (except it must have lasted at least 3 months). Hence in our model spec-

[25]Responses were recorded only if period out of labour market was at least three months in length.

Table 3.2: ELSA Wave 3 Life History Data: Transition states between jobs in ELSA wave 3 life history survey.

	State between jobs
1	unemployed & searching for a job
2	unemployed not searching for job
3	short term job (<3 months)
4	sick or disabled
5	looking after home or family
6	looking after sick/disabled relative/friend
7	retired
8	education/training
9	voluntary work
10	other - specify

Notes: Potential state between leaving school and first job, and between all subsequent jobs. Responses are recorded only if state lasted for minimum of three months.

ification we prefer to control for the incidence of unemployment and inactivity episodes experienced up until 2002 (baseline). Table 3.3 describes the number of episodes recorded out of the labour market by gender for our estimation sample.

Table 3.3: ELSA Wave 3 Life History Data: Episodes of unemployment and inactivity during working life.

Number of periods out of the labour market in 2002	Men	Women
0	568	70
1	160	255
2	43	160
3	12	51
4	1	21
5	3	3
6	0	6
7	0	1

Table 3.3 highlights that for the majority of men who did experience any episodes out of the labour market, it was most likely to only be one. Whereas for female individuals most experienced at least one period out of the labour market. Using year of birth and the retrospective work-life history it is possible

to discern when these periods out of the labour market occurred. For men this tended to be concentrated at younger ages in the lifecycle, around 16-30 years of age and declined gradually as individuals aged. Females exhibited a similar pattern, however the incidence and prevalence was much higher not only in the 16-30 and 31-40 group, but also the 41-50 group. This likely to be a combination of periods out of the labour market due to maternity leave, caring and domestic responsibilities, to be distinguished from episodes of involuntary unemployment and inactivity.

Sociodemographic and economic variables

In addition to the lifetime labour market history we control for a wide range of sociodemographic and economic characteristics available at wave 1 of ELSA. These are listed in Table 3.4 and Appendix 8.3.3 in more detail.

The sociodemographic variables attempt to adequately control for background characteristics, which with the exception of health tend to be determined earlier on in the lifecycle.[26] Similarly the economic variables inherently capture individuals lifecycle behaviour towards the labour market, not only through the lifetime employment, unemployment and inactivity measures, but also through pension contributions. We supplement our information set with detailed financial variables using the ELSA wave 1 financial derived variables data provided by the IFS, in particular we control for the non-pension net financial wealth quintile in 2002. Net non-pension wealth is defined as the sum of all wealth held by an individual (and, where applicable, their partner) in financial assets, property, other physical assets and the assets of any business they own. It is measured net of any secured or unsecured debt including mortgages (Crawford, Emmerson and Tetlow, 2010). By definition this measure of wealth does not include pension wealth. The quintiles are defined as splitting the cross section at wave 1 into five groups (of equal size and without accounting for equivalisation) from poorest to richest. [27] We also make use of detailed information from the wave 1 pension derived variables dataset, also made available by the IFS.[28] We control for the present value of total pension

[26] The majoirty of these variables were coded as dummy variables.
[27] For more information see Oldfield (2005).
[28] For more information on how these variables are derived see Banks et al. (2005).

Table 3.4: Covariate information set used in retirement regression.

Sociodemographic variables
Marital status
Education level
Social class
Lifetime ill health (prior to the age of 50)
Self reported health
Housing tenure
Economic variables
Employment status of spouse
Presence of an employer pension
Presence of a private pension
Self employed pension
Financial planning horizon
Proportion of time spent in employment
Count of instances out of labour market
Log value household income
Log present value of individual total pension wealth
Log present value of spouse's total pension wealth
Net non-pension wealth quintile

Notes: For each covairate, definition and description can be found in Appendix 8.3.3 Education level refers to highest level of attainment: Degree (minimum 16 years full time education); Above A level below degree level (Between 14 and 15 years full time education); A level (14 years full time education).

wealth in 2002, defined as the sum of the present value of private, occupational and state pension payments.[29]

We control for the labour force participation status of the spouse, which is likely to affect the individuals own retirement decision (Schirle, 2008), and also for the spouse's pension wealth. Given the cohort under consideration it is likely that in the case of females their husbands pension wealth is likely to affect their retirement decision, however it is unlikely this relationship holds vice versa (Johnson, 2004).

[29] These are derived assuming individuals work until SPA.

3.6 Results.

In this section we present plots of non-parametric survival curves which describe the proportion of individuals retiring at a particular age, depicted by Figures 3.2 and 3.3 for men and women respectively. We go onto formally present estimation results first by gender and then also conditional upon quintile position in the 2002 ELSA income distribution (for information on how this was derived see Oldfield, 2009).

3.6.1 Survivor functions for full ELSA sample by gender

Figure 3.2: Male survivor curve full sample aged 60-64 in 2002.

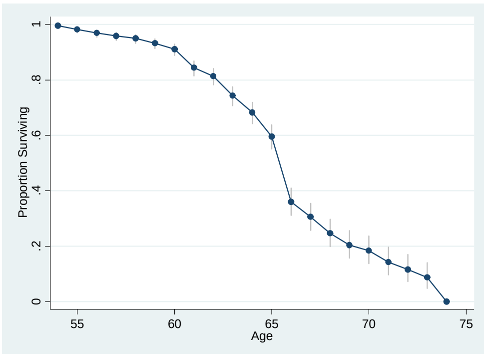
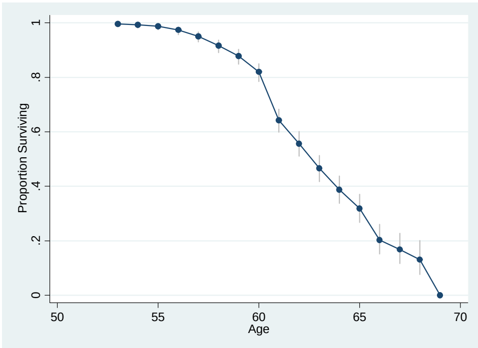


Figure 3.2 plots the survivor function defined as the probability of surviving up to a given age for our sample of men.[30] The sample used to plot Figure 3.2 is all men suitable for estimation purposes ($N = 787$) and similarly for females ($N = 587$) in Figure 3.3. It is clear that the survival probability decreases significantly around SPA. What is also clear is that a significant proportion of the sample retired; by age 64, 30% of our sample had already exited the labour market. Starting from age 60 (which coincides with the SPA for females) the survival probability falls sharply until around age 66, after which point it continues to decline at a slower rate.

[30] The vertical grey bars at each age denote 90% confidence bands for the survivor function. The survivor functions shown here are not actuarially adjusted, in order to allow for the possibility of nonuniform retirements within an interval. If we assume this assumption does not hold, Figures 3.2 and 3.3 change very little.

A similar pattern emerges for women, the survival probability decreases significantly at or around SPA. Relative to men fewer women in our sample retired early. At age 59 around 15% of our sample had retired early, from age 60 onwards the survival probability decreases significantly at a constant rate over the entire age range.[31]

Figure 3.3: Female survivor curve full sample aged 50-59 in 2002.



The relationships described in Figures 3.2 and 3.3 are likely to be due to a combination of factors. Institutional factors which are related to age govern eligibility for occupational/state pension receipt. Socioeconomic factors such as individual's marginal value of leisure, which is likely to be correlated with that of their spouse mean retirement can be viewed a strategic game (Schirle, 2008; Disney, Ratcliffe & Smith, 2010). This would explain the relatively smaller proportion of early retirees in our female sample who continue to work past SPA and coordinate their retirement decisions with their husbands. This is seen in Figure 3.3 where the survival probability is declining or alternatively the hazard of retirement is highest, between the ages of 60 and 65 which reflects the official SPA of women and men in the UK for the majority of the sample period.

[31]This may also be due to institutional factors, such as if the female spouse chose to pay a reduced level of NI contributions, known as the 'half stamp' which did not contribute to her Basic State Pension (BSP). In doing so would make her more reliant on her husbands BSP for income during retirement, and hence may lead to her staying on in work until her spouse was eligible to claim BSP.

3.6.2 Estimation Results

Results for the male sample

Table 3.5 presents estimation results based on our preferred specification for the full sample, assuming a parametric gamma mixture distribution suitably summarises individual level unobserved heterogeneity.[32] If instead of assuming a parametric distribution such as gamma summarised individual level unobserved heterogeneity and we instead believed unobservables were better characterised by a non-parametric distribution composed of mass points then in the context of a duration framework this would lead to the specification first proposed by Heckman and Singer (1984). Such a feature is advantageous in that it leads to a flexible parameterisation of heterogeneity however may lead to issues of convergence (Jones et al., 2012).

If we assume two mass points (1,-1) and associated probabilities of (0.3,0.3) then we also find some evidence of unobserved heterogeneity (see appendix 8.3.6). On balance we find little difference in the quantitative and qualitative estimates assuming a parametric approach such as proposed by Meyer (1990) or non-parametric approach such as Heckman-Singer (1984); further the latter requires a priori knowledge of the true number of mass points and associated probabilities.

In light of the implications of Nicoletti and Rondinelli (2010), we choose to model the retirement decision assuming a parametric distribution is correct. We test model specification (in terms of alternative specifications of the information set) using AIC/BIC tests in order to reflect both flexibility in the duration dependence and a parsimonious information set. In addition we test for omitted variable bias suitable for single equation non linear models (Pregibon, 1980) and find no evidence of this form of misspecification.

Estimates of the age gradient suggest the hazard of retirement increases with age and peaks at SPA. Regarding the income and wealth variables; results suggest ceterus paribus higher levels of log household income at wave 1 raised

[32] In order to estimate the model the panel is redefined in order to have a single row for each period at risk, for each individual. Hence the number denotes the number of person years for each individual in the sample and hence is much larger than the total number of actual retirement episodes (of the 887 male individuals in our estimation sample we observed 348 or 39.2% to retire over the sample period).

the retirement hazard, whereas higher levels of log non-pension wealth had no significant effect on the hazard hazard of retirement. In terms of pension wealth our results suggest higher levels of log pension wealth are positively related to the hazard of retirement, similarly those individuals who reported contributing to an employer pension in 2002 are significantly more likely to retire (relative to those who only contributed to a state pension). This is likely to be due to individuals with higher levels of pension wealth being concentrated in professional occupations which were more likely to offer a Defined Benefit (DB) pension scheme. Whilst a males own pension wealth seemed to play a role in his retirement decision, an alternative specification of the model below was to include his spouse's pension value, however this did not seem to have a significant effect in raising his own hazard of retirement.

Table 3.5: Male discrete time hazard model estimates (full sample).

Variable	$\beta\,(\sigma)$	Pr > $\lvert Z \rvert$
Age $\leq$ 54	0.02(0.01)	0.00
55$\leq$Age $\leq$56	0.83(0.03)	0.00
57$\leq$Age $\leq$58	0.89(0.28)	0.70
59$\leq$Age $\leq$60	3.47(0.89)	0.00
61$\leq$Age $\leq$62	5.06(1.37)	0.00
63$\leq$Age$\leq$64	10.18(3.04)	0.00
65$\leq$Age$\leq$66	52.48(20.73)	0.00
67$\leq$Age$\leq$72	42.39(22.99)	0.00
2^{nd} Household non-pension wealth quintile	1.31(0.50)	0.48
3^{rd} Household non-pension wealth quintile	1.05(0.42)	0.90
4^{th} Household non-pension wealth quintile	1.08(0.44)	0.84
5^{th} Household non-pension wealth quintile	1.08(0.45)	0.85
Log household income	1.27(0.13)	0.01
Log pension wealth	1.47(0.20)	0.00
1 episode out of labour market	0.81(0.21)	0.42
2+ episodes out of labour market	0.51(0.19)	0.07
50-84% of potential labour market experience in work	3.91(2.18)	0.01
85-99% of potential labour market experience in work	1.28(0.36)	0.38
Married	0.52(0.17)	0.04
Divorced	0.39(0.15)	0.01
Widowed	0.57(0.30)	0.28
Spouse in employment	1.12(0.16)	0.44
Degree	1.47(0.31)	0.07
Above A level/ Below degree level	0.97(0.19)	0.90
A level	0.93(0.23)	0.78
Baseline health: Fair	1.57(0.31)	0.02
Baseline health: Poor	4.54(2.54)	0.00
1 episode of poor health before age 50	1.06(0.13)	0.80
2 episodes of poor health before age 50	2.45(1.21)	0.07
3+ episodes of poor health before age 50	0.20(0.23)	0.16
Mortgage	0.93 (0.15)	0.63
Rent	0.72 (0.25)	0.34
Free rent	1.43 (0.93)	0.58
Employer pension	1.57 (0.33)	0.02
Private pension	0.92 (0.20)	0.69
Self employment pension	1.20 (1.31)	0.87
Professional or managerial occupation	0.85 (0.22)	0.54
Technical non manual or manual occupation	0.85 (0.20)	0.50
Long term financial planning horizon	1.03 (0.20)	0.87
Medium term financial planning horizon	1.94 (0.18)	0.75
Gamma variance	0.47	0.10
LR test of gamma variance = 0	3.05016	0.040365
Number of person-years observations[33]	47530	
Number of non retirement episodes[34]	47182	
Number of retirement episodes[35]	348	

The lifetime labour market variables relating to unemployment and inactivity tend to affect the hazard of retirement in a similar way have hence we group these together. Relative to experiencing no episodes (of unemployment or inactivity) out of the labour market, experiencing one episode reduces the hazard of retirement by 19%, whereas experiencing two or more episodes reduces the hazard by 49%. However in the specification which includes spouse's pension wealth, the size of this effect increases substantially (38% and 62% respectively) and are statistically significant. Periods out of the labour market are likely to affect the number of qualifying years an individual must spend in employment in order to make sufficient national insurance contributions to qualify for a full Basic State Pension (BSP). Prior to April 2010 in order for a male to retire he must have made at least 44 years of NI contributions, in this context one would expect that episodes of unemployment or inactivity would tend to reduce the retirement hazard.

Conditional on controlling for episodes out of the labour market, Table 3.5 indicates those with a lower proportion of time spent in employment are more likely to retire. Those individuals who have spent between 50% and 84% of their potential time in employment are three times more likely to retire, relative to those who spent all their potential life in employment. This could be due to disengagement with the labour market leading to worklessness and retirement, for example due to macro factors such as recessions specifically affecting older workers (Dorn & Sousa-Poza, 2010), or lack of appropriate active labour market policies (Maes, 2013). This is particularly true for the ELSA sample which experienced economic downturns in the 1970s and 1980s, the latter particularly affected primary industry sectors with higher levels of union coverage. More generally lower proportions of time spent in potential in employment is more likely to lead to (early) retirement and poverty in retirement (Maes, 2013; DeWilde, 2012). [36]

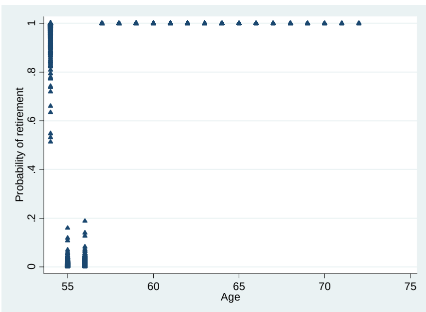
Table 3.5 indicates episodes of poor baseline and lifetime health increases the hazard of retirement of men. Relative to having good or excellent baseline

[36] An alternative specification which took into account the calender time in the individuals lifecourse at which the event occured (broken down into broad age groups), could not be used due to the relatively large number potential combinations and lack of variation in the data. However for those groups which were estimated the size and direction of the effect was similar to the 'count measure'.

health, the retirement hazard for those individuals who had poor health was four-fold higher. Similarly relative to experiencing no episodes of bad health prior the age of 50, those who experienced two or more were more than twice as likely to retire.

We include a comprehensive set of measures to control for sociodemographic characteristics. Those with higher educational attainment tend to be more likely to retire, relative to having CSE level or below qualifications the hazard of retirement is 26% higher for those with a degree. Those with a wife employed in the labour market are no more likely to retire. However that is not say spouses play no role in the retirement decision, if an individual reports being married the hazard of retirement is lowered by 26% compared to those who are single. In terms of housing tenure the hazard of retirement does not seem to systematically differ between those who own their home outright, relative to those who do not. Similarly there does not seem to be any systematic difference in the retirement hazard depending on the financial planning horizon. Figure 3.4 denotes the probability of retirement at specific ages for individuals in our sample (over the observation period).

Figure 3.4: Hazard of retirement for men aged between 53 and 72.



Notes: Hazard estimated at the mean of each individuals covariates in our sample assuming a piecewise constant specification.

There are relatively few retirements observed in our sample for those in their early 50's, this is reflected in the estimated hazard coefficient. However the drop in probability at ages 55 and 56 is potentially an outlier and warrants further investigation. It is clear the predicted hazard of retirement is very close to or equal to one for ages 57-72. As individuals approach SPA the hazard of retirement increases significantly as reflected in the retirement hazards in Table 3.4, which when combined with the individual's mean of their covariate information set leads to a predicted retirement hazard at or very close to one.

Results for the female sample

Table 3.6 presents estimation results which account for unobserved heterogeneity. The specification assumes individual specific variation which follows a gamma mixture distribution. In terms of the duration dependence the direction and trend is as anticipated, as individuals approach SPA the hazard of retirement increases however the estimated coefficients are smaller in magnitude than expected (this seems to be driven by those aged 60 and over, see Section 3.6.4). A significant proportion continue to work past SPA, perhaps to coincide retirement with their spouse. This is reflected in the female survivor function in Figure 3.5 and also in the hazard estimates of the duration dependence in Table 3.6, which tend to increase as females age beyond their own SPA.

Table 3.6: Female discrete time hazard model estimates (full sample).

Variable	$\beta\,(\sigma)$	Pr $> \lvert Z\rvert$
Age≤53	0.00 (0.00)	0.00
54≤Age≤55	0.01 (0.01)	0.00
56≤Age≤57	0.02 (0.03)	0.01
58≤Age≤59	0.04 (0.07)	0.04
60≤Age≤61	0.25 (0.40)	0.39
62≤Age≤63	0.40 (0.65)	0.57
64≤Age≤65	1.05 (1.81)	0.99
66≤Age≤68	1.67 (3.26)	0.81
2^{nd} Household non-pension wealth quintile	0.75 (0.34)	0.52
3^{rd} Household non-pension wealth quintile	1.03 (0.48)	0.94
4^{th} Household non-pension wealth quintile	0.73 (0.34)	0.50
5^{th} Household non-pension wealth quintile	1.05 (0.49)	0.92
Log household income	1.00 (0.13)	0.98
Log pension wealth	1.02 (0.11)	0.79
1 episode out of labour market	0.39 (0.23)	0.10
2+ episodes out of labour market	0.36 (0.22)	0.09
20-49% of potential labour market experience in work	1.06 (0.67)	0.92
50-65% of potential labour market experience in work	0.97 (0.39)	0.94
65-80% of potential labour market experience in work	1.20 (0.43)	0.62
80-95% of potential labour market experience in work	1.24 (0.43)	0.54
Married	1.99 (1.10)	0.22
Divorced	1.06 (0.58)	0.91
Widowed	2.99 (2.02)	0.10
Spouse in employment	1.40 (0.31)	0.13
Degree	0.44 (0.16)	0.02
Above A level/ Below degree level	1.36 (0.43)	0.33
A level	1.06 (0.35)	0.84
Baseline health: Fair	1.86 (0.54)	0.03
Baseline health: Poor	0.79 (0.55)	0.74
1 episode of poor health before age 50	1.05 (0.31)	0.87
2 episodes of poor health before age 50	0.62 (0.35)	0.40
3+ episodes of poor health before age 50	2.33 (1.80)	0.27
Mortgage	0.87 (0.21)	0.56
Rent	6.77e-07 (0.01)	0.85
Free rent	0.79 (0.36)	0.62
Employer pension	1.33 (0.33)	0.24
Private pension	0.547 (0.22)	0.13
Self employment pension	6.49e-07 ($7.11e-06$)	0.19
Professional or managerial occupation	2.60 (1.48)	0.09
Technical non manual or manual occupation	1.57 (0.36)	0.05
Long term financial planning horizon	0.92 (0.25)	0.75
Medium term financial planning horizon	1.07 (0.26)	0.77
Gamma variance	1.37	0.59
LR test of gamma variance = 0	3.96	0.023163
Number of person-years observations	33970	
Zero outcomes	33622	
Non zero outcomes	348	

Household income nor quintile position in the non-pension wealth distribution, seem to play a significant role in the retirement decision of women. This is also true for log pension wealth these results are likely to be due to cohort effects for this particular group, who were not likely to be the main breadwinner in the household (Hotz & Miller, 1988; Blundell et al., 2006). This is supported in alternative specifications which control for husbands pension wealth, and indicate this covariate played a statistically significant role in the wives retirement decision (not shown).

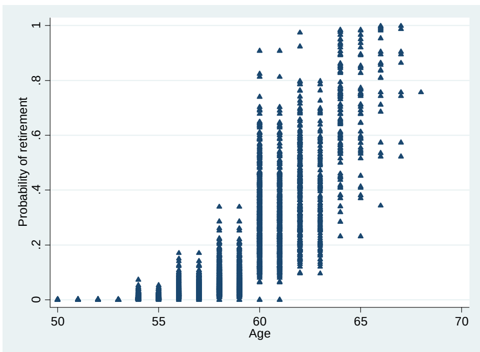
Those females who contributed to an employer pension (which can be drawn down prior to SPA) were more likely to retire however this affect was not statistically significant. Whereas contributing to a private/personal pension tended to lower the hazard of retirement even though the drawdown age is similar to that of an employer pension.

Turning to lifetime labour market factors, conditional on controlling proportion of time spent in employment periods out of the labour market tend to reduce the hazard of retirement. Experiencing one episode out of the labour market (relative to experiencing none), reduces the retirement hazard by 61 percent, whilst having two or more reduces the hazard by 64 percent. It is likely a large proportion of our sample females took time out of the labour market (in addition to reasons relating to inactivity and unemployment) due to maternity leave, caring responsibilities and home production. In terms of the proportion of time spent in employment relative to the base group (spending 95% or more the potential labour market time in employment), the hazard of retirement is not significantly higher for those who have spent less of their potential labour market experience in employment. Again this is likely to be due to cultural factors associated with this cohort of females, which would mean that less time spent in employment is unlikely to affect the retirement decision of females.

In terms of female lifetime health those who experienced episodes of poor health were more likely to retire however the effect was statistically significant. There is some evidence that poorer baseline health was positively related to the retirement hazard, compared to those with good or excellent health, the hazard of retirement for those with fair health was nearly twice as high.

Finally background sociodemographic and educational characteristics seem to play some a role in the retirement decision for women. There is some evidence of a gradient in education which suggests more highly educated females are significantly less likely to retire, having a degree lowers the hazard of retirement by 57%, relative to having CSE or below. However those individuals with a degree were on average younger in wave 1 and given our stock sample only contained those in employment, in terms of incidence of retirement for this group it was similar to those with lower educational attainment over the sample period. Having a husband in employment raises the hazard of retirement. More generally the presence of a (deceased) spouse acts to raise the retirement hazard relative to being single. Similar to men housing tenure nor financial planning horizon play an important role in the retirement decision for females. Figure 3.6 plots the probability of retirement using the model estimates from Table 3.6 for our sample of females.

Figure 3.5: Hazard of retirement for women aged between 50 and 68.



Notes: Hazard estimated at the mean of each individuals covariates in our sample assuming a piecewise constant specification.

Similar to the survivor function in Figure 3.4, Figure 3.5 shows a sharp increase in the probability of retirement at female SPA and beyond.[37] Females may wish to work past SPA and coordinate their retirement with that of their spouse due to complementarities in leisure. A recent IFS report (Cribb et al., 2013) showed that the labour supply effect of increasing the female SPA in the UK by one year from 60 to 61, increased the female labour supply by 7.2 percentage points and their husband's labour supply also rose, by 4.2

[37]For the purposes of estimating retirement probabilities in Figure 3.5, we assume the value of the gamma variance is set equal to zero.

percentage points.

3.6.3 Variation across the income distribution

In modelling retirement it is important to consider the potential heterogeneity in retirement behaviour conditional upon position in the income distribution. We split our sample based on the quintile position in the 2002 income distribution when all individuals are in employment, and highlight the main differences between the full sample and sub-sample estimation results. The cumulative effect of decisions made earlier in the lifecycle regarding education, employment, marital status and to some extent health will in turn influence income and wealth position by the time individuals are approaching retirement age (Mirer, 1979). Therefore we run each of the main specifications for two subsamples (by gender), the first on the bottom three and the latter on the top two income quintiles. Given we find no evidence of unobserved heterogeneity for either gender, Appendices 8.3.7-8.3.8 present estimates from our preferred specification which assumes a Gaussian distributed error, and also controls for attrition using IPW.[38] In the male sample there are 195 individuals in the bottom three quintiles, and 592 in the top two income quintiles, whilst for women there number is 172 and 407 respectively. This highlights that those individuals who were in the top two income quintiles in wave 1 were more likely to remain in the sample, this underlines the importance of controlling for non-random selection assuming IPW correctly control for retention.

Results for male sample

Bottom three income quintiles (Appendix 8.3.7) Relative to the full sample the pattern and direction of duration dependence is the same for those in the bottom three income quintiles. However the hazard of retirement is higher for ages 60.[39] For those in the bottom three income quintiles there does seem to be evidence of a gradient in education (which on average is lower than that of the top two income quintiles), those with lower levels of education are

[38] We do not control for non pension financial wealth quintile in these specifications given the lack of variation in the data for particular subgroups, combined with the collinearity between income and wealth quintile.

[39] These are likely to be sensitive to the relatively small sample size.

more likely to retire.

There seems little evidence of a gradient in baseline health, however the hazard of retirement (relative to being in good or excellent health) is higher for those with fair or poor health. In terms of lifetime health similar to the full sample experiencing more episodes of bad health prior to the age of 50 acts to raise the retirement hazard. There is a strong effect on lowering the retirement hazard for this group if they are married, divorced or widowed (relative to being single). Whilst household income or individual's pension wealth do not affect the retirement decision in a significant way, similar to the full sample higher levels of these variables raise the hazard of retirement. In contrast to the full sample those individuals who had an employer pension were more likely to retire, the hazard was 62% higher relative to those who had just a state pension.

Top two income quintiles (Appendix 8.3.8) For this subsample the pattern and direction of duration dependence is very similar to the full sample, however the coefficient estimates are significantly lower compared to the bottom three income quintiles. There does not seem to be as stronger role for poor health prior to the age of 50. However baseline health seems to affect the retirement hazard, relative to being in good or excellent health the hazard of retirement for those individuals who are in poor health is three times higher. Pension wealth and (to a lesser extent) household income have a significant affect on the retirement hazard for this group. Similar to the full sample episodes out of the labour market lower the hazard of retirement, relative to the base group the hazard of retirement for those who experience two or more episodes out of the labour market is 50% lower. As to is the effect of the proportion of time spent in employment, those with lower levels are much more likely to retire relative to those who spent all their potential time in employment. Similar to the males in the bottom three quintiles those who are married or divorced tend to be less likely to retire, relative to those who are single. Contributing to an employer pension significantly raised the hazard of retirement.

Results for female sample

Bottom three income quintiles (Appendix 8.3.9) The pattern and direction of the age coefficient estimates on the hazard of retirement follow a similar pattern to the full sample, however the estimates are smaller in magnitude and more of the age dummies (particularly at ages 65 and above) are significant. Lower retirement hazards may reflect the credit or financial constraints faced by these individuals and this may lower the hazard of retirement.

The effect of the lifetime labour market variables seem to affect this particular group differently to those of the full sample, namely, periods out of the labour market due to unemployment or inactivity tend to increase the retirement hazard. Relative to the experiencing no episodes out of the labour market, the hazard of retirement for those females who experience one episode or two or more is 96% and 79% higher respectively. Whilst in the main sample there seemed to be little evidence of any gradient in the proportion of time spent in employment, for those in the bottom three income quintiles those who spend a lower proportion of their time in employment are less likely to retire. Relative to spending 95% or more the potential labour market time in employment, the hazard of retirement for those who spent between 20% and 49% of their potential working life in employment is 79% lower. Similar to the full sample poor baseline health raises the hazard of retirement, whilst the qualitative effect of lifetime health act in a similar way. In contrast to the full sample higher levels of household income raised the retirement hazard, whereas there is no clear effect on the way in which baseline pension wealth affected the retirement decision.

Top two income quintiles (Appendix 8.3.10) In contrast to the bottom three income quintiles episodes out of the labour market significantly lower the hazard of retirement. Relative to having no time out, having one or two more episodes out of the labour markets reduces the hazard of retirement by around one-half. Similarly whilst for the bottom three income quintiles spending a lower fraction of potential time in employment tended to reduce the hazard of retirement which may imply individuals could not afford to retire, for those in the top two income quintiles it acted to significantly raise it (relative to females with 95% or more potential labour market experience in employment).

It may be that wealthier females in this cohort were the first to be given the opportunity to develop long term successful careers associated with strong labour force attachment .The education variables support this view, relative to having CSE level or below qualification, the retirement hazard for those with a degree was 50% lower and statistically significant. We also find social class effects, these indicate ceterus paribus the hazard of retirement for those who are in professional or technical occupations relative to those who are unskilled is 171% and 58% higher respectively. A final difference between the two groups is the way in which spousal employment affects retirement. For women in the bottom three income quintiles it acted to reduce the hazard of retirement by around 40%, whereas for women with a spouse in employment in the top two income quintiles it raises the hazard of retirement by 55%, one possible explanation could be that the former group face credit constraints or may simply be unable to afford to retire.

3.6.4 Estimation results: Early retirements

In this section we consider the way in which sociodemographic and economic characteristics (in particular lifetime labour market variables), affect the hazard of *early* retirement of men and women. We do not include separate estimation results conditional on income quintile as we did for the full panel as we do not have sufficient sample size (in terms of retirement episodes) for a step function in the baseline hazard. However we do control for position in the income quintile in the information set. In the case of early retirement there is no significant evidence of unobserved heterogeneity for the male sample, whilst there is for the female sample. This warrants modelling the unobserved error in the retirement equation differently conditional on gender. In the case of males similar to the subsample analysis by income quintile, we assume a Gaussian distributed error and control for attrition bias using inverse probability weights. Whilst for women we assume a gamma mixture distribution to summarise individual level unobserved heterogeneity.

Following Jones et al. (2010) we define early retirement as a transition into self reported retirement prior to SPA (65 for men and 60 for women).[40] [41] The empirical prevalence of early retirement is substantial as shown in Figures 3.2 and 3.3, and underlines the important of investigating the determinants of early retirement.

Men

The step function in age for the sample of early retired men is similar in trend and direction to the full sample. Table 3.7 indicates there is no gradient in the baseline income quintile position and the estimates were not statistically significant. Relative to the main sample both household income and pension wealth play a stronger role in the retirement decision of men. Higher levels of both these variables are positively related to the hazard of early retirement. Those individuals who contribute to an employer pension are more likely to retire early, relative to those who contribute to only a state pension. Employer pension schemes do allow members to start drawing down on their pension well before reaching SPA. The 2002 Pensions Green Paper proposed a rise in the minimum eligibility age from 50 to 55 which came into effect in April 2004, however this is still ten years below the SPA of males (six for females).

[40] Individuals are right censored on reaching 65 (men) and 60 (women) and had not retired, these individuals no longer contribute to the likelihood function.

[41] Given the female SPA was raised by one month from the current level (60 years of age) in 2010, for each calender month born after April 1950 and the sample period covered up until 2011. Whilst we do not have date of birth information, we can crudely approximate year of birth, and find we have 159 individuals in our sample who are born after 1950. For these individuals the SPA would have been approximately 61/62 years of age, thus strictly speaking early retirement would have included age 60/61 for these individuals. However we estimate specifications for with and without this sample and find both quantitatively and qualitatively the results are similar.

Table 3.7: Male early retired estimation results.

Variable	$\beta\,(\sigma)$	Pr > $\|Z\|$
Age $\leq$ 54	0.15 (0.01)	0.00
55$\leq$Age $\leq$56	0.80 (0.26)	0.00
57$\leq$Age $\leq$58	0.66 (0.36)	0.44
59$\leq$Age $\leq$60	3.25 (1.78)	0.03
61$\leq$Age $\leq$62	5.64 (3.11)	0.00
63$\leq$Age$\leq$64	9.18 (4.93)	0.00
2^{nd} Household non-pension wealth quintile	1.70 (0.80)	0.26
3^{rd} Household non-pension wealth quintile	1.09 (0.51)	0.85
4^{th} Household non-pension wealth quintile	0.77 (0.33)	0.54
5^{th} Household non-pension wealth quintile	0.95 (0.48)	0.92
Log household income	1.92 (0.41)	0.00
Log pension wealth	1.34 (0.17)	0.02
1 episode out of labour market	0.78 (0.23)	0.39
2+ episodes out of labour market	0.56 (0.25)	0.18
50-84% of potential labour market experience in work	3.83 (2.08)	0.01
85-99% of potential labour market experience in work	1.06 (0.32)	0.83
Married	0.99 (0.40)	0.98
Divorced	0.92 (0.61)	0.91
Widowed	0.86 (0.58)	0.83
Spouse in employment	1.01 (0.19)	0.97
Degree	1.28 (0.45)	0.46
Above A level/ Below degree level	1.06 (0.40)	0.87
A level	1.45 (0.82)	0.51
Baseline health: Fair	1.03 (0.24)	0.89
Baseline health: Poor	3.99 (1.97)	0.00
1 episode of poor health before age 50	1.04 (0.25)	0.85
2 episodes of poor health before age 50	1.58 (0.82)	0.38
3+ episodes of poor health before age 50	omitted	
Mortgage	0.86 (0.19)	0.49
Rent	0.60 (0.23)	0.18
Free rent	1.18 (0.81)	0.81
Employer pension	1.58 (0.49)	0.14
Private pension	0.68 (0.26)	0.30
Self employment pension	0.78 (0.91)	0.83
Professional or managerial occupation	0.94 (0.45)	0.90
Technical non manual or manual occupation	1.51 (0.51)	0.22
Long term financial planning horizon	1.75 (0.43)	0.02
Medium term financial planning horizon	1.36 (0.35)	0.24
Number of person-years observations	47272	
Zero outcomes	47048	
Non zero outcomes	224	
Wald chi^2(40)	2484.57	
Pr > chi^2	0.00	

The effect of lifetime labour market variables is also similar in both direction and magnitude to the full sample, namely experiencing periods out of the labour market due to unemployment or inactivity acts to reduce the hazard of retirement. Conditional on this, an individual who spends between 50 and 84% of their potential lifetime career in employment, raises their hazard of early retirement three-fold relative to an individual who did not experience any episodes out of the labour market. In terms of the magnitude only poor baseline health has a quantitatively comparable effect.

Similar to the full sample health seems to play an important role. Relative to reporting being in good or excellent health, the hazard of early retirement was three-fold higher for those individuals who reported being in poor health. In addition to baseline health, experiencing episodes of poor health during one's lifetime also had a detrimental effect on staying in the labour market. Relative to experiencing no episodes of bad health, the hazard of early retirement for those individuals who experienced two episodes of poor health prior to the age of 50 was 57% higher relative to an individual who experienced none.

In terms of background sociodemographic characteristics the main differences (as compared to the full sample estimation results) relate to there being no effect of marital status on the hazard of early retirement. Additionally, estimates from Table 3.7 suggest the hazard of early retirement is higher for individuals who have a medium (between three and five years) or long term (more than five years) financial planning horizon relative to those with a short term financial planning horizon.

Women

The gradient in the hazard of early retirement increases as females age albeit the coefficient estimates are significantly higher. Relative to the full sample estimation results Table 3.8 indicates there is no gradient in the baseline income quintile position. Having a higher level of pension wealth lowers the hazard of early retirement, whereas there does not seem to be a significant role for household income. Similarly contributing to a private pension lowers the hazard of early retirement however this was not statistically significant at conventional levels. In contrast to previous results an employer pension acted to raise the hazard of retirement but again this effect was not statistically significant; this is likely to be related to eligibility ages on employer pensions which despite having been raised in recent times remain significantly lower than SPA (Green paper, 2002).

Table 3.8: Female early retired estimation results

Variable	$\beta\,(\sigma)$	Pr $> \|Z\|$
Age≤53	0.03 (0.00)	0.00
54≤Age≤55	2.92 (0.02)	0.26
56≤Age≤57	13.02 (11.71)	0.00
58≤Age≤59	39.18(35.40)	0.00
2^{nd} Household non-pension wealth quintile	0.94(0.73)	0.94
3^{rd} Household non-pension wealth quintile	1.23(1.00)	0.80
4^{th} Household non-pension wealth quintile	0.57(0.47)	0.50
5^{th} Household non-pension wealth quintile	1.46(1.19)	0.64
Log household income	0.96(0.19)	0.83
Log pension wealth	0.73(0.09)	0.01
1 episode out of labour market	0.11(0.08)	0.00
2+ episodes out of labour market	0.09(0.07)	0.00
20-49% of potential labour market experience in work	1.61(1.53)	0.62
50-65% of potential labour market experience in work	0.51(0.36)	0.35
65-80% of potential labour market experience in work	1.28(0.77)	0.68
80-95% of potential labour market experience in work	1.12(0.65)	0.85
Married	1.02(0.81)	0.98
Divorced	0.47(0.39)	0.37
Widowed	1.12(1.11)	0.91
Spouse in employment	2.10(0.76)	0.04
Degree	0.47(0.26)	0.18
Above A level/ Below degree level	2.26(1.07)	0.08
A level	1.24(0.65)	0.68
Baseline health: Fair	1.71(0.74)	0.21
Baseline health: Poor	0.75(0.74)	0.76
1 episode of poor health before age 50	1.25(0.59)	0.63
2 episodes of poor health before age 50	0.06(0.09)	0.06
3+ episodes of poor health before age 50	2.84(3.19)	0.35
Mortgage	0.50(0.18)	0.05
Rent	$3.67e{-}07$(0.01)	0.68
Free rent	0.26(0.20)	0.08
Employer pension	1.67(0.61)	0.16
Private pension	0.57(0.34)	0.35
Self employment pension	$6.87e$-07(0.01)	0.91
Professional or managerial occupation	1.44(1.50)	0.72
Technical non manual or manual occupation	2.01(0.77)	0.07
Long term financial planning horizon	0.46(0.20)	0.07
Medium term financial planning horizon	0.53(0.21)	0.11
Number of person-years observations	33970	
Zero outcomes	99	
Non zero outcomes	33871	

Relative to having no time out of the labour market, experiencing an episodes out of the labour market due to inactivity or unemployment reduces the hazard of early retirement two-fold. This effect is much stronger than the estimation results implied from Table 3.4 for the full sample. Table 3.8 shows there was no significant effect in terms of lower levels of potential labour market experience on the hazard of early retirement.

As in the case with the full sample, lower levels of baseline health tend to raise the hazard of early retirement. In terms of lifetime health there is some evidence that more episodes of bad health prior to the age of 50 tend to raise the hazard of early retirement.

Turning to sociodemographic characteristics, our findings suggest in the case of early retirement that higher levels of education significantly raise the hazard of early retirement, as does having a spouse in employment. One difference is that the hazard of early retirement for those individuals with a mortgage is 50% lower relative to those who own their house outright. This is intuitive, individuals are likely to be in employment when they have a significant debt to repay. A final difference is that whilst having a medium or long term financial planning horizon did not affect retirement in any clear direction for the full sample, in the case of the early retirement it tends to lower the hazard by around $60-65\%$ relative to those with a short term financial planning horizon.

Diagnostics Where possible we include model specific weights following the method of Wooldridge (2002) to control for potential attrition bias (see Appendix 8.3.12).[42] Appendix 8.3.11 supplements the specifications in Tables 3.6 and 3.7 with a variable addition test (Nijman and Verbeek, 1992), and finds no evidence of particular patterns of attrition biasing our estimates.

3.7 Discussion

The results in Chapter three suggest episodes of inactivity and unemployed tend to reduce the hazard of retirement, given both of these act in the same direction we combine their effect. This indicates that individuals who exit the

[42] We trim our sample marginally by exlcuding 21 individuals who had an IPW of greater than 20. However our results are robust to including them, the main difference being that the estimated coefficients on the hazard were slightly larger in magnitude.

labour market or at least experience periods where they are not employed are less likely to retire than those who experience no interruptions in their labour market attachment over the lifecycle. Bozio et al. (2010, 2011) and Nicholls (2010) using the ELSA dataset (the former is linked with administrative National Insurance record data) investigate how lower labour attachment to the labour force using the life history data at wave 3 (and in the former case NI contribution records) show that those with more intermittent employment histories (experienced by episodes of inactivity and unemployment) were more likely to experience poverty in retirement. One method by which an individual can escape poverty is through paid employment, thus it is an appropriate response for older individual with an intermittent labour supply history to remain attached to the labour market for longer to (1) increase their flow of income (2) increase their stock of assets and (3) ensure they have made sufficient NI contributions in order to be eligible for a full state pension when they reach SPA. Therefore our results are not in conflict with studies which have used the ELSA dataset to investigate living standards in retirement.

We show our main result holds after controlling for gender and position in the income distribution. The quantitative effect is large, particularly for women which could be due to having to make up for missed national insurance contributions occurred in years related to child bearing (Pienta, 1999). The 2013 White Paper (DWP, 2013) highlighted that part of the overhaul to a single tier pension in the UK meant that for individuals to qualify for a full BSP they had to complete 35 years of 'qualifying' paid work, up from the current 30. However the proposed system does account for childbearing years whereas the current does not. The implications of our results would be that assuming one of the main periods spent out of the labour force for females is for child bearing/rearing, then ceteris paribus this should in future have a smaller effect on delaying retirement particularly amongst those who face credit constraints.

Such a policy does not support the governments aim to extend working lives of their citizens, however may be argued as being more equitable than current legislation. In fact prior to the current system for those individuals who retired before 6^{th} April 2010, men were required to work 44 (and women 39) 'qualifying' years, in order to make sufficient NI contributions in order to qualify for a full state pension. Therefore it is intuitive that the results from our analysis suggest time out of the labour market lowered the hazard of (early) retirement. The extent to which periods out of the labour market due to child bearing affect retirement behaviour in the future will also depend on the fertility rate. Recent trends in the dependency ratio have shown an increase in the fertility rate after a long period in decline, partly due to shifts in the cultural expectations of women, evidenced by the increasing numbers of females entering higher education (Heckman & Killingsworth, 1986; Universities UK, 2013).

In terms of employment effects our results suggest that individuals who spent particularly low levels of their potential lifetime labour supply in employment were more likely to retire (early). These results do not necessarily conflict with the measure of the number of counts out of the labour market, as they should be interpreted as being conditional on the number of periods spent out of the labour market.[43] The effects tend to be stronger for the early retirement samples and amongst men. For this particular group, relative to not spending any time out of the labour market those individuals who spent between 50% and 84% of their potential lifetime in the labour market were more than three times more likely to retire early. This is not unsurprising given that this particular cohort of men would have experienced severe recessionary periods, if one implication was that this lead to a sustained reduction in employment through a reduction in hours or even job loss, this may have increased the possibility of worklessness, long term unemployment or early retirement. The recessions of the 1970s and 1980s (particularly the latter) led to unemployment to be concentrated in unionised sectors, traditionally primary sectors such manufacturing. Scarring effects from this recession include increased worklessness and an increased number of men claiming long term sickness and disability, which in turn led to early retirement (Nickell, 1997). It is possible to identify when periods out of the labour market took place in terms of calendar time, and the evidence from our sample data suggest the majority of these took place over recessionary periods.

Despite the average proportion of time spent in employment for women

[43] It is also important to recall that we are not able to control for the exact length of time out of the labour market but only the incidence.

being 19% lower than men (98% vs 79%), the quantitative effect for the full sample suggests proportion of time spent in employment was not statistically important in the retirement decision of females. However for the early retirement sample the proportions do seem to have an effect in terms of the size of parameter coefficients. Given the cohort, it is likely these women took a more traditional role within the household. This is supported by specifications which control for spouses pension wealth which suggest that whilst the husbands pension wealth affects his partners retirement decision, the opposite is not true. Given that female labour supply over the past 30 years has increased dramatically, it is likely future generations of this particular cohort will not exhibit the similar behaviour in terms of retirement. For example the relative importance of 'male' pension wealth within a couple will decline, this is already true for changes made to the role of male state pensions (Bozio et al., 2010). Our results for the full sample controlling for position in the income distribution suggest the effect of lower proportions of potential labour market experience in the labour force are not identical. For those in the bottom three income quintiles lower proportions of lifetime employment tend to reduce the hazard of retirement, whilst for the top two income quintiles it acts to raise it substantially.

The fact that a substantial proportion of our sample retire early is quantitatively important if governments are aiming to extend labour supply at older ages. Our results suggest; lifetime labour market history, pension wealth and pension type, household income and baseline and lifetime health are key determinants of early retirement behaviour.[44] Of these, better lifetime and baseline health, and increased participation in the labour market will keep people in work longer.[45] There has been a raft of changes in legislation in an attempt to extend working lives and improve labour market conditions for older individuals in the UK working population. The 2008 Pensions Act aimed to increase saving for retirement particularly amongst low and middle earners by automat-

[44] Jones et al. 2009 find a similar result for health and pensions.

[45] Increasing longevity in particular the number of healthy years, reduces the burden on the state through staying in paid employment longer (or at least having the option to) and avoiding disability or incapacity benefits. It also lowers associated costs from use of the the National Health Service (NHS). The 2012 Health and Social Care Act (Department of Health, 2012) outlines the most significant changes to the NHS to date, however it is not clear whether there will be increased support for improving the health of the older population.

ically enrolling employees into workplace pensions, our results suggest those who contributed to employer pensions were more likely to retire early, however it should be noted that given the cohort it is likely these pension schemes, particularly DB pensions (which are being phased out) were more likely to be available to professional occupations.

Whilst it is important to increase participation in occupational and workplace pensions to reduce the extent of pensioner poverty, in order to extend working lives there should also be an increase in the minimum eligibility age at which individuals can claim their occupational pensions. At present there is a gap of ten years (six for females) between the date a male can claim his occupational pension and their state pension. In terms of unemployment and inactivity (excluding retirement) the UK Conservative-Liberal Democrat coalition government is in the process of overhauling the welfare system, and moving to a system of 'universal credit' which incorporates all forms of potential (in and out of work) benefits. Early reviews of the effectiveness Universal Credit and longer term measures such as the auto enrolment into employer pensions are not available at the time of writing. Doubtless these will influence labour supply behaviour at older ages.

3.8 Future work

Chapter three highlights the importance of lifetime labour market history on the retirement and early retirement decision. The analysis used a representative sample of English men and women aged 50 and over derived from the ELSA.

A limitation of the study is due to the design of the ELSA wave 3 life history survey, which meant it has not been possible to determine the exact length of time spent out of the labour market due to an episode of unemployment or inactivity, which started and finished in the same calendar year. Neither can we identify periods out of labour market which are less than three months in duration. In future work this could be overcome by using more detailed life history data available from either the National Child Development Survey 1958 (NCDS, 1958) cohort data, British Household Panel Survey (BHPS) and UK Household Longitudinal Survey (UKHLS) work history files.

Chapter three only accounts for the economic status of the spouse. Theoretical models and empirical evidence (Schirle, 2008; Disney, Ratcliffe & Smith, 2010; Gustman & Steinmeier, 2010; Cribb et al., 2013) suggest there is a degree of coordination in the timing of a couples retirement decision, due to factors such as complementarities in leisure. Therefore future work should incorporate more information relating to the spouse, in which case it may be more appropriate to model the retirement decision within a joint framework such as a bivariate probit or dynamic programming model.

3.9 Conclusion

In this chapter we investigated the effects of lifetime employment, unemployment and inactivity episodes on the hazard of retirement. We find these factors affect the hazard of (early) retirement for both men and women across the income distribution albeit in different ways. The retirement decision is particularly complex and is one of the most important decisions in an individual's life. Few papers have considered the role of lifetime experiences in relation to labour market activity on the retirement decision. Our results show given the nature of the economic problem it is appropriate to model the decision in a dynamic framework. In addition to lifetime labour market factors our results show the importance of pension type and pension wealth on the retirement decision, particularly for men. Given the cohort sample respondents in ELSA it is likely male pension wealth accounted for a significant proportion of total household pension wealth. Finally we show evidence to suggest that good lifetime and current health reduce the hazard of (early) retirement consistent with previous findings (Jones et al., 2010).

The type and level of pension wealth play an important role in the retirement decision. Policy makers have introduced a raft measures to ensure greater savings for retirement. The 2008 and 2010 Pensions Act aim to ensure all employees are offered a workplace pension, not just those in professional occupations. However our results suggest that further increases to the minimum eligibility age on occupational pensions should reduce the hazard of early retirement, particularly for men. In addition to occupational pensions there has also been an overhaul of the state pension to make it 'more simple'. Government argue it will ensure greater levels of income are made available for eligible retirees, particularly women and the self employed. However recent research by the IFS (Bozio et al., 2010) highlights these benefits are diminished in the long run particularly for those born after the calender year 1986.

Spending lower levels of potential labour market experience in employment tends to increase the hazard of retirement, irrespective of gender. Policymakers must ensure that well structured Active Labour Market Policies (ALMPs) are in place in order to help these individuals return to work relatively swiftly. The introduction of The Work Programme in 2011, the flagship ALMP of the coalition government applicable to the majority of the UK population has yet to be formally evaluated. We show that episodes out of the labour market tend to reduce the hazard of retirement, particularly for women. This may be related to missed state pension contributions, preferences for work post child rearing or credit constraints. Our results suggest lower lifetime employment may not only have contemporaneous effects but also longer term effects which affect the timing of retirement.

Chapter 4

Unretirement in England: An Empirical Perspective.

4.1 Introduction

Ageing populations are a common characteristic shared amongst advanced economies around the world. Increasing longevity has placed additional pressure on central government's resources and in particular the Welfare State. The 2011 Census showed 16.4% of the population was aged 65 and over (ONS, 2012b).[1] This is reflected in the dependency ratio defined as the number of individuals aged over State Pension Age (SPA) relative to the working population aged between 16 and 65, which increased from 0.3 in 1971 and without any change in retirement legislation is forecasted to reach 0.5 by 2050 (ONS, 2010). Put another way, in 1971 there were roughly three individuals of working age to every one pensioner, by 2050 this is forecast to reduce by one third. In response to this and other factors which show the detrimental effects of population ageing, the UK government has increased the Normal State Retirement Age (NSRA) for both men and women.[2]

Retirement in the UK has traditionally been considered as the cessation

[1] Figures based on data for England and Wales.
See Office for National Statistics website: http://www.ons.gov.uk/ons/dcp171778_-270487.pdf pp. 2.

[2] At present men and women are eligible to claim their state pension when they turn 65 and 61 respectively, by April 2020 this will rise to 66 for both. The UK government has also abolished the compulsory retirement age for both men and women.

of a career job. However, over the past thirty years individuals have altered their labour market behaviour as they approach retirement age, for example through phased retirement (Honig and Hanoch 1985; Ruhm 1990 and Blau 1994). The latter two studies also found that retirees re-entered the labour market i.e. unretired.[3] Starting in the 1980s a host of studies from the US have since noted such behaviour. Gustman and Steinmeier (1984a), using the Retirement History Survey (RHS) highlight 16.6% of their sample exhibited unretirement behaviour.[4] Subsequently Berkovec and Stern (1991), using the National Longitudinal Survey (NSL) report re-entry rates ranging from 6.3% to 13.2% depending on age of first retirement. Hardy, Hayward & Liu (1994), using the same dataset restrict attention to those who are aged 55 and over when they first retire, and report an unretirement rate of 10.69%.[5] Hardy (1991), using a sample of nationally representative older workers in the US state of Florida, observes labour force re-entry rates of 6.89%.[6] A common finding amongst these studies is that younger retirees were more likely to unretire.

More recently Maestas (2010), using a sample of men and women from the Health Retirement Survey (HRS) shows that more than one quarter of sample respondents who are in employment subsequently exhibit unretirement behaviour.[7] Her findings show of the sample that unretired 80% expected to work post retirement, and the main motivation to unretire was that retirement did not conform to their a priori expectations, whilst the role of financial

[3]Both studies reported an identical unretirement rate of 25% using the Social Security Administration Retirement History Longitudinal Survey (RHLS).

[4]Ruhm (1990) notes the significant difference between his results and that of Gustman and Steinmeier (1984) who also use the RHLS. Ruhm (1990) concludes the discrepancy between their results (the first study reports unretirement rates of 24.9%, whilst the latter reports unretirement rates of 16.6%) is due to the time window of observation. Gustman and Steinmeier (1984) only use one and two year windows to observe re-entry, whereas Ruhm (1990) uses a ten year window and therefore increases the probability of observing an episode of unretirement.

[5]Hayward et al. define 'exposure intervals' which relates to labour force experiences for an individual for a single year, with a full set of accompanying covariates. The authors observe 6263 intervals and observe 670 episodes of unretirement.

[6]Hardy (1991) finds that 11.7% of 'unretirees' stated they initially retired involuntarily.

[7]This figure increases to 35% if analysis is restricted to those individuals who first reported being retired at age 53 or 54.

shocks or inadequate financial planning had a less significant role.[8][9] Congdon-Hohman (2009) using the same dataset finds similar results and highlights the importance of private health insurance and similar to the research presented in this chapter, uses duration analysis to model the unretirement decision.[10]

In contrast to analysing unretirement amongst those who are initially employed, little research has focused on re-entry into the labour market conditional on being in retirement. The few which do include Larsen and Pederson (2013), who use Danish administrative register data to show that the probability of being in paid work post normal retirement age in Denmark is higher for: males who own their own home, have made higher pension contributions and are better educated. Peterrsson (2011) investigates unretirement in Sweden using register data, and similar to Larsen and Pedrson (2013) models unretirement using a static framework. Peterrsson (2011), estimates an unretirement rate in the region of 6% to 14% depending on the definition of unretirement and found unretirement was more common amongst: younger retirees, men, those with a spouse in the labour force and amongst individuals with a high level of educational attainment. Similar to Maestas (2010), the study suggested unretirement was a lifecycle decision and not (in general) a response to negative financial shocks.

In this paper we consider unretirement in England.[11] In contrast to other papers the aim of our research is to focus on the shape of the hazard function for a sample of *retired* men. We use a duration approach and account for individual level unobserved heterogeneity, to investigate the relationship

[8]Maestas (2010) specifies a pre/post retirement multinomial logit for alternative retirement paths and supplements her model with expectations data. Benítex-Silva and Dwyer (2003) formally test whether the rational expectations hypothesis hold in the HRS sample, and conclude that on average individuals do exhibit rationality, in particular with respect to forming retirement expectation. Their findings are similar to those found by Mastrogiacomo (2003) for the case of the Netherlands.

[9]Cahill, Giandrea & Quinn (2010) also use the HRS to analyse unretirement rates for those who in their baseline interview were in full time career jobs. They find that 15% of their sample exhibit an episode of unretirement.

[10]The role of private healthcare is likely to be less important in the case of England due to universal state healthcare.

[11]Early work regarding the British retirement experience (which mentions unretirement) can be found in Parker (1980), 11% of his sample respondents indicated they would consider looking for work in the future. This is despite the fact that at the time prohibitively high taper rates existed on earnings after reaching state retirement age and claiming a state pension (Bozio et al., 2010).

between time spent in retirement and the hazard of moving back into paid work. We find a number of interesting results; similar to Peterrsson (2011), retired individuals with a spouse in the labour force are significantly more likely to subsequently return to paid work. Therefore, despite females not unretiring themselves they play a role in the unretirement decision of their husband, this is likely to be linked to complementarities in shared leisure preferences (Schirle, 2008; Disney, Ratcliffe & Smith, 2010). There is no clear pattern in the hazard of unretirement, however it does tend to be higher in the first 5-10 years following initial retirement after which it diminishes. This is particularly important in terms of recognising a propensity to unretire; potential policies which encourage a return to paid work may be less effective if they are too slow acting post initial retirement.[12]

We find some evidence of individuals who retire 'early' which we define as 60 or under, as being less likely to unretire. This likely to be due to relatively generous financial incentives available in early retirement schemes in particular professions. Indeed our results suggest strong pension wealth effects, which act to lower the hazard of unretirement. Similar to Maestas (2010) we find little evidence of unexpected changes in wealth and debt, in raising the hazard of unretirement. Similarly we find only weak evidence of social class effects, those who self report themselves to have been in a professional or managerial occupation were marginally less likely to unretire than those who were unskilled.

Education plays a role in the unretirement decision, those individuals with an A level or higher are more likely to unretire. Finally, individuals with a medium term (1-3 years) and long term financial planning horizon (3+ years) are also significantly more likely to unretire. Therefore, on balance it seems unretirement is more common amongst individuals who are relatively well educated and did not retire early, suggesting it may be linked to a preference for work.

Using lifetime labour market history information available in ELSA, it is possible to determine preretirement characteristics of unretired individuals. Estimates indicate that the average annual salary in the final main job prior

[12] Maestas and Li (2007) refers to this as a 'burnout effect'. Individuals retire for a short period after their main career job due to career burnout before subsequently returning to work.

to retirement for our sample of unretirees was approximately £38,919.13 (2007 prices). Unretirement jobs themselves are similar in character to partial retirement jobs, both in terms of earnings and hours of work. Taken together with the results above, this suggests unretirement is not due to financial constraints nor is it a consequence of having low income during working life. Instead it is a type of behaviour associated with those individuals who were well educated and had a relatively well paid job prior to retirement. Given the potential untapped economic capacity of retired men in England, these results are of importance to policymakers in their attempt to extend working lives or in this case incentivise a return to work.

The rest of this chapter is set out as follows: Section 4.2 contains detailed information regarding ELSA and how we define unretirement. Section 4.3 outlines the regression specification and modelling approach. Section 4.4 presents our estimation results and tests for robustness. Section 4.5 looks at characteristics of unretirees and unretirement jobs in England. Section 4.6 considers future work. Section 4.7 concludes and considers policy implications.

4.2 Data.

4.2.1 Sample and ELSA

For a description of the ELSA dataset readers should consult the Section 3.5 in chapter 3, Appendix 8.3.1 and Appendix 8.4.1. We use the first four waves of data which cover the period 2001-2009 and restrict attention to male wave 1 core respondents aged between 50 and 74, who report having a retirement month and year.[13] The main reason for excluding females from the analysis is that for this cohort, female labour supply is characterised by sustained periods out of the labour market due to child rearing and caring responsibilities. Preliminary research showed the magnitude of unretirement for this cohort was too low for any substantive analysis to be undertaken.

We impose these age and labour market restrictions to ensure a degree of

[13]Despite there existing an additional wave of data known as wave 0, from which the original ELSA sample were constructed this wave of data contains little socioeconomic data compared to wave 1 onwards.

homogeneity in our stock sample.[14] Our aim is to investigate the unretirement behaviour of only fully retired men and therefore choose not to include partially retired individuals at wave 1 as their underlying labour market behaviour maybe somewhat different, additionally only a very small sample of wave 1 ELSA respondents self report themselves being in this group. After placing these sample restrictions we achieved an unbalanced panel of 857 retired individuals. We do not allow for re-entry once an individual non-responds in a particular wave. Appendix 8.4.1 contains information pertaining to sample construction and summary information.

We test for attrition bias due to non-response using a variable addition test proposed by Nijman and Verbeek (1992). Separately we also weight our data using model specific weights following the method of Inverse Probability Weighting (IPW) proposed by Wooldridge (2002). In the models for estimating model specific non-response weights we use a combination of sociodemographic and survey/interviewer information available in ELSA, which are not included in the covariate set used for modelling unretirement.[15] The reason for this is because the strategy used in this chapter relies on assuming individuals are missing at random conditional on controlling for factors which are likely to correlated to non-response i.e. selection on observables and unobservables. Fitzgerald et al. (1998) note that for this approach to work there exist variables which are available in the dataset which are deliberately excluded from the information set used to predict the outcome of interest. This is commonly referred to as the conditional independence assumption. By assuming conditional independence then consistent estimates can be derived using the inverse of the probability of observation. This is true even when the excluded covariates (instruments) are not included in the model for the outcome of interest, even if they are endogenous (Jones et al. 2012). We assume non-response is a function of: accuracy of interviewee response to work and pension questions, accuracy of interviewee response to income and asset questions, household net financial wealth, calendar quarter and year of interview, whether respondent has a long-standing illness and whether respondent feels health will affect

[14] We cross check individuals self-reported status with weekly earnings and number of hours worked per week.

[15] Future work will amend the probit model specification used in the estimation of the inverse probability weight to reduce the variance of the distribution of attrition weight.

ability to work.[16] Appendix 8.4.3 contains estimation results from the probit models of non-response used to estimate the IPW.

4.2.2 Definition of unretirement

Our definition of unretirement relies on observing the re-entry date to the labour market. At each wave of the ELSA sample members are asked the month and year of re-entry, therefore using this we can compute an unretirement date based on those individuals who give a valid response (conditional on them being in retirement and having not yet unretired). Combining this information with the month and year of initial retirement it is possible to compute the exact length of time an individual has spent in retirement before they return to work. Under this definition 9.21 percent of our unbalanced panel ($N = 857$) exhibited unretirement behaviour.

An alternative definition could be based on the number of hours reported working in paid employment, if an individual is in receipt of a pension, or changes in the self reported economic status across waves. What is important for these definitions is the opportunity set available to the individual in a particular economic state. In England it is possible to retire and defer both state and/or private pension payments, although this is relatively uncommon (Coleman et al., 2008). The aim of this research is to focus on the duration spent in retirement and this is underlined by choice to focus on month and year of labour market re-entry in our definition of unretirement. Changes in self reported measures are at best reported biennially and therefore potentially inaccurate, we report these next for completeness. Table 4.1 gives an overview of potential retirement paths which feature unretirement.[17]

[16] We estimate a mispecification test (to detect omitted variable bias), suitable for single equation models such as our non-response probit models. Results suggest no evidence of this form of mispecification, however there was some evidence to suggest that for the case of men the model lacked predictive power, this is due to the lack of appropriate variables available in ELSA which could be convincingly excluded from our retirement equation and were suitable for the non response equation.

[17] The ELSA questionnaire does not differentiate between part-time and full-time employment in the self reported labour force status. Therefore we use number of hours reported in paid work per week in addition to the self reported status.

Table 4.1: Hypothetical retirement paths featuring unretirement.

Wave 1	Wave 2	Wave 3	Wave 4
Retired→	Retired→	Employed→	Employed
Retired→	Unemployed→	Employed→	Retired
Retired→	Retired→	Retired→	Unemployed

4.2.3 Alternative measures of unretirement using ELSA

Self reported labour force status definition. An alternative definition of unretirement would be to measure the changes in self reported labour market status across waves from retired to employed. [18] Following this definition we estimate an unretirement rate of 5.86% for our sample of unbalanced panel men. Whilst this is lower than the definition based on job start dates it is likely to be due to the difficulty in individuals perceptions of the precise definition of retirement, individuals reporting themselves as retired may still engage in some form of paid work, but still consider themselves as 'retired' perhaps because they are claiming a state pension or social norms related to passing the state pension age (Kohli et al., 1991). Maestas (2010) using the Health and Retirement Study (HRS) using a similar definition estimates an unretirement rate of 26%.[19] The difference in the prevalence of unretirement in the US relative to the UK is striking, however the rates reported for the UK rates are similar to those documented in the US using the Retirement and Health Survey (RHS) from the 1970's and 1980's (Rust, 1987; Diamond and Hausman, 1984; Gustman and Steinmeier 1984a,1986).

Due to the ELSA being a biennial study it is possible for individuals to exhibit short-term unretirement between surveys. We found 18 respondents exhibit such behaviour over the sample period including these episodes of unretirement, raises the unretirement rate to around 8%. Maestas (2010) computes

[18] Survey respondents were asked their Labour Force Status (LFS) in each wave of ELSA. Respondent's are asked 'Which one of these, would you say best describes your current situation?'. Interviewers are only allowed to code one response from the following categories: Retired, Employed, Self-employed, Unemployed, Spontaneous (semi retired), Permanently sick or disabled, Looking after home or family, Other (specify).

[19] Maestas (2010) defines unretirement in two ways; the first is based on self reported economic status and hours worked, whilst the second is based on hours of work only. Maestas (2010) includes both men and women, and uses only those individuals who are in employment in wave 1.

a similar statistic, and finds her unretirement rates increase from 26% to 31%, similarly she concludes that the majority of these short term unretirements report either zero or very low values of income and therefore 'given their trivial nature we do not include them in analysis to overstate the importance of unretirement' (Maestas, 2010 pp.28).

Hours based definition We may also define unretirement rates based on wave by wave changes (from zero to positive) in the number of hours working in paid employment per week. Maestas (2010) follows a similar approach, the effect of using an hours based definition raises the unretirement rate due to unemployed individuals being included. Given our sample conditions on individuals to be in retirement at wave 1, very few individuals transition into unemployment.[20] This underpins the similarity in the unretirement rate estimated using the self reported and hours based definition.[21] Under the hours based definition we report an unretirement rate of 3.27 percent.

Sensitivity analysis As a sensitivity measure we test each definition of unretirement using a binary framework to model the retirement decision similar to Peterrsson (2011), Larsen and Pederson (2013) and Cahill et al. (2010). We construct consecutive two-wave balanced panel logit models and find estimation results are broadly similar irrespective of the definition used (not reported). In light of this we choose to present results based on the labour market re-entry date, given that under this definition it is possible to accurately determine the duration effect of being in retirement on the unretirement hazard.

[20] We include individuals who move from self reported retirement to unemployment.

[21] Maestas (2010) follows a similar method. All the measures of unretirement outlined in the chapter may underestimate the rate of unretirement if by returning to work this leads to an increase in the probability of survey non-response: if an individual returns to work they have reduced leisure time, this may negativly affect the likelihood of responding to a household survey, for recent evidence in the case of the BHPS see Uhrig (2008). We test for the pattern of non response and find that this does not bias our results.

Work environment for older workers in England

Involuntary retirement Until April 2011 UK retirement legislation allowed employers to force employees to retire once they became eligible to claim state pension.[22] The sample period for this chapter spans 2001-2009, therefore an individual who wanted to continue to work past the State Retirement Age (SRA) against the will of their employer would have to unretire by law. Dorn and Sousa-Poza (2010) find evidence which suggests involuntary retirement increases the incidence of early retirement in selected EU countries, from their Great Britain sample they found almost 70% of their respondents between the age of 45 and 69 took involuntary early retirement. At each wave of ELSA respondents were asked their main reason for taking (early) retirement, one category is 'made redundant/dismissed/had no choice'. Of the entire sample this was applicable to 4.43% of individuals and 2.5% of the 'unretired' sample. The reason cited most frequently was reaching retirement age, or in the case they retired early, that they were offered reasonable financial terms. Therefore whilst involuntary retirement did contribute to the flows into retirement, it did not contribute to the same extent to unretirement.

The budget set. An individual is eligible to claim their State Pension once they reach NSRA, which until 2011 was 65 for men and 60 for women. A recent DWP report (Coleman et al., 2008) finds that the labour supply decision and decision to claim SP are correlated. However flexible working practices mean that an individual can choose to claim their pension and also continue working, they may also defer their pension and in return receive a considerable rate of return. In the context of this chapter, the budget set of an unretiree is not penalised by a high marginal tax rate for choosing to claim their State Pension and continue working, in this sense there is an absence of nonlinearities in the budget set.[23]

[22] This law held for both men and women, despite their default state retirement age differing.

[23] This has not always been the case. Between 1948 and 1989, if an individual wanted to claim their state pension within five years of retiring they had to terminate regular employment. Specifically, an individual was not allowed to claim state pension if they worked more than 12 hours per week. Even if they worked less than this threshold, and earned above a certain higher limit (similar to the Higher Earnings Limit), their state pension was reduced accordingly. Between 1948-1958 the taper rate was 100%, between 1958 and

4.3 Specification and Modelling approach

4.3.1 Covariate information set

ELSA contains a range of economic and sociodemographic variables which are likely to affect the hazard of unretirement, in guiding the specification described in Table 4.2 we tested alternative specifications using BIC/AIC. Appendix 8.4.2 provides a formal description of how each of the variables in Table 4.2 was coded for estimation purposes.

Health has also been shown to be an important determinant of labour supply behaviour at older ages in the UK (Jones et al., 2010). We control for whether the individual has private health insurance and also the number of limiting illnesses.[24] The former of these is also likely to serve as a proxy for economic position; given the cost of private health insurance in England and the fact that public healthcare is provided universally by the state.

We include sociodemographic characteristics such as whether an individual is married and the labour force status of their spouse. Previous research has noted the importance of the spousal effects in the labour supply decision of the partner, due to factors such as a preference for shared leisure (Disney et al., 2010; Cribb et al., 2013). Schirle (2008) estimates 25% of the labour supply of older UK married men can be explained by the labour force status of his wife.

Of the economic variables we include dummy variables to control for the highest education level obtained.[25] We also account for social job class relating to the type of job prior to initial retirement. Using an identical method to Maestas (2010) we test whether a potential route for unretirement is due

1989 it was reduced to 50%, and increased to 100% for earnings over the HEL. This was seen as very detrimental to work incentives for older people. In 1989 the earnings rules described above were abolished. Pension income and earnings from employment whilst in retirement are now taxed at a rate similar to that of the general working age population. For more information see Bozio et al (2010).

[24] We do not include measures for self reported health, due to the routing of the wave 1 questionnaire which meant it was only asked of half the retired wave 1 ELSA sample.

[25] The education level and social class variables use imputed information from wave 1. The social class is on a 7 point system in wave 1, from professional through the unskilled. We do not include self reported health status because almost half of the final sample for estimation report their SRH to be not applicable, however we do cross tabulate self reported health in wave 1 with our unretired sample. We find a positive correlation, that is to say unretirement episodes were concentrated amongst those reported they were in very good or excellent health.

to unexpected changes in wealth or debt. The Institute for Fiscal Studies (IFS) derive a range of financial derived variables available with each release of ELSA. Using these it is possible to construct measures for unanticipated shocks to debt and wealth, defined as a 25% change in the non housing net financial wealth or non housing net financial debt, in any two consecutive waves. The stock sample contains individuals who are in retirement therefore the level of pension wealth is likely to play a role in the labour market behaviour of retired individuals (Disney, Ratcliffe & Smith., 2010), our preferred specification controls for baseline (2002) private and public pension wealth.[26]

4.3.2 Model specification

Existing research has focused on static or sequential methods such as a probit or multinomial logit model to analyse the unretirement decision (Cahill et al., 2010; Pettersson, 2011; Maestas, 2010). The focus of this chapter is to consider the effect of duration spent in retirement on the unretirement decision. A natural way to consider this in the context of unretirement is within a discrete time hazard framework.

Modelling unretirement in a duration framework allows one to establish whether the decision to unretire is made immediately following initial retirement i.e. to establish the speed at which individuals reoptimise their behaviour. Duration analysis goes beyond what is possible to infer from static or sequential models in terms of when an individual becomes 'at risk'.

Discrete time hazard model

Having both the retirement date and the return to paid employment information we are able to identify the exact interval in which unretirement occurred, conditional on being in retirement. We model unretirement using a discrete time complementary log-log model. This is the Prentice-Gloeckler (1978) complementary log-log model and its extension assuming a gamma mixture dis-

[26] Pension wealth is calculated such that we assume individuals retired at state pension age. We choose pension wealth instead of pension income to allow for individuals who may choose to defer their pension. For more information regarding the construction of the pension wealth variables in ELSA see Banks et al (2005).

Table 4.2: Covariate information set used in discrete time hazard model.

Sociodemographic variables
Married at wave 1
Whether first retired between the age of 50 and 55
Whether first retired between the age of 56 and 60
Spouse in employment at wave 1
Whether has private health insurance
Whether has a limiting illness
Education level
Economic variables
Unanticipated debt shock *(IFS)*
Unanticipated wealth shock *(IFS)*
Log of total pension wealth in 2002
Non-pension financial wealth quintile in 2002
Income quintile 2002
Opportunity to work past retirement age
Whether respondent feels they do not have enough income
1 day -1 year (short term) financial planning horizon (base group)
1-3 year (medium term) financial planning horizon
3+ year (long term) financial planning horizon
Self reported social class by preretirement job occupation

Notes: For each covairate, definition and description can be found in appendix 8.4.2 Education level refers to highest level of attainment: Degree (minimum 16 years full time education); At least A level and below degree level (Between 13 and 15 years full time education); CSE/ O level (Between 10 and 11 years full time education).

tributed error (Meyer, 1990).[27] Nicoletti & Rondinelli (2006) show that by allowing for unobserved heterogeneity and assuming a non-parametric baseline hazard, this mitigates the effects of potential bias in the duration dependence and covariates. Additionally such a specification provides better validation for the detection and true extent of unobserved heterogeneity relative to a tightly constrained parametric model (Dolton and Van der Klaauw, 1995).

We test for the presence of individual level unobserved heterogeneity assuming it is summarised by a gamma mixture distribution.[28] We do not find evi-

[27] This is the analogous discrete time version to the continuous proportional hazards model, and is particularly suitable given the relatively low probability of observing an episode of unretirement (Jenkins,1997).

[28] The starting values for the estimation of the vector of parameters β in model 2, are taken from (1). The proportional hazard in this case is: $\lambda_{i,t} = \lambda_0(t)e^{[x_{i',t}\beta+\log(v_i)]}$. Where v_i

dence of this type of unobserved heterogeneity and therefore choose to present results for the preferred specification which assumes a Gaussian error term. We estimate model specific weights using the method of IPW (Wooldridge, 2002) to account for non observable non-response (Rubins, 1976), estimation results for modelling the non-response decision can be found in Appendix 8.4.3.[29]

The central aim is to model the relationship between the survival time and our information set. Jenkins (1997) and Stewart (1996) present a detailed discussion of these estimators, we draw heavily on the exposition of Jenkins (1997). In the discrete case the proportional hazard is given as:

$$\lambda_{i,t} = \lambda_0(t)e^{[x'_{i,t}\beta]} \tag{4.1}$$

Where $\lambda_0(t)$ is the baseline hazard. The discrete time hazard in the j^{th} interval is given by:

$$h_j\left(X_{i,j}\right) = 1 - e\{-e^{[x'_{i,j}\beta+\tau_j]}\} \tag{4.2}$$

Where:

$$\tau_j = \log \int_{f_{j-1}}^{f_j} \lambda_0(\tau)d\tau \tag{4.3}$$

We specify a non-parametric baseline hazard, which allows for complete flexibility in the hazard function (Jenkins, 1997). We reorganise our data such that the unit of analysis is changed from the individual to the time at risk of event (Jones et al., 2010). All estimation is carried out using Stephen Jenkins Stata routine pgmhaz8.

is a random variable which follows a gamma distribution such that $v_i \sim (1, \sigma^2)$. The hazard rate changes accordingly for more information see Jenkins (1997).

[29] We test our models of non response and find there is no evidence of omitted variable bias, however estimation results do suggest our specification lacks predictive power. This is due to the relative sparcity of variables which can be convincingly exluded from the unretirement equation and included in the non response equation.

4.4 Estimation results

Non-parametric retirement survival curves

To infer more detail about the relationship between the time in retirement and the return to paid work, Figure 4.1 plots non-parametric retirement survival curves for the whole sample by age in wave 1 (2002). The unretirement hazard is defined as the slope of minus the log survival curve (Maestas, 2010 pp.9). The top left survival curve in Figure 4.1 indicates there is no clear spike in the unretirement hazard, only weak evidence it is higher in the first ten years following initial retirement.[30]

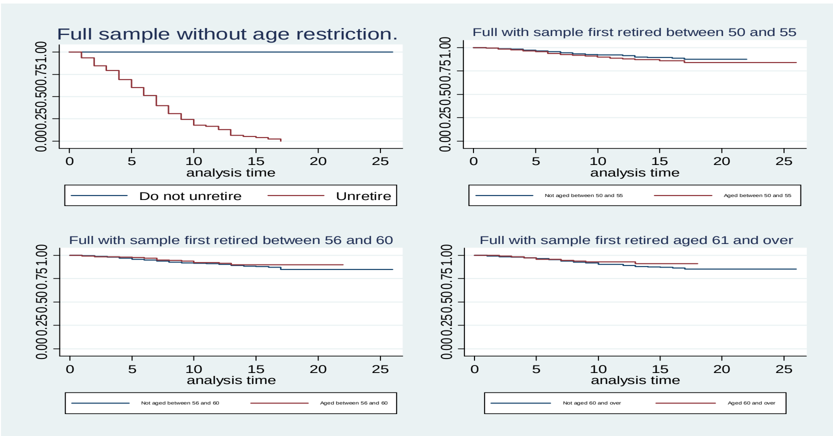
The panel in the top right hand corner of Figure 4.1 is the survivor function for those who unretire and those who do not (i.e. stay in retirement over the sample period) for the whole sample irrespective of their age of first retirement. Therefore by construction the red line in the top right hand panel of Figure 4.1 show unretirement episodes. The other three panels restrict attention to individuals who exhibit unretirement behaviour and investigate whether there is a difference in the hazard of unretirement by stratifying over particular groups. Maestas (2010) finds a much steeper decline (particularly in the 2-4 years following initial retirement) in the survivor functions estimated for her sample of HRS respondents, highlighting that unretirement behaviour was more common soon after initial retirement; in addition it was also clear she observed a higher incidence of unretirement episodes. Our sample consisted of 857 individuals of which 628 or 73% retired prior to state pension age, suggesting significant evidence of early retirement behaviour for this particular cohort.[31] Such is the extent of early retirement in England that the average retirement age at wave 1 for our ELSA sample of retired men is 59.7 years. Coincidentally this is very close to the official SPA of females in the UK and it is likely spousal effects such as joint complementarities in leisure are in operation (Cribb et al., 2013). It is also identical to the mean age of HRS sample members used by Maestas (2010), however her sample only included

[30] By construction we assume the hazard between observed unretirement episodes is constant.

[31] We derive this statistic using the information relating to month and year of retirement, combined with in an individuals year of birth. Whilst every effort has been made to ensure this is accurate there may be some measurement error, for example due to recall error or rounding.

individuals who were in employment at wave 1. It is likely that there will be a fundamental difference in the labour market behaviour of a stock sample of individuals in retirement, versus those initially in employment even within the same country. Nonetheless it clear that given the mean retirement age in this study is approximately equal to that of the HRS sample respondents in Maestas (2010) that at present unretirement is much more common in the US relative to the UK.

Figure 4.1: Kaplin-Meier survival curves of unretirement by age.



Estimation results

Table 4.5 indicates there is no clear pattern in the duration dependence of unretirement, as indicated by Figure 4.1 and Figure 4.2.[32] Coefficient estimates are slightly bigger in the 10 years following initial retirement after which point they tend to diminish. Such a pattern is quite different to that reported in the US, Maestas (2010) found that the majority of unretirement transitions were made in the first 2-4 years following initial retirement. Human capital theory would suggest a swift return to work given that an individual's stock of skills depreciates the longer they stay in retirement.

Turning to our economic and sociodemographic covariates, Table 4.5 suggests there is little evidence of a social gradient in the hazard of unretirement.

[32] The fact that standard errors are large compared to coefficient estimates on the duration dummies is likely to be related to the relatively low number of unretirement transitions observed in the data.

Relative to the base group of unskilled or semi skilled, those individuals who reported their social class to be either professional or managerial were no less likely to unretire. One exception is individuals who reported themselves as being skilled non-manual workers, who were nearly twice as likely to unretire. Whilst the hazard of unretirement for those who reported being skilled manual workers was 60% lower than that of the base group. Those individuals who were allowed to work past retirement age were 10% less likely to unretire relative to those who were not. This is intuitive given that these individuals could continue working until they decided to retire, and were not forced to retire and then unretire as would have been the case under the retirement legislation at the time. Table 4.5 highlights an education gradient. Specifically those individuals with a degree were 1.5 times more likely to unretire, relative to the base group who held no qualifications.

The early retirement indicators suggest the hazard of unretirement for those individuals who first retired prior to the age of 60 was not significantly higher than those who retired after this point. For those who retired between the ages of 50-55 the unretirement hazard was 12% higher, whereas the hazard for those who first retired between the ages of 56-60 was 7% lower than the base group. Therefore whilst younger retirees tended to be more likely to unretire these effects were not significant at conventional levels.

The total of log private and public pension wealth measures the present value of total pension wealth in 2002 (assuming individuals retired at SPA). Our results indicate conditional on educational attainment those with higher levels of total pension wealth are significantly less likely to unretire. We also control for the total non-pension financial wealth in 2002, which indicates relative to the base group (being in the top quintile) the hazard of unretirement is not significantly different for those lower down the non-pension wealth distribution. Therefore whilst financial wealth is important, it is pension wealth which plays a significant role in the labour supply behaviour of retired individuals.[33]

Turning to the covariates summarising financial planning, Table 4.5 indicates that unretirement is not related to having a short financial planning

[33] Almost one third of our sample reported being in the top wealth quintile, therefore this result may be due to a lack of variation in non-pension financial wealth.

horizon. Those individuals with a medium (3-5 years) or long term financial planning horizon (5 years+), are at least two times more likely to unretire relative to the base group of short term (<3 years). We also include a measure for whether a retiree felt they did not have enough income at the time of their wave 1 interview. The hazard of unretirement was two-fold higher for those who responded positively, combined with financial planning results, suggests that unretirement may be a foreseen event.

We also include measures which control for debt or wealth shocks. These are binary variables which take the value one if an individual experiences a 25% change in the level of net debt or wealth they hold respectively, between any two consecutive survey waves. Table 4.5 suggests that wealth shocks have a negligible impact in reducing the hazard of unretirement, by around 6% relative to those who do not report a shock. Similarly those individuals who experienced an unexpected debt shock were no more likely to unretire. In summary our results suggest that over the sample period there was no clear pattern between financial shocks and unretirement.

Those individuals who report being married were nearly 60% more likely to unretire, however this effect was not significantly significant. We do find some evidence for shared preferences amongst couples, the hazard of unretirement was three-fold higher for a man who had a wife in employment when they were initially in retirement, relative to those who did not (or were divorced/single/widowed). This does suggest there is some role for preferences for shared leisure amongst couples, or perhaps for social interaction possible through paid employment.

Finally we control for limiting illnesses and find having at least one limiting illness (relative to having none) reduces the hazard of unretirement by 30%. It is less likely these individuals will be able to return to work. We also control for the presence of private health insurance which is likely to be correlated to income or wealth, our results indicate the unretirement hazard is 39% higher for those who have such insurance.

Test for attrition bias We test for attrition bias using a variable addition test first proposed by Nijman and Verbeek (1992). This was carried out by including a variable which corresponds to the number of survey waves an individual responded to, which is regressed along with the full information set in the unretirement equation. We find no evidence of this particular type of attrition bias whilst the coefficient estimates (not reported) changed only marginally relative to those reported in Table 4.3.

Table 4.3: Discrete time hazard model with Gaussian frailty.

Time spent in retirement	$\beta\,(\sigma)$
1 year	3.76
	(3.85)
2 years	4.38
	(4.29)
3 years	2.83
	(2.82)
4 years	5.77*
	(5.70)
5 years	5.86*
	(6.07)
6 years	4.74
	(5.05)
7 years	7.18**
	(6.49)
8 years	4.83*
	(4.51)
9 years	4.78
	(4.77)
10 years	6.48*
	(7.19)
11 years	2.59
	(3.85)
12 years	4.82
	(5.55)
13 years	9.64**
	(10.62)
14 years	3.53
	(4.07)
15 years	4.30
	(6.09)
16 years	0.48
	(0.64)
17 years	1.45
	(1.68)
Robust standard errors in parentheses	
*** p<0.01, ** p<0.05, * p<0.1	

Table 4.4: Discrete time hazard model with Gaussian frailty (continued).

Financial and income variables	$\beta\,(\sigma)$
Total pension wealth in 2002	0.51***
	(0.05)
1st quintile: non-pension wealth in 2002	0.68
	(0.52)
2nd quintile: non-pension wealth in 2002	0.65
	(0.35)
3rd quintile: non-pension wealth in 2002	1.17
	(0.49)
4th quintile: non-pension wealth in 2002	0.76
	(0.31)
1-3 year (medium term) financial planning horizon	2.31*
	(1.21)
3 years+ (long term) financial planning horizon	3.01**
	(1.67)
Experienced a 25% unanticipated decrease in wealth	0.92
	(0.28)
Experienced a 25% unanticipated increase in debt	0.99
	(0.46)
Occupation dummies	
Professional job occupation	0.84
	(0.48)
Managerial job occupation	0.94
	(0.44)
Skilled / nonmanual job occupation	1.98
	(1.06)
Skilled / manual job occupation	0.51
	(0.28)
Robust standard errors in parentheses	
*** p<0.01, ** p<0.05, * p<0.1	

Table 4.5: Discrete time hazard model with Gaussian frailty (continued).

Sociodemographic characteristics	$\beta\,(\sigma)$
Whether has private health insurance	1.39
	(0.55)
Opportunity to work past retirement age	0.91
	(0.42)
First retired between the age of 50 and 55	1.13
	(0.43)
First retired between the age of 56 and 60	0.93
	(0.33)
Married at wave 1	1.67
	(0.71)
Has a limiting illness	0.70
	(0.20)
Respondent feels they do not have enough income	2.22
	(1.24)
Spouse in employment at wave 1	3.08***
	(1.09)
Education dummies	
Holds a degree	2.55**
	(1.21)
Below degree level but at least an A level	2.59
	(0.96)
Holds an O-level or CSE	1.70
	(0.68)
Number of person-year observations	9617
Number of failures	79
Wald $chi^2(45)$	1459.95
Prob > chi^2	0.00
Robust standard errors in parentheses	
*** p<0.01, ** p<0.05, * p<0.1	

Discussion. Our results indicate that there are a number of factors which affect the likelihood of a return to work. These include: relative income position; log pension wealth; financial planning horizon; spouse's employment status and education. It is likely that these factors are related to one another, for example those who are better educated tend on average to have higher lifetime earnings, and so are likely to have higher levels of pension wealth given that by definition pension wealth (and income) is generally deferred income from an earlier period (Card, 1999). Table 4.5 suggests the hazard of unretirement is not higher or lower for individuals in specific occupations, despite certain occupations having access to generous defined benefit pension schemes, which have in part led to the rise in early retirement (Smith, 2006; Jones et al., 2010).

Figure 4.2 plots the predicted hazard of unretirement using the estimated probabilities from the complementary log-log model. Similar to Figure 4.1, Figure 4.2 indicates there is no clear pattern between length of time in retirement and hazard of unretirement.

Figure 4.2: Predicted hazard of unretirement.

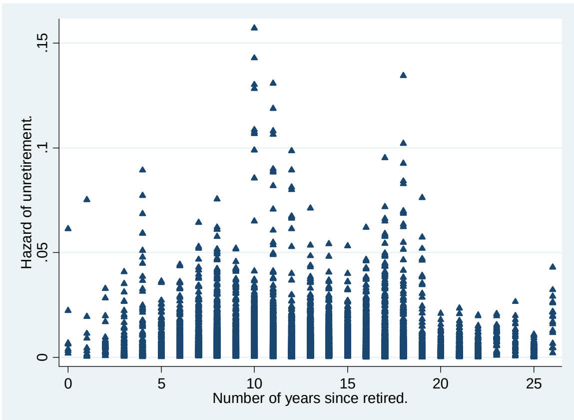


Table 4.5 indicates retired men with a wife in the labour force are more likely to return to work, suggesting a role for shared leisure preferences. Similar findings have been found in modelling the retirement and labour supply

decision at older ages in the UK (Schirle, 2008; Cribb et al., 2013). Our results indicate these complementarities in leisure extend into retirement for men with a working spouse. The recent legislated increase in the SPA for females in the context of our findings suggests retired men may return to work if their spouse is 'forced' to stay in the labour force for longer. Alternatively for those men already in work it may be the case they delay retirement (Cribb et al., 2013).

Given that nearly 10% of our sample exhibit unretirement behaviour, it is important to establish the characteristics of an unretirement job. The types of jobs these individuals are engaged in have implications for potential future labour market policies which act to incentivise unretirement. Equally, supply side factors such as whether only certain retirees can access unretirement jobs because they depend on 'having the appropriate skill set' also has implications for policymakers. Part of the legacy of the financial crisis has been a rise in the number of unemployed individuals, including a rising trend in the number of young individuals Not Employed in Education or Training (so called NEET), and also unemployed graduates (ONS, 2013d). In the context of unretirement, if NEETs are competing with unretirees for the same job then this could have adverse implications for either group. ELSA records job characteristic information; in the next section we use this to investigate the characteristics of unretirement jobs in more detail.

4.5 Characteristics of unretirement jobs

Similar to Maestas (2010) we find unretirement jobs are very similar in character to partial retirement jobs. The median number of hours worked per week is around 16 and earn an average monthly income of £700 per month or £8500 per annum.[34] The majority of individuals who unretire self report themselves to be in the top three deciles of the social class ladder, and in terms of job activity report being in sedentary jobs, with a small proportion engaging themselves with work which involves standing or some physical aspect. In terms of preretirement occupation characteristics, a significant proportion of the unretired sample contained individuals who reported being in supervisory

[34] Figures are estimated based on gross incomes from main employment and net of tax for secondary jobs. ELSA does not contain information regarding gross income figures for secondary jobs.

or managerial professions. Taken together with the estimation results from Section 4.4, this indicates unretirement jobs are concentrated amongst those who are better educated, higher up the income distribution and tend to have a longer term financial planning horizon. This could feed into demand and supply side factors, for example employers are only willing to hire retired individuals who embody a sufficiently high skill set or it is these individuals who have a preference for returning to work post retirement.

Final preretirement salary The life history survey carried out at wave 3 (2007) of the ELSA survey, contains detailed information regarding each job in an individual's life. Using this information it is possible to estimate average annual salary income in the final preretirement job, for our sample of unretired individuals. [35] [36] We estimate this figure to be £38,919.13 (2007 prices).This supports our earlier observation that unretirement jobs are not generally sought by those who were on low income prior to retirement, but those who (given the cohort) were likely to be in established occupations. Comparing pretirement versus postretirement labour market income for our sample of unretirees shows that unretirement jobs replace around just over 20% of the individuals preretirement annual salary income. As a comparison, State Pension replaces around 15% of the average labour income in 2008 (Coleman et al, 2008). [37]

4.5.1 Voluntary work

Our estimates suggest the prevalence of unretirement is similar to that observed in Sweden and Denmark, and significantly lower than that reported in the US. This does not mean older English men completely separate from the labour market when they retire. ELSA contains information regarding the frequency of voluntary work undertaken per month. A recent report by

[35] It is not possible to determine the occupation of the final career job.

[36] The majority of our sample (circa 98%+ were paid in New English currency (decimalisation took place on the 15^{th} February 1972), for our sample of unretired individuals only one individual was paid in Old English money for this reasons we do not include them for this section of analysis. We adjust final career incomes to 2007 prices (the year of the wave 3 history survey), using the Bank of England Inflation calculator.

[37] Conditional on unretiring we find no correlation between preretirement income and time spent in retirement.

nfpSynergy (2011) estimated around 30% of individuals aged between 50 and 65 did informal or formal volunteering at least once a month. Based on our sample of men we find that approximately 23% of those individuals who report being in full retirement, undertake voluntary work at least twice a month.[38] Therefore retired individuals do maintain some attachment to the labour force albeit at the voluntary level.

4.6 Future work

Chapter four models the unretirement decision for a sample of retired men using data from ELSA. The main reason for excluding females from the analysis is that for this cohort, female labour supply is characterised by sustained periods out of the labour market due to child rearing and caring responsibilities. Preliminary research showed the magnitude of unretirement for this cohort was too low for any substantive analysis to be undertaken.

However since the 1970s female labour supply has increased significantly in developed economies including the UK, and is now much more akin to that of men (Chevalier and Viitanen, 2002). Therefore future research should carry out a similar investigation for younger cohorts of females using future waves of ELSA, this would improve our understanding of whether it is the same factors which influence male and female unretirement behaviour.

Whilst the current work focuses on retired men, future work should replicate the study using a sample of individuals initially observed to be in employment, and to study their labour supply behaviour as they approach SPA and thus would be akin to the work of Maestas (2010). In this case the sample of individuals will represent a younger cohort compared to our retired sample. It is likely that this group of individuals will experience policies aimed at extending working lives. It is important to note the magnitude of future unretirement flows will in part depend on (a) The abolishment of legislation allowing employers to force workers to retire at SPA and (b) The legislated increases in the SPA itself.

[38] We take the average response based over the four waves of data. There is no information available about the number of hours worked in the voluntary sector in the ELSA data.

4.7 Conclusion and policy implications

Using a longitudinal panel survey of older individuals in England we estimate nearly one in ten of our sample members exhibit unretirement behaviour. We model the unretirement decision and investigate the determinants of such behaviour in a duration framework. Our results indicate there is no clear pattern in the duration dependence of the hazard of unretirement. However we show there are a number of important factors which act to raise the hazard of retirement: (1) Having a wife in the labour force, (2) Having at least an A-level, (3) Having a medium or long term financial planning horizon, (4) Being in the top quintile of the 2002 income distribution and (5) Having lower levels of total pension wealth.

Similar to results reported for the US individuals who report having a longer term financial planning horizon are more likely to unretire. Combined with the previous results this suggests that unretirement is likely to be related to lifestyle and preference factors. It unlikely to be linked with being in low paid employment prior to retirement; nor is it due to poor financial planning which tends to be associated with individuals who have lower educational attainment and are also concentrated further down the wealth distribution (Dow and Jin, 2013).

Our results suggest both demand and supply side forces are at work. On the supply side our results indicate individuals who have at least an A-level education are more likely to unretire, for example due to preferences for work. Given the changing structure of the labour market in all advanced economies over the past thirty years, higher educated individuals are more likely to secure paid employment. On the demand side employers seek individuals who can demonstrate they are skilled and have extensive labour market experience, which cannot be substituted for by younger less skilled individuals.

Our results have important implications for retired English men who are considering re-entry into the labour force. Our research suggests that the opportunity to unretire may not be equal across older individuals. Low skilled retired workers face greater barriers to work relative to their high skilled counterparts. This may go some way in explaining the difference in unretirement rates observed in England relative to the US, given that average educational attainment in the US is higher than that in the UK. However it is also important to note that the studies from the US have concentrated on younger cohorts who are initially in employment. There are also important differences in labour market regulation in these countries, and also significant differences in institutional factors such as the provision of healthcare. These factors make it not only easier but more important for individuals in the US to be in employment.

Ceterus paribus the results found in this chapter combined with the fact that future cohorts approaching SPA will have on average higher educational attainment, imply unretirement will become more likely in the future. However recent changes to UK retirement legislation which came into effect in 2011 mean employers can no longer lay off individuals because they have reached SPA. Changes such as these are likely to affect retirement planning. Individuals who have strong preferences for work no longer need to unretire instead they may reduce their hours and continue to work. Flexible retirement options are becoming increasingly common in advanced economies such as the UK. This will affect the magnitude of future unretirement flows and will also alter the level of labour market activity amongst older workers in the UK, which until recently has been in decline.

Chapter 5

Accounting for Attrition in the two-quarter UK Labour Force Survey.

5.1 Introduction

Attrition is inherent in surveys which follow the same individuals or households over time; attrition may be related to economic, sociodemographic or survey characteristics (Falaris and Peters, 1998; Wooldridge, 2002; Nicoletti and Perrachi, 2005; Jones et al., 2012). The consequences of attrition are that it may cause severe bias in estimators and therefore inferences drawn from subsequent analysis will be incorrect. Longitudinal survey weights are one way to overcome this bias, such weights account for the original population of interest whilst controlling for factors known to affect non-response in each subsequent wave of data. One method to produce longitudinal weights is using automatic iterative raking software such methods are based on the following idea: adjust the sample so it is more reflective of the underlying population it is being drawn from and at the same time take account of the survey design specific to the survey in question, in this case the United Kingdom Labour Force Survey (UKLFS).[1]

[1]An alternative strategy is to use IPW to predict the likelihood of non-response in a subsequent wave. This strategy is not adopted in this piece of research, given that all longitudinal surveys carried out by the ONS use a raking macro, and the ONS (and GSS

The work of Clarke and Tate (1999) led to the current specification of the two-quarter longitudinal weights used in the UKLFS, which is estimated using the SAS raking macro CALMAR. However survey response rates have declined substantially since their investigation (see Section 5.2). This chapter investigates whether the factors which affected response rates as established by Clarke and Tate (1999) still hold in 2012. We also estimate revised longitudinal weights using an alternative raking engine called Generalised Estimation System (GES), in order to align the survey methodology used in the two-quarter longitudinal dataset to that in the quarterly cross section UKLFS and the Government Statistical Service (GSS) more widely.[2]

We show: marital status, initial interview outcome and initial economic state, in addition to the factors already controlled for in the current longitudinal weights, are also correlated with non-response. These findings are incorporated in a revised calibration specification using GES. Using a range of diagnostic tests we compare the revised longitudinal weights to those currently estimated using CALMAR. Our tentative results show the revised specification is preferred.

The rest of this chapter is set out as follows, Section 5.2 describes particular features of the UKLFS and the recent trend in response rates. Section 5.3 analyses the discrepancy between the cross section and longitudinal estimates in more detail. Section 5.4 analyses estimation results from models of non-response. Section 5.5 is concerned with estimating longitudinal weights under the revised specification and comparing them to existing longitudinal weights. Section 5.6 discusses the results from Section 5.5 in the context of previous work carried out by the Department of Work and Pensions (DWP). Section 5.7 highlights acknowledgements and future work. Section 5.8 concludes.

more) widely wish to align survey methodology within and between departments.

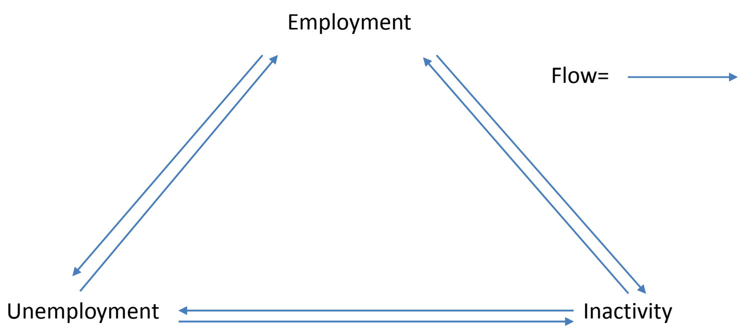
[2]The author is grateful for financial support from the ESRC in order to undertake this research. A special thanks to Dr. Nuovella Williams at the Office for National Statistics for assistance with estimation of the proposed weights, and Katie Stuart for research assistance. The author would also like to thank Nicholas Palmer, Dr. Gareth James, Greg Dixon and Matthew Greenaway for helpful comments and suggestions.

5.2 Data

The UK Labour Force Survey (UKLFS) is a quarterly survey of private households in the UK. THE UKLFS typically interviews 35,000 households each quarter, and is primarily concerned with tracking labour market circumstances of individuals residing in private households in the UK. In this respect the main motivation for the UKLFS is to develop, manage, evaluate and report on labour market policies (ONS, 2011c). The LFS is compiled and managed by the Social Surveys division of the ONS in Great Britain and by the Central Survey Unit of the Department of Finance and Personnel in Northern Ireland on behalf of the Department of Enterprise, Trade & Investment (DETINI). It has been in a quarterly format since 1992.

A distinguishing feature of the UKLFS is that it follows households for five quarters after which they are rotated out. Therefore at any given quarter 20% of the sample is new to the survey. In addition to the cross section survey the ONS produces two-quarter and five quarter longitudinal datasets, in order to track flows between different labour market states over time. The focus of this chapter is to investigate whether the longitudinal weights supplied with the two-quarter longitudinal dataset adequately control for survey drop-out or attrition.[3] The flows between different economic states measured by the two-quarter UKLFS are summarised in Figure 5.1.

Figure 5.1: Labour Force Flows.

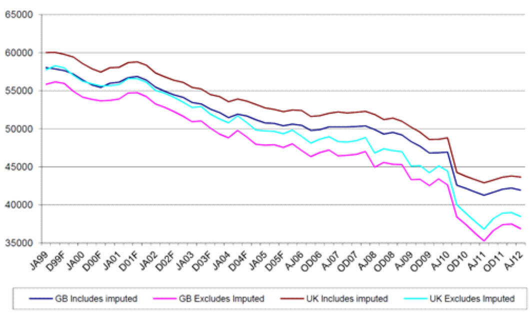


[3]During 2008 ONS conducted some initial investigation work for the five quarter sample, and GES in some instances produced negative and extreme weights. Therefore at present the longitudinal weights for the 5-quarter sample are estimates using CALMAR.

5.2.1 Response Rates

The ONS investigates quality assurance with each release of cross section data, including reporting the achieved response rate (ONS, 2012a).[4] Figures 5.2 and 5.3 show response rates have steadily declined over the sample period between June-August 1999 and April- June 2012. It is worth noting that the quarterly UKLFS changed from being based on seasonal quarter to calender quarters. If this changed affected the response rate of UKLFS respondents then this effect is also reflected in the general trends depicted in the diagrams. However it is clear that the decline in response rates occurred before the introduction of the APS in 2004 and that the gradient of the decline did not seem to change from 2004 onwards. Figure 5.2 shows the achieved number of household interviews declined from approximately $55,000 - 60,000$ to $35,000 - 45,000$.

Figure 5.2: Repsonse rate by household interviews 1999-2012.

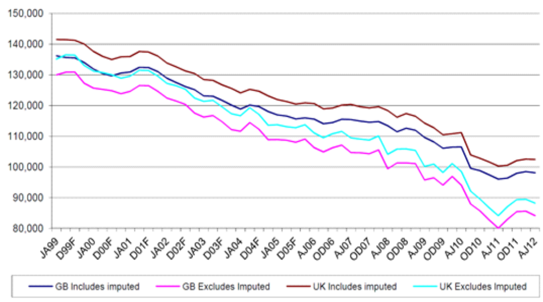


Source: ONS (2012).

Figures 5.2 and 5.3 highlight a steep decline in household and individual response rates in 2010, which represent two major changes in the design of the UKLFS. The first effected the way multiple households were interviewed at the same address, prior to 2010 when an interviewer visited an address with multiple households they were all interviewed, however in 2010 this was changed to interviewing one household at random. The second was the way in which individuals who were aged 75 and over were sampled, if all individuals

[4] The ONS at present does not routinely produce detailed information regarding non-response for the 2-quarter LFS using longitudinal methods. The quality assurance document focuses on reponse rates at a given quarter and analyses reponse rates for a particular wave.

Figure 5.3: Repsonse rate person interviews 1999-2012.



Source: ONS (2012).

in the household were aged 75 and over then these individuals were no longer followed in subsequent waves as their economic status tended to be inactive in all quarters. However if there were individuals who were younger than 75 in the household then the household would be followed. The 75+ group had a very high group response rate given they tended to be at home and available for interview, hence this in part led to the decline noted in Figures 5.2 and 5.3 above. Given the longitudinal files only contain individuals who are 15-69 this group does not directly affect the longitudinal weights.

Nonetheless Figures 5.2 and 5.3 show even prior to these changes there was a 25% decline in response rates between June-August 1999 and October-December 2009. It is likely differential non-response amongst particular sub-groups was attributable to the decline and this should be accounted for the in the specification of longitudinal weights. It is also suggests there is merit in investigating the determinants of non-response since the work of Clarke and Tate (1999), which only used UKLFS data from the calendar year 1997.

5.3 Raking macros and their use in the UKLFS

The UKLFS has been designed in such a way that it aims to be representative of the target population. However it may by the case that differences arise and certain segments of the target population are under-represented whilst others are over-represented. This can be due to a number of reasons, for example, non-response or sampling fluctuations. Raking methods are one way in which it is possible to make the sample more reflective of the underlying population it is being drawn from. This is done by adjusting base/initial weights (so called G weight) of cases in the sample such that the marginal totals of the adjusted weights (F weights) conform to specified characteristics with the corresponding totals for the population (Izrael, Hoaglin and Battaglia, 2004).

The raking/weighting engine used to construct the weighted estimates for the cross section quarterly UKLFS is GES, a SAS macro developed by Statistics Canada. At present the longitudinal weights estimated for the two-quarter dataset is carried out by CALMAR also a SAS macro developed by the National Institute of Statistics and Economic Studies (Insee). Both GES and CALMAR are based on the principle of adjusting base weights to sum to population (control) totals. In 2008 as part of the updating and aligning of methods used across different government departments the ONS changed from using CALMAR to GES. GES is also a software package designed for the calibration of weights but the way it does this is different to CALMAR, the latter sets the weights to sum to calibration totals for each partition (shown in Table 5.1) in turn and does this iteratively until the weights sum to all population totals in all the partitions; whereas GES calibrates to all the partitions simultaneously and is viewed as being more statistically robust, efficient and produces good variance estimates (ONS, 2011c pp.65). One final difference is that GES minimises the distance between prior and final weights using a linear distance function.[5] The intuition here is the same as before: raking takes the initial weight from the sample and adjusts it to known population totals in order to make the sample more representative of the target population.

As noted raking requires known population totals (controls) to sum to. The Demography Department at ONS do not have population totals for each auxiliary variable used in our preferred calibration specification highlighted in section 5.6. They do however have population totals using the 2001 Census by age, gender and region. These are then revised each year until the next Census data is available.[6] We use the ONS person weight (PWT11) in the first stage

[5] CALMAR and GES produce similar estimates so long as the estimated G weight is not bounded as each raking engine does this differently.

[6] At the time of writing the 2011 Census information was unavailable; moreover Scotland had yet to undertake their version of the 2011 Census.

of the estimation in order to establish population totals to sum to (for controls where no available totals exist) when undertaking the weighting procedure. The exact way in which longitudinal weights are estimated (in both GES and CALMAR) is described below:

1. Take any cross section UKLFS data (apply sample restrictions ensuring to drop individuals aged <15 and >70+ in both quarters).
2. Set macro to pick up auxiliary variables.
3. Estimate GB and NI population.
4. Merge with consecutive quarter of data.
5. Keep only the balanced sample.
6. Check for empty cells (cells which are in the population but not in the sample).
7. Estimate initial design weight.
8. Adjustment needs to be made for multi household adjustment (change in the UKLFS made in 2010).
9. Keep the partition variable auxiliary totals (this is done for each category in the partition variable so for example in our revised partition 2 we controlled for age*sex*region which had 308 categories) and the initial design weight.
10. Setup the partition and auxiliary variables in the correct manner.
11. Call in the raking macro GES/CALMAR.
12. Compute G and F weights.
13. Check diagnostic measures.
14. Check to make sure our sample is the same as that used in the Survey Sample Design (SSD) Department, who are responsible for estimation of the current two-quarter longitudinal weights and labour force flows data.

The current specification of the longitudinal weights was carried out in 1999 (Clarke and Tate, 1999) and thus prior to the move to GES (for the cross section UKLFS) which took place in 2008. Whilst the raking engine for the two datasets is different so too is the calibration specification (the population controls). For the quarterly cross section the calibration partitions are: Age, Gender and Region in various combinations. Whilst for the current longitudinal specification there are extra partitions to account for attrition due to tenure and economic activity.[7] [8] In principle the cross section estimates should be equal the longitudinal net flows for each state at any given quarter, however due to differences in the raking engine and partition variables there exists a discrepancy, the extent of which can be seen in Section 5.4.

As highlighted in the previous section, the raking engine used to carry out the weighting of the cross section and longitudinal datasets is no longer the same. Until 2008 the raking software CALMAR was used on licence from the French National Statistical Institute (Insee). This uses a logit function to minimise the distance between the initial base weight derived from the sample and final (adjusted) weight which has been adjusted to sum to known population totals.[9]

The G weight is defined as the modification factor δ which when multiplied by the initial design weight $\left(\frac{N}{n}\right)$ equals the final F weight and reduces the calibration error to zero.[10] At present in both the two-quarter and five quarter longitudinal datasets G weights are bounded whereas in the cross section they are not.[11] This is due to constraints placed on the data by partitions in the calibration specification, which cannot accommodate non-empty cells or those with a very low cell count (in order to avoid extreme weights being estimated). This is less likely in the quarterly cross section due to the greater sample size and fewer number of partitions. The partitions used in the current cross section and longitudinal specification are detailed in Table 5.1.

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[7] This is due to account for the surey design of the LFS in that it reinterviews the same household, it does not follow households if they move from the property.

[8] The parition factors in the cross section UKLFS are chosen given the equivalent population estimates (which figures are aggregated to) in the UK Census.

[9] Using a logit function to minimise the distance implicitly implies the makro is constrained to always producing adjusted weights which are strictly positive.

[10] The design weight is equal to the inverse of the probability of being selection.

[11] The bounds applied are such that the $0.5 < gweight < 2.1$.

Table 5.1: UKLFS raking specification

	Current cross section	Current longitudinal
Partitions		
Age	Yes	Yes
Gender	Yes	No
Region	Yes	Yes
Economic activity	No	Yes
Tenure	No	Yes

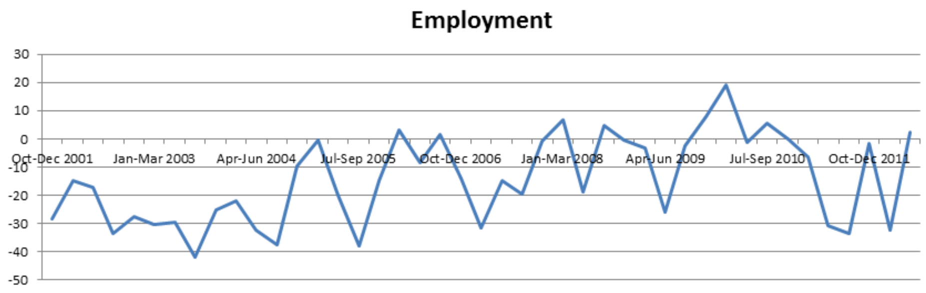
Whilst the partition variables are listed separately it is important to note they may be specified independently or as a combination, for example it could be 'region *by* broad age group *by* gender'. The variables highlighted in Table 5.1 were those chosen following the work of Clarke and Tate (1999). In their study they found that the longitudinal weights should control for the partitions used in the cross section, in addition due to the sample design of the UKLFS (in that it re-interviews at the same household) then longitudinal weights should also control for tenure due to the fact that individuals who lived in rented accommodation were much more likely to become non-responders.

5.4 Discrepancy cross section versus longitudinal

The discrepancy between the cross section and net longitudinal flow can be explained with reference to Figure 5.1. The Non Seasonally Adjusted (NSA) net flow for each state should be equal (or very close) to the cross sectional estimates reported every quarter. Figures 5.4-5.6 show this is not the case. Figures 5.4-5.6 chart the difference between the NSA cross section estimate minus the net flow (estimated using the existing longitudinal weights) for employment, unemployment and inactivity between October 2001 and June 2012.[12]

[12] We use data from 2001 onwards as this has been updated with the 2001 Census figures. At the time of writing the 2011 Census figures were not available.

Figure 5.4: Discrepancy between stock and longitudinal estimates of employment.

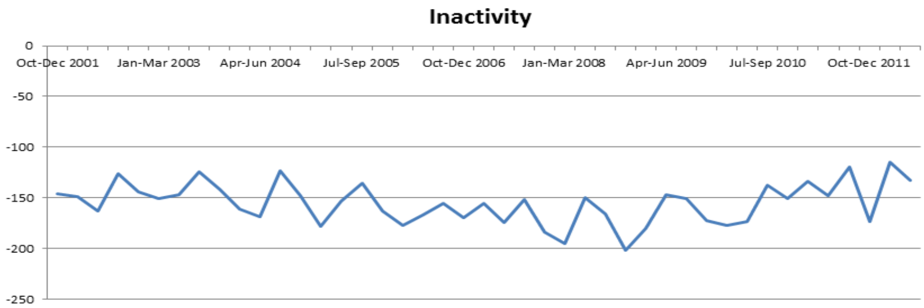


Source: ONS.
Notes Scale (000's); 16-64 population.

Figure 5.5: Discrepancy between stock and longitudinal estimates of unemployment.

Source: ONS.
Notes Scale (000's); 16-64 population; ILO definition.

Figure 5.6: Discrepancy between stock and longitudinal estimates of inactivity.



Source: ONS.
Notes Scale (000's); 16-64 population.

Comparing Figures 5.4-5.6 shows that the smallest discrepancy is for the employment series, whereby the NSA stock estimate is usually $-20,000$ to $-30,000$ smaller than the NSA net flow estimate at each quarter. In the case of the unemployment series the NSA stock estimate is consistently below the NSA flow estimate (bar one exception), the magnitude of the discrepancy is slightly bigger than that of the employment series, approximately $-30,000$ at any given quarter. Finally the most substantial discrepancies between the stock and flow estimates is for the inactivity series, these are on average $-160,000$ at any given quarter, moreover when these are broken down in to full time and part time work this discrepancy is even more substantial (Cousins, 2012a).

Data: The UKLFS

To guide the specification of calibration groups in the weighting procedure, we first estimate logit models to understand which factors are correlated to survey attrition across two consecutive quarters of the UKLFS. To do this we merge two separate cross sections (Q4 2011 and Q1 2012) and then construct a dependent binary indicator which is equal to 1 if the individual is attrited from the survey in the second wave, zero otherwise. We use a range of sociodemographic and economic controls, partially guided by the specification used in Clarke and Tate (1999) and also by the survey methodology and economics literature.

We construct an unbalanced panel and only drop individuals if they are (1) In their final wave of observation (i.e. wave 5) in the first quarter observed or (2) The interview outcome in the first quarter of observation is not productive or (3) Aged 70 or over in the first quarter we observe them.[13] The final sample size for estimation purposes comprised of approximately $50,000$ individuals for any two consecutive quarters.

5.5 Estimation results

5.5.1 Logit model of attrition

Table 5.2 highlights the marginal effect of each covariate on the likelihood of attriting from the sample between the first and second and wave of observation.[14]

Definition 5.1 *Conditional on being in the eligible sample we define attrition as only observing an individual in the first quarter of observation in any two consecutive quarters.*

That is to say if we take the two calendar quarters Q1 and Q2 2011, then we would only observe the individual in Q1 but not Q2. In describing the effect our information set has on the probability of non-response we split our information set into two groups. The first focuses on sociodemographic covariates whilst the latter economic.

Sociodemographic variables

Our estimation results indicate that only married respondents are more likely to attrit relative to the base group of being widowed. Individuals who are single or divorced are no more likely to non-respond. In addition to marital

[13] We drop individuals who described themselves as seperated and were previously in a civil partnership. These individuals constituted less than 0.1% of our sample. Individuals who are interviewed by proxy at both waves are treated as attriting. Thus our dependent variable accounts for survey attrition and the likelihood of repeat proxy interviews for those who were interviewed by proxy in the first quarter of observation.

[14] Marginal effects predicted at mean of covariates.

Table 5.2: Marginal effects: UKLFS Q4 2011-Q1 2012.

Variable	$\frac{dy}{dx}$	$S.E$	Z	$P > z$
Single	.00	0.014	0.13	0.898
Married	.048	0.013	3.61	0
Married not living with partner	-0.01	0.017	-0.68	0.496
Divorced	.008	0.014	0.58	0.564
Civil partnership	.056	0.040	1.39	0.164
Age 16-19	-.06	0.011	-5.34	0
Age 20-24	-.028	0.012	-2.35	0.019
Age 25-29	.015	0.012	1.25	0.21
Age 30-34	.006	0.011	0.53	0.598
Age 35-39	.013	0.011	1.17	0.243
Age 40-44	.013	0.011	1.14	0.253
Age 45-49	.001	0.011	0.14	0.891
Age 50-54	.005	0.011	0.51	0.607
Age 55-59	.020	0.011	1.83	0.067
Age 60-64	-.001	0.009	-0.18	0.856
Proxy respondent	.059	0.004	13.2	0
Employee	-.002	0.005	-0.36	0.719
Self Employed	-.012	0.007	-1.58	0.115
Government trainee	-.019	0.044	-0.44	0.662
Family worker	.021	0.042	0.51	0.608
Unemployed	.013	0.010	1.3	0.192
Retired	.011	0.009	1.17	0.242
Free rent	.034	0.023	1.48	0.14
Mortgage	-.001	0.005	-0.11	0.912
Part rent	.012	0.029	0.42	0.672
Fully rent	.012	0.006	2	0.045
North East	-.003	0.013	-0.23	0.818
North West	.006	0.011	0.53	0.593
Merseyside	.005	0.016	0.31	0.756
Yorkshire & Humberside	.001	0.011	0.1	0.918
East Midlands	.008	0.012	0.7	0.481
West Midlands	-.007	0.011	-0.67	0.503
Eastern	.016	0.011	1.38	0.166
London	0	0.011	0.03	0.975
South East	.008	0.011	0.76	0.445
South West	.010	0.011	0.91	0.362
Wales	-.001	0.012	-0.06	0.953
Scotland	.008	0.011	0.76	0.45

For the purposes of estimation the base (reference) group to which estimates should be compared to are: Northern Ireland; Age 65-69; Inactive (excluding retired); Own property outright; Widowed and Full interview.

status we included controls for age, using dummy variables with 4 year bands (base group individuals aged 65-69).Our results show those in the 16-19 and 20-24 age group are significantly *less* likely to attrit, and those in the 55-59 age groups *more* likely to attrit relative to individuals aged 65 and over. This is in stark contrast to the results found in Clarke and Tate (1999) who found younger groups were more likely to attrit.[15]

Clarke and Tate (1999) note the importance of housing tenure on non-response, the survey design of the UKLFS is such that it re-interviews the same postal address. Therefore those who live in rented accommodation are much more likely to non-respond given that the likelihood that they will move at a given quarter is substantially higher than someone who permanently resides at an address. Our results indicate that relative to those who own their own house, individuals who fully rent are more likely to non-respond, which is intuitive given that it is easier for this group to move address.

We also include geography variables to capture any regional effects. We do not any evidence of respondents in a particular region being more likely to attrit than those in Northern Ireland (base group).

Economic variables

In terms of economic variables we control for economic status and for the type of interview conducted. Relative to the base group of inactive (excluding retired) being in another economic state had no significant effect on the likelihood of attriting.

We control for whether the interview in the first wave of observation was by proxy or otherwise, in order to capture effects of the survey design of the UKLFS itself. Our estimation results suggest those individuals who were first interviewed via a proxy, were early 6 percentage points more likely to non-respond in the following quarter.

Summary and implications of estimation results. The estimation results indicate there are four factors which raise the probability of attriting

[15]It is important to remember we include those are proxy interviewed at both waves as attriting, and if indiviuals are in work then it might be more likey another household respondents answers questions on their behalf. We do however control for economic status.

(relative to the appropriate base group). These are: Age; Tenure; Marital Status and Type of interview. Broadly speaking these results are similar to the findings of Clarke and Tate (1999). However there are some differences, in particular the previous study found younger individuals aged between 16 and 24, were more likely to attrit our results indicate this is no longer the case respondents in younger age groups are in fact less likely to attrit. Also of importance is whether the first interview was carried out via proxy which seems to increase the probability of non-response in the following quarter.

At present the weighting procedure in CALMAR uses a raking engine using a logit distance function with five partitions, that is to say five sets of constraints (applied iteratively) on the data cells which allow weights to be constructed for the two-quarter longitudinal datasets. The models of non-response indicate that in addition to the existing five partitions, the weighting specification should also calibrate on aggregate totals of the type of individual interview and account for the non random sample retention in terms of age. However placing a greater number of constraints on the data implies more stringent conditions on each of the cells of data. Therefore in order to ensure weights can be estimated we have to aggregate the data from local authority to region level. In effect we have to balance the number of partitions versus aggregation, otherwise the raking engine will find empty cells, or estimate weights which are in the tails of the distribution and create skewed distributions, this in turn will have implications for the bounding on G weights (Silva, 2003).

Diagnostics

In order to test the robustness of the empirical specification in Section 5.3, we apply a range of diagnostic measures for consecutive two-quarter samples of the UKLFS, covering the period between Q1 2011 and Q1 2012.

Predicted versus actual attrition We estimate the predicted rate of attrition as the percentage of individuals not observed in the second of two consecutive quarters, assuming the covariates in Table 5.2 are equal to their mean value.

Table 5.3: Predicted versus actual attrition rate.

Sample period	(P)redicted	(A)ctual	Difference (P-A)
$Q4$ 2011 – $Q1$ 2012	0.249	0.2523	−0.0033

In the two-quarter panel covering the period between Q4 2011 and Q1 2012, the predicted rate of attrition was very close to the actual rate of attrition. Indicating on average our information was doing a satisfactory job of predicting attrition.

Specification tests. The Wald Statistic indicates that our information set has substantial explanatory and covariates are jointly significant. The R^2 is low however this is not unexpected given we estimate across two waves and the information set contains relatively few explanatory variables.

A link test for misspecification (Table 5.4) found the null hypothesis of no misspecification could not be rejected at conventional levels of significance.

Table 5.4: Specification test.

Sample period	Null Hypothesis	Test result
$Q4$ 2011 – $Q1$ 2012	$H_0 : No\ misspecification$	Cannot reject H_0

Classification test A classification test makes it is possible to estimate the predicted probability of non-responding or otherwise, conditional on the information set $(X'\beta)$.[16] Results are presented in Table 5.5.

Table 5.5: Classification test.

Sample period	Correctly classified (%)	Incorrectly classified (%)
$Q42011 - Q12012$	74.77	25.23

[16] The cutpoint used for the classification was p=0.5.

Table 5.5 indicates that the model predicts roughly three quarters of the cases correctly. Given the relatively low number of covariates this specification seems to correctly classify a substantial proportion of the cases.

Adding additional covariates would imply adding more partitions in the weighting procedure and cause convergence issues. Therefore building on the results of Clarke and Tate (1999) and the new results highlighted in the previous section we chose to proceed the with specification described in Table 5.6.

5.6 Weighting

The second part of this investigation is to implement the findings from the model of non-response in the calibration used to estimate longitudinal weights using GES. The strategy we implement is a two stage weighting process summarised in Section 5.3.[17]

Partition variables. We specify our sample data to sum to population totals using information available in the UKLFS 2011 cross section data.[18] In order to do this we create auxiliary groups from our sample conditional on certain characteristics, known as partitions. The current longitudinal datasets estimated in CALMAR have 4 partitions. We implement a revised feasible specification with 6 partitions described in Table 5.6.[19]

[17] An alternative to estimating longitudinal weights using raking software is to use an Inverse Probability Weighting (IPW) estimator. The ONS prefers to use raking software given that it makes use of the inverse of the probability of selection and can also adjust weights optimally to aggregate to known population totals, moreover the GSS is aiming to align software used by its departments such as that used for estimating survey weights. One would expect raking software and IPW to produce similar results, given an identical specification of non response.

[18] The cross section UKLFS is calibrated itself by the ONS population department, to ensure the labour force estimate is equal to the population estimate using information derived from the 2001 Census and is updated each year (mid-year estimates) to account for net population growth.

[19] Final spec: p1=(northerni*22)+(sex-1)*11+agemid; p2=govtorr+sex+agewide; p3=marsta; p4=ten1; p5=ioutcome; p6=economicact1.

Table 5.6: Feasible specification.

Partition variable	Definition
P1	Adjustment for NI by gender and age group
P2	Government region by gender and age group
P3	Marital status
P4	Tenure
P5	First interview outcome
P6	Economic Activity

The revised specification is estimated using GES and G weights are automatically bounded to ensure they are positive.[20] The most important changes relative to the specification in Table 5.1 is the introduction of the 'agemid' and 'ioutcome' variables. In particular the 'agemid' places greater focus on younger age groups which from Table 5.2 were less likely to non-respond. We also explicitly account for the type of (first) interview in particular whether it was via proxy. Finally, we also controlled for gender within partition P1 and P2. The revised specification places greater constraints on the sample data, ensuring there are no empty cells and at least 20 respondents for each auxiliary constraint. In terms of feasibility and 'production' convergence was achieved for all panels over the sample period.

G weights.

Definition 5.2 *G weight : The G-weight is defined as the modification factor δ, which when multiplied by the initial design weight $\left(\frac{N}{n}\right)$ (to give the final F weight), reduces the calibration error to zero.*

The design weight itself is calculated as the inverse of the probability of selection, so individuals with a lower probability of selection receive a higher

[20] GES runs P1-P6 in an iterative manner and not simultaneously. The bounding is undertaken by CALMAR automatically and pre-sets the bounds on the design weight to be between 0.4 and 1.2. The optimal g-weight is that which leads to the smallest adjustments to the initial design weight whilst satisfying the population totals which are being summed to. If the pre-set bounds are not satisfied they can be adjusted manually by the user, for more information see Silva (2003).

design weight (ONS, 2011c pp.63). Thus the design weight will vary by individual and geographic region. An optimal G weight should have mean equal to one, and look approximately normally distributed. The next section graphically depicts the estimated G weights under the revised specification, unfortunately we were unable to obtain the equivalent G weights for the current weighting procedure in order to compare them. However the F weights were available for both and we compare these in the next section.

It is important to note that since we are undertaking a two stage weighting procedure, the initial set of weights we use (the person weights from the cross section data) have already gone through this procedure once. In effect the strategy is to construct the longitudinal weights assuming the initial cross section is the target population.

GES with 6 partitions under linear boundary constraint. Figures 5.7-5.10 depict the G weights estimated for four sample panels covering the period Q1 2011-Q1 2012. The majority of the G weights lie close to 1 which indicates that each representative unit in the sample is appropriately represented in the target population.[21] There is some evidence of a fat right hand tail, which could be reduced or eliminated by placing more partition constraints, however given the smaller sample size in the balanced panel (relative to the cross section) we found GES was unable to converge (due to empty cells) when additional constraints were added.[22] The estimated G weights in Figures 5.7-5.10 and those depicting the estimated F weights in Figures 5.11-5.14 indicate a bimodal distribution, this warrants attention in future work. Having tested a number of different specifications in terms constraint combination, the specification in Table 5.6 was optimal in terms of smallest variance and business practicality.[23]

[21] We estimated a range of post estimation diagnostic measures such as moments, basic statistical measures, tests for location, quantile ranges and reporting extreme values. Detailed results can be found in Appendix 8.5.1.

[22] In each of the histograms it was rare to obtain G weights of greater than 2. See Silva (2003) Section 4.3 for further details regarding G weight distributions.

[23] Business practicality in this context refers to the fact that the ONS is responsible for the production of the UKLFS datasets and therefore is obliged to ensure that the datasets are available by a certain (predefined) date.

Figure 5.7: G Weight Distribution: UKLFS Q1-Q2 2011.

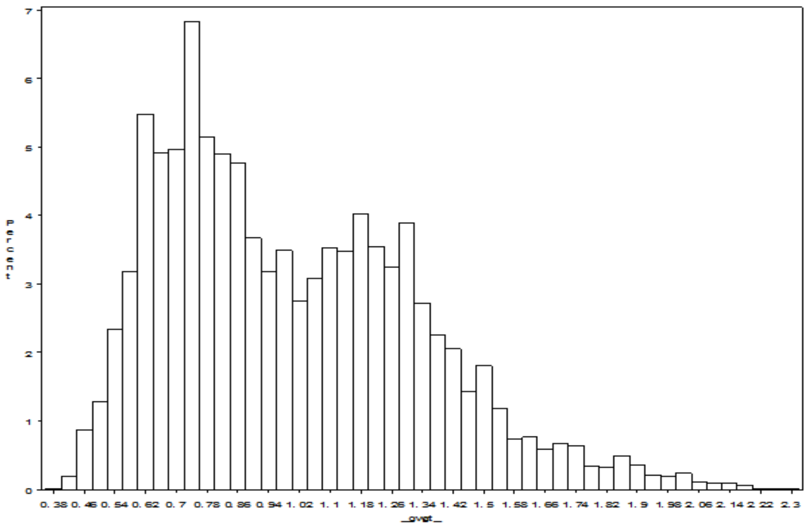


Figure 5.8: G Weight Distribution: UKLFS Q2-Q3 2011.

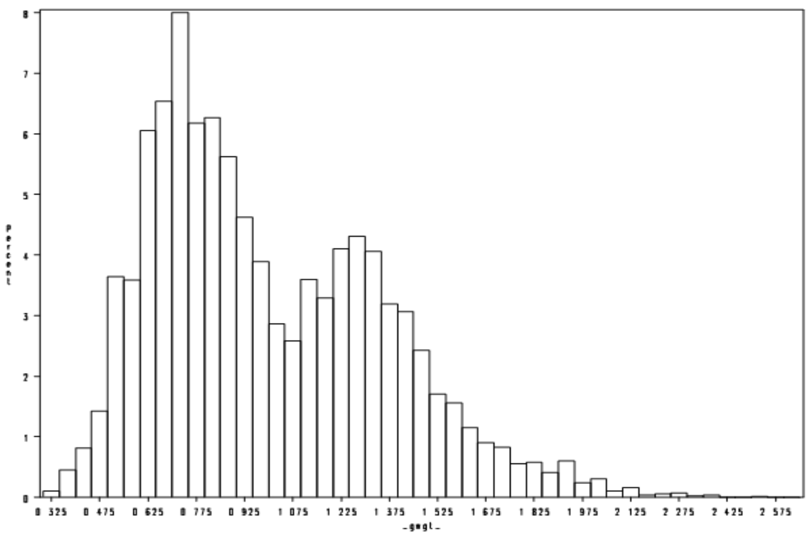


Figure 5.9: G Weight Distribution: UKLFS Q3-Q4 2011.

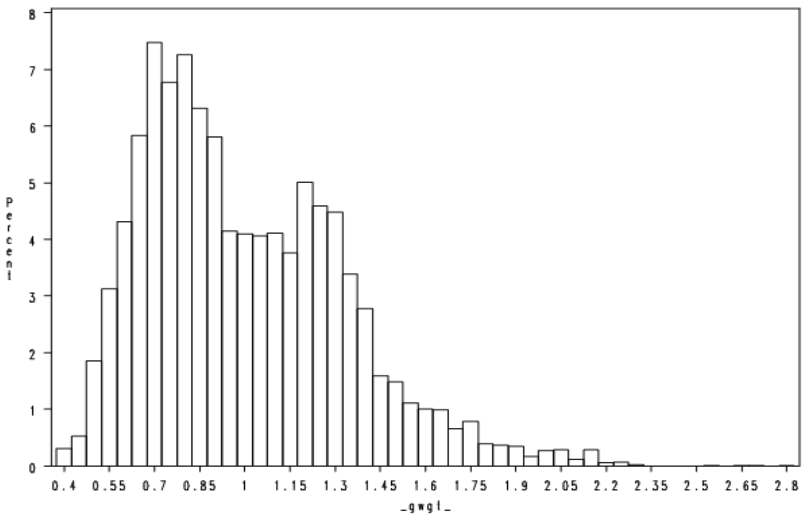
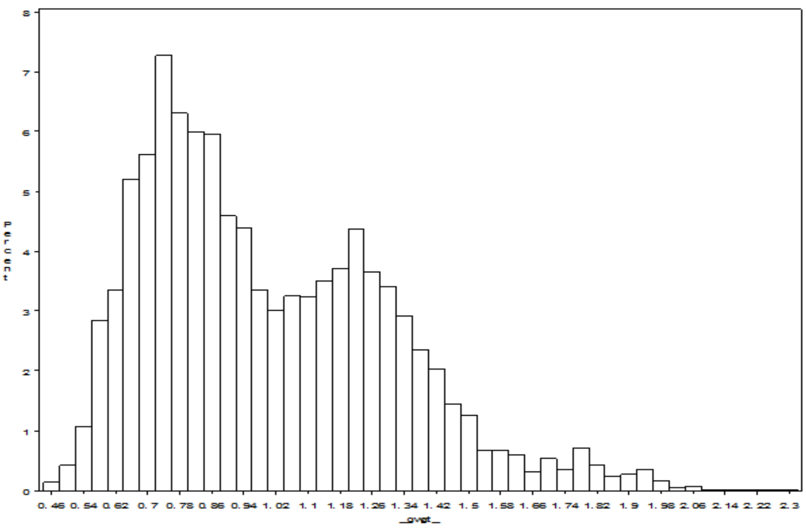


Figure 5.10: G Weight Distribution: UKLFS Q4 2011-Q1 2012.



F weights.

Definition 5.3 *F weight: G weight*design weight*

The F weight is equal to the G weight multiplied by the design weight which together gross up sample counts to give an estimated population count. In this sense they represent the frequency of representative individuals, for example if it happened to be the case that in the target population all respondents from the South East responded, then they would have a relatively small F weight. However if only one individual happened to respond from the North East then conversely they would have a relatively large F weight. The aim of all sample surveys is to have a distribution of weights which do not contain extreme weights, that is to say where one individual is representing a very large number of individuals in the population. For a number of reasons such as differential and severe attrition amongst particular subgroups it is possible for extreme weights to be estimated.

CALMAR with 4 partitions using logit raking engine (Clarke and Tate (1999) specification). Following the work by Clarke and Tate (1999) Figures 5.11-5.14 plot the F weights which are included in the current two-quarter longitudinal files produced by the ONS. The 4 partitions used for construction of the longitudinal weights are detailed in Table 5.1. Under the existing strategy when calibration takes place and convergence is not achieved the bounds on the G weights are increased. The initial bounds for the G weights are set between 0.4 and 2.1.

Longitudinal weights.

Figure 5.11: F Weight Distribution: UKLFS Q1-Q2 2011.

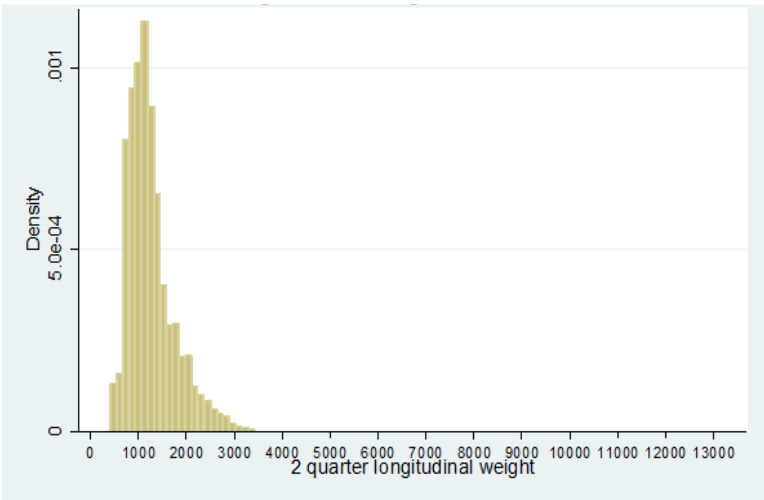


Figure 5.12: F Weight Distribution: UKLFS Q2-Q3 2011.

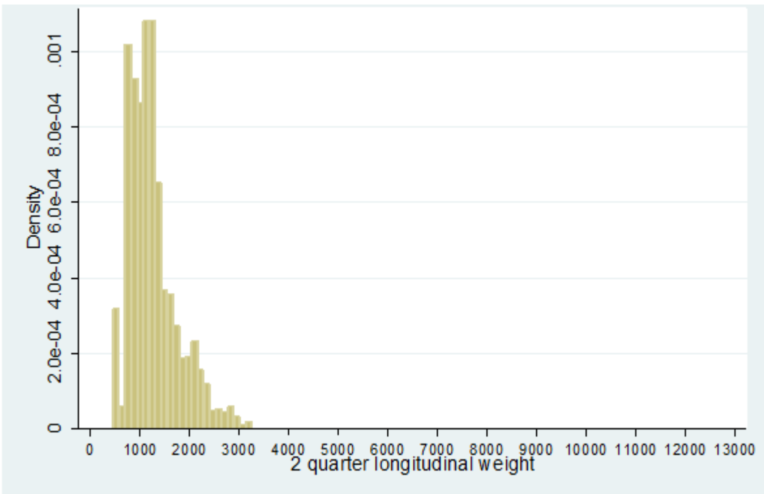


Figure 5.13: F Weight Distribution: UKLFS Q3-Q4 2011.

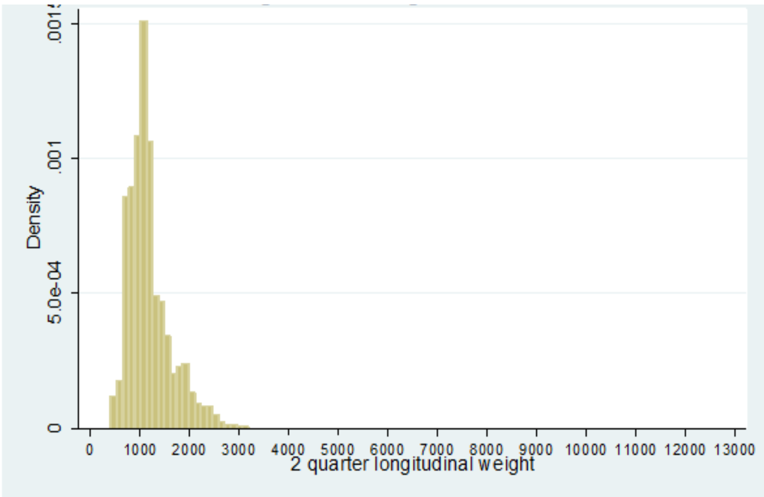
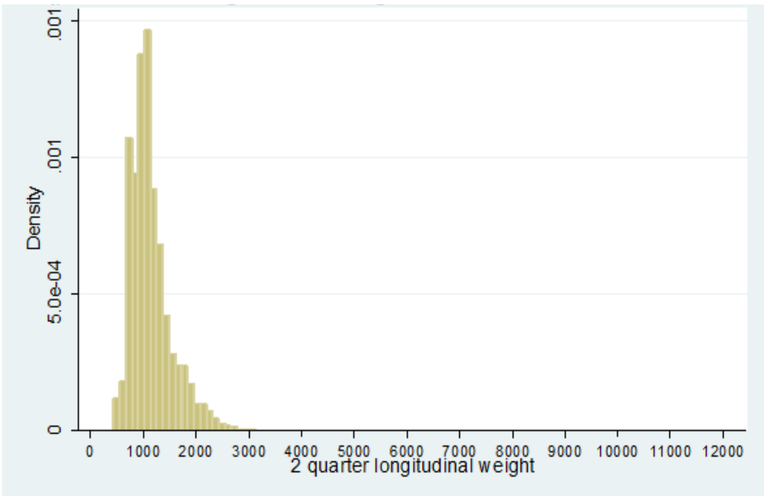


Figure 5.14: F Weight Distribution: UKLFS Q4 2011-Q1 2012.



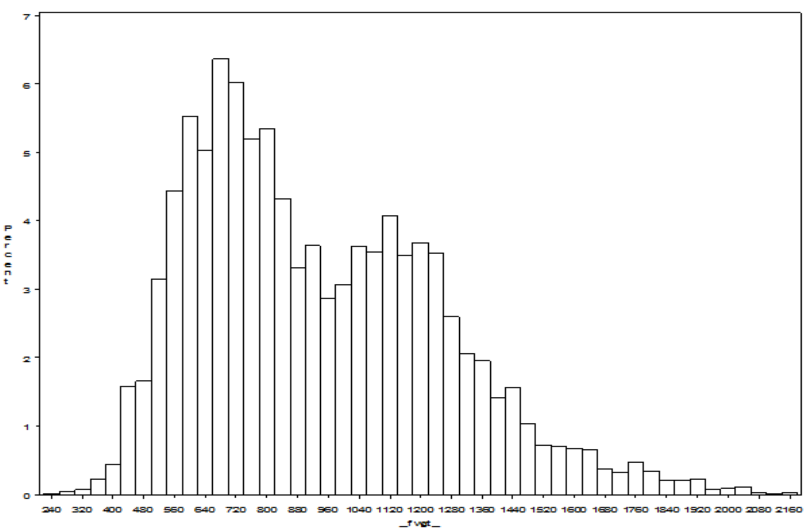
Figures 5.11-5.14 show that average person weight is approximately 1500. By comparison the cross section UKLFS weights are approximately 500. Figures 5.11-5.14 clearly show the presence of a heavy right hand tail, hence the existence of outliers and large weights (in excess of 15,000 in some cases). This is unattractive from a methodological and policy viewpoint, it is not

good practice to produce data or rely on statistics (available to the research community and general public) where one individual represents a very large number of people in the population, particularly if researchers are to draw policy implications from their analysis.[24]

GES with 6 partitions using linear raking engine. As shown in Section 5.5 we extended the specification of Clarke and Tate (1999) to include additional controls for interview outcome, age and gender. Whilst we experimented with different specifications, varying the levels of disaggregation/aggregation for particular partitions, the over-arching aim was to provide a specification which controlled for attrition and also converged.[25] This led to the specification as outlined in Table 5.6, the F weights estimated using this specification are shown in Figures 5.15-5.18.

Longitudinal weights.

Figure 5.15: F Weight Distribution: UKLFS Q1-Q2 2011.



[24]For further adverse issues pertaining to extreme weights see Silva (2003).
[25]The calibration to the constraining variables is an interative procedure. The greatest constraints placed on the data were by constraint 2.

Figure 5.16: F Weight Distribution: UKLFS Q2-Q3 2011.

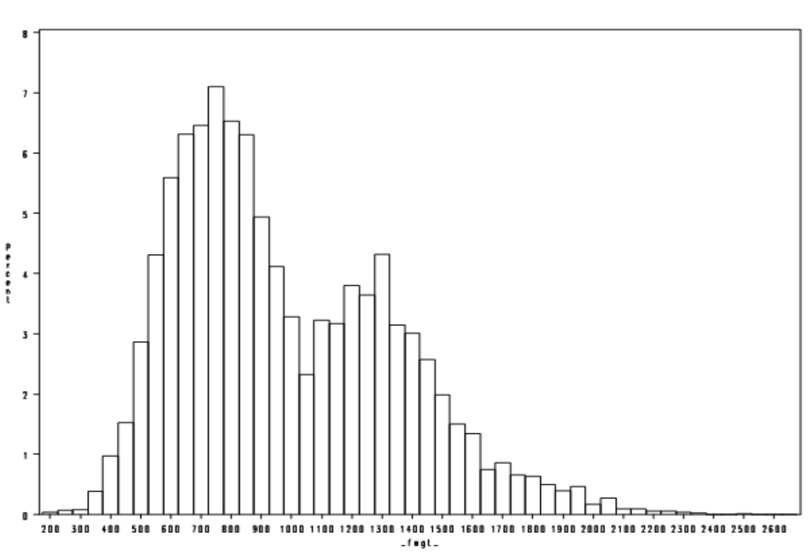


Figure 5.17: F Weight Distribution: UKLFS Q3-Q4 2011.

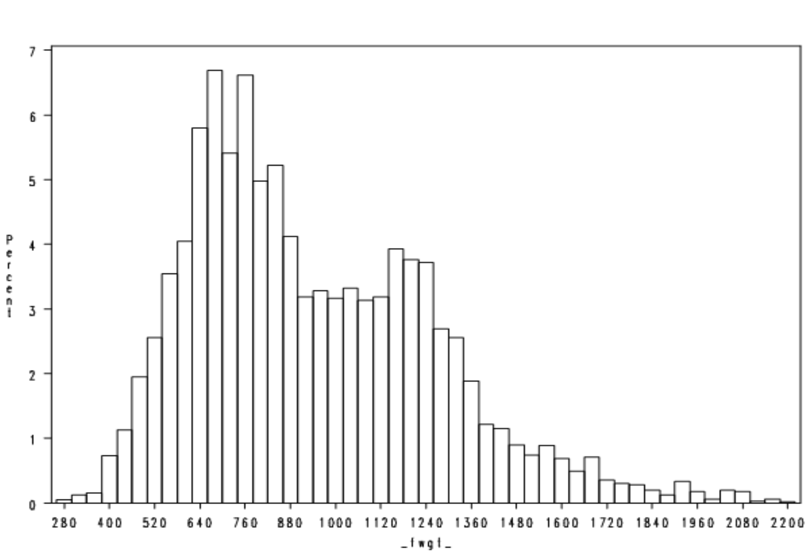
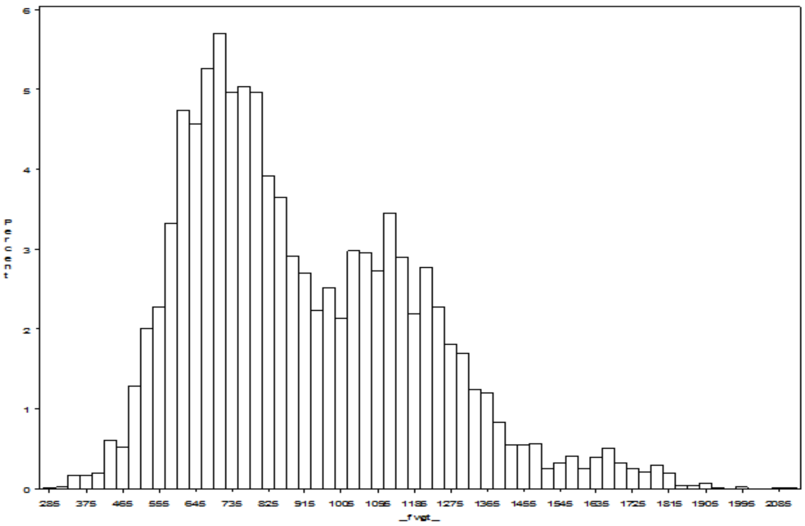


Figure 5.18: F Weight Distribution: UKLFS Q4 2011-Q1 2012.



Figures 5.15-5.18 indicate the peak of the distribution was centred around 900, less than two thirds of the average F weight in the specification shown in Figures 5.11-5.14.[26] Importantly there is no evidence of extreme weights in any of the sample periods. Part of the reason for our weights being smaller than the current specification is due to the fact that our balanced panel sample size is bigger. After placing necessary sample restrictions (highlighted in Section 5.2.1) we achieved a balanced sample in the order of 46,000-48,000, whilst the existing two-quarter longitudinal sample files contain only around 34,000-39,000 individuals. After inspecting the syntax file for the existing longitudinal sample, it is not clear as to why this is the case and warrants further investigation.[27] The larger sample meant we had better coverage of the target population and could estimate more accurate and hence smaller weights, and were less likely to run into convergence issues such as empty cells in the constraining process. Therefore it is possible estimate a more detailed partition specification i.e. constrain to a greater number of auxiliary population totals, such as interview type, economic status and gender. This is important because

[26] We estimated a range of post estimation diagnostic measures such as moments, basic statistical measures, tests for location, quantile ranges and reporting extreme values. Detailed results are available on request.

[27] ONS methodologists have been notified of this issue.

the method used in the weighting procedure for both the existing and proposed weights, meant that in both cases the target population size (the first cross section) was identical and so the population which was being aggregated to was the same.[28] The implication is that in Section 5.6 we are able to compare the flow estimates under the current and proposed weighted estimates.

5.7 Discussion

Cousins (2012a) shows discrepancies exist between the cross section and longitudinal estimate of a particular economic activity at any given quarter. Cousins (2012a) defines two different longitudinal estimates:

1. Longitudinal definition 1: The two-quarter longitudinal dataset where that quarter first appears;

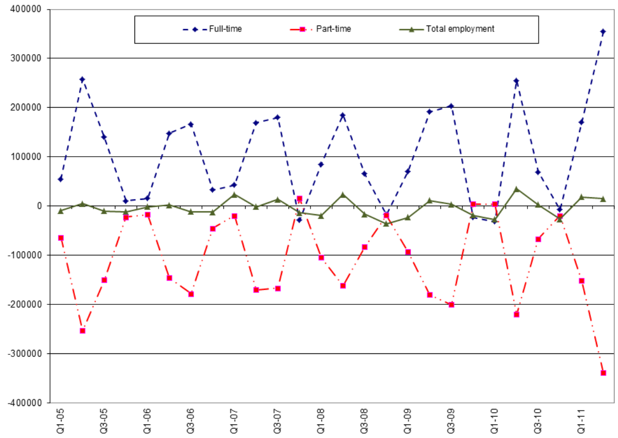
2. Longitudinal definition 2: The two-quarter longitudinal dataset where that quarter appears for a second time.

Relative to the cross section estimate Cousins (2012a) shows that due to attrition the 'Longitudinal 2' definition consistently estimates more individuals in full time work than the 'Longitudinal 1' estimate (see Figure 5.19). This order reverses in the case of part time work, due to individuals who flow into full time work becoming less likely to respond in the following quarter. Overall the estimated figure in total employment under definitions 1 and 2 is roughly equal as the differences essentially cancel each other out. Cousins (2012a) shows the estimated stock of individuals in part time work at a given quarter, is estimated to be greater using either longitudinal definition versus the cross section estimate. Whereas the estimated stock of individuals in full time work is greater in the cross section data than in the longitudinal data.

From Table 5.1 it is clear the current weighting regime is unable to appropriately control for the differential effect of employment type in the first wave, which contributes to the differential attrition effect and impacts the weighted longitudinal flows. The revised specification outlined in Table 5.6 goes some

[28] The differences in the balanced samples took place in the merging process. We can only assume the existing methodology dropped certain cases whilst we did not, however it is unclear where this was.

Figure 5.19: Difference between first and second longitudinal estimate of the same quarter.



Source: Cousins (2012a)

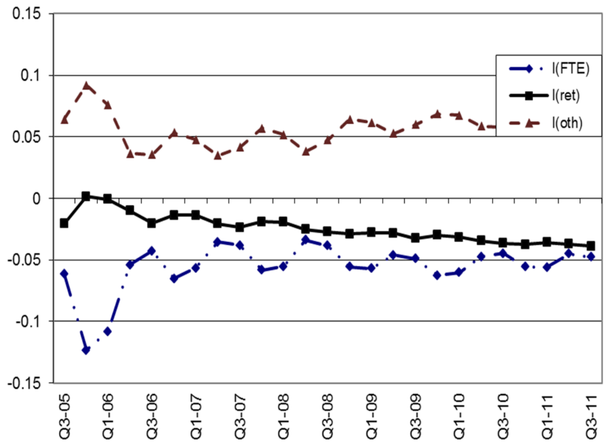
way to control for this. In the calibration process we account for whether the individual is in employment, self employment, government trainee scheme, unemployed, family worker or inactive. We did not include the full time and part time categories in the models of non-response reported in STATA, due to multicollinearity issues with certain economic status variables. However we do control for whether the outcome of the first interview was either a full interview or via proxy, which is likely to be related to whether an individual is in full time work. Whilst we do not explicitly control for whether the individual is in part time work or full time work in the first wave we observe them, given the early stage of this research it would be possible to alter the calibration specification to accommodate this. However it may mean that if this additional constraint is combined with another partition that GES does not converge, therefore the level of disaggregation at which it is possible to control for this factor requires further investigation and is left for future research.

Cousins (2012b) notes that due to this differential attrition effect the cases rolled forward are more likely to be full time workers, due to these respondents being less likely to respond in their first interview. Identical to the strategy used in the current longitudinal methodology, in the revised specification we drop those individuals prior to carrying out the weighting process and therefore do not consider the effect these individuals have on weighted estimates explicitly. However as noted in the new specification we do control for the interview outcome in the first quarter and therefore if it is the case that full time workers are more likely to be initially interviewed by proxy this will be accounted for. The new specification could be amended to control for cases carried forward, the full time and part time employment variable would need to be interacted with the outcome variable, additionally all those who non-respond in the target population (cross section) would also need to be included, in order for GES to have population totals to sum to.

Cousins (2012b) reconciles the longitudinal versus cross section stock estimate of individuals within particular sections of the inactive population. Cousins (2012b) shows the current longitudinal definitions underestimate the number of individuals in Full Time Education (FTE), and over estimate the magnitude who are inactive but not retired. The current weighting methodology does account for economic status, as does the revised specification, however as previously noted due to the large number of categories within the inactive group, it is likely that by breaking this down further would lead to GES not converging. It may be possible to include a partition at an aggregate level, which conditions on activity status within the inactive group however additional aggregation of other partition variables may be necessary, again we leave this for future research. It also worth noting that the attrition behaviour of retired individuals was not significantly different to that of the inactive group, as shown in Table 5.2.

Figure 5.20 shows the cumulative attrition bias per quarter (defined below) is roughly constant and positive for the 'other' group, whilst for those in full time education it is constant and negative. Finally for the retired group the cumulative attrition bias is negative and increasing over the sample period. This indicates that whilst there is attrition, the magnitude and direction varies depending on the particular subgroup and future revisions to the weighting strategy should try to account for this. Cousins (2012b) also shows the longitudinal estimates underestimate the stock of individuals in the economically active segment of the population. Whilst the current cross section weighting methodology does not control for economic status in the partition

Figure 5.20: Cumulative attrition bias.



Source: Cousins (2012b)
Notes: units in millions I(FTE) = Inactive and in full-time education I(retired) = Inactive, not in FTE and reporting that they are retired I(other) = Inactive and neither in FTE or retired
Attrition bias: Measured by the change in estimated stock for a given quarter, between the second time it is estimated in a longitudinal dataset (as the 'origin' of any flows) and the first time it is estimated (in the previous longitudinal dataset as the 'destination' of any flows).
Cumulative attrition bias: Sum the bias for each quarter since Q3 2005, in order to show whether the bias is systematic and builds up over time, or random and fluctuates around zero.
Cumulative attrition bias per quarter: Gives the average quarterly bias since Q3 2005. This shows whether the size of the bias is stable over the long term.

variables, the current and revised methodology does. Therefore future research should reconcile this by considering whether it is feasible to calibrate the main cross section UKLFS to population totals of employment, unemployment and inactivity.

In summary, the revised specification is able to address some of the potential drivers which may be causing a discrepancy to exist between the existing longitudinal and cross section estimates of labour force activity, as highlighted by Cousins (2012a, 2012b) but not all. Additional partitions could be introduced to help overcome this, however may require aggregating other partitions depending on the calibration specification. It is beyond the scope of this chapter to formally compare the revised longitudinal estimates under definitions 1 and 2 and compare these to the cross section estimate, nonetheless this should be done in future work. We can however compare the flow estimates under the existing and revised weights, we do this next.

Comparison of flows

To understand the implications of the revised specification we compare the labour market flows between Q1 2011- Q2 2011 and Q4 2011-Q1 2012 under the existing and revised longitudinal weights. If the revised weights are superior in terms of being able to control for longitudinal attrition they should be able to reconcile part of the discrepancy between the longitudinal and cross section estimates of economic activity reported in Section 5.3. By construction our longitudinal samples contains 16-69 year olds (in order to compare them to the existing longitudinal dataset) whilst the cross section data includes individuals aged 16-64. Therefore without constraining the current and revised specification to 16-64 year olds we cannot directly compare the longitudinal estimates with the cross section. Moreover the data is held securely at the ONS and at the time of writing we did not have the necessary permissions to access it. Therefore it is not possible to provide an accurate response to the discrepancy highlighted in Section 5.3 nonetheless we try to give some indication of what estimated flows imply. Clearly this would also be desirable in order to provide a response to the issues highlighted by Cousins (2012a, 2012b). We leave this for future work.

Nonetheless it is still possible to analyse the magnitude and direction of flows estimated between the proposed and existing longitudinal files for the 16-69 sample using the current and revised F weights. These are described in Tables 5.8-5.11 and can be interpreted using the two-quarter flow matrix in Table 5.7.

Table 5.7: Two quarter transition matrix.

Quarter	Q_{t+1}			
	Economic state	E	U	I
	E	X_{EE}	X_{EU}	X_{EI}
Q_t	U	X_{UE}	X_{UU}	X_{UI}
	I	X_{IE}	X_{IU}	X_{II}

Notes: The diagonal elements of the matrix correspond to individuals who do not flow into a different economic state between two consecutive quarters, for example they report being in employment in two consecutive quarters.

Table 5.8: Q1 2011-Q2 2011.

Flow	Existing Weights (EW)	Revised Weights (RW)	Difference: EW-RW $\left(\frac{\lvert \text{Diff} \rvert}{\text{EW}}\%\right)$
Aged 15 at both qtrs	553,197	472,165	81,032 (14.6)
Becomes of working age	212,886	166,064	46,822 (22)
Employed⟶Employed	27,893,264	28,187,609	-294,345 (1.05)
Employed⟶Unemployed	438,299	293,274	145,025 (33.08)
Employed⟶Inactive	483,757	324,275	159,482 (32.96)
Unemployed⟶Employed	520,199	352,612	167,587 (32.21)
Unemployed⟶Unemployed	1,502,984	1,818,684	-315,700 (21.00)
Unemployed⟶Inactive	416,283	267,565	148,718 (35.73)
Inactive⟶Employed	436,830	347,440	89,390 (20.46)
Inactive⟶Unemployed	502,551	386,181	116,370 (23.15)
Inactive⟶Inactive	10,756,694	11,081,790	-325,096 (3.02)
Reached retirement age by final qtr	131,178	132,676	-1,498 (1.14)
Total	43,848,122	43,830,336	-17,786 (0.04)

Table 5.9: Q2 2011-Q3 2011.

Flow	Existing Weights (EW)	Revised Weights (RW)	Difference (EW-RW) $(\frac{\|Diff\|}{EW}\%)$
Aged 15 at both qtrs	523,272	459,945	63,327 (12.67)
Becomes of working age	192,154	147,452	44,702 (23.26)
Employed⟶Employed	27,869,305	28,166,217	-296,912 (1.06)
Employed⟶Unemployed	395,523	274,224	121,299 (30.66)
Employed⟶Inactive	580,077	402,984	177,093 (30.52)
Unemployed⟶Employed	523,059	371,621	151,438 (28.95)
Unemployed⟶Unemployed	1,620,132	1,879,671	-259,539 (16.02)
Unemployed⟶Inactive	323,519	213,164	110,355 (34.11)
Inactive⟶Employed	472,791	394,967	77,824 (16.46)
Inactive⟶Unemployed	662,649	507,153	155,496 (23.46)
Inactive⟶Inactive	10,584,332	10,938,857	-354,525 (3.35)
Reached retirement age by final qtr	137,167	138,982	-1,815 (1.32)
Total	43,883,980	43,895,236	11,256 (0.026)

Table 5.10: Q3 2011-Q4 2011.

Flow	Existing Weights (EW)	Revised Weights (RW)	Difference (EW-RW) $(\frac{\|Diff\|}{EW}\%)$
Aged 15 at both qtrs	518,168	435,286	82,882 (16)
Becomes of working age	190,330	151,461	38,869 (20.42)
Employed⟶Employed	27,801,715	28,113,331	-311,616 (1.12)
Employed⟶Unemployed	439,476	325,911	113,565 (0.128)
Employed⟶Inactive	641,592	442,889	198,703 (30.97)
Unemployed⟶Employed	616,496	446,210	170,286 (27.62)
Unemployed⟶Unemployed	1,718,306	2,007,525	-289,219 (16.83)
Unemployed⟶Inactive	374,842	253,798	121,044 (32.29)
Inactive⟶Employed	485,892	413,742	72,150 (14.84)
Inactive⟶Unemployed	446,155	395,847	50,308 (11.27)
Inactive⟶Inactive	10,578,377	10,810,012	-231,635 (2.19)
Reached retirement age by final qtr	130,051	125,911	4,140 (3.18)
Total	43,941,400	43,921,923	19,477 (0.04)

Table 5.11: Q4 2011-Q1 2012.

Flow	Existing Weights (EW)	Revised Weights (RW)	Difference (EW-RW)($\frac{\lvert\text{Diff}\rvert}{\text{EW}}\%$)
Aged 15 at both qtrs	538,888	477,018	61,870 (11.48)
Becomes of working age	157,119	125,660	31,459 (20.02)
Employed⟶Employed	27,942,481	28,262,777	-320,296 (1.14)
Employed⟶Unemployed	443,843	300,835	143,008 (32.22)
Employed⟶Inactive	527,000	351,334	175,666 (33.33)
Unemployed⟶Employed	533,401	446,254	87,147 (16.33)
Unemployed⟶Unemployed	1,694,728	1,894,948	-200,220 (11.81)
Unemployed⟶Inactive	390,698	273,912	116,786 (29.89)
Inactive⟶Employed	363,427	344,712	18,715 (5.14)
Inactive⟶Unemployed	445,202	357,979	87,223 (19.59)
Inactive⟶Inactive	10,864,929	11,016,987	-152,058 (1.39)
Reached retirement age by final qtr	127,327	128,599	-1,272 (1)
Total	44,029,043	43,981,016	48,027 (0.109)

Tables 5.8-5.11 show that under the proposed weighting the estimated magnitude of the flows into identical states across two consecutive waves is significantly higher than under the existing weighting. This can be seen clearly in the third column of Tables 5.8-5.11 which includes the difference between the flows under existing and proposed weights as a proportion of the existing flows, some of the differences are in excess of 30%. To compensate for this (given the population totals are roughly the same) the estimated magnitude of flows which involve a transition into a different economic state (under the proposed weights) is lower. By taking into account additional factors which are correlated with attrition and estimating revised weights using GES, the impact on estimated flows is significant. Clarke and Tate (1999) note that gross flows between two different economic states based on existing weights may be biased upwards due to response error; such as proxy interview and survey mode. Their findings suggest it is particularly severe amongst certain subgroups such as the inactive. The revised weighting does account for certain types of non-response error (although not by economic state) and the estimated flows from one economic state to another are lower compared to the existing weights, therefore this may partially be correcting for response error

in the UKLFS.

In terms of the discrepancies reported by Cousins (2012a), the flows reported in Tables 5.8-5.11 cannot offer any tentative suggestions as to whether the revised weights offer an improvement in dealing with differential initial non-response and attrition depending on whether an individual is in part time or full time work. For this to be possible one should estimate revised flows for an identical population (aged 16-64) and compare existing, revised and cross section labour force estimates under each definition reported in section 5.6. Similarly, the main finding of Cousins (2012b) is that there exists attrition bias within particular subgroups of the inactive. We do not break down flows for the inactive group and therefore future work should condition on economic state (retired, in full time education or other) and estimate flows from these states and compare them under definition 1 and 2 using the longitudinal estimates to determine the magnitude and trend of the bias.

Tables 5.8-5.11 suggest the existing weights significantly overestimate the gross flows between different states over two consecutive quarters.[29] Alternatively it could be that the revised weights are not fully accounting for the magnitude of the flows between different states, although they do take into account all the existing partitions used in the current weighting procedure. In relation to the discrepancy highlighted in Section 5.3 between the cross section and existing longitudinal dataset in relation to the stock estimate for a given quarter, there is no clear pattern in Tables 5.8-5.11 as to whether the revised weights consistently estimate more or less individuals in employment, unemployment or inactivity at a given quarter. Therefore future work should investigate why such a discrepancy exists building on the work of Cousins(2012a,b) and combining this with the revised calibration specification in this chapter.

The fact that the balanced panel used in deriving the revised longitudinal weights is significantly larger than that used in the current procedure, implies we are able to derive a more comprehensive picture of the flows between economic states due to improved ‘sample coverage’. This is supported by the fact the F weights estimates under the revised specification are two thirds the size of those currently estimated.

[29] See Bell and Smith (2002) for evidence on the magnitude of worker flows using the longitudinal UKLFS datasets.

It is clear the difference between the existing and revised calibration specification significantly effects the longitudinal flow estimates, and given their importance in understanding labour market dynamics underlines the importance of future research in this area.

5.8 Future work

Future research looks to test alternative specifications for the model of non-response, to ensure the optimal combination of covariates guides the choice of constraints used in the calibration of longitudinal weights. Cousins (2012a) highlights that attrition patterns for UKLFS sample members is different in magnitude and direction, depending on whether the individual was in full time or part time work in their first interview, future work should incorporate such factors in the calibration specification. We have ignored duration dependence which may effect the likelihood of response (Zabel, 1998); a simple way to control for this is to include the wave number of the survey, future research should test for the direction and magnitude of duration dependence.

Cousins (2012b) highlights the discrepancy in the estimated flows into and out of inactivity using the existing two quarter UKLFS compared to the cross section UKLFS for a given quarter. The effect is particularly severe amongst those in full time education or inactive (but not retired). Future research should incorporate a more detailed specification of the initial economic state in the calibration specification. Similar to Cousins (2012b) in order to judge the accuracy of the revised longitudinal weights, these should be compared to the cross section estimates for each quarter.[30]

The revised specification only constrains to first quarter marginal totals. Existing weights constrain to Q1 and Q2. If the revised weights do not satisfactorily reproduce the Q2 cross section then this could be source for the large discrepancy found in estimated flows. In future work one should reproduce the revised weights using information from Q1 and Q2 using pseudo-control totals to ensure weighted estimates account for the economic activity distribution

[30] Whilst the revised weights indicate a higher a number of individuals in each state at a given quarter, this does not necessarily mean the discrepancy will be larger than that which already exists, as the flows into other states will be lower for a given quarter, given that under the exisiting and revised weights the population total is very similar.

at Q1 and Q2. However it is worth noting that if the Q1 and Q2 economic activity marginal distributions are correlated then this will distort estimated gross flows (Clarke and Tate, 1999).

A note of caution is that whilst it is desirable to place more constraints in the calibration specification, this in turn places more demands on the data. Depending on how these constraints are specified may cause the raking engine to find empty or very low cell sizes, which would inhibit the estimation of estimate longitudinal weights. This may be overcome by additional aggregation in other constraining factors such as geographical locality or age, however this would have to be justified. Moreover given the 'production' nature of the ONS it should be the case that longitudinal weights should be estimable as required. Finally the procedure requires automation through a user written SAS macro for business use.

5.9 Conclusion

In this chapter we have proposed a revised specification for the estimation of longitudinal weights for the two-quarter longitudinal UKLFS. We model non-response using a binary framework and use the results to guide the choice of the auxiliary variables in the weighting specification. In addition to the existing partitions following the work of Clarke and Tate (1999), we additionally account for interview outcome, age and gender in the calibration. We also show it is feasible to weight the two-quarter longitudinal files using the GES raking engine, and show the subsequent weights are a significant improvement from a statistical and analytical perspective compared those currently estimated. The specification of the partition and logit variables is driven by existing research, economic theory and business practicality. This is to ensure the correct balance is struck between enriching the number of partition variables to improve the accuracy of the weights and ensuring a parsimonious specification to ensure GES converges on each run.

As highlighted in Section 5.2 there has been a substantial decline in response rates by households in the UKLFS. This decline is likely to be more severe amongst particular subgroups. Such differential attrition underlines the importance of having up-to-date longitudinal weights to account for this.

Chapter 6

Approaches to the Seasonal Adjustment of Labour Market Flows

6.1 Introduction

The United Kingdom Labour Force Survey (UKLFS) measures the stock of employment, unemployment and inactivity at each quarter. In doing so it helps researchers and policymakers understand the trends in labour market transitions across consecutive quarters, for example to track changes in labour force dynamics during a recessionary period or due to a policy intervention.

Data such as the UKLFS represent a quarterly time series of observations and therefore may exhibit cyclic variation or seasonal factors. It is important to seasonally adjust data in order to understand how calendar effects can effect the trend component of a series, and thus aid interpretation between consecutive time periods (ONS, 2007). Ignoring seasonal factors may lead to incorrect inference about the underlying trend of the data, and makes it difficult to derive valid comparisons over time particularly for very recent periods (Atuk and Ural, 2002).

The ONS currently publishes estimates of labour market flows using data from the two-quarter longitudinal datasets; however at these are not seasonally adjusted. The indirect approach to seasonal adjustment involves adjusting subcomponent series to derive a seasonally adjusted aggregate, whilst the direct approach involves adjusting the aggregate itself. The aim of this chapter is to investigate the extent of seasonality in the flows estimates derived from the two-quarter longitudinal datasets. Conditional on seasonality being present we then compare direct and indirect seasonally adjusted estimates of inflows and outflows associated with labour market status in the UK; and subsequently recommend a preferred approach to the seasonal adjustment of these flows.

The rest of this chapter is set out as follows; Section 6.2 describes the UKLFS. Section 6.3 gives a description of labour market flows and estimates of seasonally adjusted LFS data. Section 6.4 details results from a range of diagnostic measures to access the relative performance of the direct and indirect seasonal adjustment. Section 6.5 considers future work. Section 6.6 concludes.

6.2 Data

The UK Labour Force Survey (UKLFS) is a quarterly household survey which interviews approximately 35,000 households, and is primarily concerned with tracking labour market circumstances of households in the UK. The LFS is a longitudinal survey such that it follows households for five quarters, after which they are rotated out.[1] [2] Therefore at any given quarter 20% of the sample is new i.e. it is the first time the household is observed in the sample. The LFS is compiled by the ONS and in its current quarterly version format has been running since 1992.

In addition to the cross section estimates the ONS produces two-quarter and five quarter longitudinal datasets, in order to track flows between different labour market states. It is the two-quarter datasets which are the concern of this chapter. These allow one to follow an individual from one quarter to the next and therefore by definition constitute a panel.[3] In order to eligible to be part of this longitudinal study an individual should be present in each quarter,

[1] This only holds true if there is no attrition otherwise as a proportion of the sample the refreshment will constitute more than one fifth of the sample.

[2] For more detailed information see the ONS UKLFS methodology website: http://www.ons.gov.uk/ons/guide-method/method-quality/specific/labour-market/labour-market-statistics/index.html

[3] The questions in the LFS mean it is not possible to determine transitions that occur within these three month intervals.

thus by construction panels are balanced.[4] It is possible that an individual can change economic status across the two-quarters and therefore this investigation is related to flows between employment, unemployment and inactivity.

6.3 Labour Market Flows and approaches to their Seasonal Adjustment

6.3.1 Description of the labour market

Conditional on being observed in two consecutive quarters in the two-quarter longitudinal datasets, an individual can either stay or make a transition into one of the following states: (E)mployed, (U)nemployed or (I)nactive. This gives rise to nine possible transitions summarised in Table 6.1.

Table 6.1: Two quarter transition matrix.

Quarter	Q+1			
	Status	E	U	I
Q	E	X_{EE}	X_{EU}	X_{EI}
	U	X_{UE}	X_{UU}	X_{UI}
	I	X_{IE}	X_{IU}	X_{II}

Each of the elements (X_{ij}) in the matrix reflects the magnitude of flows between two consecutive quarters. From this information estimates of gross inflows and outflows for each of the statuses can be obtained, as summarised in Table 6.2.

[4] In some cases which are related to the age (75+) of the individual in their first interview, respondent's information is only collected in the first and last wave. In other cases information may be rolled forward if individuals are not contactable in two consecutive quarters. Cases such as these are not included in the longitudinal datasets.

Table 6.2: Definitions of flows across two consecutive quarters.

	Definition
Inflows to	
Employment	$X_{UE}+X_{IE}$
Unemployment	$X_{EU}+X_{IU}$
Inactivity	$X_{EI}+X_{UI}$
Outflows from	
Employment	$X_{EU}+X_{EI}$
Unemployment	$X_{UE}+X_{UI}$
Inactivity	$X_{IE}+X_{IU}$

6.3.2 Seasonal adjustment in ONS

Seasonal adjustment aims to remove effects associated with the time of year or arrangement of the calendar, so that underlying movements within time series may be more easily interpreted. An economic time series may be thought of as an aggregation of a number of unobservable components, namely:

- A trend-cycle (C): the underlying long-term movement in the series, plus cyclical movements about it
- A seasonal component (S): within-year movements about the trend-cycle that remain roughly constant in magnitude and direction, and in the same month/quarter, from year to year
- An irregular component (I): residual variation after the trend-cycle and seasonal component (plus calendar-related effects) have been removed from the series, for example short-term shocks

The way in which the components are aggregated may be additive (whereby the components are summed i.e. $Y = C + S + I$) or multiplicative (whereby the components are multiplied together i.e. $Y = C * S * I$). Series that have a multiplicative pattern are typically log transformed to enforce additivity in order to estimate the components.

Seasonal adjustment aims to estimate the seasonal component and remove it (as well as calendar-related effects), from the observed time series to leave the trend-cycle and irregular component unchanged. Throughout ONS, the primary method for seasonal adjustment is the X-11 algorithm, as detailed in

Ladiray and Quenneville (2001). The method is based on the iterative application of moving averages, which are used to decompose a time series into its unobserved components. However, due to the symmetrical nature of such moving averages, decomposed values for the most recent periods are obtained after the series is extended with forecasts. The forecasts are appended to "regARIMA" (regression with Autoregressive Integrated Moving Average errors) models, which are also used to derive adjustments for additive outliers and level shifts. These adjustments are known as "prior adjustments", because they are made prior to the application of the X-11 algorithm (if prior adjustments were not made for such effects, seasonally adjusted estimates might be distorted). More information on ARIMA and regARIMA models can be found in Box et al. (2008), Findley et al. (1998) and US Census Bureau (2011).

6.3.3 Approaches to seasonally adjusting labour market flows

Seasonal adjustment of each of the six aggregate flows series as listed in Table 6.2 can be done in two ways:

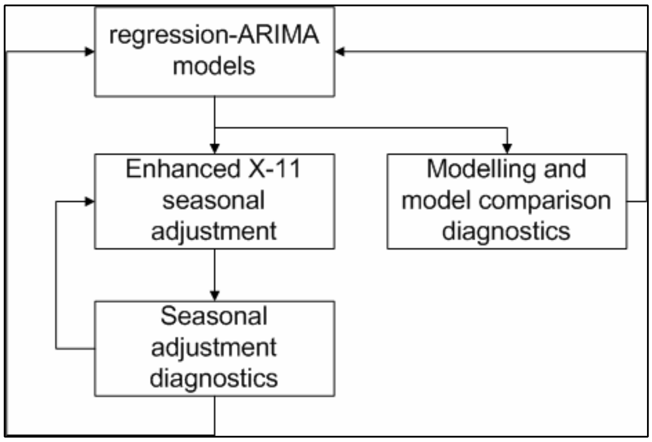
1. Direct estimation: seasonally adjust each of the six aggregate flows series for example seasonally adjust the inflows to employment as the sum of $X_{UE}+X_{IE}$
2. Indirect estimation: seasonally adjust each of subcomponents for example seasonally adjust X_{UE} and X_{IE} separately and then sum these to derive the indirect seasonal adjustment of inflows to employment.

Seasonal adjustment of net inflows to a particular labour force status also leads to a choice between direct and indirect estimation. For example should one seasonally adjust aggregate inflows and outflows to derive net inflows, or seasonally adjust net inflows itself? However, the analysis reported here focused solely on seasonal adjustment of the six aggregate flows series.

It is worth noting that these are not equivalent and will not give exactly the same estimates. The direct approach is conceptually appealing, as seasonal adjustment is performed directly on the series of interest. However, the indirect approach guarantees that the sum of the seasonally adjusted subcomponents is equal to the seasonally adjusted aggregate, which is not the case for direct estimation. For more information and discussion on the two approaches see Eurostat (2009) and Ladiray and Mazzi (2003).

In order to obtain directly and indirectly seasonally adjusted estimates, each of the six transition series and six aggregate flows series was seasonally adjusted using the X-12-ARIMA software package (US Census Bureau, 2011). The X-12-ARIMA process is described in Figure 6.1.

Figure 6.1: The X-12 ARIMA method.



Source: ONS (2007).

Regression-ARIMA is used by X-12 ARIMA to identify and quantify factors which will impact on the seasonal factor estimation (ONS, 2007).[5] This is described in more detail next.

Regression-ARIMA model time series in such a way that prior adjustments are estimated prior to seasonal adjustment. A regression-ARIMA model can be defined as:

$$\log(Y_t) = \beta' X_t + Z_t$$

Where the dependent variable Y_t has been log transformed, Z_t is an ARIMA process and X_t are regressors for trading day, holiday or calender effect, additive temporary changes, level shift, ramps or other effects. Diagnostic tests

[5] The following exposition of X-12-ARIMA draws heavily on the ONS Guide to Seasonal Adjustment (2007).

are included in X-12-ARIMA to evaluate the fit of the model.

As noted a time series is made of a trend (C_t), seasonal (S_t) and irregular (I_t) component. Each of these is defined above. The X-12-ARIMA method makes use of the X-11 process (Moore et al. 1967). The labour market flows examined below were found to demonstrate a multiplicative relationship between the components. X-11 performs the following procedure on the series:

1. A preliminary trend cycle C_t' is derived by applying a trend moving average to the original series Y_t

This can smooth a series or estimate and remove seasonality. Weights are symmetrical for months either side of the month of interest, the effect is to remove any stable annual variation and reduce the variance of a purely random component (leaving the linear trend unchanged).

2. The initial estimate of trend is removed from the original series to give a detrended time series: $S_t * I_t = \frac{Y_t}{C_t'}$

The 'SI_t' ratio can be plotted to determine whether they are below or above trend. They also depict any breaks in the series.

3. It is here outliers are detected automatically and replaced in the SI_t series

Outliers reduce distortion in the series. Outliers are replaced in such a way that progressively better estimates of the outliers are derived. Outliers are identified by calculating the standard deviation for each five year moving span of the irregular component, if the irregular component is 1.5σ away from 0 then it is replaced. The modified SI_t ratio is used to estimate the seasonal component.

4. The preliminary estimate of the seasonal component $\hat{S}_t$is derived by applying a seasonal moving average to the modified SI_t ratio for each quarter.

If the estimated moving averages represent the seasonal factor then the irregular component is the deviation from each point from the moving averages.

5. Divide Y by S to give the preliminary seasonally adjusted series

This provides an estimate of $C * I$.

The process described in 1-5 is then repeated but instead of using the original detrended series one starts with the seasonally adjusted series derived in 5 to give improved estimates of the trend component (by using Henderson moving averages).

Finally the entire process is repeated twice more, each time using the modified series with extreme values removed or reduced.

Many of X-12-ARIMA's automatic modelling and selection capabilities were utilised during this process, including:

- A test for the need for a log transformation
- Selection of the ARIMA model orders
- Additive outlier and level shift detection and correction
- Selection of the trend and seasonal moving average lengths

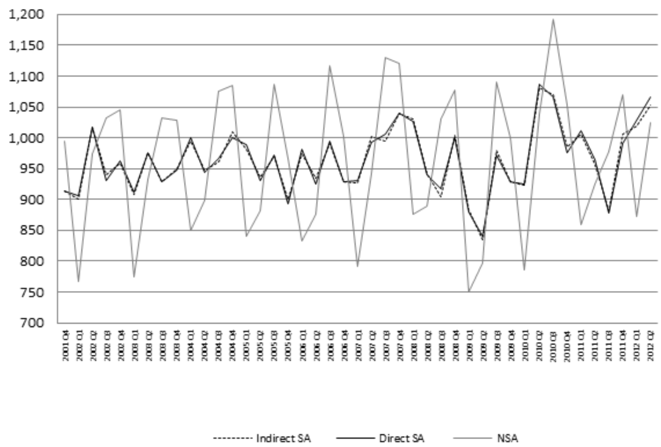
In particular, the selection of the ARIMA part of the model is chosen by selecting the order such that the most simplest model (smallest number of parameters) which gives a satisfactory fit is used. The method used by X-12-ARIMA is to check the model fits the data in a satisfactory manner i.e. to check the autocorrelation of the residuals: any significant correlation in the residuals suggest a potentially misspecified model. X-12-ARIMA automates two procedures: (1) use a predetermined list of candidate models and choose the model which best fits the data or (2) start with simple model and make it increasingly complex until it meets a goodness of fit criterion.[6] For the purposes of this work relatively simple models (in terms of lag order) were chosen using the automatic X-12-ARIMA in built selection method described above.

[6] Other tests include testing whether the moving average part of the model for evidence of overdifferencing or estimating within-sample forecasts: the absolute average percentage error of within sample forecasts in the the last three years should be less than 15% (ONS, 2007). We did not need to resort to manual selection in which the use of AIC and BIC tests are used to compare alternative specifications.

Where necessary X-12-ARIMA's automatic selections were amended via manual intervention following, for example, visual inspection of the plotted original and seasonally adjusted data however this was rare in practice.

Figures 6.1 to 6.6 illustrate directly and indirectly seasonally adjusted estimates for each of the six aggregate flows series. The sample used for estimation is all individuals aged 16-64.[7] All of the series exhibit a clear seasonal pattern. Some series are more volatile than others for example outflows to employment, and some contain abrupt changes in level for example inflows to and outflows from unemployment, which are related macroeconomic shocks such as recent recessionary period.

Figure 6.2: Inflows to employment: UKLFS Q4 2001-Q2 2012.



[7]Figures 6.1-6.6 are quoted in 000's.

Figure 6.3: Inflows to unemployment: UKLFS Q4 2001-Q2 2012.

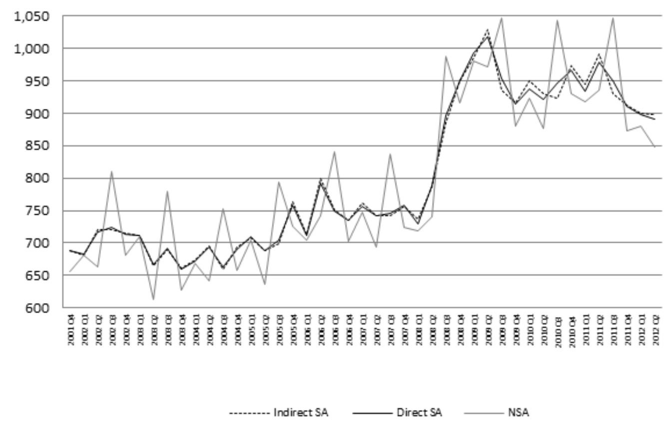


Figure 6.4: Inflows to inactivity: UKLFS Q4 2001- Q2 2012.

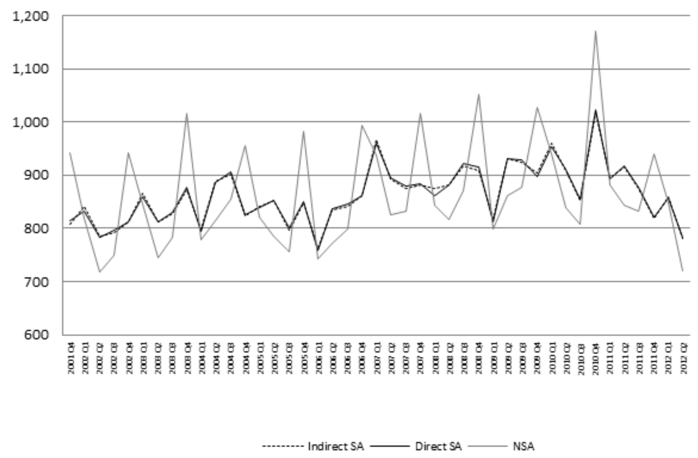


Figure 6.5: Outflows to employment: UKLFS Q4 2001-Q2 2012.

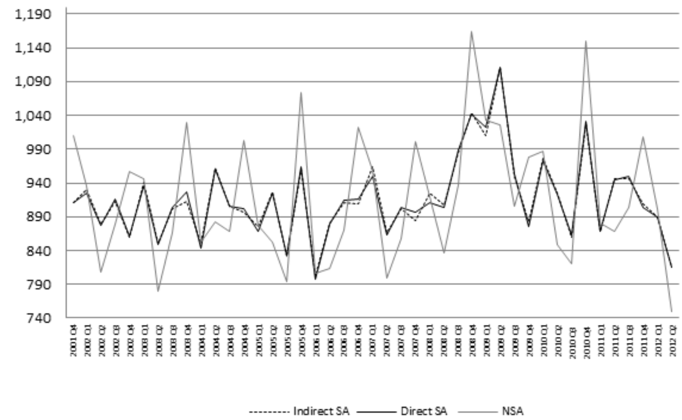


Figure 6.6: Outflows to unemployment: UKLFS Q4 2001-Q2 2012.

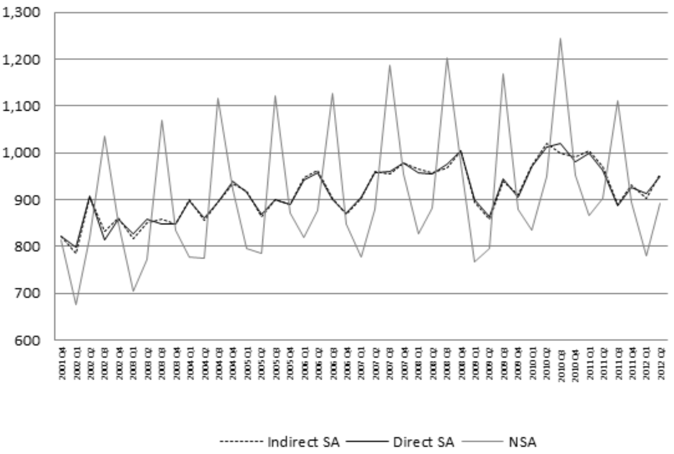


Figure 6.7: Outflows to inactivity: UKLFS Q4 2001-Q2 2012.

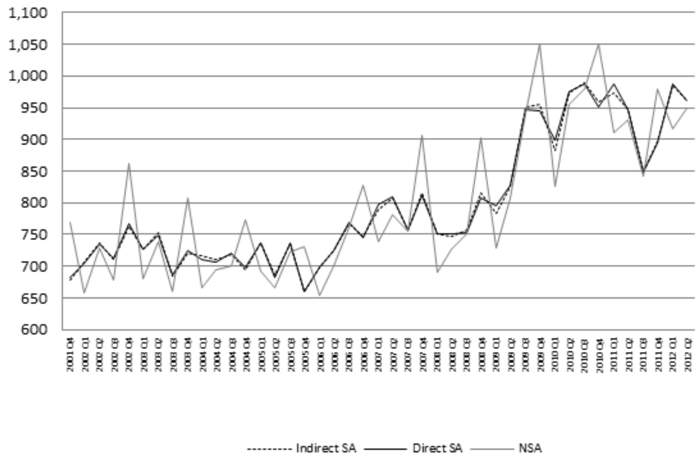


Table 6.3 summarises mean and maximum absolute percentage differences (MeAPD and MxAPD respectively) between directly and indirectly seasonally adjusted estimates for each series, calculated over the sample period 2001Q4 to 2012Q2 (43 observations) as:

$$MeAPD = \frac{1}{43}\sum_{t=1}^{43}\left|\left(\frac{DSA_t - ISA_t}{ISA_t}\right) * 100\right| \tag{6.1}$$

$$MxAPD = \max\left|\left(\frac{DSA_t - ISA_t}{ISA_t}\right) * 100\right| \qquad t = 1, 2, ..., 43 \tag{6.2}$$

There are clearly differences between the direct and indirect estimates, and these differences are typically larger for some series and for some time periods than others.[8] Table 6.3 indicates that the largest MeAPD for inflows is into unemployment, whilst for outflows it is from inactivity. In terms of MxAPD,

[8]The aim of this chapter is to determine which adustment produces the more stable seasonally adjusted estimates in general. Thus, we should focus on the entire span of data

Table 6.3: Magnitudes of differences between directly and indirectly seasonally adjusted estimates.

	MeAPD	MxAPD
Inflows to		
Employment	0.77	1.89
Unemployment	0.91	5.04
Inactivity	0.76	3.36
Outflows from		
Employment	0.43	1.22
Unemployment	0.62	3.27
Inactivity	0.75	3.16

Source: Office for National Statistics

the pattern is similar for both inflows and outflows; the difference is relatively large for unemployment and – to a lesser extent – inactivity, and relatively small for employment.

The financial recession between 2007 and 2009 had a clear impact on inflows to employment. If the downturn had a particular effect on specific subcomponents of total inflows into unemployment ($X_{EU}+X_{IU}$) in Table 6.2 this would lead to a discrepancy in the direct and indirect estimate of the seasonal adjustment of the time series. For example if the recession affected the flows (and hence potentially the seasonal component in the time series) from employment to unemployment (X_{EU}) in a different way to flows from inactivity to unemployment (X_{IU}) then this would be accounted for in the indirect estimate but not the direct estimate which adjusts the total of the two subcomponents.[9]

that we would be looking to publish. The other consideration when choosing a span to analyse is how many periods are included in the span. If we focus on just the recession period, we would be limiting ourselves to a small sample of periods to base our comparison on (particularly as we are dealing with quarterly rather than monthly data). Giving some periods more weight than others but comparing the series over the whole span gets round this problem, but the problem then becomes choosing the weights in some non-arbitrary way.

[9] Part of the work for this project included estimating the seasonally adjusted sub components of the series including their trend, seasonal and irregular. A plot of these would show the financial recession affected particular series differently to others. As the main point of this chaper is to discern whether seasonality exists and not the effect of the recession on seasonal adjustment estimates of labour market flows (some work has been done in this area for labour market flows in the US see Greenaway-McCrevy, 2013) we leave this for future work.

If the direct and indirect estimates yielded only marginal differences for all six series, there would be little motivation to formally assess which of the two approaches is preferred; one might opt to use the indirect approach as it has the property of its constituent components being additive. However, as some of the differences are quite substantial, a formal comparison involving quantitative measures is required.

6.4 Quality Comparison of the Direct and Indirect Approaches to Seasonal Adjustment

For each of the six aggregate flow series, three dimensions of seasonal adjustment quality were used to compare the direct and indirect approaches. These dimensions are:

1. Residual seasonality
2. Revisions
3. Roughness

The measures associated with each of these three dimensions were produced using X-12-ARIMA, and are described in detail in Findley et al. (1998), ONS (2007) and US Census Bureau (2011).

6.4.1 Residual seasonality

Residual seasonality can be defined as seasonality present in a time series after seasonal adjustment has been performed. By definition this makes it an obvious indicator of seasonality adjustment quality, because a completely seasonally adjusted series should be free of seasonality.

Residual seasonality was tested for in two ways. The first was an F-test for stable seasonality, performed on the seasonally adjusted data (after taking differences between successive values, in order to remove the trend in the series). This test is obtained from the classical one-way analysis of variance (ANOVA) approach, whereby total variance is broken down into a variance of the four quarterly mean levels, due to seasonality, and a residual variance (Ladiray and Quenneville, 2001).

For each of the six aggregate flows series, two null hypotheses were tested:

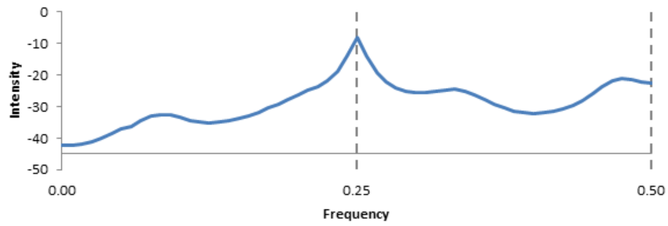
- H_1: no residual seasonality in the entire series
- H_2: no residual seasonality in the last three years of the series (reflecting the relative importance generally placed on more recent observations)

Neither of these null hypotheses was rejected for any of the six series at the 1% significance level.

The second test for residual seasonality was visual inspection of the spectral plot for the seasonally adjusted data. If a quarterly time series is seasonal, one would expect the observation in the current time period to be related to that four periods ago, the observation in the previous time period to be related to that five periods ago, and so on. Such a series is said to exhibit cyclical variation with a "period" of four quarters, or a "frequency" of 0.25 cycles per quarter (so that the cycle repeats itself every four quarters). The estimated spectrum is a plot of intensity by frequency. The total area under the curve represents the variance of the series, so a peak at a certain frequency marks an important contribution to the variance by a cyclical component of that frequency. Hence one would expect to see a peak in the estimated spectrum of a seasonal quarterly series at the frequency 0.25, but no such peak in the estimated spectrum of the corresponding seasonally adjusted data if the series has been completely seasonally adjusted. For more details on spectral analysis of time series see Nerlove (1964).

Figure 6.7 illustrates the estimated spectrum for non-seasonally adjusted inflows to employment. As expected, there is an obvious peak at the frequency 0.25 cycles per quarter, indicating the presence of seasonality. Figures 6.8 and 6.9 illustrate the estimated spectra for directly and indirectly seasonally adjusted inflows to employment respectively. Neither of the estimated spectra have a peak at the seasonal frequency, corroborating the result obtained from the F-tests: that there is no evidence of residual seasonality in either of the seasonally adjusted estimates. Spectra for the inflows to employment series have been arbitrarily selected for illustration, as the results are representative of seasonal adjustments for the other five aggregate flows series (whose spectra are not shown here).

Figure 6.8: Estimated spectrum for non-seasonally adjusted inflows to employment.

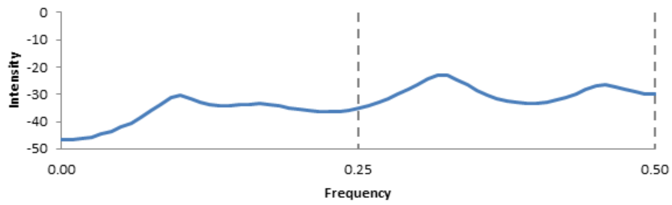


Source: Office for National Statistics

Notes: 1. The spectrum has been estimated from the first differenced, log transformed, prior adjusted data.

2. Intensity is presented on the decibel (10xlog10) scale

Figure 6.9: Estimated spectrum for directly seasonally adjusted inflows to employment.

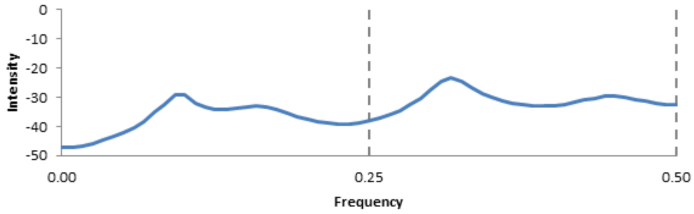


Source: Office for National Statistics

Notes: 1. The spectrum has been estimated from the first differenced, log transformed, prior adjusted data.

2. Intensity is presented on the decibel (10xlog10) scale

Figure 6.10: Estimated spectrum for indirectly seasonally adjusted inflows to employment.



Source: Office for National Statistics

Notes: 1. The spectrum has been estimated from the first differenced, log transformed, prior adjusted data.

2. Intensity is presented on the decibel (10xlog10) scale

6.4.2 Revisions: Stability of UKLFS time series

A desirable characteristic of a seasonally adjusted series is stability. Whenever a new observation is added to the current end of a time series, and the series is then seasonally adjusted, there will be revisions to seasonally adjusted estimates, particularly in the most recent time periods. Seasonally adjusted estimates that are subject to relatively small revisions over time are said to be stable. On the other hand, seasonally adjusted estimates that are subject to relatively large revisions over time are said to be unstable. In the latter case, seasonally adjusted estimates may not be a reliable source of information for users, particularly if revisions result in changes in direction as well as magnitude.

An analysis of revisions history was performed for each of the six aggregate flows series in order to assess the stability of the directly and indirectly seasonally adjusted estimates. The process for each series is summarised below and described visually in Figure 6.10.

1. 2006 Q4 was selected as the start date for the span to be analysed

2. The series was seasonally adjusted up to and including the start date

3. The start date was moved forward one time period and the series was seasonally adjusted again; this process continued until the end of the series was reached

4. The percentage revision between first and final seasonally adjusted estimates was calculated for each time period included in the analysed span (excluding the most recent period, for which only one seasonally adjusted estimate is available)

5. The mean and maximum absolute percentage revisions (MeAPR and MxAPR respectively) across all 22 time periods included in the analysed span were calculated as:

$$MeAPD = \frac{1}{22}\sum_{t=1}^{21}\left|\left(\frac{Final_t - First_t}{First_t}\right) * 100\right| \tag{6.3}$$

$$MxAPD = \max\left|\left(\frac{Final_t - First_t}{First_t}\right) * 100\right| \qquad t = 1, 2, ..., 22 \tag{6.4}$$

Where:
$First_t$ = first seasonally adjusted estimate at time t
$Final_t$ = final seasonally adjusted estimate at time t

Figure 6.11: Overview of the process used for the revisions history analysis.

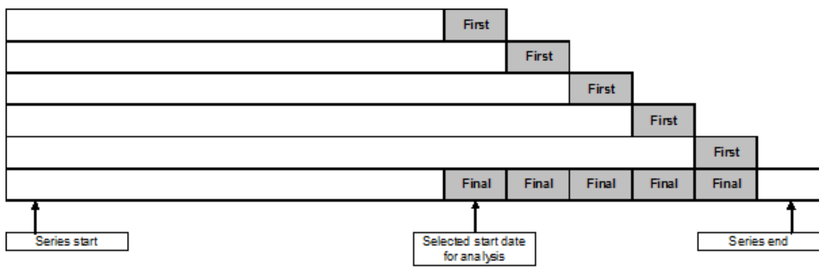


Table 6.4 summarises MeAPR and MxAPR values for the direct and indirect approaches for each of the six aggregate flows series. The results show neither of the approaches is superior to the other. Whether considering MeAPR or MxAPR, each approach is preferred for exactly half of the series.

Table 6.4: Mean and maximum absolute percentage revisions between first and final seasonally adjusted estimates.

	MeAPR		MxAPR	
	Direct	Indirect	Direct	Indirect
Inflows to				
Employment	1.21	1.29	3.57	3.08
Unemployment	0.43	0.83	1.26	2.18
Inactivity	1.13	0.90	3.71	2.73
Outflows from				
Employment	1.00	0.72	2.25	1.74
Unemployment	1.34	1.14	2.75	3.88
Inactivity	0.69	0.82	1.82	2.12

Source: Office for National Statistics.

6.4.3 Roughness of a seasonally adjusted time series

In general, there is no requirement for a seasonally adjusted time series to be smooth. If the non-seasonally adjusted data are relatively volatile, then one should expect the seasonally adjusted data to also be volatile, as seasonal adjustment aims to remove the seasonal component, but not the irregular component, from the time series. However, smoothness (or roughness) can be a useful criterion for comparing competing seasonal adjustments.

For each of the six aggregate flows series, roughness is measured as the Root mean Square Difference (RMSD) between the seasonally adjusted data and a smooth trend estimate, where the latter is obtained via a differencing operation. This measure is reported for the entire series and for the latest three years. A relatively large RMSD value indicates a relatively rough seasonally adjusted series, whilst a relatively small RMSD value indicates a relatively smooth seasonally adjusted series.

Table 6.5 summarises RMSD values for the direct and indirect approaches for each of the six aggregate flows series. The results are again mixed and neither of the approaches can be said to be superior.

Table 6.5: Root mean square differences between seasonally adjusted and trend estimates.

	RMSD (Entire series)		RMSD (Last 3 years)		Percentage Change	
	Direct	Indirect	Direct	Indirect	Entire Series	Last 3 years
Inflows to						
Employment	66537	66222	74145	73686	0.47	0.62
Unemployment	37116	40069	29107	32302	-7.96	-10.98
Inactivity	61800	61027	77935	77343	1.25	0.76
Outflows from						
Employment	78377	77990	90559	89069	0.49	1.64
Unemployment	47798	49004	55131	56619	-2.52	-2.70
Inactivity	45088	46845	41322	42824	-3.90	-3.64

Source: Office for National Statistics.
Note: positive percentage changes indicate that the indirect seasonally adjusted composite is smoother than the direct seasonally adjusted composite.

6.5 Future work

Future research should investigate seasonality in the UKLFS using an alternative software package such as "Time Series Regression with ARIMA Noise, Missing Observations and Outliers" and "Signal Extraction in ARIMA Time Series" (TRAMO/SEATS). This has a broader range in ARIMA model selection criteria as compared to X-12-ARIMA.[10] Confirmation of an identical model specification would provide further evidence the correct specification was chosen.

We show there is no evidence of residual seasonality conditional on adjustment, however Atuk and Ural (2002) formally test ARIMA versus TRAMO/ SEATS on Turkish monetary data, and find some evidence to suggest that

[10] There is also an abridged version known as X-13-ARIMA-SEATS.

TRAMO/ SEATS removes the seasonal component from a series more effectively than X-12-ARIMA.[11] However the US Census Bureau finds contradictory evidence which suggests TRAMO/SEATS can induce seasonality into a series when the underlying NSA series exhibits no seasonality (Hood, 2002). Nonetheless in all other respects Atuk and Ural (2002) show the two software perform very similarly, and conclude that due to the additivity property the indirect method of seasonal adjustment is preferred.

More recently Greenaway-McCrevy (2013) proposes a semi-parametric approach to seasonal adjustment, which he argues captures the effects of economic recessions more adequately than existing methods. The 2008-2009 financial crisis is easily distinguishable in the UKLFS data in terms of inflows into unemployment and inactivity during the sample period. Given such an approach has only recently been applied to the area of seasonal adjustment, further research needs to be done; nonetheless such an approach clearly offers desirable features (Greenaway-McCrevy, 2013).

Finally, the results of chapter five show that existing longitudinal weights (which are used to estimate labour force flows used in chapter six) do not capture attrition appropriately. Therefore future research should carry out a similar investigation, but instead using labour force flows estimates derived from revised longitudinal weights.

6.6 Conclusion

It has been shown that labour force flows measured from the UKLFS data exhibit seasonality. Two approaches to seasonal adjustment have been investigated – direct and indirect estimation – and have been shown to produce different estimates. The two approaches have been compared in terms of three dimensions of seasonal adjustment quality: residual seasonality, revisions and roughness. On balance neither of the approaches is superior. There is no evidence of residual seasonality in any of the six aggregate flows series for either adjustment, and the results for the revisions and roughness dimensions are mixed. It is therefore recommended that the six aggregate flows series

[11] Atuk and Ural (2002) also find X-12-ARIMA can in certain instances further adjust a series when there is no significant evidence of seasonality, however our results suggest there is clear evidence of a seasonal pattern.

be seasonally adjusted via indirect estimation. This approach does not appear to produce seasonally adjusted estimates that are inferior to those of the direct approach, and guarantees that the sum of seasonally adjusted subcomponents is equal to the corresponding seasonally adjusted aggregate. This additivity property is potentially valuable from a user viewpoint, as it allows, for example, contributions to unusually large quarter-on-quarter changes in an aggregate series to easily be attributed to changes in its subcomponents.

Chapter 7

Conclusion

In order to summarise the contribution of this thesis we highlight the main contribution of each chapter in turn. We also discuss substantive issues which have arisen as a consequence of our work; these issues provide us with an agenda for future research.

7.0.1 Chapter one: Work and Play Pave the Way: The Importance of Part Time Work in a Lifecycle Model

Chapter one presented a structural lifecycle model à la Gustman and Steinmeier (2002). Using backward induction and a isoelastic/quasilinear specification for utility, we show that with perfect foresight it is possible to derive closed form solutions for labour supply, consumption and savings.

We find a number of striking results. In particular, we establish the value function takes the same functional form as the within period utility function. This holds even with two decision variables per period, one of which is isoelastic and the other which is quasilinear, and there is the possibility of corner solutions.

Another defining feature of the model is the particularly simple expressions which emerge for the value function when an individual experiences a period of part time work. Our results show that in these cases optimal within period labour supply is only dependent on adjacent period variables, and the value function is linear in assets. The specification of the model implies that the form of consumption crucially depends on current and previous labour supply.

Analytical solutions provide a complete understanding of the general properties of the framework presented in chapter one. Our findings highlight the importance of the future on optimal within period labour supply, consumption and savings decisions. This provides guidance for specifying an empirical application, which we leave for future work.

7.0.2 Chapter two: To Defer or Not Defer: State Pension in a Lifecycle Model

Chapter two modelled the decision to defer State Pension within a lifecycle framework. Given the context of the decision we restrict attention to a two period framework, in which the first period can be thought of as reaching the age at which an individual is eligible to claim SP. In a general framework we show in the absence of credit constraints, the decision to defer ones SP depends only on the net present value of non-labour income.

We show the decision to defer ones SP may impact labour supply in one or both periods. The exact effect depends on exogenous factors such as the wage rate and the marginal utility of leisure. In order to show this explicitly we assume a quasilinear specification for utility à la Gustman and Steinmeier (2002), commonly used in the lifecycle literature. A recent DWP report (Coleman et al., 2008) concluded that the UK government should aim to increase public awareness regarding SP deferral, in light of survey evidence which (contrary to legislation) suggested that the decision to defer and continue working was not treated independently.

We also formally compare the two deferral options available under the existing UK SP system. Our results show that under most simulations the deferred higher weekly income option (versus the lump sum option) is preferred, in line with previous studies (Farrar et al., 2012).

Such research helps inform policymakers which factors are important in the SP deferral decision from a lifecycle perspective. By comparing the deferral options available under current legislation it is possible to consider the implications of our theoretical results in a policy context, and highlight the potential disparities between particular options currently available.

7.0.3 Chapter three: Lifetime Labour Market Activity and Retirement Decisions: Evidence from ELSA

Chapter three modelled the retirement and early retirement decision for a representative sample of English men and women aged 50 and over using ELSA. The sample data spans the period 2001-2011 and focuses on a sample of initially employed individuals.

Previous research has shown lifetime labour market histories are an important determinant of whether an individual experiences poverty in retirement (Nicholls, 2010; Bozio et al., 2010, 2011). We show preretirement work life histories play an important role in the timing of the retirement and early retirement decision. Specifically, they tend to reduce the retirement hazard. There are a number of reasons why this may be the case, for example due to an insufficient number of National Insurance contributions paid during ones working career. Other important factors in the (early) retirement decision include; pension wealth, lifetime and baseline health, spousal employment status, age and quintile position in the income distribution. Of these, higher levels of pension wealth act to raise the hazard of (early) retirement which is likely to be due to the generous pension schemes (in particular occupations) available to this cohort.

Our results indicate that the covariate set had a differential effect on the hazard of retirement when we controlled for quintile position in the income distribution. In shaping policies to extend working lives, policymakers should be aware of the potential for differential policy effects depending on position in the income distribution.

We show lifetime labour market history may not only have contemporaneous affects but also long term ramifications which are visible at retirement. A priori one may hypothesise periods of worklessness and inactivity raise the hazard of early retirement however our results suggest otherwise. Nonetheless, similar to Jones et al. (2010) we do find evidence to suggest that higher levels of pension wealth and poorer self-reported health do indeed raise the likelihood of retirement.

To the best of our knowledge this is the first study to incorporate the ELSA work history information in modelling the retirement and early retirement decision. Understanding which factors affect the decision to withdraw (often permanently) from the labour market is important, particularly given the changes in labour supply behaviour at older ages and the legislated rise in the SPA.

7.0.4 Chapter four: Unretirement in England: An Empirical Perspective

Chapter four modelled the unretirement decision for a sample of retired English men aged 50 and over. The study utilises sample data from ELSA covering the period 2001-2009.

Based on the date of labour market re-entry, we estimate an unretirement rate of nearly ten percent. In terms of magnitude this is similar to recent studies carried out for Sweden and Denmark (Pettersson, 2011; Larson and Pederson, 2013); however it is significantly lower than that reported in the US (Maestas, 2010). Our results show the likelihood of unretirement is higher amongst those with: a degree, a spouse in employment in 2002, higher levels of pension wealth and a medium or long term financial planning horizon. The duration approach we follow suggests there is no clear evidence of a gradient in the unretirement hazard.

Using the work history data available at wave 3 of ELSA, we estimate annual salary income in the main preretirement job to be nearly £39,000 (2007 prices). Combined with our estimation results this suggests that unretirement is unlikely to be related to low lifetime income or credit constraints.

This is the first study to analyse unretirement in England. Understanding the factors driving the unretirement decision is important, given the significant proportion of the UK population aged over SPA (ONS, 2013b). Our results suggest certain sections of the retired population are more likely to exhibit unretirement behaviour. Given the wider implications of increasing longevity on fiscal revenues coupled with a focus by central government on extending working lives, understanding the unretirement decision will help shape current and future labour market policies aimed at retired individuals.

7.0.5 Chapter five: Accounting for Attrition in the two-quarter UK Labour Force Survey

Chapter five investigated the determinants of non-response in the UKLFS. We show it is feasible to incorporate the factors related to attrition in an alternative calibration engine in order to estimate revised longitudinal weights.

Our results show in addition to the factors highlighted by Clarke and Tate (1999), survey attrition is more likely to be concentrated amongst; individuals in the 25-29 and 30-34 age categories, those whose first interview was by proxy and economic status. A recent ONS report (2012a) indicates survey response rates have declined by around 25% between 2000-2010, our results indicate the determinants of survey attrition have altered over this period. Controlling for factors correlated to non-response helps inform the specification of longitudinal weights used to correct for any resulting bias.

Using a revised specification, our results show the longitudinal weights are on average two thirds the size of those currently estimated. Moreover, by analysing the distribution of the revised weights it is clear the variance is significantly smaller and does not feature extreme weights.

We show the extent to which labour market flow estimates differ due to alterations in the raking specification. The revised weights consistently estimate a smaller magnitude of individuals moving into a different economic state across two consecutive quarters and in some cases this difference can be large. Given the importance of understanding the dynamics of the UK labour market, the ONS is currently investigating how best to incorporate the findings of this research into their production of quarterly labour force statistics.

7.0.6 Chapter six: Approaches to the Seasonal Adjustment of Labour Market Flows

Chapter six investigated the existence and magnitude of seasonality in the UKLFS covering the period 2001-2012. We show UK labour force flows exhibit a seasonal pattern and warrant being adjusted. Comparing each adjustment method using a broad range of diagnostic tests with quarterly UKLFS data our results indicate neither direct or indirect seasonal adjustment is superior. Therefore, we choose to indirectly seasonally adjust each flow. The latter method guarantees that the sum of seasonally adjusted subcomponents is equal to the corresponding seasonally adjusted aggregate.

We also set up a file system in which seasonal adjustment is undertaken automatically for future releases of the UKLFS. This will allow researchers to directly compare the gross and adjusted series in order to understand the effect of seasonal factors. The impact of this research has been such that the ONS now release seasonally adjusted estimates of labour force flows each quarter.

7.1 Substantive issues to be addressed in future research

In answering the questions we first set out to investigate, our analysis has raised additional lines of inquiry which provide an agenda for future research efforts. In chapter one we showed that for a particular set of preferences, it is possible to derive closed form solutions. It would be worthwhile to investigate whether a more general result could be established à la Merton (1971). That is to say, when a utility function is composed of two variables and each assumes a different power form is the optimisation problem analytically soluble? Can the value function be derived? Such results help inform our understanding of lifecycle models and guide empirical modelling.

In chapter two we studied the effect of state pension deferral in a lifecycle model. Private and employer pensions are another important source of retirement income. However, the heterogeneity in private and employer pensions means there has been little academic research focused on deferral of these particular sources of retirement income. Nonetheless, it is true that these schemes do share some common features; thus research into understanding how deferral of these types of pensions depends on, and affects, key economic characteristics such as labour supply and savings would be valuable. This is particularly relevant given: (a) The recent announcement of a 'workplace pension' in the UK and (b) The fact there exists a ten year gap (six for females) between the age at which a male can claim his private/employer pension (age 55) versus his state pension (age 65).

In order to better understand an individuals labour supply decision at older ages (as was the aim of chapters three and four), more detailed information is needed regarding an individuals labour supply history. This would be achievable through linked administrative data. Whilst some advancements have been made, such as wave one of ELSA being linked to DWP administrative records, future work should attempt to link additional waves of ELSA and other datasets such as National Cohort Studies (1946 and 1958). This is the focus of ongoing research being carried out by the Institute for Fiscal Studies and the Institute of Education. This will provide researchers with more detailed and accurate information relating to an individuals labour market history when modelling the retirement decision.

Underpinning all longitudinal analysis (such as the estimation of non-response weights and the seasonal component in labour force flows) is the quality of survey data. One aspect of quality assurance is sample size and how this evolves over time due to attrition. Whilst longitudinal weights are able to account for various survey specific characteristics, minimising non-response is of paramount importance for statistical agencies. To this end, one avenue of future research is to investigate non-response using experimental methods via the Understanding Society Innovation Panel.

To conclude, population ageing is an important issue for the UK. One in six individuals is aged over 65 and recent estimates indicate one in three children born in 2013 will live to reach 100 (ONS, 2011a, 2013c). In light of these statistics this thesis has sought to determine factors which determine labour supply behaviour at older ages. Such timely research aids academics and policymakers in their attempt to meet the labour market challenges of an ageing population.

Chapter 8

Appendices

8.1 Appendix for Chapter one

8.1.1 Data and sample construction

The Panel Survey of Income Dynamics (PSID) is a representative longitudinal survey of the US population administered by the University of Michigan. The sample began in 1968 and contained $30,000$ households (McGonagle et al., 2012). For the past four decades it has followed sample members and their children, collecting a range of economic and sociodemographic variables at each wave of the survey. The fact that the PSID has such a long panel dimension makes it an ideal candidate to analyse key labour market characteristics such as: weekly hours in paid employment, wages, non-labour income and assets over the lifecycle.

Each sample is derived by retaining only those individuals who are in the age bracket (in 2006) defined on the x-axis in Figures 1.1-1.3 and hence provides a cross section of individuals.[1] We only consider lifecycle characteristics of males since the number of female HOHs is much lower, however at the individual level females have similar distribution of work and wages to males except during child bearing years (not shown).

Each of the key economic characteristics was derived using the following formula:

[1] Given that one characteristic we are interested in is hours worked, for individuals to be eligible for our sample they must be in employment.

1. Assets = value of all car(s) in the residence + value of all family members AMT balances + value of all bonds/insurance and excludes all residential wealth.[2]

2. Annual non-labour income = HOH annual dividend income + HOH annual interest income + HOH annual rental income.

3. The hourly wage rate = wage rate reported in main job (2006 \$).

Individuals education level is 'college' if they have spend at least 16 years in full time education, 'high school' if they spend between 12 and 15 years in full time education, and 'below high school' if they spend strictly less than 12 years in full time education.

8.1.2 M recursion

To show this take the three periods prior to the terminal period as an example, starting from the end substitute back into the relevant expression at each period to derive the expression for M_{T-t}:

$$\begin{aligned} M_{T-1} &= \delta[1 + Q_T(\delta Q_T)^{1/(\alpha-1)}]^{1-\alpha} \\ &= \delta[\delta^{1/(\alpha-1)}(\delta^{1/(1-\alpha)} + Q_T^{\alpha/(\alpha-1)}]^{1-\alpha} \\ &= \delta\delta^{-1}[\delta^{1/(1-\alpha)} + Q_T^{\alpha/(\alpha-1)}]^{1-\alpha} \end{aligned}$$

$$\begin{aligned} M_{T-2} &= \delta M_{T-1}[1 + Q_{T-1}(\delta Q_{T-1} M_{T-1})^{1/(\alpha-1)}]^{1-\alpha} \\ &= \delta M_{T-1}[(\delta M_{T-1})^{1/(\alpha-1)}((\delta M_{T-1})^{1/(1-\alpha)} + Q_{T-1}^{\alpha/(\alpha-1)})]^{1-\alpha} \\ &= [(\delta M_{T-1})^{1/(1-\alpha)} + Q_{T-1}^{\alpha/(\alpha-1)}]^{1-\alpha} \\ &= [(\delta[\delta^{1/(1-\alpha)} + Q_T^{\alpha/(\alpha-1)}]^{1-\alpha})^{1/(1-\alpha)} + Q_{T-1}^{\alpha/(\alpha-1)}]^{1-\alpha} \\ &= [\delta^{1/(1-\alpha)}[\delta^{1/(1-\alpha)} + Q_T^{\alpha/(\alpha-1)}] + Q_{T-1}^{\alpha/(\alpha-1)}]^{1-\alpha} \\ &= [\delta^{2/(1-\alpha)} + \delta^{1/(1-\alpha)} Q_T^{\alpha/(\alpha-1)} + Q_{T-1}^{\alpha/(\alpha-1)}]^{1-\alpha} \end{aligned}$$

[2] We do not include individuals who report constituent asset component values in excess of 2006 US \$1 million.

$$
\begin{aligned}
M_{T-3} &= [(\delta M_{T-2})^{1/(1-\alpha)} + Q_{T-2}^{\alpha/(\alpha-1)}]^{1-\alpha} \\
&= [(\delta[\delta^{2/(1-\alpha)} + \delta^{1/(1-\alpha)} Q_T^{\alpha/(\alpha-1)} + Q_{T-1}^{\alpha/(\alpha-1)}]^{1-\alpha})^{1/(1-\alpha)} + Q_{T-2}^{\alpha/(\alpha-1)}]^{1-\alpha} \\
&= (\delta^{1/(1-\alpha)}[\delta^{2/(1-\alpha)} + \delta^{1/(1-\alpha)} Q_T^{\alpha/(\alpha-1)} + Q_{T-1}^{\alpha/(\alpha-1)}] + Q_{T-2}^{\alpha/(\alpha-1)}]^{1-\alpha} \\
&= [\delta^{3/(1-\alpha)} + \delta^{2/(1-\alpha)} Q_T^{\alpha/(\alpha-1)} + \delta^{1/(1-\alpha)} Q_{T-1}^{\alpha/(\alpha-1)} + Q_{T-2}^{\alpha/(\alpha-1)}]^{1-\alpha}
\end{aligned}
$$

Thus for period $T-t$ we have:

$$
\begin{aligned}
M_{T-t} &= (\delta^{t/(1-\alpha)} + \delta^{(t-1)/(1-\alpha)} Q_T^{\alpha/(1-\alpha)} + \delta^{(t-2)/(1-\alpha)} Q_{T-1}^{\alpha/(1-\alpha)} + \delta^{(t-3)/(1-\alpha)} Q_{T-2}^{\alpha/(1-\alpha)} \\
&\quad + \ldots Q_{T-t+1}^{\alpha/(1-\alpha)})^{1-\alpha} \\
&= (\Sigma_{s=0}^{t} \delta^{(t-s)/(1-\alpha)} Q_{T-s+1}^{\alpha/(1-\alpha)}) \text{ with } Q_{T+1} = 1
\end{aligned}
$$

8.1.3 Proofs for proposition 1.1 (iii)

If the future value is isoelastic and optimal current participation is at a corner then the current value is also isoelastic:

$$
V_t|L_t = \max h_t L_t + \frac{c_t^{\alpha}}{\alpha} + \frac{\delta M_{t+1}(N_{t+1}^i + Q_{t+1}(r_t A_t + y_t - c_t + w_t(1-L_t))^{\alpha}}{\alpha}
$$

$$
\begin{aligned}
\frac{\partial V_t}{\partial c_t} &= c_t^{\alpha-1} - \delta M_t Q_t (N_t^i + Q_t(r_t A_t + y_t - c_t + w_t(1-L_t))^{\alpha-1} = 0 \\
c_t &= \frac{\delta M_t Q_t^{\frac{1}{\alpha-1}} \left(N_t^i + Q_t \left(r_t A_t + y_t + w_t \left(1 - L_t\right)\right)\right)}{\left(1 + Q_t \left(\delta M_t Q_t\right)^{\frac{1}{\alpha-1}}\right)}
\end{aligned}
$$

This implies

$$
A_{t+1} = r_t A_t + y_t - \frac{\delta M_t Q_t^{\frac{1}{\alpha-1}} \left(N_t^i + Q_t \left(r_t A_t + y_t + w_t \left(1 - L_t\right)\right)\right)}{\left(1 + Q_t \left(\delta M_t Q_t\right)^{\frac{1}{\alpha-1}}\right)} + w_t(1 - L_t)
$$

and

$$
V_t|L_t = M_t(N_t^i + Q_t A_t)^{\alpha}/\alpha
$$

8.1.4 Final period

At T choose L_T to

$$\max \frac{[y_T + w_T(1-L_T) + r_T A_T]^\alpha}{\alpha} + h_T L_T \text{ st } L_T \leq 1$$

$$\frac{d}{dL_T} = -w_T[y_T + w_T(1-L_T) + r_T A_T]^{\alpha-1} + h_T$$

If this is < 0 at $L_T = 1$ have optimal $L_T < 1$, if ≥ 0 have corner $L_T = 1$, if ≤ 0 at $L_T = 0$ have corner $L_T = 0$ i.e.

$$\begin{aligned}
L_T = 0 \text{ if } \frac{h_T}{w_T} &\leq (y_T + w_T + r_T A_T)^{\alpha-1} \\
= [y_T + r_T A_T + w_T - (\frac{h_T}{w_T})^{1/(\alpha-1)}]/w_T \\
\text{if } w_T + y_T + r_T A_T > (\frac{h_T}{w_T})^{1/(\alpha-1)} &> y_T + r_T A_T \\
= 1 \text{ if } (\frac{h_T}{w_T})^{1/(\alpha-1)} &\leq y_T + r_T A_T
\end{aligned}$$

which gives

$$\begin{aligned}
v_T = (y_T + w_T + r_T A_T)^\alpha/\alpha \text{ if } \frac{h_T}{w_T} \leq (y_T + w_T + r_T A_T)^{\alpha-1}(L_T = 0) \\
= (\frac{1}{\alpha} - 1)(\frac{h_T}{w_T})^{1/(\alpha-1)} + (\frac{h_T}{w_T})(y_T + r_T A_T + w_T) \\
\text{if } w_T + y_T + r_T A_T > (\frac{h_T}{w_T})^{1/(\alpha-1)} > y_T + r_T A_T (L_T \text{ interior}) \\
= (y_T + r_T A_T)^\alpha/\alpha + h_T \text{ if } (\frac{h_T}{w_T})^{1/(\alpha-1)} \leq y_T + r_T A_T \ (L_T = 1)
\end{aligned}$$

Using this at T

$$\begin{aligned}
v_T(A_T) = \max[P_T^i + M_T^i(N_T^i + Q_T^i A_{Tt})^\alpha/\alpha, R_T + S_T A_T] \\
= P_T^2 + M_T^2(N_T^2 + Q_T^2 A_{Tt})^\alpha/\alpha \text{ if } \frac{h_T}{w_T} \leq (y_T + w_T + r_T A_T)^{\alpha-1} \\
= R_T + S_T A_T \text{ if } (w_T + r_T A_T)^{\alpha-1} < \frac{h_T}{w_T} < (y_T + r_T A_T)^{\alpha-1} \\
= P_T^1 + M_T^1(N_T^1 + Q_T^1 A_{Tt})^\alpha/\alpha \text{ if } \frac{h_T}{w_T} \geq (y_T + r_T A_T)^{\alpha-1}
\end{aligned}$$

where

$$P_T^1 = h_T, N_T^1 = y_T, Q_T^1 = r_T, M_T^1 = 1$$
$$P_T^2 = 0, N_T^2 = y_T + w_T, Q_T^2 = r_T, M_T^2 = 1$$
$$R_T = h_T(1 + \frac{y_T}{w_T}) + (\frac{1}{\alpha} - 1)(\frac{h_T}{w_T})^{\alpha/(\alpha-1)}, S_T = r_T\frac{h_T}{w_T}$$

(R_t^1, R_t^2,R_t^3 and S_t^1, S_t^2,S_t^3 coincide)

Then

$$v_T = \max[P_T + \frac{M_T(N_T + Q_T A_T)^\alpha}{\alpha}, R_T + S_T A_T]$$

8.1.5 Epochs

Epochs Preceding an Epoch with a Power Function Value Function

Consider the epoch lasting for periods from t_2 to $t_1 - 1$ where the value function at t_1 is a power function.

$$v_{t_1-1} = \max_{c,L} c_{t_1-1}^\alpha/\alpha + h_{t_1-1}L_{t_1-1}+$$
$$\delta[P_{t_1}^i + \frac{M_{t_1}(N_{t_1}^i + Q_{t1}(r_{t_1-1}A_{t_1-1} + y_{t1} - c_{t_1} + w_{t_1}(1 - L_{t_1}))^\alpha}{\alpha}]$$

$$\frac{\partial}{\partial c_{t_1-1}} = c_{t_1-1}^{\alpha-1} - \delta M_{t_1} Q_{t_1}(N_{t_1}^i + Q_{t_1}(r_{t_1}A_{t_1-1} + y_{t_1-1} - c_{t_1-1} + w_{t_1-1}(1 - L_{t_1-1}))^{\alpha-1} = 0$$

Optimal consumption at t_3 is then:

$$c_{t_1-1} = \frac{(\delta M_{t_1}Q_{t_1})^{1/(\alpha-1)}}{1 + Q_{t_1}(\delta M_{t_{t1}}Q_{t_1})^{1/(\alpha-1)}}(N_{t_1}^i + Q_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} - c_{t_1-1} + w_{t_1-1}(1 - L_{t_1-1}))$$

Substituting in back into the value function gives:

$$v_{t_1-1} = \max_L h_{t_1-1}L_{t_1-1} + \frac{\delta M_{t_1}(N_{t_1}^i + Q_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1}(1 - L_{t_1-1}))^\alpha}{(1 + Q_{t_1}(\delta M_{t_1}Q_{t_1})^{1/(\alpha-1)})^{\alpha-1}}$$

$$\frac{\partial v_{t_1-1}}{\partial L_{t_1-1}} = h_{t_1-1} - \frac{\delta M_{t_1}Q_{t_1}w_{t_1-1}(N_{t_1}^i + Q_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1}(1 - L_{t_1-1}))^{\alpha-1}}{(1 + Q_{t_1}(\delta M_{t_1}Q_{t_1})^{1/(\alpha-1)})^{\alpha-1}}$$

Optimal labour supply at t_3 is either; full time work, part time work or zero work according to the sign of the marginal value of leisure evaluated at $L_{t_1-1} = 0, 1$. In particular:

$$L_{t_1-1} = 0 \text{ if } \frac{\partial v_{t_1-1}}{\partial L_{t_1-1}}|_{L_{t_1-1}=0} < 0$$
$$\text{i.e. if } h_{t_1-1} - \frac{\delta M_{t_1} Q_{t_1} w_{t_1-1}(N^i_{t_1} + Q_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1})^{\alpha-1}}{(1 + Q_{t_1}(\delta M_{t_1} Q_{t_1})^{1/(\alpha-1)})^{\alpha-1}} < 0$$

$$L_{t_1-1} = 1 \text{ if } \frac{\partial v_{t_1-1}}{\partial L_{t_1-1}}|_{L_{t_1-1}=1} > 0$$
$$\text{i.e. if } h_{t_1-1} - \frac{\delta M_{t_1} Q_{t_1} w_{t_1-1}(N^i_{t_1} + Q_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1})^{\alpha-1}}{(1 + Q_{t_1}(\delta M_{t_1} Q_{t_1})^{1/(\alpha-1)})^{\alpha-1}} > 0$$

$$0 < L_{t_1-1} < 1 \text{ if } \frac{\partial v_{t_1-1}}{\partial L_{t_1-1}}|_{L_{t_1-1}=0} > 0, \frac{\partial v_{t_1-1}}{\partial L_{t_1-1}}|_{L_{t_1-1}=1} < 0$$
$$\text{i.e. if } h_{t_1-1} - \frac{\delta M_{t_1} Q_{t_1} w_{t_1-1}(N^i_{t_1} + Q_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1})^{\alpha-1}}{(1 + Q_{t_1}(\delta M_{t_1} Q_{t_1})^{1/(\alpha-1)})^{\alpha-1}} < 0$$
$$\text{and } h_{t_1-1} - \frac{\delta M_{t_1} Q_{t_1} w_{t_1-1}(N^i_{t_1} + Q_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1})^{\alpha-1}}{(1 + Q_{t_1}(\delta M_{t_1} Q_{t_1})^{1/(\alpha-1)})^{\alpha-1}} > 0$$

The value function at $t_1 - 1$ remains a power function if there is either full time work or zero work at $t_1 - 1$ but becomes linear if there is optimally part time work at $t_1 - 1$. Optimal part time work solves

$$h_{t_1-1} = \frac{\delta M_{t_1} Q_{t_1} w_{t_{1-1}}(N^i_{t_1} + Q_{t_1} - 1(r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1}(1 - L_{t_1-1}))^{\alpha-1}}{(1 + Q_{t_1}(\delta M_{t_1} Q_{t_1})^{1/(\alpha-1)})^{\alpha-1}}$$

which gives

$$\left(\frac{h_{t_1-1}}{\delta M_{t_1} Q_{t_1} w_{t_1-1}}\right)^{1/(\alpha-1)} (1 + Q_{t_1}(\delta M_{t_1} Q_{t_1})^{1/(\alpha-1)}) =$$
$$N^i_{t_1} + Q_{t_1}\left[r_{t_1-1}A_{t_1-1} + y_{t_1-1}\right] + Q_{t_1} w_{t_1-1}(1 - L_{t_1-1})$$

Effectively L is linear in wealth and labour income and this makes c linear in wealth. Moreover the resources carried forward term $N^i_{t_1} + Q_{t_1}(r_{t_1-1}A_{t_1-1} +$

$y_{t_1-1} + w_{t_1-1}(1 - L_{t_1-1})$ is independent of current wealth.

$$Q_{t_1} w_{t_1-1} L_{t_1-1} = N^i_{t_1} + Q^i_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1}) - \left(\frac{h_{t_1-1}}{\delta M_{t_1} Q_{t_1} w_{t_1-1}}\right)^{1/(\alpha-1)} (1 + Q_{t_1}(\delta M_{t_1} Q_{t_1})^{1/(\alpha-1)})$$

$$L_{t_1-1} = \frac{\left[N^i_{t_1} + Q_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1})\right]}{Q_{t_1} w_{t_1-1}} - \frac{\left[\left(\frac{h_{t_1-1}}{\delta M_{t_1} Q_{t_1} w_{t_1-1}}\right)^{1/(\alpha-1)} (1 + Q_{t_1}(\delta M_{t_1} Q_{t_1})^{1/(\alpha-1)})\right]}{Q_{t_1} w_{t_1-1}}$$

$$\begin{aligned}
v_{t_1-1} = h_{t_1-1}L_{t_1-1} + \frac{\delta M_{t_1}(N^i_{t_1} + Q_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1}(1 - L_{t_1-1}))^{\alpha}}{(1 + Q_{t_1}(\delta M_{t_1} Q_{t_1})^{1/(\alpha-1)})^{\alpha-1}\alpha} \\
= \frac{h_{t_1-1}}{Q_{t_1} w_{t_1-1}}(N^i_{t_1} + Q_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1}) \\
- \left(\frac{h_{t_1-1}}{\delta M_{t_1} Q_{t_1} w_{t_1-1}}\right)^{1/(\alpha-1)} (1 + Q_{t_1}(\delta M_{t_1} Q_{t_1})^{1/(\alpha-1)})) \\
+ \frac{\delta M_{t_1-1}(\left(\frac{h_{t_1-1}}{\delta M_{t_1} Q_{t_1} w_{t_1-1}}\right)^{1/(\alpha-1)} (1 + Q_{t_1}(\delta M_{t_1} Q_{t_1})^{1/(\alpha-1)})^{\alpha}}{(1 + Q_{t_1}(\delta M_{t_1} Q_{t_1})^{1/(\alpha-1)})^{\alpha-1}} \\
= \frac{h_{t_1-1}}{w_{t_1-1}}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1}) + \\
\frac{h_{t_1-1}}{Q_{t_1} w_{t_1-1}}(N^i_{t_1} - \left(\frac{h_{t_1-1}}{\delta M_{t_1} Q_{t_1} w_{t_1-1}}\right)^{1/(\alpha-1)} (1 + Q_{t_1}(\delta M_{t_1} Q_{t_1})^{1/(\alpha-1)})) + \\
\delta M_{t_1} \left(\frac{h_{t_1-1}}{\delta M_{t_1} Q_{t_1} w_{t_1-1}}\right)^{\alpha/(\alpha-1)} (1 + Q_{t_1}(\delta M_{t_1} Q_{t_1})^{1/(\alpha-1)}) \\
= \frac{h_{t_1-1}}{w_{t_1-1}}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1}) + \frac{h_{t_1-1}}{Q_{t_1} w_{t_1-1}} N^i_{t_1} \\
+ \delta M_{t_1} \left(\frac{h_{t_1-1}}{\delta M_{t_1} Q_{t_1} w_{t_1-1}}\right)^{\alpha/(\alpha-1)} (1 + Q_{t_1}(\delta M_{t_1} Q_{t_1})^{1/(\alpha-1)}) \\
- \frac{h_{t_1-1}}{Q_{t_1} w_{t_1-1}} \left(\frac{h_{t_1-1}}{\delta M_{t_1} Q_{t_1} w_{t_1-1}}\right)^{1/(\alpha-1)} (1 + Q_{t_1}(\delta M_{t_1} Q_{t_1})^{1/(\alpha-1)}) \\
v_{t_1-1} = R_{t_1} + S_{t_1} A_{t_1}
\end{aligned}$$

Epochs Preceding an Epoch with a Linear Value Function

From proposition 1 we know the value function at t_1 is linear in assets, substituting in the $t_1 - 1$ budget constraint we have:

$$S_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} - c_{t_1-1} + w_{t_1-1}(1 - L_{t_1-1}) + R_{t_1}$$

This could be either the first period of part time work or any period which is followed at some point by a period of part time work. Optimal choice at $t_1 - 1$

$$\max u(c_{t_1-1}) + h_{t_1-1}L_{t_1-1}$$
$$+\delta[S_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} - c_{t_1-1} + w_{t_1-1}(1 - L_{t_1-1}) + R_{t_1}]$$

Optimal labour at $t_1 - 1$ is then either; full time leisure, part time or full time work:

$$L_{t_1-1} = 1 \text{ if } h_{t_1-1} > \delta S_{t_1} w_{t_1-1}$$
$$0 < L_{t_1-1} < 1 \text{ if } h_{t_1-1} = \delta S_{t_1} w_{t_1-1}$$
$$L_{t_1-1} = 0 \text{ if } h_{t_1-1} < \delta S_{t_1} w_{t_1-1}$$

Optimal consumption c_{t_1-1} is equal to $c_{t_1-1} = \delta^{1/(\alpha-1)} S_{t_1}^{1/(\alpha-1)}$.The value function at $t_1 - 1$ is then

(i) if $L_{t_1-1} = 1$

$$\frac{c_{t_1-1}^{\alpha}}{\alpha} + h_{t_1-1}L_{t_1-1} + \delta[S_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1}(1 - L_{t_1-1}) - c_{t_1-1}) + R_{t_1}]$$
$$= \frac{c_{t_1-1}^{\alpha}}{\alpha} + h_{t_1-1} + \delta[S_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} - c_{t_1-1}) + R_{t_1}]$$
$$= \frac{\delta^{\alpha/(\alpha-1)} S_{t_1}^{\alpha/(\alpha-1)}}{\alpha} + h_{t_1-1} + \delta S_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1}) - \delta S_{t_1} \delta^{1/(\alpha-1)} S_{t_1}^{1/(\alpha-1)}) + \delta R_{t_1}$$
$$= h_{t_1-1} + \delta S_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1}) + \delta R_{t_1} + \delta^{\alpha/(\alpha-1)} S_{t_1}^{\alpha/(\alpha-1)}[1/\alpha - 1]$$
$$v_{t_1-1} = h_{t_1-1} + \delta S_{t_1}[r_{t_1-1}A_{t_1-1} + y_{t_1-1}] + \delta R_{t_1} = S_{t_1-1}^1[r_{t_1-1}A_{t_1-1} + y_{t_1-1}] + R_{t_1-1}^1$$

where $S_{t_1-1}^1 = \delta S_{t_1}$ and $R_{t_1-1}^1 = h_{t_1-1} + \delta R_{t_1} + \delta^{\alpha/(\alpha-1)} S_{t_1}^{\alpha/(\alpha-1)}[1/\alpha - 1]$

(ii) if $L_{t_1-1} = 0$

$$\frac{c_{t_1-1}^{\alpha}}{\alpha} + \delta[S_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1} - c_{t_1-1}) + R_{t_1}]$$

$$= \frac{\delta^{\alpha/(\alpha-1)}S_{t_1}^{\alpha/(\alpha-1)}}{\alpha} + \delta S_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1}) - \delta S_{t_1}\delta^{1/(\alpha-1)}S_{t_1}^{1/(\alpha-1)}) + \delta R_{t_1}$$

$$= \delta S_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1}) + \delta R_{t_1} + \delta^{\alpha/(\alpha-1)}S_{t_1}^{\alpha/(\alpha-1)}[\frac{1}{\alpha} - 1]$$

$$v_{t_1-1} = S_{t_1-1}^{0}[r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1}] + R_{t_1-1}^{0}$$

where $S_{t_1-1}^{0} = \delta S_{t_1}$ and $R_{t_1-1}^{0} = h_{t_1-1} + \delta R_{t_1} + \delta^{\alpha/(\alpha-1)}S_{t_1}^{\alpha/(\alpha-1)}[\frac{1}{\alpha} - 1]$

(iii) if $L_{t_1-1} =$ interior

$$\frac{c_{t_1-1}^{\alpha}}{\alpha} + h_{t_1-1}(1 - L_{t_1-1}) + \delta[S_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1}(1 - L_{t_1-1}) - c_{t_1-1}) + R_{t_1}]$$

$$= \frac{c_{t_1-1}^{\alpha}}{\alpha} + \delta[S_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1}) - c_{t_1-1}) + R_{t_1}]$$

$$= \delta S_{t_1}(r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1}) + \delta R_{t_1} + \delta^{\alpha/(\alpha-1)}S_{t_1}^{\alpha/(\alpha-1)}[\frac{1}{\alpha} - 1]$$

$$v_{t_1-1} = S_{t_1-1}^{I}[r_{t_1-1}A_{t_1-1} + y_{t_1-1} + w_{t_1-1}] + R_{t_1}^{I}$$

where $S_{t_1-1}^{I} = \delta S_{t_1}$ and $R_{t_1-1}^{I} = \delta R_{t_1} + \delta^{\alpha/(\alpha-1)}S_{t_1}^{\alpha/(\alpha-1)}[\frac{1}{\alpha} - 1]$,since $h_{t_1-1} = \delta S_{t_1}w_{t_1-1}$ and the same equation for c holds.

8.2 Appendix for Chapter two

8.2.1 Semi-indirect utility

Individuals optimally choose consumption in each period for fixed values of L_{T-1}, L_T. This gives semi-indirect utility $v(L_{T-1}, L_T, x)$:

$$\begin{aligned}\frac{\partial v}{\partial L_{T-1}} &= \frac{\partial u_{T-1}}{\partial c_{T-1}}\frac{\partial c_{T-1}}{\partial L_{T-1}} + \delta\frac{\partial u_T}{\partial c_T}\frac{\partial c_T}{\partial L_{T-1}} + \frac{\partial u_{T-1}}{\partial L_{T-1}} \\ &= \delta\frac{\partial u_T}{\partial c_T}[r\frac{\partial c_{T-1}}{\partial L_{T-1}} + \frac{\partial c_T}{\partial L_{T-1}}] + \frac{\partial u_{T-1}}{\partial L_{T-1}}\end{aligned} \tag{8.3}$$

From 8.3 and the fact that $rc_{T-1} + c_T = x$ we know:

$$r\frac{\partial c_{T-1}}{\partial L_{T-1}} + \frac{\partial c_T}{\partial L_{T-1}} = \frac{\partial x}{\partial L_{T-1}} = -rw_{T-1}$$

so

$$\frac{\partial v}{\partial L_{T-1}} = -\delta r w_{T-1}\frac{\partial u_T}{\partial c_T} + \frac{\partial u_{T-1}}{\partial L_{T-1}}$$

Similarly

$$\frac{\partial v}{\partial L_T} = \delta\frac{\partial u_T}{\partial c_T}[r\frac{\partial c_{T-1}}{\partial L_T} + \frac{\partial c_T}{\partial L_T}] + \frac{\partial u_T}{\partial L_T}$$

and

$$r\frac{\partial c_{T-1}}{\partial L_T} + \frac{\partial c_T}{\partial L_T} = \frac{\partial x}{\partial L_T} = -w_T$$

The remaining problem for the individual is to choose optimal labour supply in each period:

$$\max_{L_T, L_{T-1}} v(L_{T-1}, L_T, x) \text{ st } 0 \leq L_i \leq 1$$

If each $u()$ is concave due to time additivity then $v()$ is also.

8.2.2 The value function for quasilinear-isoelastic preferences

Defining A_T as the financial wealth carried forward from period $T-1$ to period T, we can substitute out the lifetime budget constraint to write c_{T-1} in terms of initial wealth minus savings and leave the problem

$$U = \frac{(rA_{T-1} + y_{T-1} + w_{T-1}(1 - L_{T-1}) - A_T)^\alpha}{\alpha} + h_{T-1}L_{T-1}$$
$$+\delta(\frac{(rA_T + y_T + w_T(1 - L_T))^\alpha}{\alpha} + h_T L_T)$$

Maximising U wrt A_T gives

$$A_T = \frac{x_{T-1} - (\delta r)^{1/(\alpha-1)}(y_T + w_T(1 - L_T)}{1 + r(\delta r)^{1/(\alpha-1)}}$$

where $x_{T-1} = rA_{T-1} + y_{T-1} + w_{T-1}(1 - L_{T-1})$ and putting this back into U gives

$$U = \frac{(rA_{T-1} + y_{T-1} + w_{T-1}(1 - L_{T-1}) - \left[\frac{x_{T-1} - (\delta r)^{1/(\alpha-1)}(y_T + w_T(1-L_T)}{1 + r(\delta r)^{1/(\alpha-1)}}\right])^\alpha}{\alpha}$$
$$+h_{T-1}L_{T-1} + \delta(\frac{(r\left[\frac{x_{T-1} - (\delta r)^{1/(\alpha-1)}(y_T + w_T(1-L_T)}{1 + r(\delta r)^{1/(\alpha-1)}}\right] + y_T + w_T(1 - L_T))^\alpha}{\alpha} + h_T L_T)$$

The value function is then

$$v = \frac{(r(rA_{T-1} + y_{T-1} + w_{T-1}(1 - L_{T-1})) + y_T + w_T(1 - L_T))^\alpha}{\alpha}((\delta r)^{\alpha/(\alpha-1)} + \delta)$$
$$+h_{T-1}L_{T-1} + \delta h_T L_T$$

which can be rewritten as

$$v = \frac{(K + rw_{T-1}(1 - L_{T-1})) + w_T(1 - L_T))^\alpha}{\alpha}D + h_{T-1}L_{T-1} + \delta h_T L_T$$

where:

$$K = r(rA_{T-1} + y_{T-1}) + y_T, D = ((\delta r)^{\alpha/(\alpha-1)} + \delta)$$

8.2.3 The wage profiles giving indifferent participation profiles

Each pairwise utility combinations is defined as follows:

(i) $v_{00} = v_{01}$

$$(K + rw_{T-1} + w_T)^\alpha = (K + rw_{T-1})^\alpha + \frac{\alpha}{D}\delta h_T$$
$$w_T^1 = \left((K + rw_{T-1}^1)^\alpha + \frac{\alpha}{D}\delta h_T\right)^{1/\alpha} - K - rw_{T-1}^1$$

(ii) $v_{00} = v_{10}$

$$\frac{(K + rw_{T-1} + w_T)^\alpha}{\alpha}D = \frac{(K + w_T)^\alpha}{\alpha}D + h_{T-1}$$
$$rw_{T-1}^2 = \left((K + w_T^2)^\alpha + \frac{\alpha}{D}h_{T-1}\right)^{1/\alpha} - K - w_T^2$$

(iii) $v_{00} = v_{11}$

$$\frac{(K + rw_{T-1} + w_T)^\alpha}{\alpha}D = \frac{K^\alpha}{\alpha}D + h_{T-1} + \delta h_T$$
$$K + rw_{T-1}^3 + w_T^3 = (K^\alpha + \frac{\alpha}{D}(h_{T-1} + \delta h_T))^{1/\alpha}$$

(iv) $v_{01} = v_{10}$

$$(K + rw_{T-1}^4)^\alpha = (K + w_T^4)^\alpha + \frac{\alpha}{D}(h_{T-1} - \delta h_T)$$
$$rw_{T-1}^4 = ((K + w_T^4)^\alpha + \frac{\alpha}{D}(h_{T-1} - \delta h_T))^{1/\alpha} - K$$

(v) $v_{01} = v_{11}$

$$rw_{T-1}^5 = (K^\alpha + \frac{\alpha}{D}h_{T-1})^{1/\alpha} - K$$

(vi) $v_{10} = v_{11}$

$$w_T^6 = (K^\alpha + \frac{\alpha}{D}\delta h_T)^{1/\alpha} - K$$

For convenience we repeat the indifference relations here, but setting wages on the RHS to zero:

$$
\begin{aligned}
(1) &= V_{00} - V_{01} : w_T^1 = \left(K^\alpha + \frac{\alpha}{D}\delta h_T\right)^{1/\alpha} - K \\
(2) &= V_{00} - V_{10} : rw_{T-1}^2 = \left(K^\alpha + \frac{\alpha}{D}h_{T-1}\right)^{1/\alpha} - K \\
(3) &= V_{00} - V_{11} : rw_{T-1}^3 + w_T^3 = (K^\alpha + \frac{\alpha}{D}(h_{T-1} + \delta h_T))^{1/\alpha} - K \\
(4) &= V_{10} - V_{01} : rw_{T-1}^4 = (K^\alpha + \frac{\alpha}{D}(h_{T-1} - \delta h_T))^{1/\alpha} - K \quad (\text{ref w}_{T-1}) \\
(5) &= V_{11} - V_{01} : rw_{T-1}^5 = (K^\alpha + \frac{\alpha}{D}h_{T-1})^{1/\alpha} - K \\
(6) &= V_{10} - V_{11} : w_T^6 = (K^\alpha + \frac{\alpha}{D}\delta h_T)^{1/\alpha} - K
\end{aligned}
$$

Comparing the loci we see that for wages such that $V_{10} = V_{01}$ and $V_{00} = V_{01}$ we must also have $V_{00} = V_{10}$, in terms of Figure 2.1 in chapter two the loci (1),(2) must cross each other on the locus (4). Similarly the loci (5),(6) ($V_{11} = V_{01}$ and $V_{11} = V_{10}$) must cross on the locus (4) ($V_{01} = V_{10}$). For similar reasons loci (1),(3),(5) must intersect at a common point; and so must loci (2),(3),(6).

The indifference relations $V_{11} = V_{01}, V_{11} = V_{10}$ and $V_{00} = V_{11}$ are all linear in the wage rates with the last being negatively sloped and the other two respectively horizontal and vertical. Relation (4), (1) and (2); $V_{10} = V_{01}$, $V_{00} = V_{01}$ and $V_{00} = V_{10}$ respectively are all positively sloped. For example differentiating $v_{00} - v_{01}$ implicitly

$$
\begin{aligned}
\alpha(K + rw_{T-1} + w_T)^{\alpha-1}(rdw_{T-1} + dw_T) &= \alpha(K + rw_{T-1})^{\alpha-1} rdw_{T-1} \\
\frac{dw_T}{dw_{T-1}} &= r\frac{(K + rw_{T-1})^{\alpha-1} - (K + rw_{T-1} + w_T)^{\alpha-1}}{(K + rw_{T-1} + w_T)^{\alpha-1}}
\end{aligned}
$$

$\alpha < 1$ so $(K + rw_{T-1})^{\alpha-1} > (K + rw_{T-1} + w_T)^{\alpha-1}$ and the slope of locus (1) is always positive at any $w's$. The same logic applies to locus (2):

$$
\begin{aligned}
\alpha(K + rw_{T-1} + w_T)^{\alpha-1}(rdw_{T-1} + dw_T) &= \alpha(K + w_T)^{\alpha-1}(rdw_T) \\
\frac{dw_T}{dw_{T-1}} &= r\frac{(k + rw_{T-1})^{\alpha-1} - (K + rw_{T-1} + w_T)^{\alpha-1}}{(K + rw_{T-1} + w_T)^{\alpha-1}}
\end{aligned}
$$

Comparing the intercept of the loci: those of (1) and (6) are equal as are those of (2) and (5). But the intercept of locus (1) is below that of locus (3) on the w_T axis , and of locus (2) is below that of locus (3) on the w_{T-1} axis. Combining this information gives Figure 2.1 in chapter two.

8.2.4 The intersections of the loci all exist

Assets, y's and h's may be such that not all the intersections happen at strictly positive wages. But a finite positive solution must exist: both sides continuous in w_T, at $w_T = 0$ LHS greater than RHS

$$[K^\alpha + \frac{\alpha h_{T-1}}{DD}]^{1/\alpha} > \{K^\alpha + \frac{\alpha(h_{T-1} - \delta h_T)}{DD}\}^{1/\alpha}$$

and as $w_T \to \infty$

$$\lim_{w_T \to \infty} \{[(K + w_T)^\alpha + \frac{\alpha h_{T-1}}{DD}]^{1/\alpha} - [(K + w_T)^\alpha + \frac{\alpha(h_{T-1} - \delta h_T)}{DD}]^{1/\alpha} < \lim_{w_T \to \infty} w_T$$

A possible problem is that w_{T-1} where $v_{01} = v_{10}$ may not be positive: e.g. looking above if δh_T is huge compared with h_{T-1} may give $w_{T-1} < 0$ where they cross.

8.2.5 Comparative statics of the optimal lifecycle labour participation regimes

In order to ascertain the effect of pension deferral on participation one must notice that the critical wage expressions (as a function of K) with the exception of w^4 all take the form:

$$w = (K^\alpha + z)^{1/\alpha} - K$$

where $z > 0$. Differentiate wrt K

$$\frac{dw}{dK} = (K^\alpha + z)^{(1-\alpha)/\alpha} K^{\alpha-1} - 1$$
$$= (1 + zK^{-\alpha})^{(1-\alpha)/\alpha} - 1 > 0 \text{ if } z > 0$$

In the case of w^4 we have $(h_{T-1} - \delta h_T)$ so if $h_{T-1} > \delta h_T$ then $dw/dK > 0$ but if $h_{T-1} < \delta h_T$ then $dw/dK < 0$. So if $h_{T-1} > \delta h_T$ the wage region with full time work at T expands at the expense of the wage region with full time work only in $T - 1$, or vice versa if $h_{T-1} < \delta h_T$.

8.3 Appendix for Chapter three

8.3.1 The English Longitudinal Study of Ageing (ELSA)

The data utilised in chapter three is drawn from the English Longitudinal Study of Ageing (ELSA). ELSA is a biennial longitudinal survey which is representative of the English household population aged 50 and over. The first wave of data was collected between April 2002 and March 2003, and was drawn from multiple samples (1998, 1999 and 2001) of the Health Survey for England (HSE). HSE is a study conducted on behalf of the Department of Health by the Department of Epidemiology and Public Health, UCL, and the National Centre for Social Research. The wave 1 sample consisted of 12,099 individuals of which 11,391 were core sample members, these comprised of 7,894 benefit units (i.e. an individual or couple with dependents). Due to non-response and sample attrition refreshment samples of individuals aged between 50 and 74 were introduced to the main survey at wave 3 (2006/7), wave 4 (2008/9) and wave 6 (2012/3). Similar to the initial sample these were drawn from recent waves of the HSE. For the purpose of analysis we do not include any refreshment sample members. At the time of writing there were five waves of ELSA available (in addition there is also a wave 0 file, however this contains limited economic and sociodemographic information), chapter three makes use of all five waves of data to track changes in individuals retirement behaviour, with the exception of wave 0.

ELSA collects a variety of information relating to an individual's circumstance at the time of survey. This ranges from detailed information regarding income, assets, work and pensions through to information relating to an individuals health status and medical conditions. There is also a module relating to subjective expectations regarding future expectancy regarding paid work, health and life expectancy.

In terms of chapter three it is important to note how we derive the period at risk, i.e. the length of time before first retirement. The questions we use to derive this measure come from the following survey questions:

1. Age at wave 1 survey question
2. Calendar year and month of interview in wave 1

3. Calendar year and month of retirement

From 1. and 2. it is possible to derive the calendar year of birth of the individual, we can subtract the calendar year of birth from the information in 3. to derive the number of years at risk i.e. the age at retirement. We then round this number to the nearest whole integer to facilitate estimation in the discrete time hazard model.

8.3.2 Pension wealth

Our sample consists of individuals aged 50 and 74 in wave 1 of ELSA. Therefore we have mixture of individuals who are above and below SPA. Total pension wealth is the sum of private and state pension. We use the pension wealth variables derived by the IFS (for more information See Banks, Emmerson and Tetlow, 2005).

In deriving the total pension wealth a number of assumptions are required. First, it is important to note that pension wealth is only estimated for those below SPA. For those who are above SPA a more accurate measure of pension wealth is derived using actual income and then discounting (at a rate of 2.5%) to derive a Net Present Value for the calendar year 2002 (assuming individuals have not deferred their pension entitlements).

In calculating state pension wealth for those below SPA we assume individuals work until they reach SPA (which is an upper bound to true pension wealth as it credits individuals with maximum future accrual of rights). Whilst this is an extreme assumption it is worth noting the median age in our sample is 69 and 75% of the sample is at or above SPA in wave 1. Therefore the total state pension wealth is potentially overestimated for a maximum of 25% of the sample.

It is assumed private pension wealth is the total of defined contribution (DC), defined benefit (DB), wealth from pensions that an individual no longer contributes to (but has rights) and wealth from past pensions which an individual is receiving income from. Income from these streams can be observed for those over SPA and can be calculated in terms of 2002 net present value.

For those individuals below SPA total private pension is calculated given respondents answers to pension questions such as value of their pension fund (which is assumed to receive an annual rate of return of 5%). We assume that an individual carries on contributing to their private pension at the rate they did in 2002. Again the amount calculated will be an upper bound (again this will be for at most 25% of the sample). In the case of DB schemes ELSA asks about length of time in scheme, accrual fraction and also has information on gross income from main job (imputed for those where it is missing). We also assume individual retires at normal retirement age from their occupational pension scheme.

For past pensions yet to be received respondents are asked about schemes to which they have rights but are not yet in receipt of income. For DB schemes information is also collected on tenure in the scheme and accrual /contribution rate. Combining this with inflation figures and average earnings profiles it is possible to derive a net present value for such pensions. A similar method is carried for DC schemes i.e. "we assume that sufficient contributions were made to produce a fund that, if annuitised at the SPA at its real value in the year the individual left the scheme, would produce an income equal to that of a DB scheme that had been contributed to over the same period. In other words, the fund value upon leaving the scheme is calculated by taking the years in the scheme, the accrual fraction and the final salary, in the same way as was done for the DB schemes" (Banks et al., 2005).

For past pensions it is irrelevant whether an individual retires now or in the future as they are no longer making additional contributions. For past pensions already in receipt it is possible to calculate annual income received in 2002 and derive a measure of NPV. Individuals are assumed to pay basic tax rate on their pension income.

For spousal/widow pensions information is collected on level of pension received in 2002 or the expected amount if not currently in receipt. This is assumed to drawn on at SPA.

Banks et al. (2005) perform sensitivity analysis on their assumptions and find the value of pension wealth is sensitive to the discount rate and contracting out histories but not sensitive to assumptions about future earnings growth, future annuity rates and future asset returns.

Chapter three also makes use of the Financial Derived Variables (FDV) file released with each wave of ELSA. Specifically we use a measure of total non-pension household wealth by quintile derived by the IFS. Total non-pension financial wealth is the sum of total net housing wealth and total net non-housing wealth, this then gives a distribution across all benefits units (weighted to include sample members only) in a given calendar year.

8.3.3 Summary statistics for estimation sample

Table 8.1: Male summary statistics.

Variable	$\bar{x}$	σ	N
1^{st} income quintile	0.07	0.26	787
2^{nd} income quintile	0.18	0.38	787
3^{rd} income quintile	0.24	0.43	787
4^{th} income quintile	0.29	0.46	787
5^{th} income quintile	0.21	0.41	787
Log household income	6.21	0.84	787
Log pension wealth	12.08	0.66	787
No episodes out of labour market	0.72	0.45	787
1 episode out of labour market	0.20	0.40	787
2+ episodes out of labour market	0.08	0.26	787
50-84% of potential labour market experience in work	0.02	0.15	787
85-99% of potential labour market experience in work	0.20	0.40	787
100% of potential labour market experience in work	0.78	0.42	787
Single	0.04	0.20	787
Married	0.82	0.38	787
Divorced	0.11	0.32	787
Widowed	0.02	0.15	787
Spouse in employment	0.43	0.50	787
Degree	0.22	0.42	787
Above A level/Below degree level	0.19	0.39	787
A level	0.12	0.32	787
O level and below	0.47	0.47	787
Baseline health: Excellent or good	0.84	0.36	787
Baseline health: Fair	0.14	0.35	787
Baseline health: Poor	0.01	0.12	787
Zero episodes of poor health before age 50	0.87	0.33	787
1 episode of poor health before age 50	0.11	0.31	787
2 episodes of poor health before age 50	0.01	0.12	787
3+ episodes of poor health before age 50	0.01	0.08	787
Owned outright	0.27	0.26	787
Mortgage	0.64	0.64	787
Rent	0.08	0.27	787
Free rent	0.01	0.11	787
Employer pension	0.55	0.55	787
Private pension	0.24	0.24	787
Self employment pension	0.01	0.01	787
State pension only	0.20	0.40	787
Professional or managerial occupation	0.46	0.49	787
Skilled manual or non manual occupation	0.42	0.32	787
Unskilled occupation	0.12	0.50	787
Long term financial planning horizon	0.39	0.49	787
Medium term financial planning horizon	0.39	0.49	787
Short term financial planning horizon	0.22	0.41	787

Table 8.2: Female summary statistics.

Variable	$\bar{x}$	σ	N
1^{st} income quintile	0.09	0.29	567
2^{nd} income quintile	0.22	0.41	567
3^{rd} income quintile	0.22	0.41	567
4^{th} income quintile	0.23	0.42	567
5^{th} income quintile	0.24	0.42	567
Log household income	5.95	0.99	567
Log pension wealth	11.61	1.01	567
Zero episodes out of labour market	0.12	0.33	567
1 episode out of labour market	0.45	0.50	567
2+ episodes out of labour market	0.43	0.50	567
20-49% of potential labour market experience in work	0.04	0.19	567
50-65% of potential labour market experience in work	0.13	0.34	567
65-80% of potential labour market experience in work	0.29	0.45	567
80-95% of potential labour market experience in work	0.33	0.47	567
95-100% of potential labour market experience in work	0.21	0.41	567
Single	0.04	0.21	567
Married	0.72	0.45	567
Divorced	0.19	0.39	567
Widowed	0.04	0.20	567
Spouse in employment	0.41	0.49	567
Degree	0.16	0.37	567
Above A level/Below degree level	0.11	0.32	567
A level	0.095	0.29	567
O level and below	0.63	0.48	567
Baseline health: Excellent or good	0.83	0.37	567
Baseline health: Fair	0.15	0.35	567
Baseline health: Poor	0.02	0.14	567
Zero episodes of poor health before age 50	0.84	0.37	567
1 episode of poor health before age 50	0.12	0.32	567
2 episodes of poor health before age 50	0.03	0.17	567
3+ episodes of poor health before age 50	0.01	0.12	567
Owned outright	0.31	0.46	567
Mortgage	0.58	0.49	567
Rent	0.002	0.04	567
Free rent	0.10	0.30	567
Employer pension	0.58	0.49	567
Private pension	0.10	0.30	567
Self employment pension	0.001	0.04	567
State pension only	0.31	0.46	567
Professional or managerial occupation	0.04	0.18	567
Non manual or manual skilled occupation	0.33	0.47	567
Unskilled occupation	0.63	0.48	567
Long term financial planning horizon	0.35	0.48	567
Medium term financial planning horizon	0.39	0.49	567
Short term financial planning horizon	0.26	0.44	567

8.3.4 Set of covariates used in discrete time hazard model

Variable	Description
Sociodemographic variables	
Marital status	1 if applicable, zero otherwise
Education level	1 if applicable, zero otherwise
Social class	1 if applicable, zero otherwise
Lifetime ill health	1 if episode of ill health prior to age 50, zero otherwise
Self reported health	1 if applicable, zero otherwise
Housing tenure	1 if applicable, zero otherwise
Economic variables	
Employment status of spouse	1 if applicable, zero otherwise
Presence of employer pension	1 if applicable, zero otherwise
Presence of a private pension	1 if applicable, zero otherwise
Self employed pension	1 if applicable, zero otherwise
Financial planning horizon	1 if applicable, zero otherwise
Proportion of time spent in employment	See Appendix 8.3.4
Count of instances out of labour market	See Appendix 8.3.4
Log value of household income	Log value of 2002 household annual income
Log present value of individual total pension wealth	See Appendix 8.3.1
Log present value of spouse's total pension wealth	See Appendix 8.3.1
Net non pension wealth quintile	See Appendix 8.3.1

8.3.5 Wave 3 life history file

The lifetime history file available at wave 3 of ELSA contains a detailed record of all labour market related activity (using calendar methods); from the time individuals left full time education to their final job in the labour market. For each job the calendar year start and end date is recorded, as is whether the job is part time, full time or a mixture of the two. Using this information it is possible to compute the potential number of years an individual spent in the labour market, defined as the period between the year they entered their first job and the year they left their final job.

By summing the duration (in years) of each job, it is possible to compute the total number of years spent in employment. Due to the questionnaire design it is not possible to determine the length of any jobs which start and end in the same year (for more information see Nicholls, 2010). However we plot histograms for job spell length for each individual and find only a small number of male or females report a job spell length which is less than a year. This is reflected in the total number of lifetime jobs, which for males and females was 5.6 and 5.9 respectively. Therefore we believe the potential measurement error due to missing short-term employment spells is minimal. Using this information it is possible to compute the proportion of time spent in employment as:

$$\frac{\text{Number of years spent in actual employment}}{\text{Potential number of years in labour market}}$$

$$= \text{Proportion of potential labour market experience spent in employment}$$

We use this statistic in our regression specifications. Eight individuals in our sample had employment histories which had job start dates which predated their previous job end date, we follow the method of Brendan (1997) who for the BHPS data gives the first/previous job precedence in terms of dictating the next (chronological) consecutive job start date.

For the same reason as employment duration, it is not possible to detect the length of any period of unemployment or inactivity which starts and ends in the same year. However it is still possible to detect if an episode of unemployment or inactivity takes place (so long as it is at least three months in length) which is less than one year in duration. Unlike the reasons highlighted for employment, an episode (or perhaps many episodes) out of the labour market between 3 and strictly less than twelve months due to inactivity or unemployment, could have an effect on labour market attachment. Hence we use the number of reported counts of unemployment and inactivity in the regression specification.

8.3.6 Male estimation results: Full sample with Heckman-Signer frailty

Table 8.3: Male discrete time hazard model estimates (full sample).

Variable	β (σ)	Pr > $\|Z\|$
Age $\leq$ 54	0.02(0.01)	0.00
55$\leq$Age $\leq$56	0.80(0.03)	0.00
57$\leq$Age $\leq$58	0.87(0.28)	0.67
59$\leq$Age $\leq$60	3.49(0.89)	0.00
61$\leq$Age $\leq$62	5.37(1.40)	0.00
63$\leq$Age$\leq$64	12.30(3.37)	0.00
65$\leq$Age$\leq$66	101.53(41.23)	0.00
67$\leq$Age$\leq$72	144.12(96.38)	0.00
2^{nd} Household non-pension wealth quintile	1.15(0.43)	0.75
3^{rd} Household non-pension wealth quintile	0.97(0.47)	0.95
4^{th} Household non-pension wealth quintile	1.06(0.49)	0.88
5^{th} Household non-pension wealth quintile	1.05(0.49)	0.90
Log household income	1.31(0.13)	0.01
Log pension wealth	1.46(0.21)	0.01
1 episode out of labour market	0.81(0.21)	0.42
2+ episodes out of labour market	0.42(0.16)	0.03
50-84% of potential labour market experience in work	4.88(2.94)	0.01
85-99% of potential labour market experience in work	1.288(0.35)	0.36
Married	0.62(0.25)	0.24
Divorced	0.45(0.20)	0.08
Widowed	0.68(0.50)	0.61
Spouse in employment	1.02(0.17)	0.87
Degree	1.59(0.39)	0.05
Above A level/ Below degree level	1.02(0.26)	0.91
A level	0.97(0.24)	0.91
Baseline health: Fair	1.64(0.38)	0.03
Baseline health: Poor	4.26(2.00)	0.00
1 episode of poor health before age 50	1.11(0.25)	0.61
2 episodes of poor health before age 50	4.60(2.29)	0.01
3+ episodes of poor health before age 50	0.09(0.11)	0.04
Mortgage	0.92 (0.16)	0.62
Rent	0.59 (0.25)	0.22
Free rent	2.11 (1.49)	0.29
Employer pension	1.57 (0.35)	0.02
Private pension	0.77 (0.21)	0.34
Self employment pension	1.04 (1.19)	0.97
Professional or managerial occupation	0.78 (0.22)	0.39
Technical non manual or manual occupation	0.81 (0.20)	0.39
Long term financial planning horizon	0.97 (0.20)	0.91
Medium term financial planning horizon	0.96 (0.20)	0.83
m2		
_cons	12.80(6.64)	0.00
logit p2		
_cons	1.53(0.36)	0.07
Probability type 1	0.40(0.05)	0.00
Probability type 2	0.6(0.05)	0.00
Number of person-years observations[3]	47530	
Number of non retirement episodes[4]	47182	
Number of retirement episodes[5]	348	

8.3.7 Male estimation results: Bottom three income quintiles

Table 8.4: Male bottom three quintiles.

Variable	β (*robust* σ)	Pr > $|Z|$
Age $\leq$ 54	0.03 (0.03)	0.00
55$\leq$Age $\leq$56	0.83 (0.06)	0.01
57$\leq$Age $\leq$58	0.33 (0.38)	0.34
59$\leq$Age $\leq$60	4.88 (3.18)	0.01
61$\leq$Age $\leq$62	3.90 (2.78)	0.05
63$\leq$Age$\leq$64	11.71 (7.73)	0.00
65$\leq$Age$\leq$66	73.74 (47.19)	0.00
67$\leq$Age$\leq$72	47.85 (36.62)	0.00
Log household income	1.16 (0.25)	0.47
Log pension wealth	1.60 (0.50)	0.14
1 episode out of labour market	0.89 (0.42)	0.79
2+ episodes out of labour market	1.26 (0.96)	0.76
50-84% of potential labour market experience in work	0.67 (0.86)	0.76
85-99% of potential labour market experience in work	1.72 (0.78)	0.24
Married	0.44 (0.27)	0.17
Divorced	0.15 (0.15)	0.05
Widowed	0.49 (0.76)	0.65
Spouse in employment	0.85 (0.29)	0.63
Degree	0.30 (0.31)	0.24
Above A level/ Below degree level	0.65 (0.37)	0.45
A level	1.46 (0.84)	0.51
Baseline health: Fair	1.56(0.0.61)	0.25
Baseline health: Poor	1.32(1.49)	0.81
1 episode of poor health before age 50	1.18(0.66)	0.77
2 episodes of poor health before age 50	2.59(2.40)	0.31
3+ episodes of poor health before age 50	omitted	
Mortgage	0.75(0.26)	0.41
Rent	1.08(0.50)	0.86
Free rent	14.34(19.55)	0.05
Employer pension	1.62(0.74)	0.28
Private pension	0.67(0.39)	0.49
Self employment pension	omitted	
Professional or managerial occupation	1.20(0.66)	0.74
Technical non manual or manual occupation	1.23(0.51)	0.63
Long term financial planning horizon	1.32(0.54)	0.49
Medium term financial planning horizon	0.47(0.19)	0.06
Number of person-years observations	11648	
Zero outcomes	11575	
Non zero outcomes	73	
Wald chi^2(40)	739.05 ($p < 0.000$)	

Notes: Omitted indicates no respondents in relevant category.

8.3.8 Male estimation results: Top two income quintiles

Table 8.5: Male top two quintiles.

Variable	β (*robust* σ)	Pr > $\|Z\|$
Age $\leq$ 54	0.09 (0.06)	0.00
55$\leq$Age $\leq$56	0.83 (0.02)	0.00
57$\leq$Age $\leq$58	0.52 (0.28)	0.23
59$\leq$Age $\leq$60	2.27 (1.28)	0.15
61$\leq$Age $\leq$62	4.27 (2.42)	0.01
63$\leq$Age$\leq$64	6.57 (3.66)	0.00
65$\leq$Age$\leq$66	18.77 (9.22)	0.00
67$\leq$Age$\leq$72	12.01 (6.12)	0.00
Log household income	1.28 (0.22)	0.14
Log pension wealth	1.44 (0.16)	0.00
1 episode out of labour market	0.83 (0.20)	0.43
2+ episodes out of labour market	0.50 (0.16)	0.03
50-84% of potential labour market experience in work	5.90 (3.29)	0.00
85-99% of potential labour market experience in work	0.88 (0.25)	0.67
Married	0.58 (0.20)	0.13
Divorced	0.69 (0.43)	0.56
Widowed	0.60 (0.28)	0.28
Spouse in employment	1.06 (0.20)	0.76
Degree	1.65 (0.56)	0.14
Above A level/ Below degree level	1.40 (0.47)	0.31
A level	1.40 (0.79)	0.55
Baseline health: Fair	1.10 (0.27)	0.71
Baseline health: Poor	4.27 (2.74)	0.02
1 episode of poor health before age 50	1.10 (0.25)	0.70
2 episodes of poor health before age 50	1.55 (0.82)	0.41
3+ episodes of poor health before age 50	0.23 (0.24)	0.15
Mortgage	1.08 (0.24)	0.74
Rent	0.67 (0.25)	0.28
Free rent	1.29 (0.77)	0.67
Employer pension	1.71 (0.52)	0.07
Private pension	1.02 (0.35)	0.95
Self employment pension	0.73 (0.83)	0.78
Professional or managerial occupation	0.84 (0.35)	0.68
Technical non manual or manual occupation	1.63 (0.50)	0.11
Long term financial planning horizon	1.35 (0.31)	0.19
Medium term financial planning horizon	1.46 (0.38)	0.15
Number of person-years observations	35821	
Zero outcomes	35546	
Non zero outcomes	275	
Wald chi^2(40)	2018.81	
Pr > chi^2	0.00	

8.3.9 Female estimation results: Bottom three income quintiles

Table 8.6: Female bottom three income quintiles.

Variable	β (*robust* σ)	Pr > $\|Z\|$
Age≤ 55	0.00 (0.00)	0.00
56≤Age≤ 57	0.01 (0.01)	0.01
58≤Age≤ 59	0.01 (0.01)	0.01
60≤Age≤ 61	0.04 (0.01)	0.09
62≤Age≤ 63	0.04 (0.07)	0.09
64≤Age≤ 65	0.08 (0.07)	0.18
66≤Age≤ 68	0.03 (0.06)	0.10
Log household income	1.40 (0.27)	0.06
Log pension wealth	0.94 (0.12)	0.58
1 episode out of labour market	1.96 (1.58)	0.32
2+ episodes out of labour market	1.79 (1.34)	0.42
20-49% of potential labour market experience in work	0.21 (0.16)	0.04
50-65% of potential labour market experience in work	0.57 (0.30)	0.28
65-80% of potential labour market experience in work	1.07 (0.40)	0.85
80-95% of potential labour market experience in work	0.69 (0.25)	0.32
Married	2.77 (2.23)	0.20
Divorced	2.21 (1.87)	0.34
Widowed	3.07 (2.93)	0.19
Spouse in employment	0.61 (0.24)	0.19
Degree	0.93 (0.50)	0.88
Above A level below degree level	0.38 (0.26)	0.17
A level	0.42 (0.29)	0.16
Baseline health: Fair	2.05(0.80)	0.06
Baseline health: Poor	6.32(4.85)	0.01
1 episode of poor health before age 50	0.60(0.32)	0.43
2 episodes of poor health before age 50	1.14(0.77)	0.85
3+ episodes of poor health before age 50	omitted	
Mortgage	0.82(0.24)	0.49
Rent	omitted	
Free rent	0.29(0.15)	0.01
Employer pension	0.56(0.20)	0.07
Private pension	0.98(0.46)	0.97
Self employment pension	omitted	
Professional or managerial occupation	omitted	
Technical non manual or manual occupation	1.31(0.43)	0.40
Long term financial planning horizon	0.67(0.28)	0.30
Medium term financial planning horizon	1.20(0.37)	0.54
Number of person-years observations	9775	
Zero outcomes	9696	
Non zero outcomes	79	
Wald chi^2(40)	568.40	
Pr > chi^2	0.00	

Notes: Omitted indicates no respondents in relevant category.

8.3.10 Female estimation results: Top two income quintiles

Table 8.7: Female top two income quintiles.

Variable	β (*robust* σ)	Pr > $\|Z\|$
Age≤ 53	0.00(0.00)	0.00
54≤Age≤ 55	0.01(0.01)	0.00
56≤Age≤ 57	0.03(0.04)	0.01
58≤Age≤ 59	0.07(0.09)	0.03
60≤Age≤ 61	0.31(0.42)	0.39
62≤Age≤ 63	0.28(0.36)	0.32
64≤Age≤ 65	0.44(0.56)	0.52
66≤Age≤ 68	0.59(0.79)	0.69
Log household income	0.85(0.12)	0.23
Log pension wealth	0.99(0.09)	0.86
1 episode out of labour market	0.56(0.20)	0.11
2+ episodes out of labour market	0.44(0.16)	0.02
20-49% of potential labour market experience in work	2.82(1.54)	0.07
50-65% of potential labour market experience in work	1.32(0.53)	0.48
65-80% of potential labour market experience in work	1.53(0.53)	0.21
80-95% of potential labour market experience in work	1.65(0.56)	0.14
Married	1.32(0.51)	0.47
Divorced	0.77(0.33)	0.55
Widowed	1.75(1.11)	0.37
Spouse in employment	1.49(0.27)	0.03
Degree	0.54(0.15)	0.02
Above A level/ Below degree level	1.42(0.35)	0.16
A level	1.25(0.31)	0.45
Baseline health: Fair	1.13(0.26)	0.47
Baseline health: Poor	1.01(0.47)	0.99
1 episode of poor health before age 50	1.21(0.30)	0.42
2 episodes of poor health before age 50	0.73(0.33)	0.48
3+ episodes of poor health before age 50	1.32(0.65)	0.58
Mortgage	1.02(0.19)	0.89
Rent	omitted	
Free rent	1.55(0.50)	0.17
Employer pension	1.87(0.40)	0.00
Private pension	1.08(0.34)	0.81
Self employment pension	omitted	
Professional or managerial occupation	2.71(1.07)	0.01
Technical non manual or manual occupation	1.58(0.35)	0.04
Long term financial planning horizon	1.06(0.22)	0.76
Medium term financial planning horizon	1.32(0.30)	0.17
Number of person-years observations	24009	
Zero outcomes	23782	
Non zero outcomes	227	
Wald chi^2(40)	1341.89	
Pr > chi^2	0.00	

Notes: Omitted indicates no respondents in relevant category.

8.3.11 Life history parameter estimates from a discrete time hazard model applying test for attrition bias proposed by Nijman and Verbeek (1992) (full sample of ELSA respondents by gender).

Table 8.8: Test for attrition bias.

	Male		Female	
Covariate	β	Pr > $\lvert Z \rvert$	β	Pr > $\lvert Z \rvert$
One episode out labour market	0.80	0.39	0.38	0.12
Two or more episodes out of the labour market	0.51	0.07	0.36	0.11
50-84% of potential labour market experience in work	3.82	0.01	N/A	N/A
84-99% of potential labour market experience in work	1.28	0.37	N/A	N/A
20-49% of potential labour market experience in work	N/A	N/A	1.06	0.92
50-65% of potential labour market experience in work	N/A	N/A	0.97	0.95
65-80% of potential labour market experience in work	N/A	N/A	1.20	0.62
80-95% of potential labour market experience in work	N/A	N/A	1.24	0.54

Notes: Parameter estimates highlighting the effect of life history variables on the retirement decision, controlling for the number of survey waves an individual responds to, seperate for each gender . Results show that when one controls for this, the parameter estimates remain very similar to those presented in Tables 3.5 and 3.6 which indicate that this type of attrition bias does not affect results.

8.3.12 Models of non-response required to estimate Inverse Probability Weights (IPW)

Men

Wave 4

Table 8.9: Wave 4 Non response equation (males).

Log pseudolikelihood = -165.3024		N = 787
Variable	β (*robust* σ)	Pr > $\lvert z \rvert$
Work and pensions accuracy (fairly accurate)	-0.40 (0.21)	0.05
Work and pensions accuracy (not very accurate)	-0.05 (0.18)	0.80
Work and pensions accuracy (not accurate at all)	-0.64 (0.46)	0.15
Income and assets accuracy (fairly accurate)	-0.76 (0.23)	0.00
Income and assets accuracy (not very accurate)	-0.67 (0.20)	0.00
Income and assets accuracy (not accurate at all)	-0.80 (0.34)	0.01
2^{nd} Household net financial wealth quintile	-0.49 (0.23)	0.03
3^{rd} Household net financial wealth quintile	-0.94 (0.26)	0.00
4^{th} Household net financial wealth quintile	-0.58 (0.22)	0.00
5^{th} Household net financial wealth quintile	-0.45 (0.24)	0.06
Second third of calendar year	-0.26 (0.23)	0.24
Final third of calendar year	-0.58 (0.27)	0.03
Interview in 2002	0.22 (0.25)	0.39
Long-standing illness	-0.04 (0.15)	0.81
25-50% chance health will affect future work	-0.30 (0.27)	0.26
51-75% chance health will affect future work	0.17 (0.19)	0.36
76-100% chance health will affect future work	-0.31 (0.19)	0.10
Wald $\varkappa^2(17)$ =424.87		Pr > $\varkappa^2$ = 0.00

Notes: Work and pensions/ income and assets accuracy refers to the interviewers perception of how accurate they deemed the interviewees answers to the survey questions relating to work and pensions, on a four point scale: very accurate (base group), fairly accurate, not very accurate, not accurate at all.

Wave 5

Table 8.10: Wave 5 Non response equation (males).

Log pseudolikelihood =-305.83569		$N = 787$
Variable	β (*robust* σ)	Pr $> \|z\|$
Work and pensions accuracy (fairly accurate)	0.95(0.16)	0.56
Work and pensions accuracy (not very accurate)	-0.10(0.15)	0.48
Work and pensions accuracy (not accurate at all)	0.14(0.30)	0.96
Income and assets accuracy (fairly accurate)	0.40(0.20)	0.04
Income and assets accuracy (not very accurate)	0.33(0.19)	0.07
Income and assets accuracy (not accurate at all)	0.51(0.28)	0.07
2^{nd} Household net financial wealth quintile	0.11(0.19)	0.57
3^{rd} Household net financial wealth quintile	0.62(0.20)	0.00
4^{th} Household net financial wealth quintile	0.61(0.18)	0.00
5^{th} Household net financial wealth quintile	0.37(0.20)	0.06
Second third of calendar year	0.15(0.18)	0.40
Final third of calendar year	0.56(0.21)	0.01
Interview year 2002	-0.08(0.21)	0.71
Long-standing illness	0.74(0.11)	0.52
25-50% chance health will affect future work	0.16(0.20)	0.44
51-75% chance health will affect future work	0.01(0.17)	0.94
76-100% chance health will affect future work	0.32(0.16)	0.05
Wald $\varkappa^2(17)$ =348.07		Pr $> \varkappa^2 = 0.00$

Notes: Work and pensions/ income and assets accuracy refers to the interviewers perception of how accurate they deemed the interviewees answers to the survey questions relating to work and pensions, on a four point scale: very accurate (base group), fairly accurate, not very accurate, not accurate at all.

Women

Wave 4

Table 8.11: Wave 4 Non response equation (females).

Log pseudolikelihood =-96.920537		$N = 539$
Variable	β (*robust* σ)	Pr $> \|z\|$
Work and pensions accuracy (fairly accurate)	-0.17(0.25)	0.49
Work and pensions accuracy (not very accurate)	-0.04(0.21)	0.85
Work and pensions accuracy (not accurate at all)	omitted	
Income and assets accuracy (fairly accurate)	omitted	
Income and assets accuracy (not very accurate)	-0.40(0.22)	0.07
Income and assets accuracy (not accurate at all)	-0.46(0.21)	0.02
2^{nd} Household non-pension wealth quintile	-0.19(0.26)	0.47
3^{rd} Household non-pension wealth quintile	-0.34(0.27)	0.20
4^{th} Household non-pension wealth quintile	-1.16(0.38)	0.00
5^{th} Household non-pension wealth quintile	-0.06(0.29)	0.84
Second third of calendar year	-0.212(0.33)	0.51
Final third of calendar year	-0.20(0.37)	0.57
Interview in 2002	-0.45(0.36)	0.21
Long-standing illness	0.08(0.19)	0.67
25-50% chance health will affect future work	-1.10(0.41)	0.01
51-75% chance health will affect future work	-0.63(0.25)	0.01
76-100% chance health will affect future work	-0.22(0.21)	0.30
Wald $\varkappa^2(15)$ =273.46		Pr $> \varkappa^2 = 0.00$

Work and pensions/ income and assets accuracy refers to the interviewers perception of how accurate they deemed the interviewees answers to the survey questions relating to work and pensions, on a four point scale: very accurate (base group), fairly accurate, not very accurate, not accurate at all. Omitted indicates either an empty category or all respondents in category did not respond.

Wave 5

Table 8.12: Wave 5 Non response equation (females).

Log pseudolikelihood =-191.19507		$N = 564$
Variable	β (*robust* σ)	Pr $> \|z\|$
Work and pensions accuracy (fairly accurate)	0.19(0.20)	0.34
Work and pensions accuracy (not very accurate)	-0.07(0.16)	0.67
Work and pensions accuracy (not accurate at all)	-0.13(0.34)	0.72
Income and assets accuracy (fairly accurate)	omitted	
Income and assets accuracy (not very accurate)	0.19(0.22)	0.38
Income and assets accuracy (not accurate at all)	0.24(0.19)	0.21
2^{nd} Household non-pension wealth quintile	-0.11(0.20)	0.58
3^{rd} Household non-pension wealth quintile	0.07(0.21)	0.74
4^{th} Household non-pension wealth quintile	1.27(0.31)	0.00
5^{th} Household non-pension wealth quintile	0.29(0.23)	0.20
Second third of calendar year	-0.05(0.26)	0.98
Final third of calendar year	0.09(0.27)	0.76
Interview in 2002	0.33(0.29)	0.25
Long-standing illness	0.12(0.15)	0.42
25-50% chance health will affect future work	0.58(0.27)	0.01
51-75% chance health will affect future work	0.48(0.20)	0.01
76-100% chance health will affect future work	0.33(0.18)	0.07
Wald $\varkappa^2(16)$ =242.84		Pr $> \varkappa^2 = 0.00$

Work and pensions/ income and assets accuracy refers to the interviewers perception of how accurate they deemed the interviewees answers to the survey questions relating to work and pensions, on a four point scale: very accurate (base group), fairly accurate, not very accurate, not accurate at all. Omitted indicates either an empty category or all respondents in category did not respond.

8.4 Appendix for Chapter four

8.4.1 Data and sample construction: ELSA

For a detailed description of ELSA and the variables which are of importance to the construction of the dataset used in Chapter four readers should refer to Appendix 8.3.1. Chapter four uses waves 1-4 to track changes in labour market behaviour for a sample of retired English men.

In terms of chapter four it is important to note how we derive the period at risk, i.e. the length of time before unretirement. The questions we use to measure this derive from the following survey questions:

1. Calendar year and month of labour market entry

2. Calendar year and month of retirement

From 1. and 2. it is possible to derive the exact period before an individual unretired, conditional on them reporting being retirement. We then round this number to the nearest whole integer to facilitate estimation of the discrete time hazard model.

Our final sample contains 857 individuals with a complete information set suitable for estimation purposes, we detail their average characteristics in Table 8.12.

Table 8.13: Sample characteristics.

Variable	$\bar{x}$	N
Age at wave 1	66.59	857
Married at wave 1	0.79	857
Whether first retired between the age of 50 and 55	0.20	857
Whether first retired between the age of 56 and 60	0.30	857
Spouse in employment at wave 1	0.11	857
Whether has private health insurance	0.16	857
Whether has a limiting illness	0.58	857
Whether holds a degree	0.18	857
Whether has a qualification below degree but above A level	0.21	857
Whether holds an O-level or CSE	0.23	857
No/foreign qualification (base group)	0.38	857
Bottom income quintile	0.15	857
2^{nd} income quintile	0.20	857
3^{rd} income quintile	0.23	857
4^{th} income quintile	0.21	857
Top income quintile	0.21	857
Log present value of pension income in 2002	11.91	857
Bottom non-pension net financial wealth	0.10	857
2^{nd} non-pension net financial wealth	0.15	857
3^{rd} non-pension net financial wealth	0.19	857
4^{th} non-pension net financial wealth	0.25	857
Top non-pension net financial wealth	0.31	857
25% fall in net financial wealth between two consecutive waves	0.66	857
25% increase in net financial between two consecutive waves	0.11	857
Opportunity to work past retirement age	0.13	857
Whether respondent feels they do not have enough income	0.07	857
<3 years (short term) financial planning horizon (base)	0.29	857
3-5 years (medium term) financial planning horizon	0.40	857
5+ years (long term) financial planning horizon	0.31	857
Self reported social class: professional	0.11	857
Self reported social class: managerial	0.36	857
Self reported social class: skilled non manual	0.12	857
Self reported social class: skilled manual	0.27	857
Self reported social class: non skilled/foreign qualification (base)	0.14	857

8.4.2 Set of covariates used in discrete time hazard model

Sociodemographic variables	Description
Married at wave 1	1 if applicable, zero otherwise
First retired between the age of 50 and 55	1 if applicable, 0 otherwise
First retired between the age of 56 and 60	1 if applicable, 0 otherwise
Spouse in employment at wave 1	1 if applicable, 0 otherwise
Has private health insurance	1 if applicable, 0 otherwise
Has a limiting illness	1 if applicable, 0 otherwise
Economic variables	
Holds a degree	1 if applicable, 0 otherwise
Has a qualification below degree but above A level	1 if applicable, 0 otherwise
Holds an O-level or CSE	1 if applicable, zero otherwise
No/foreign qualification (base group)	1 if applicable, 0 otherwise
Debt shock in non-housing net financial debt *(IFS)*	25% increase across two consecutive waves
Wealth shock in non housing net financial wealth *(IFS)*	25% decrease across two consecutive waves
Log of total pension wealth in 2002	See Appendix 8.3.1
Non pension financial wealth quintile in 2002	See Appendix 8.3.1
Income quintile 2002	See Appendix 8.3.1
Opportunity to work past retirement age	Allowed to work past SPA, 0 otherwise
Respondent feels they do not have enough income	1 if responded yes, 0 otherwise
$<$1 year (short term) financial planning horizon (base) *(IFS)*	1 if applicable, 0 otherwise
1-3 year (medium term) financial planning horizon *(IFS)*	1 if applicable, 0 otherwise
3+ years (long term) financial planning horizon *(IFS)*	1 if applicable, 0 otherwise
Self reported social class by preretirement job occupation	1 if in particular social group, 0 otherwise

8.4.3 Models of non-response

Wave 3

Table 8.14: Wave 3 Non response equation

Log pseudolikelihood =−314.86		$N = 827$
Variable	β (*robust* σ)	Pr $> \|z\|$
Work and pensions accuracy:fairly accurate	omitted	
Work and pensions accuracy:not very accurate	omitted	
Work and pensions accuracy:not accurate at all	1.04(0.80)	0.19
Income and assets accuracy:fairly accurate	0.14(0.30)	0.63
Income and assets accuracy:not very accurate	0.25(0.30)	0.38
Income and assets accuracy:not accurate at all	0.29(0.39)	0.45
2^{nd} Income quintile	-0.09(0.19)	0.62
3^{rd} Income quintile	-0.07(0.18)	0.71
4^{th} Income quintile	-0.13(0.19)	0.49
5^{th} Income quintile	-0.20(0.19)	0.29
Second third of calendar year	-0.28(0.16)	0.08
Final third of calendar year	-0.23(0.19)	0.22
Interview in 2002	-0.04(0.20)	0.83
25-50% chance health will affect future work	-0.93(0.68)	0.17
51-75% chance health will affect future work	omitted	
76-100% chance health will affect future work	1.01(0.33)	0.00
Wald $\varkappa^2(13)$ =413.62		Pr $> \varkappa^2 = 0.00$

Notes: Robust standard errors in brackets.
Work and pensions/ income and assets accuracy refers to the interviewers perception of how accurate they deemed the interviewees answers to the survey questions relating to work and pensions, on a four point scale: very accurate (base group), fairly accurate, not very accurate, not accurate at all.
Omitted indicates either an empty category or all respondents in category did not respond.

Wave 4

Table 8.15: Wave 4 Non response equation

Log pseudolikelihood =−341.50		$N = 849$
Variable	β (*robust* σ)	Pr $> \|z\|$
Work and pensions accuracy:fairly accurate	-0.05(0.54)	0.93
Work and pensions accuracy:not very accurate	-0.31(0.56)	0.58
Work and pensions accuracy:not accurate at all	1.22(0.97)	0.21
Income and assets accuracy:fairly accurate	-0.05(0.24)	0.85
Income and assets accuracy:not very accurate	-0.04(0.24)	0.86
Income and assets accuracy:not accurate at all	-0.36(0.39)	0.35
2^{nd} Income quintile	-0.21(0.17)	0.21
3^{rd} Income quintile	-0.14(0.17)	0.41
4^{th} Income quintile	-0.21(0.18)	0.24
5^{th} Income quintile	-0.37(0.19)	0.04
Second third of calendar year	-0.02(0.17)	0.92
Final third of calendar year	-0.16(0.19)	0.39
Interview in 2002	-0.31(0.21)	0.14
25-50% chance health will affect future work	omitted	
51-75% chance health will affect future work	0.078(0.57)	0.89
76-100% chance health will affect future work	-0.67(0.28)	0.01
Wald $\varkappa^2(15)$ =391.74		Pr $> \varkappa^2 = 0.00$

Notes: Robust standard errors in brackets.
Work and pensions/ income and assets accuracy refers to the interviewers perception of how accurate they deemed the interviewees answers to the survey questions relating to work and pensions, on a four point scale: very accurate (base group), fairly accurate, not very accurate, not accurate at all.
Omitted indicates either an empty category or all respondents in category did not respond.

8.5 Appendix for Chapter five

8.5.1 Summary statistics

Diagnostic measures

For each consecutive two-quarter panel constructed the estimated coefficients from the models of non-response were very similar. Therefore we choose to report only one set of results relating to the period Q1-Q2 2011.

G weight.

Table 8.16: G weight: Sample moments.

N	46999	Sum weights	46999
$\bar{x}$	1	Sum observations	46999
σ_x	0.334966	σ_x^2	0.11220222
γ	0.6773533	Kurtosis	-0.0143484
Uncorrected SS	52272.2801	Corrected SS	5273.28006
Coefficient variation	33.496	Std error mean	0.0015451

Table 8.17: G weight: Statistical measures.

Location		Variability	
$\bar{x}$	1.00	σ_x	0.334966
$\tilde{x}$	0.939821	σ_x^2	0.11220222
Mo	0.847220	Range	1.91955
		Interquartile range	0.50159

Table 8.18: G weight:Tests for location $\mu_0 = 0$

Tests for location $H_0 : \mu_0 = 0$			
Test	Statistic	P value	Test result
Student's	$t = 647.2076$	Pr $> \|t\| < 0.0001$	Reject H_0
Sign	$M = 23499.5$	Pr $>= \|M\| < 0.0001$	Reject H_0
Signed Rank	$S = 5.5224E8$	Pr $>= \|S\| < 0.001$	Reject H_0

Table 8.19: G weights: By quantile.

Quantiles	
Quantile	Estimate
100% Max	$2.30E+00$
99%	$1.92E+00$
95%	$1.61E+00$
90%	$1.45E+00$
75% Q3	$1.23E+00$
50% Median	$9.40E-01$
25% Q1	$7.31E-01$
10%	$6.15E-01$
5%	$5.65E-01$
1%	$4.77E-01$
0% Min	$3.76E-01$

Table 8.20: G weight: extreme observations.

Lowest		Highest	
Value	Observations	Value	Observations
$3.76E-01$	40231	2.28638	342
$3.76E-01$	39354	2.28638	1938
$3.76E-01$	39106	2.29553	493
$3.85E-01$	38902	2.29553	1404
$4.15E-01$	46813	2.29553	2372

F weight.

Table 8.21: F weight: Sample moments.

N	46999	Sum weights	46999
$\bar{x}$	932.580183	Sum observations	$43,830,336$
σ_x	320.101589	σ_x^2	102465.027
γ	0.67480387	Kurtosis	0.00775405
Uncorrected SS	$4.5671E10$	Corrected SS	4815651346
Coefficient variation	34.3242967	Std error mean	1.47653423

Table 8.22: G weight: Statistical measures

Location		Variability	
$\bar{x}$	932.5802	σ_x	320.10159
$\tilde{x}$	867.5711	σ_x^2	102465
Mo	801.7706	Range	1937
		Interquartile range	476.18341

Table 8.23: F weight:Tests for location $\mu_0 = 0$

Tests for location $H_0 : \mu_0 = 0$			
Test	Statistic	P value	Test result
Student's	$t = 631.6008$	Pr $> \|t\| < 0.0001$	Reject H_0
Sign	$M = 23499.5$	Pr $>= \|M\| < 0.0001$	Reject H_0
Signed Rank	$S = 5.5224E8$	Pr $>= \|S\| < 0.001$	Reject H_0

Table 8.24: F weights: By quantile.

Quantiles	
Quantile	Estimate
100% Max	$2.17E + 03$
99%	$1.82E + 03$
95%	$1.51E + 03$
90%	$1.36E + 03$
75% Q3	$1.16E + 03$
50% Median	$8.68E + 02$
25% Q1	$6.82E + 02$
10%	$5.69E + 02$
5%	$5.13E + 02$
1%	$4.29E + 02$
0% Min	$2.35E + 02$

Table 8.25: F weight: extreme observations.

Extreme observations			
Lowest		Highest	
Value	Observations	Value	Observations
$2.4E + 02$	40231	2163.72	342
$2.4E + 02$	39354	2163.72	1938
$2.4E + 02$	39106	2172.39	493
$2.4E + 02$	38902	2172.39	1404
$2.6E + 02$	40674	2172.39	2372

Chapter 9

Definitions

Table 9.1: Definitions.

Abbreviation	Description
AIC	Akaike Information Criterion
ANOVA	ANalysis Of VAriance
ARIMA	Auto Regressive Integrated Moving Average
BIC	Berkake Information Criterion
BHPS	British Household Panel Survey
BSP	Basic State Pension
DWP	Department for Work and Pensions
ELSA	English Longitudinal Study for Ageing
GSS	Government Statistical Service
HOH	Head of Household
HRS	Health and Retirement Survey
HSE	Health Survey for England
IFS	Institute for Fiscal Studies
Insee	National Institute of Statistics and Economic Studies
MeAPR	Mean Absolute Percentage Revisions
MRS	Marginal Rate of Substitution
MxAPR	Maximum Absolute Percentage Revisions
NCDS	National Child Development Survey
NCSR	National Centre for Social Research
NEET	Not Employed in Education or Training
NHS	National Health Service
NI	National Insurance
NSRA	Normal State Retirement Age
NSL	National Longitudinal Survey
OECD	Organisation for Economic Co-operation and Development
ONS	Office for National Statistics
PSID	Panel Survey of Income Dynamics
PV	Present Value
RHS	Retirement and Health Survey
RMSD	Root Mean Square Difference
SP	State Pension
SPA	State Pension Age
SRA	State Retirement Age
TRAMO	Time series Regression with ARIMA noise, Missing observations and Outliers
SEATS	Signal Extraction in ARIMA Time Series
UK	United Kingdom
UKHLS	United Kingdom Household Longitudinal Survey
UKLFS	United Kingdom Labour Force Survey

Chapter 10

Glossary

Table 10.1: Glossary

Term	Description
CALMAR	SAS raking macro (uses exponential distance metric)
CPI	Consumer Price Index: inflation metric
Earnings Rule	Tax on post retirement labour market income abolished in 1989
FDV	See Appendix 8.3.1 and 8.4.1
GES	SAS raking macro (uses linear distance metric)
IPW	Inverse Probability Weight (accounts for attrition)
NMW	Legal minimum hourly wage rate for individuals aged 21+
NSA	Non-Seasonally Adjusted (data unadjusted for calendar effects)
X-12-ARIMA	Official Seasonal Adjustment software of US Census Bureau

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