A Simulation Analysis of the Effects of the Socio-economic Environment on Fertility and Female Labour Supply Decisions in the United Kingdom*

Justin van de Ven†, Andrew Skeen‡ and Sarah Voitchovsky§

Abstract

The importance of contemporary trends in fertility and female labour supply is well recognised. Unfortunately, our understanding of these inter-related phenomena has been hampered by the difficulties that are associated with formulating a structural model of behaviour that reflects the joint nature of the fertility and labour supply decisions in the context of an uncertain future. In this paper we describe a model that we have developed to address these issues of concern. The model is calibrated to survey data for the cohort of women born in the United Kingdom in 1953, and its out-of-sample properties are explored with reference to data reported for the cohort of women born in 1963. Our analysis explains the observed delay in the timing of fertility, the reduction in completed fertility rates, and the rise in female labour market participation, as responses to the coincident decline in marriage and the growth of the labour incomes earned by women.

1 Introduction

In the UK, as in other industrialised countries, there have been substantial shifts in the demographics of the family during the last 50 years. Fertility rates have declined steadily since the mid 1960s, whilst marital rates have fallen, divorce rates have risen, cohabitation has become increasingly common, and female career opportunities and participation have increased. These inter-related trends have important social and economic implications (Becker (1988)), and have been the subject of much research. The existing literature has, however, struggled to take into account the endogenous nature of fertility, and labour market decisions, or to account for uncertainty in a way that is behaviourally consistent. Here we develop the framework needed to address these issues. We use this framework to consider how far observed changes in female labour market opportunities and partner relationships can explain the trends towards delayed fertility, lower total fertility rates, and increased female labour participation that have been observed during the last thirty years. We also explore how fertility behaviour is influenced by the financial cost of child-rearing.

Research undertaken during the 1960s and 1970s under New Home Economics found that rising incomes – and those of women in particular – were negatively correlated with fertility. Recent econometric studies have, however, cast some doubt over the intertemporal stability of these early findings.

*Please do not quote without the prior permission of the authors. We gratefully acknowledge financial support from the ESRC.

†NIESR. jvandeven@niesr.ac.uk

‡NIESR. askeen@niesr.ac.uk

§University College Dublin. sarah.voitchovsky@ucd.ie

Specifically, it has been found that the cross-country correlation between income and fertility switched sign from negative to positive in the mid-1980s. Kogel (2004), for example, reports substantial heterogeneity across countries in the time-series relationship between income and fertility, and a distinct weakening of the prevailing negative correlation.

The changing nature of the relationship between the labour market and fertility has been attributed to a number of factors, including interactions with unemployment (and the consequent uncertainty regarding lifetime incomes), changes in social norms toward working mothers, and the introduction of family friendly working policies. The nature of the marital contract, and spousal relationships more generally, have also changed markedly during recent decades, and have an important influence on contemporary fertility trends. A study based on qualitative data from Australia (Weston et al. (2004)), for example, suggests that although the average desired family size remains above the replacement rate (2.1 children per woman), expected fertility is much lower (at 1.7 children per woman). This mismatch between aspirations and experienced reality is attributed to pre-conditions for fertility, which include the adequacy and stability of both relationship status and income. It appears that the time taken to resolve uncertainty regarding these pre-conditions results in a delay of first issue, and a reduction in total fertility due to the consequent shortening of the reproductive lifetime.[1] In a similar vein, Berrington (2004) reports observations drawn from panel data for the United Kingdom, which indicate that women tend to revise down their fertility intentions as they age, in response to the experienced evolution of fertility (particularly fertility postponement), relationship status, and socio-economic circumstances.

In a closely related paper, Attansio et al. (2008) use a life-cycle model of consumption and labour supply to explore female labour market trends of three birth cohorts in the United States. They find that the observed trends in female labour supply are likely to be largely attributable to changes in the costs of child rearing. The current study extends the work of Attansio et al. (2008) by taking into account the endogenous nature of labour supply and fertility decisions in the context of uncertainty. We find that our model is sufficiently flexible to capture the trends described by survey data with which we are concerned; in the context of increasing uncertainty regarding partner relationships, and the strong growth observed for female labour incomes, our model predicts higher rates of female labour market participation, a delay in the fertility decision, and a reduction in completed rates of fertility.

The paper begins in Section 2 by reporting survey statistics that place contemporary demographic and labour market trends in their historical context, and which describe the specific observations around which the study is based. The structural model of behaviour that was devised to undertake the study is described in Section 3, and it's calibration is reported in Section 4.[2] An out-of-sample analysis

[1] The view that the delay in first issue is partly responsible for the trend toward lower total fertility rates is not new – see, for example, Macunovich (1996) and Adsera (2005).

[2] Much of the research regarding fertility is undertaken using reduced form models. See, Arroyo & Zhang (1997) for a

of the model's ability to reflect contemporary trends observed for fertility and female labour supply is reported in Section 5, and fertility responses to the financial costs of child-rearing are reported in Section 6. Section 7 concludes.

2 The Changing Nature of Household Demographics and Female Employment

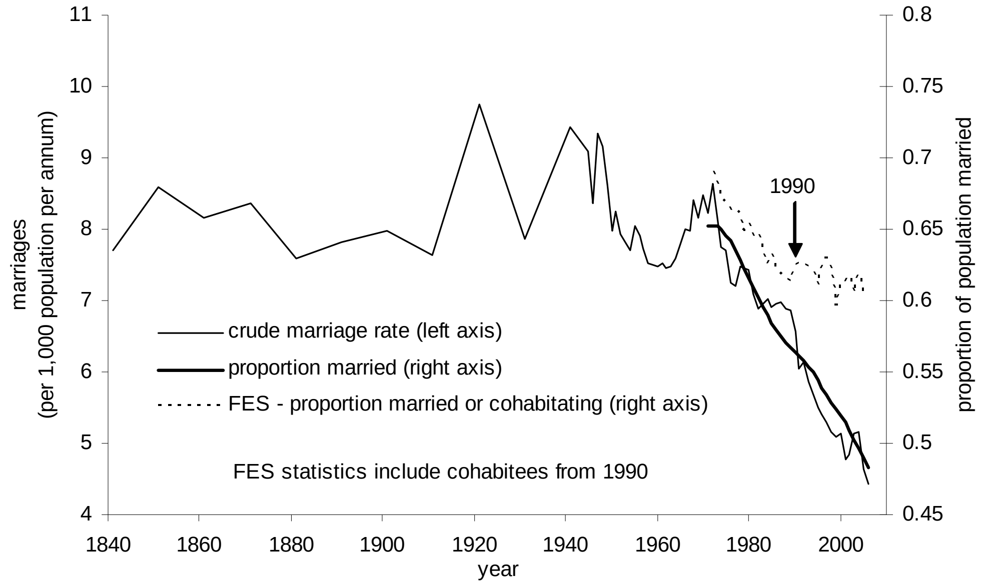
The current study focuses upon interactions between four key household characteristics: relationship status, wages, labour supply, and fertility. It is well recognised that marriage has become less important in recent decades, that women are working more than ever before, and that fertility rates are at historically low levels. This section places recent trends observed for these inter-related characteristics in their historical context, and draws out the hypotheses that motivate the analysis conducted later in the study.

We begin by exploring temporal trends observed for statistics of population aggregates. Figure 1 reports rates of marriage and divorce observed in England and Wales during the last 150 years. These statistics indicate the extent to which marriage has "broken down" during the last half century. Prior to 1940, marriage represented a core social institution; marital rates were high and divorce almost non-existent. Following the end of the Second World War, however, divorce rates spiked to previously unobserved levels, and marriage rates fell. Although divorce rates fell away rapidly during the 1950's, this recovery was short lived – the 35 years between 1971 and 2006 saw divorce rates climb from fewer than 6 out of every 1000 marriages per year to approximately 13 today. At the same time, the proportion of women reported as married has fallen in a smooth trend from 65% of the population in 1971 to 48% in 2006, replaced in large part by a rise in cohabitating relationships.

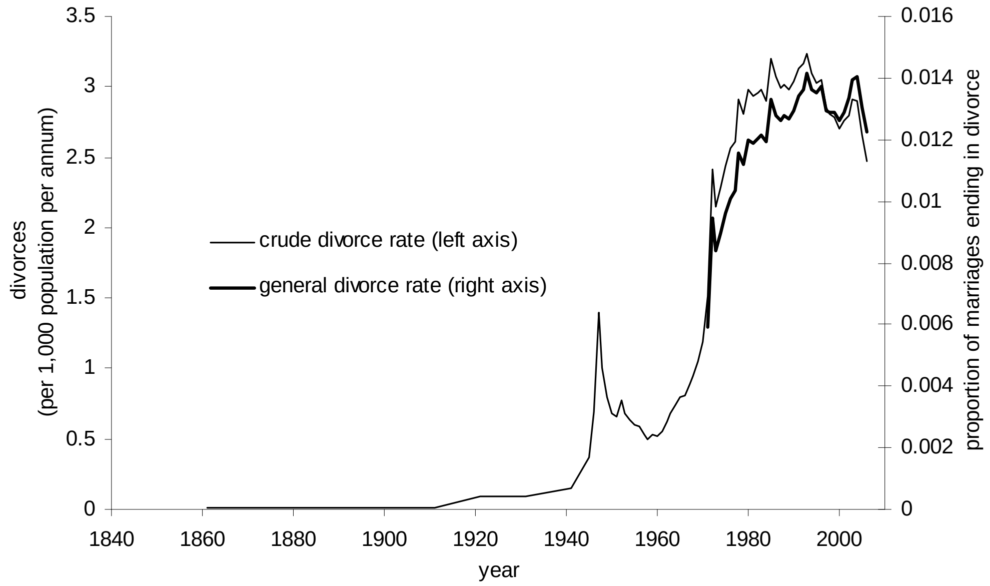
Erosion of the marital state has important social and economic implications. From the perspective of household budgets, the trend away from marriage, *ceteris paribus*, suggests higher costs (due to the lost economies of scale) and greater exposure to risk (due to the ability to risk-share when financial resources are pooled). Although the coincident rise in rates of cohabitation may have off-set these effects, the off-set is likely to be less than complete due to the greater instability that is associated with cohabitation, relative to formal marriages. The break-down of the "bread-winner" model of the family associated with the failure of marriage also points to evolving gender roles.

One of the most profound effects of changing gender roles on the economy has been the increase in female labour market participation. Figure 2 displays the proportion of the population of working age who were identified as employed by sex and year since 1959 (the earliest year for which comparable data are available). These statistics reveal that fewer than half of all working aged women were employed

survey of fertility trend studies that focuses upon the distinction between structural and reduced form models.



Panel A: marital trends



Panel B: divorce trends

Notes: authors' calculations based upon data from the Office for National Statistics (ONS), and the Expenditure and Food Survey (EFS)
crude marriage rate = number of marriages / population size . 1000
proportion of population married based on population estimates for women aged 16 and over
crude divorce rate = number of divorces / population size . 1000
general divorce rate = number of divorces / size of married population

Source: marriages reported by ONS data sets PMH38A (1841-1931), PMH39A (1941-1946), and PMH39B (1947-2006)
divorces reported by ONS data set PVH41
married population and total population estimates supplied by Michaela Morris at the Population Estimates Unit of the ONS
EFS data reported in repeated cross-sections from 1972 to 2005/06 – see Appendix A for details

Figure 1: Long-run Trends of Marriage and Divorce in England and Wales

Notes: rates for 1959-1971 based on population estimates for males aged 15-64 and females aged 15-59
rates from 1972 based on population estimates for males aged 16-64 and females aged 16-59

Source: rates for 1959-2000 derived from Department for Work and Pensions, file D5079
rates for 2001-2006 derived from April 2008 edition of Economic and Labour Market Review Table 2.01
rates for 2001-2006 based upon estimates for the UK, adjusted to match extended series for England and Wales

Figure 2: Employment Rates by Age, Year and Sex for England and Wales

in 1960, compared with over 70% in 2006. At the same time, employment rates of men have fallen – particularly following recessionary periods – so that the difference between male and female rates of employment has fallen from 46% in 1960 (when almost all men of working age were employed) to just 8% in 2006.

As female rates of employment have risen over the last half century, so too have the earnings paid to women in full-time employment. The rate of this growth is reported by statistics displayed in Figure 3. Panel A of the figure indicates that the real wages of all full-time employed women grew by an average rate of 2.7% per annum between 1970 and 2007 (the period for which data are available), and are now more than 2.8 times what they were 37 years ago. During the same period, the real earnings of full-time employed men grew by 1.8% per annum, so that women's average earnings rose from approximately half of men's earnings in 1970, to just over three quarters in 2007. In contrast, the average earnings of women employed full-time in manual labour fell relative to men's earnings during the 20 years prior to 1970.

Panel B of Figure 3 indicates that similar rates of 'catch-up' were observed for women's wages, relative to those of men, across the wage distribution prior to 1980. From the early 1980's, however, women's wages (relative to men) have tended to grow more rapidly at the bottom of the wage distribution than at the top. As a consequence of this dis-proportional growth, women's average full-time earnings were 85% of men's in the bottom earnings decile in 2007, and were 74% of men's in the top earnings decile.

Taken together, Figures 1 to 3 reflect increasing independence of women from men. The statistics are also likely to be jointly determined: reduced emphasis on marriage and the male 'bread-winner' model of the household, combined with relatively strong wage growth for women, imply that women now have a more powerful incentive to participate in the labour market than they did in the past; increased female labour market experience is likely to have contributed to their relative wage growth; and the financial independence that women derive from employment limits the negative financial impact on them of relationship breakdown. These trends are also likely to have had important implications for fertility. Under the classical Barro-Becker model, increased female labour market participation represents a negative influence on fertility due to the time cost associated with child-rearing. This effect is, of course tempered by the coincident fall observed for rates of male employment – there is a very slight upward trend in average employment rates reported in Figure 2, from 71% in 1959 to 75% in 2006. It is also off-set by the fact that increased female labour supply means that women are better able to meet the financial burden of child rearing.

Figure 4 reports historical trends observed for fertility rates in England and Wales, which reflect the experience of most other European countries. This figure indicates that crude birth rates have approximately halved during the last 160 years, from around 25 births per 1,000 members of the population per year in the mid 1800s, to approximately 12.5 births today.[3] Importantly, however, most of this fall occurred prior to the second world war. The brief revival of fertility rates at the end of the second world war (the baby-boom), was reversed during the 1960s and 1970s, leaving cross-sectional fertility rates relatively stable during the last 30 years. This stability is in spite of the strong trends observed for marriage and female labour market participation that are discussed above.

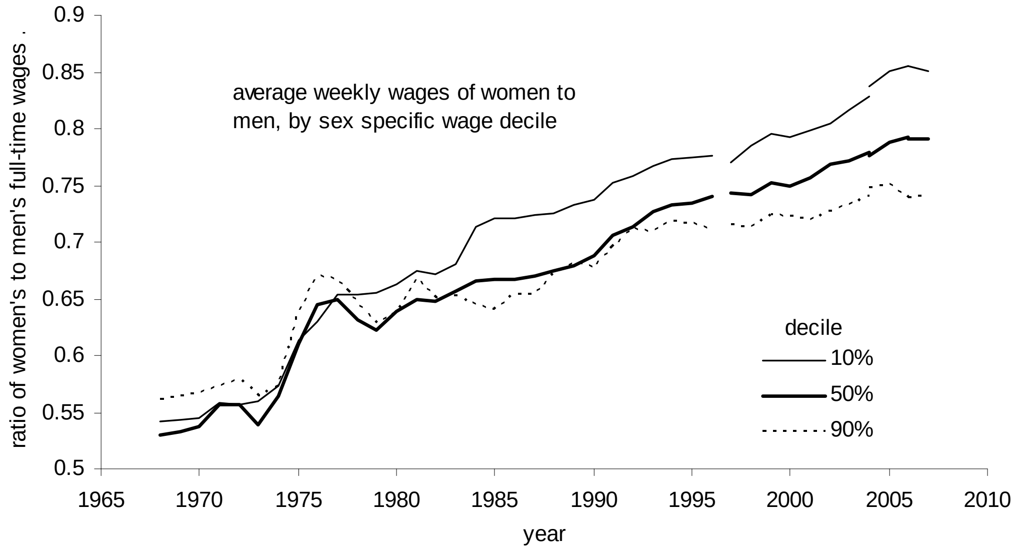
The statistics reported in Figure 4 suggest that it is important to consider social changes over the last 150 years when seeking to identify the determinants of fertility. This is beyond the scope of the current study. Rather, we are interested here in understanding how the increasing uncertainty associated with partner-relations and the strong wage growth observed for women since the 1970's, may have contributed to increased female labour supply and associated fertility decisions during the period. We turn now to discuss the specific empirical trends considered for analysis.

2.1 Trends for analysis

We focus upon the experience of the cohort of women who were born in 1953, and how this relates to the cohort of women born in 1963. These cohorts were selected for analysis because: a) data are currently

[3] The fall in the crude birth rate that is displayed in Figure 4 is driven by the fall in mortality rates, as well as by the fall in fertility rates. Cohort specific fertility rates that control for increased longevity are reported in the next subsection.

Panel A: population averages

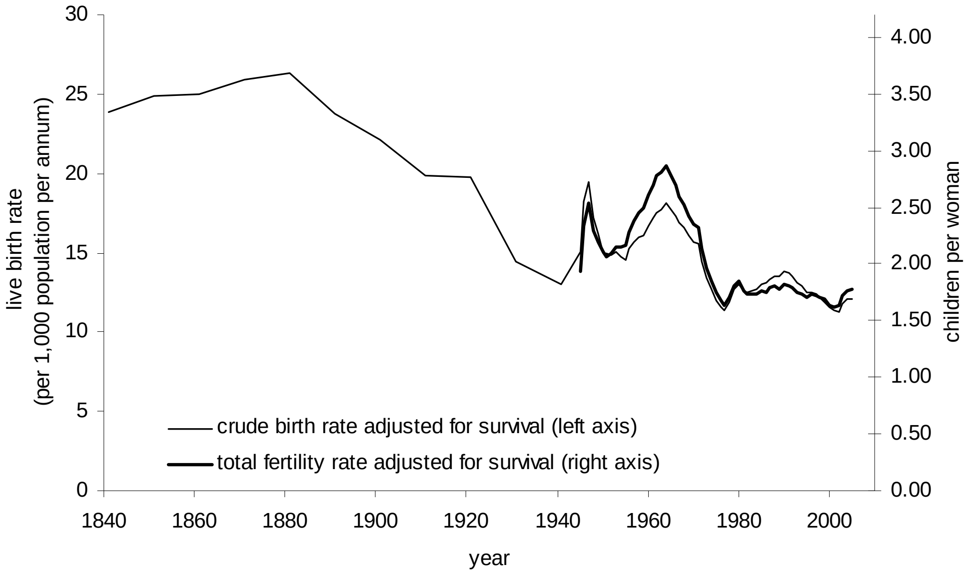


Panel B: distributional statistics

Notes: authors' calculations based upon data from the Office for National Statistics (ONS)
wage data discounted by the National Accounts consumer price deflator to 2005 prices
wage data for 1939 taken as average between 1938 and 1940 observations

Source: price deflator data from ONS code YBFS
price deflators for 1938-1947 calculated to match the ten year annual average rate of inflation observed between 1948-1958
ONS earnings statistics supplied by Alyson Box at the Earnings Helpdesk, ONS

Figure 3: Long-run Trends of Full-time Employed Weekly Wages in Great Britain



Notes: authors' calculations based upon data from various sources as reported below

Source: number of births for 1841-1931 derived from Office for National Statistics (ONS) dataset PBH21A

number of births for 1941 derived from ONS dataset PBH11

population size for 1841-1941 derived from census data, as reported by the Great Britain Geographic Information System Project

crude birth rates and total fertility rates for 1945-2006 derived from unpublished datasets, provided by June Leach at Vital Statistics, ONS

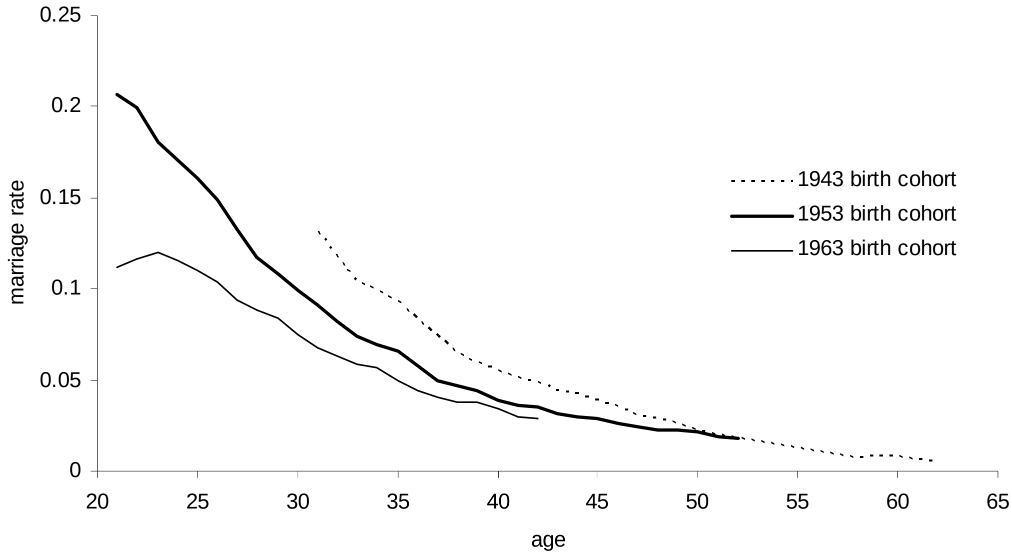
death rates for 1841-2006 derived from the Human Mortality Database

Figure 4: Cross-sectional Fertility Rates observed for England and Wales

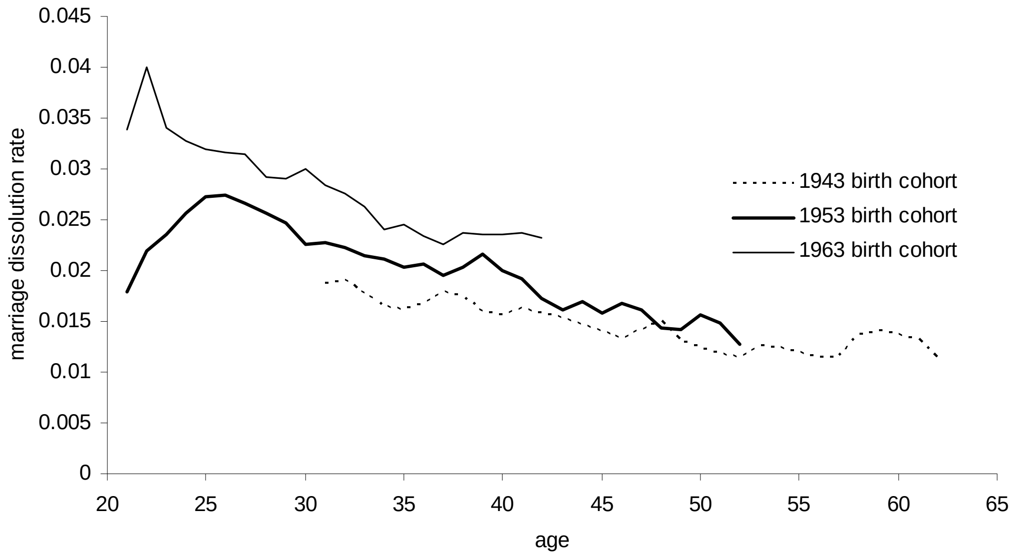
available for the full fertile life of each cohort; and b) differences between the two cohorts describe trends that are most relevant for the current historical context.[4] For comparison, we also report here statistics for the cohort of women who were born in 1943. Statistics for marriage and divorce are reported in Figure 5 during the period for which data are available. The statistics reported in Figure 5 reflect the temporal trends observed for population aggregates that are discussed above; marital rates by age have fallen, and rates of marital dissolution have risen in younger birth cohorts. Figure 5 reveals that the largest disparities between cohorts were observed during young ages. In the ten years that separate the 1953 and 1963 birth cohorts, rates of marriage amongst women in their early 20's almost halved, and rates of marital dissolution rose by approximately 50%. In contrast, statistics reported for the 1943 and 1953 birth cohorts indicate similar rates of marriage and marital dissolution for women in their 50's. In relation to the wider focus of the current study, it is of note that the early 20's of a woman's life also constitute an important period for career development and fertility decisions.

We now report statistics for the labour market experience of women from the 1943, 1953, and 1963 birth cohorts. Labour supply statistics are reported in Figure 7, and these are best interpreted in

[4] We have been careful to select for analysis women who entered their fertile life after the 'baby bust', commonly identified as accompanying the introduction of the oral contraceptive pill. The British minister for health announced that the oral contraceptive pill could be obtained through the National Health Service on December 4 1961. Between 1962 and 1969 the number of users of the oral contraceptive in the UK increased from approximately 50,000 to 1 million. Abortion was made legal in 1967, and Family Planning Services were introduced into the National Health Service in 1974.



Panel A: marriage rates



Panel B: marriage dissolution rates

Notes: authors' calculations based upon data from the Office for National Statistics (ONS)

marriage rates = marriages / population not married

marriage dissolution rates = marital dissolutions / population married

Source: Data regarding the numbers of marriages and divorces by age of wife and year of divorce were derived from Tables 3.19, 3.6, and 4.1 of back issues of the ONS publication *Marriage, Divorce, and Adoption Statistics*, Series FM2.

Probabilities of relationship dissolution include the effects of attrition through spousal mortality, as implied by the principal projections for male cohort life-expectancy calculated by the ONS, and under the assumption that all marriages are between same aged partners.

Population aggregates for England and Wales by sex, age, and year were provided by Michaela Morris of the Population Estimates Unit, ONS.

Issues of Series FM2 prior to 1999 were made available by June Leach at the ONS

Figure 5: Rates of Marriage and Marital Dissolution by Age and Birth Cohort for England and Wales

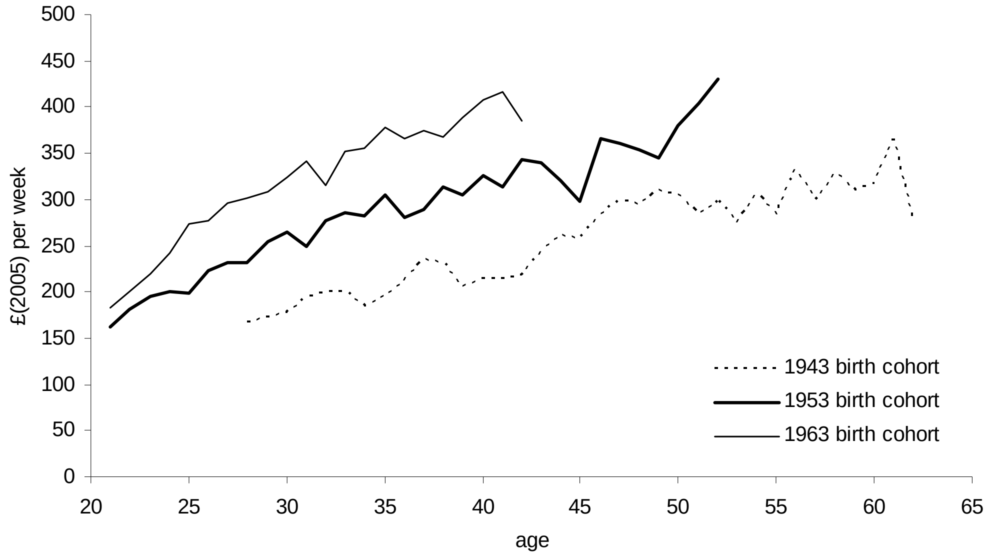
conjunction with the associated wage statistics, which are reported in Figure 6. Figure 7 indicates that rates of full-time employment during peak child-rearing years were higher amongst younger birth cohorts, with part-time employment more prevalent amongst women from the 1953 birth cohort than the 1963 cohort. Furthermore, overall rates of employment also tend to be higher amongst younger cohorts for women between ages 25 and 35, with very similar rates of employment observed thereafter. These observations echo the statistics for marriage that are discussed above: women from younger birth cohorts, are less likely to marry in their 20's, are more likely to divorce if married, and tend to work more than women from older birth cohorts.

Figure 6 reveals that the average weekly wages of each of the three birth cohorts start out at similar levels at the beginning of the working lifetime, with the profiles of younger cohorts growing more rapidly with age early in life than those of older cohorts. It is likely that the statistics observed for labour market participation and wages are endogenously determined: the anticipation of strong wage growth is an incentive to labour market participation early in the working life; and – when wages increase with labour market experience – high rates of employment can generate strong wage growth. It is not possible to distinguish which of these two considerations might dominate on the basis of the statistics that are reported here, and full consideration of this issue remains a subject for future research.

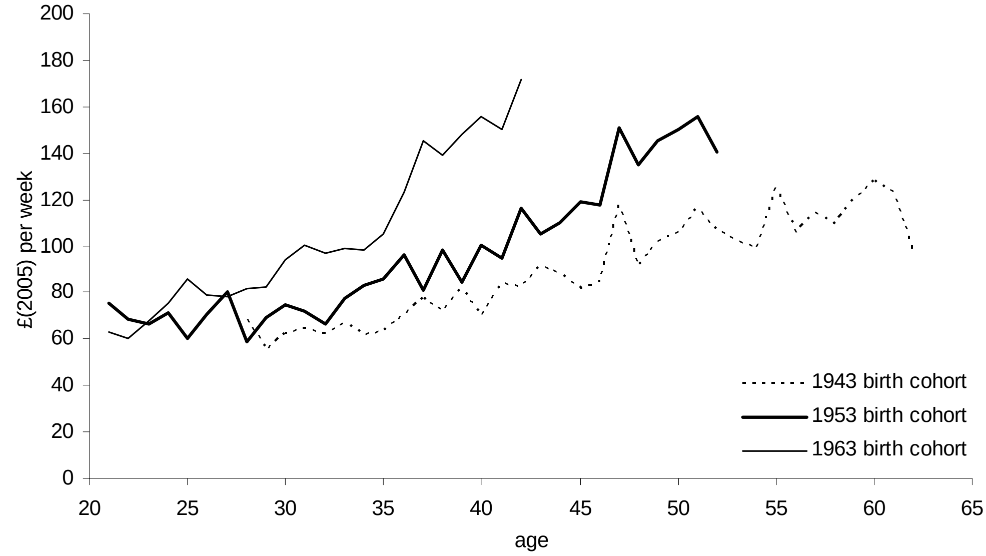
The population aggregate fertility rates that are reported in Figure 4 indicate very little variation since 1970. It is of note, however, that the population aggregates reported in Figure 4 obscure the experience of individual birth cohorts, and we consequently report cohort specific fertility rates in Figure 8. Panel A of this figure, which echoes the statistics reported in Figure 4, indicates that the most pronounced falls in completed fertility were observed between birth cohorts who were aged in their peak child-bearing years during the 1960s. From the 1948 birth cohort – which had modal fertility at age 23 in 1971 – the downward trend in completed fertility rates has been slow and reasonably stable, at just over 0.01 children per year by cohort age. Coincidentally, the 1948 birth cohort was also the last cohort to have had a completed fertility above the replacement rate.

The most evident and well documented of the contemporary trends in fertility is the tendency for women to have children later in life than they did in the past. This is made clear by Panel B of Figure 8, which reports fertility rates for the three birth cohorts that are discussed above. Panel B of Figure 8 reveals that the distribution of fertility is now less concentrated than it was in the past, as the mode has shifted to higher ages and the positive skew has diminished: the mode of the distribution of births occurred at a maternal age of 23 years for the 1943 cohort, and increased to 27 years for the 1963 cohort. At the same time, the (sample) skewness fell from 0.774 to 0.287.

Trends in the distribution of completed fertility by year of birth of women are reported in Table 1. This table reveals that the proportion of childless women fell sharply between the 1920 and 1930 birth



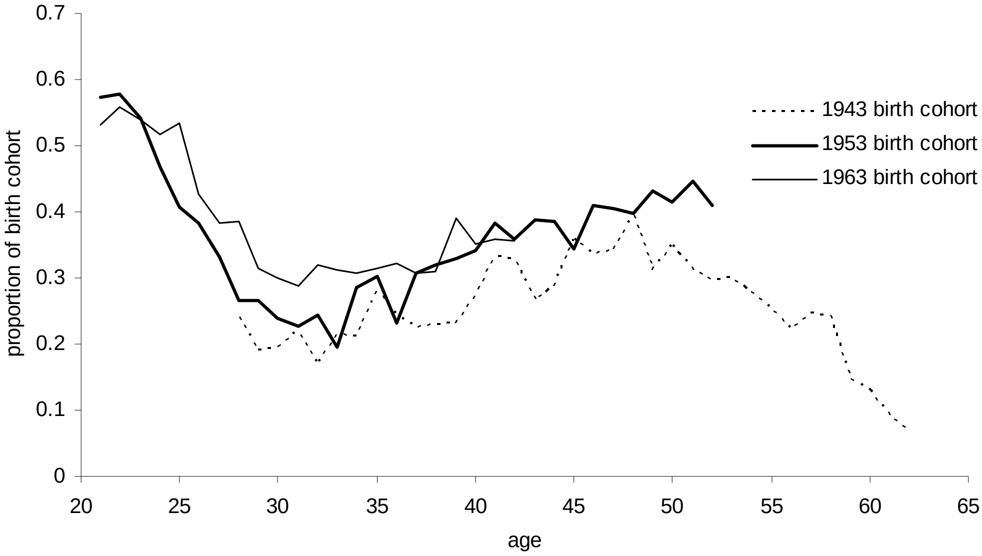
Panel A: full-time employment



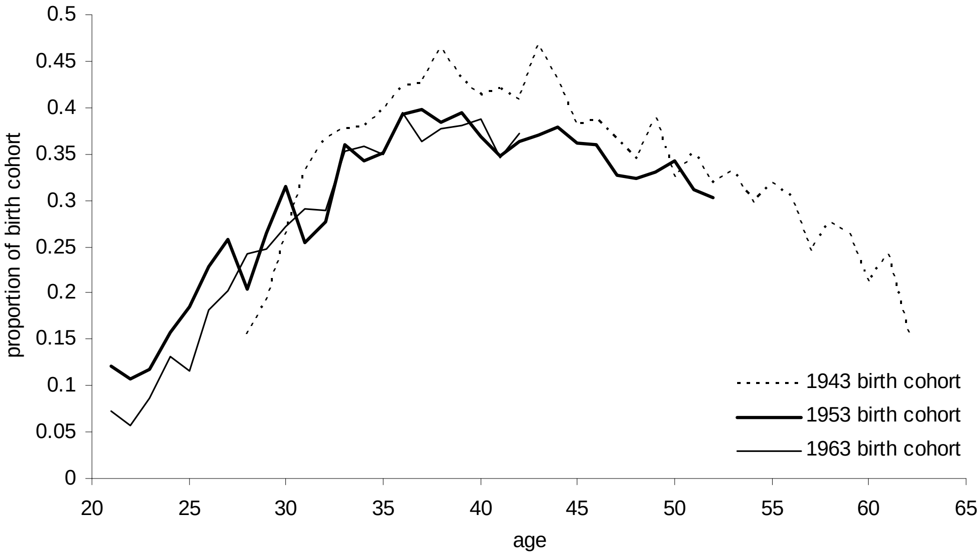
Panel B: part-time employment

Notes: authors' calculations based upon Expenditure and Food Survey / Family Expenditure Survey data
wage data discounted by the National Accounts consumer price deflator to 2005 prices
Source: Repeated cross-sectional samples for all years between 1972 and 2005/06
See Appendix A for details of surveys used
price deflator data from Office for National Statistics, code YBFS

Figure 6: Female Average Gross Labour Income by Employment Status, Age and Birth Cohort



Panel A: full-time employment



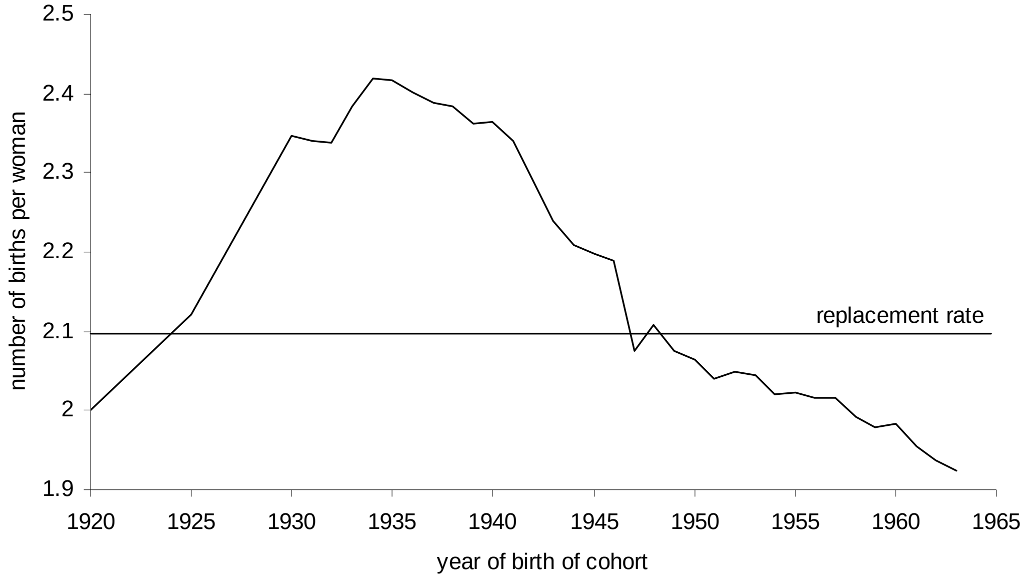
Panel B: part-time employment

Notes: authors' calculations based upon Expenditure and Food Survey / Family Expenditure Survey data

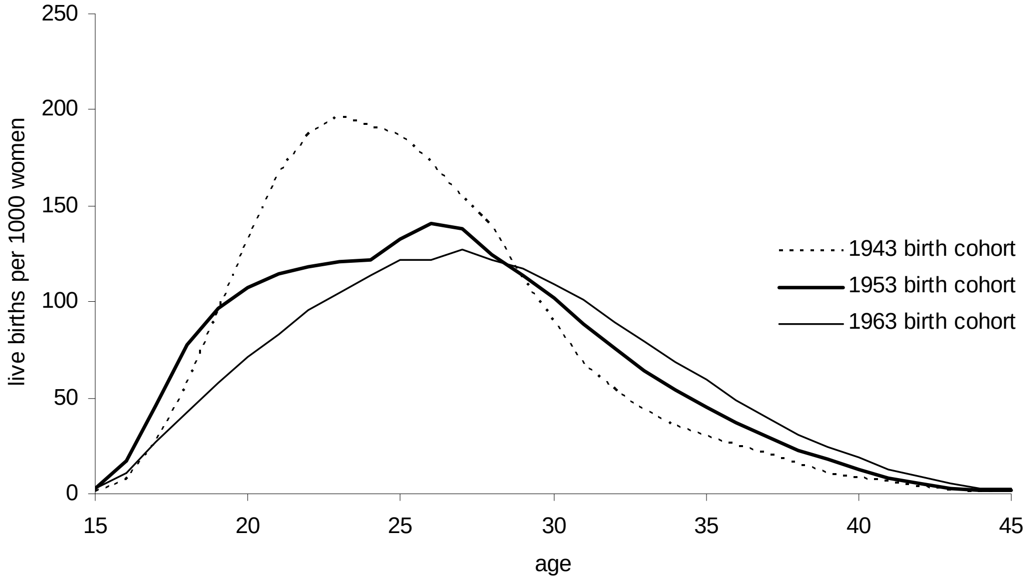
Source: Repeated cross-sectional samples for all years between 1972 and 2005/06

See Appendix A for details of surveys used

Figure 7: Rates of Female Employment by Age and Birth Cohort



Panel A: completed fertility rates by birth cohort



Panel B: fertility rates by age and birth cohort

Notes: author calculations based upon data from the Office for National Statistics publication, *Birth Statistics*, Table 10.1

Figure 8: Fertility Statistics by Female Birth Cohort

Table 1: Distribution of Women by Birth Cohort and Completed Fertility – England and Wales

year of birth of woman	number of live births 0	1	2	3	4 or more
1920	21	21	27	16	15
1930	13	18	30	19	20
1940	11	13	36	22	18
1945	10	14	43	21	12
1950	13	13	44	20	10
1955	16	13	41	20	10
1960	18	13	38	20	10
1961	19	13	38	20	10

Source: Office for National Statistics, *Birth Statistics* , FM1, no. 35, Table 10.5

cohorts, and continued to fall more gradually until the 1945 birth cohort. From the 1945 birth cohort, however, the proportion of women who remained childless during their entire lives has grown, and was just under the peak observed for 1920 for the cohort of women born in 1961 – the most recent cohort for which completed fertility statistics are available. More generally, the statistics reported in Table 1 for the four cohorts of women born between 1920 and 1945 indicate substantial variation across the completed fertility distribution: first a wide-spread movement toward larger family sizes between the 1920 and 1930 birth cohorts, and then a gradual fall in fertility to the 1945 birth cohort. In contrast, the distributional statistics reported for the 1950 to 1961 birth cohorts indicate that the contemporary fall in fertility is largely the product of a fall in the proportion of women who had two children, and a coincident rise in the proportion of women had no children. The proportions of women who had just one, or more than two children during their lives has remained unchanged for women born between 1950 and 1961.

The current study focuses upon how far the increased uncertainty regarding personal relationships, and the strong wage growth observed for women can explain the delay in the timing of fertility, the slight fall in total fertility rates, and the changing nature of female labour market participation observed during the last thirty years.

3 Modelling Consumption, Labour Supply, and Fertility Decisions

The analysis follows women through their respective life courses, with the life course disaggregated into annual increments. Longevity is uncertain, subject to an exogenously defined age specific probability of mortality, and decisions are considered to be made at the level of the household. Households choose their consumption, fertility, and labour supply to maximise expected lifetime utility, given their existing circumstances, preferences, and beliefs regarding the future. Circumstances are described by a woman's age, relationship status, number of children, wage potential (received if they choose to work), and survival, plus the wage potential of a woman's spouse (if one is present, and received if they work), and the household's net wealth. Preferences are defined by a utility function (that is the same for all households), and beliefs are rational in the sense that they are consistent with the processes that generate household circumstances.

Incorporating an appreciation of uncertainty into individual expectations regarding future circumstances increases the complexity of the utility maximisation problem. We consequently limit uncertainty to the timing of mortality and the key characteristics of interest – relationship status and wages – with the remaining characteristics (age, number of children, and net wealth) considered to evolve deterministically, given the decisions that household's choose to make.

In the terminology of the dynamic programming literature, consumption, labour supply, and fertility are control variables, which are selected to maximise the value function described by a time separable utility function, subject to seven state variables, four of which are stochastic, and three deterministic. This section begins by defining the assumed preference relation. The wealth constraint is then described, followed by the processes that are assumed for the evolution of wages and relationship status. The section concludes with an explanation of the approach adopted to solve the lifetime utility maximisation problem.

3.1 The utility function

Expected lifetime utility of household i at age t is described by the time separable function:[5]

$$
\begin{aligned}
U_{i,t} &= E_t \left[\sum_{j=t}^{T} \delta^{j-t} \phi_{j-t,t} u \left(\frac{c_{i,j}}{\theta_{i,j}}, l_{i,j}, n_{i,j}^{c} \right)^{1-1/\gamma} \right]^{\frac{1}{1-1/\gamma}} && (1) \\
&= \left[u \left(\frac{c_{i,t}}{\theta_{i,t}}, l_{i,t}, n_{i,t}^{c} \right)^{1-1/\gamma} + \delta E_t \left(\phi_{1,t} U_{i,t+1}^{1-1/\gamma} \right) \right]^{\frac{1}{1-1/\gamma}} && (2)
\end{aligned}
$$

where E_t is the expectations operator; T is the maximum potential age; δ is the discount factor (assumed to be the same for all households and time invariant); $\phi_{j-t,t}$ is the probability of living to age j, given survival to age t; $u(.)$ is within period (year) utility; and $1/\gamma$ is relative risk aversion. $c_{i,t} \in R^{+}$ is composite consumption; $\theta_{i,t} \in R^{+}$ is adult equivalent size based on the revised OECD scale; $l_{i,t} \in [0,1]$ is the proportion of a household's time spent in leisure; and $n_{i,t}^{c}$ is the number of dependant children in the household.

Adult women are considered to have three discrete labour options; they can choose to be full-time employed, $l_{i,t}^{f} = l_{t}^{FT,f}$, part-time employed, $l_{i,t}^{f} = l_{t}^{PT,f}$, or not employed, $l_{i,t}^{f} = l_{t}^{NE,f}$. Men are considered to be either employed, $l_{i,t}^{m} = l_{t}^{FT,m}$, or not employed, $l_{i,t}^{m} = l_{t}^{NE,m}$, in view of the fact that very few men are observed to work part-time in the UK.[6] Household leisure is defined as $l_{i,t} = l_{i,t}^{f}$

[5] It is usual to assume that utility is time separable in this context, despite concerns raised in the wider literature (see Deaton & Muellbauer (1980), pp. 124-125, or Hicks (1939), p. 261).

[6] A part-time labour option for men was originally included in the analysis. Including an option for men to work

for single women, and $l_{i,t} = 0.5\left(l_{i,t}^{f} + l_{i,t}^{m}\right)$ for couples. We have chosen to focus on a discrete rather than continuous labour supply decision because we believe that this provides a closer approximation to the practical reality, as is described at greater length in Section 4. Nevertheless, if people do have greater flexibility over their labour decisions than we consider here (as is almost certainly the case in practice – again described at greater length below), then our considered framework will dampen labour supply responsiveness to incentives, and may consequently require a labour elasticity that overstates the practical reality.

The equivalence scale considered for analysis depends upon the numbers of adults, $n_{i,t}^{a}$, and children, $n_{i,t}^{c}$ in a household, and its inclusion in the preference relation reflects the fact that household size has been found to have an important influence on the timing of consumption (e.g. Attanasio & Weber (1995) and Blundell et al. (1994)).[7] The OECD-modified scale is currently the standard scale for adjusting before housing costs incomes in European Union countries, and is consequently adopted for the current study.[8]

The assumption that discount rates are time invariant has been relaxed by other studies in two important respects. Gustman & Steinmeier (2005), for example, allow variation in the rate of time preference to be an important factor in matching observed heterogeneity of household labour supply behaviour. We have chosen not to do this to ensure that heterogeneity of household behaviour generated by the model is driven by heterogeneity in observable household characteristics. Alternatively, behavioural myopia has been considered through the assumption of time-varying discount rates, usually in the form of quasi-hyperbolic discounting following Laibson (1997). Such preferences complicate the model because they are time inconsistent, giving rise to the potential for "conflict between the preferences of different intertemporal selves" (Diamond & Köszegi (2003), p. 1840). Myopia is not considered here.

A Constant Elasticity of Substitution function was selected for within period utility, augmented to include the welfare effects of dependant children:

$$u\left(\frac{c_{i,j}}{\theta_{i,j}}, l_{i,t}, n_{i,t}^{c}\right) = \left[\left(\frac{c_{i,j}}{\theta_{i,j}}\right)^{(1-1/\varepsilon)} + \alpha_{l}^{1/\varepsilon} l_{i,t}^{(1-1/\varepsilon)} + \alpha_{c}\left(n_{i,t}^{c}, t\right)^{(1-1/\varepsilon)}\right]^{\frac{1}{1-1/\varepsilon}} \tag{3}$$

where $\varepsilon > 0$ is the (period specific) elasticity of substitution between equivalised consumption $(c_{i,t}/\theta_{i,t})$ and leisure $(l_{i,t})$. The parameter $\alpha_l > 0$ is referred to as the utility price of leisure, and $\alpha_c(.)$ is a step-wise function that depends upon age and the number of dependant children in a household. This structure of perfernces in relation to children abstracts from the altruism that is assumed in the standard

part-time does not substantially increase the computation time of the model. The scarcity of associated survey data, however, complicated model calibration, and so was omitted from the study.

[7] An empirical study by Fernandez-Villaverde & Krueger (2006) of US data from the Consumer Expenditure Survey suggests that roughly half of the variation observed for lifetime household consumption can be explained by changes in household size, as described by equivalence scales. See Balcer & Sadka (1986) and Muellbauer & van de Ven (2004) on the use of this form of adjustment for household size in the utility function.

[8] This scale assigns a value of 1 to the head of household, 0.5 to each additional person aged 14 and over, and 0.3 to each child aged under 14.

Barro-Becker model. It can also be contrasted with the model considered by Boldrin & Jones (2002), in which parents derive utility from children solely because the children are assumed to care for their parents in old age. This specification of preferences implicitly assumes that characteristics which affect utility, but are not explicitly stated, enter the utility function in an additive way.

3.2 The wealth constraint

Equation (1) is considered to be maximised, subject to an age specific credit constraint imposed on liquid net worth, $w_{i,t} \geq D_t$. We define liquid net worth by:

$$w_{i,t} = \begin{cases} w_{i,t-1} + \tau\left(l_{i,t-1}, w_{i,t-1}, x^f_{i,t-1}, x^m_{i,t-1}, n^a_{i,t-1}, n^{c,a1}_{i,t-1}, n^{c,a2}_{i,t-1}, n^{c,a3}_{i,t-1}, t-1\right) - c_{i,t-1} & \text{if } t \lesseqgtr t_{SPA} \\ (1-\eta)\left[w_{i,t-1} + \tau\left(l_{i,t-1}, r_i w_{i,t-1} + x_{i,t-1}, n^a_{i,t-1}, n^c_{i,t-1}, t-1\right) - c_{i,t-1}\right] & \text{if } t = t_{SPA} \end{cases} \quad (4)$$

where $\tau(.)$ is the tax and benefit function, $x^f_{i,t}$ is private non-property income of the woman in household i at age t, $x^m_{i,t}$ is the private non-property income of the woman's spouse (if one exists), $n^{c,aj}_{i,t}$ indicates the number of dependant children in the household (distinguished by age group j), t_{SPA} is state pension age, and η is the (exogenously imposed) proportion of wealth annuitised at state pension age. In practice, liquid net worth, $w_{i,t}$, is comprised of housing, cash balances, risky financial investments, and so on. Demand for these alternative asset classes is affected by a range of considerations, including transactions costs, the uncertainty of investment returns, differential tax treatment, and the consumption of housing services. We simplify the analysis by abstracting from the asset allocation problem, and leave associated sensitivity analysis as an issue for further research. D_t is specified to ensure that a household will never be forced to consume a negative sum, subject to the constraint that all debts are repaid by age t_{SPA}.

During the working lifetime, $t < t_{SPA}$, $x^k_{i,t}$ is equal to labour income, $y^k_{i,t}$ (described below). During retirement, $t \geq t_{SPA}$, $x^f_{i,t}$ is equal to the annuity income of the household (with $x^m_{i,t} = 0$), so that:[9]

$$x^f_{i,t} = \begin{cases} y^f_{i,t} & \text{if } t < t_{SPA} \\ \eta\chi\left[w_{i,t_{SPA}-1} + \tau_{i,t_{SPA}-1} - c_{i,t_{SPA}-1}\right] & \text{if } t = t_{SPA} \\ x^f_{i,t-1}\frac{\left(0.5+0.5\left(n^a_{i,t}-1\right)\right)}{\left(0.5+0.5\left(n^a_{i,t-1}-1\right)\right)} & \text{if } t > t_{SPA} \end{cases} \quad (5)$$

$$x^m_{i,t} = \begin{cases} y^m_{i,t} & \text{if } t < t_{SPA} \\ 0 & \text{if } t \geq t_{SPA} \end{cases} \quad (6)$$

where χ is an actuarially fair annuity rate. The assumption that pension rights are indistinguishable from liquid wealth prior to t_{SPA} simplifies the analysis, and significantly speeds up computation times, which facilitates analysis. Furthermore, the lower line of (5) indicates that the annuity purchased at age t_{SPA} falls by 50% (in real terms) in the event that a woman looses her spouse, which we have found to be an important factor when seeking to capture consumption late in life.

[9] The annuity purchased at age t_{spa} is assumed to reduce to 65% when the number of adults in a simulated household decreases to 1 in response to the mortality of a spouse. This adjustment to retirement income was necessary to capture the decline in expenditure with age observed in survey data.

The interest rate accruing to net liquid wealth is assumed to depend upon whether $w_{i,t}$ indicates net investment assets, or net debts:

$$r_{i,t} = \begin{cases} r^I & \text{if } w_{i,t} > 0 \\ r_l^D + \left(r_u^D - r_l^D\right)\min\left\{\frac{-w_{i,t}}{\max\left[x_{i,t}^f, x_{i,t}^m, \Phi h_{i,t}^f, \Phi h_{i,t}^m\right]}, 1\right\}, r_l^D < r_u^D & \text{if } w_{i,t} \leq 0 \end{cases}$$

where $h_{i,t}^k$ is the wage that adult k would earn if they chose to be full-time employed (and received a wage offer, discussed below). This specification for the interest rate implies that the interest charge on debt increases from a minimum of r_l^D when the debt to income ratio is low, up to a maximum rate of r_u^D, when the ratio is high. Assuming $\Phi < 1$ implies that households in debt are treated more generously if at least one adult member chooses to be full-time employed than if not.

3.3 Labour income dynamics

The focus of the current study places particular emphasis on the way in which wages are modelled. Define $h_{i,t}^f$ as the human capital of the adult woman in household i at age t, replacing f with m for the coincident male (if one exists). Labour income is then described by:

$$y_{i,t}^k = \begin{cases} \Omega_{i,t}^k . h_{i,t}^k & \text{if } l_{i,t}^k = l_t^{FT,k} \\ \Omega_{i,t}^k . \phi_t^k h_{i,t}^k & \text{if } l_{i,t}^k = l_t^{PT,k} \\ 0 & \text{if } l_{i,t}^k = l_t^{NE,k} \end{cases} \tag{7}$$

where k superscripts define sex-specific variables, and $\Omega_{i,t}^k$ is a dummy variable that identifies whether an individual is considered to receive a 'wage offer'. $\Omega_{i,t}^k$ is included to reflect the incidence of (involuntary) unemployment, and is consequently assumed to evolve stochastically, subject to an age and sex specific probability. Labour supply decisions are considered to be made after the current period's evaluations of $\Omega_{i,t}^k$ are revealed, but before the uncertainty regarding future wage offers is resolved.

In the first period of the simulated lifetime, t_0, each woman is allocated human capital, h_{i,t_0}^f, via a random draw from a log-normal distribution, $\ln\left(h_{i,t_0}^f\right) \sim N\left(\mu_{t_0}, \sigma_{t_0}^2\right)$. Men only enter the analysis when a woman is identified as beginning a new (cohabitating) relationship, and they exit the model in the event of a relationship dissolution. In other work (e.g. Sefton et al. (2008)) we have simplified the analytical problem by focussing upon the household's wage potential, and distinguishing the wages of cohabitating partners on a fixed proportional basis. In the current context, however, it is important that we take into consideration the influence that past labour market activity has on a woman's current and future wage potential. As such, it is necessary to record the human capital of a woman separately from that of her partner.

It is assumed that a single woman does not know with precision the human capital of her future partner in the event that she enters a new relationship, but that she is aware of the stochastic process that is assumed to exist between the full-time wages of new partners. As such, a male's human capital is only stored for households in which the woman of interest is considered to be in a relationship. When a woman enters a new relationship in the model, her partner's human capital is drawn from the following stochastic process:

$$\ln\left(h_{i,t}^{m}\right) = \omega_0 + \omega_1 \ln\left(h_{i,t}^{f}\right) + \sum_{i=1}^{A} \omega_i^a age_t + \omega_2 n_{i,t}^{c,a1} + \omega_3 n_{i,t}^{c,a2} + \omega_4 n_{i,t}^{c,a3} + \varepsilon_{i,t} \tag{8}$$

where age_t represent age specific dummy variables, $\varepsilon \sim N\left(0, \sigma_\varepsilon\right)$ is a normally distributed disturbance term, and all other variables are as defined previously.

The human capital of each adult in a household is considered to evolve as:[10]

$$\ln\left(\frac{h_{i,t}^k}{\mu_t^k}\right) = \begin{cases} \beta^k \ln\left(\frac{h_{i,t-1}^k}{\mu_{t-1}^k}\right) + \varepsilon_{i,t}^{1,k} & \text{if } l_{i,t}^k = l_t^{FT,k} \\ \beta^k \ln\left(\frac{h_{i,t-1}^k}{\mu_{t-1}^k}\right) + \alpha_{2,t}^k + \varepsilon_{i,t}^{2,k} & \text{if } l_{i,t}^k = l_t^{PT,k} \\ \beta^k \ln\left(\frac{h_{i,t-1}^k}{\mu_{t-1}^k}\right) + \alpha_{3,t}^k + \zeta_{i,t}^k & \text{if } l_{i,t}^k = l_t^{NE,k} \end{cases} \tag{9}$$

where k superscripts define sex specific variables, and $\varepsilon^{j,k} \sim N\left(0, \sigma_\varepsilon^{j,k}\right)$ and $\zeta^k \sim N\left(0, \sigma_\zeta^k\right)$ are normally distributed disturbance terms. The parameters β reflect intertemporal persistence of wages. Trend wage growth, is captured by the μ and α terms. As in the case of the wage offer identifier (Ω) described above, labour decisions in each period are considered to be made after the current period's evaluations for $h_{i,t}^k$ are revealed, but before uncertainty regarding the future evolution of human capital is resolved.

This specification for the evolution of wages is closely related to the associated literature (see Sefton & van de Ven (2004) for discussion), although the assumption that the dynamic form depends upon labour supply is something of an innovation. We have included labour in the dynamic process assumed for human capital to capture an experience effect of employment on wages – in the current context, individuals are considered to build up 'careers' during their simulated working lives. This experience effect is important for a study of fertility decisions as it can be an important factor in determining the foregone earnings of childcare (e.g. Joshi (1990)).

An experience effect on wages is most commonly allowed for in the wider econometric literature by including some measure of the accumulated number of years of employment as an explanatory variable. In the current context, this would increase the computational burden substantially, as it would require the addition of associated state variables. The form that was adopted to incorporate an experience effect requires no such addition, and consequently limits this computational burden.

[10] This specification for wage dynamics was arrived at after testing an alternative in which the β terms were allowed to vary between labour market states. Allowing the β terms to vary by employment state has the advantage that it permits the effects of differential labour market experience to vary by income level. In the current context, where we do not distinguish by socio-economic classification, occupation, or education attainment, econometric analysis supported widely differing values for β by labour market state. The alternative values for β implied potentially perverse incentives for some income levels – e.g. substantial wage growth for women on low incomes in return for reduced labour market participation in the middle of the working life, and vice versa for women on high incomes. We attributed these results to omitted variable bias, and leave associated sensitivity analysis as an issue for further research.

The endogeneity assumed for the wage generating processes has two important implications for the analysis reported here. First, it complicates solution of the utility maximising problem by invalidating two stage budgeting. And second, the endogeneity of the wage process has an influence on the relationship between preferred savings rates and an agent's wealth endowment. Given our assumption of homothetic preferences, the preferred consumption to leisure ratio would be independent of an agent's wealth endowment if wages were entirely exogenous and the leisure decision was considered to be made over a continuous intensive margin.[11] The endogeneity assumed for wages, however, implies that the preferred consumption to leisure ratio is not independent of the asset endowment. As assets rise, the influence that the experience effect on wages has on the labour / leisure decision is weakened. This implies that savings rates tend to fall more steeply with wealth when a positive experience effect on wages is considered for analysis.

The functional form that was adopted for the wage generating process is likely to embody a distortion of the practical reality in a number of respects. One of the most important of these is the assumption that the entire population, distinguished by age and sex, tends to regress to the same mean (μ). In practice, it is reasonable to suppose that the μ terms should depend upon various individual specific characteristics – such as occupation, education, socio-economic status, and indeed accumulated labour market experience – many of which are not taken into consideration by the current study. As a consequence, the model of labour income dynamics that is considered here is likely to over-state the distributional mobility of labour incomes that is observed in practice.

Furthermore, wage data are often modelled under the assumption of an MA(1) error structure (as in Attansio et al. (2008)) – again, we have had to omit an allowance for this as it would require the addition of a state variable, with a proportional increase in computation time. Computational limitations also bore upon the specification of uncertainty that is considered for analysis. Specifically, we were forced to choose between two discrete alternatives: to capture the imperfect correlation that exists between the probabilities that each partner in a cohabitating relationship receives a wage offer, or to capture the imperfect correlation between the year to year variation of in-work labour incomes of spouses. We chose the former option, as we believe that behaviour regarding female labour supply and fertility is likely to be more sensitive to uncertainty over the receipt of wage offers than it is to heterogeneous variation of the human capital of each partner in cohabitating relationships. Sensitivity analysis in relation to each of these issues remains an issue for further research.

To mitigate computation time we have ignored the stochastic term described in equation (8) for

[11] The assumption of a discrete labour supply decision implies that the proportional relationship between preferred consumption and labour supply would not be a fixed function of the price ratio, even if wages were exogenous in the context that is considered here.

simulating the incomes of new male partners, and have assumed that the human capital of each adult in established couples evolves stochastically, subject to perfectly correlated innovations. Note that ignoring the stochastic term in equation (8) does not imply that single women are considered to know with certainty their future partners' wages. This is because women remain uncertain about the future of their own wages, upon which the wages of their potential spouses are considered to depend. Furthermore, they do not know whether either they, or their future partner, will receive a wage offer. Nevertheless, the effect of omitting the stochastic term of equation (8) will be to reduce the extent of uncertainty associated with labour income when entering a new cohabitating relationship, and to reduce the dispersion of aggregate labour incomes amongst newly cohabitating couples.

The assumption that the incomes of established couples evolve subject to perfectly correlated innovations will tend to exaggerate the dispersion of aggregate labour incomes for cohabitating couples, thereby off-setting the understatement of dispersion amongst newly cohabitating couples. Furthermore, it is of note that allowing for imperfect correlation in the receipt of wage offers by each partner in a cohabitating relationship implies that the model is sufficiently flexible to capture at least part of the insurance effect of spousal labour supply.

3.4 Modelling adults and children

All households in the model are comprised of either one or two adults, as we follow women through their respective life-courses and allow for cohabitating partners; all other adults that might share the same residence in practice – including off-spring who are older than 17 years of age – are assumed to constitute separate households. The relationship status of women is considered to be uncertain between adjacent years, subject to age dependant probabilities of relationship formation and dissolution. These probabilities do not depend upon whether there are dependant children in the household due to associated data limitations. Associated sensitivity analysis to this assumption remains an issue for further research.

The number of children in a household is an endogenous decision, which is considered to be made between discrete alternatives. The fact that children typically remain dependant in a household for a limited number of years means that it is necessary to record both their numbers and ages when including them in a life-cycle model such as this, which substantially exaggerates the computational burden. If, for example, a household was considered to be able to have children at any age between 20 and 45, with no more than one birth in any year, and no more than six dependant children at any one time, then this would add an additional 334,622 state variables to the computation problem (with a proportional increase in computation time). It was consequently necessary to limit fertility decisions to a number of discrete 'birth ages'. Households are assumed to have perfect control over their fertility decisions at each of these birth ages, subject to an upper limit on the number of births that can take place at each. Once born, children are assumed to remain dependants of the woman until they exceed 17 years of age.

3.5 Model solution procedure

Structural analyses of behavioural responses to changes in the decision making environment most commonly make a series of assumptions that permit the solution of utility maximising decisions in the form of estimable equations. Analysis then proceeds by a) applying standard regression techniques to estimate the parameters of the assumed model, and b) conducting behavioural experiments given the model's estimated parameters. The focus of the current study, however, implies that we are unable to make the assumptions that are necessary to solve for closed form regression equations. This is due to our concern with female labour market opportunities, and the uncertainty that is associated with their intertemporal development. As no analytical solution exists to our behavioural problem, we use numerical methods to undertake our analysis. Nevertheless, the main features of our analysis remain the same as those of structural analyses more generally: we postulate a behavioural framework (as described above), we specify the parameters of the assumed model to reflect observations drawn from survey data (described in the next section), and we then conduct behavioural experiments given our estimated model (reported in Section 5).

The numerical analysis that we use for the current study proceeds in two discrete stages. The first involves solving for decisions that maximise expected lifetime utility, given any potential combination of household characteristics. That is, if we were randomly to select one woman from the adult population, then the first stage of analysis should describe the decisions of that woman's household that will maximise expected lifetime utility, given our assumed preference structure and intertemporal dynamics, the woman's age, her relationship status, the number of dependant children, and the household's labour market opportunities. The second stage of analysis then uses Monte Carlo methods and the information provided by the first stage to project the entire life course for a synthetic birth cohort. The analyses that are reported here are based upon the panel data generated for synthetic birth cohorts.

Regarding the first stage of analysis referred to above, the procedures required to solve for utility maximising decisions in the context of uncertainty are now routine, and the current study is based upon the approach adopted by Sefton et al. (2008). In brief, this involves dividing the state space – that is, all of the characteristics that a household may potentially have – into a series of age specific grids, with log scales used for continuous state variables to provide greater detail where the population is likely to be concentrated. Backward induction methods based upon Euler conditions are then used to solve for the single continuous control variable (consumption) at each of the grid loci, given an assumed combination of the discrete control variables (leisure and fertility). A decision is then considered to be made on the basis of the associated value function. Gaussian quadrature is used to evaluate expectations taken over the log-normal distributions that are assumed for the sex specific income processes, and cubic interpolation is used to evaluate behaviour between grid loci. This approach is standard in most respects, with the exception of its reliance on Euler conditions.

The reliance on Euler conditions to solve for utility maximising decisions is complicated in our context because the value function is neither smooth, nor concave (though it is increasing and continuous). Non-concavities arise because the fertility and labour supply decisions are considered to be made between discrete alternatives, and because the budget set is non-convex (due to income tests imposed on welfare benefits). These non-concavities imply that Euler conditions may not identify the global optima with which we are concerned.

A number of alternative approaches can be used to guard against the selection of sub-optimal decisions in the current context. French (2005), for example, adopts a brute-force method by searching across the grid that defines all possible combinations of his assumed control variables. This is very time consuming, which complicates calibration and associated analysis. The approach that we adopt involves two discrete stages. In the first stage, we use the Bus & Dekker (1975) bisection algorithm to search over all feasible (bounded) consumption choices for a value (of consumption) that satisfies the associated Euler condition. Having found a local optimum, we use a localised grid to search above and below for an alternative solution.[12] If an alternative is found, then we search recursively for any further solutions above and below. This is repeated until no further solutions are found. From these solutions we select only those that are feasible.[13] Of all feasible solutions, the one associated with the highest evaluation of the value function is selected. This is relatively straightforward for our decision problem, as we are concerned with a single continuous control variable (consumption).

4 Model Calibration

The model calibration that is reported here was arrived at by the following two-stage procedure. In the first stage, estimates were obtained for observable model parameters, based upon historical survey data. Given the estimates obtained in the first stage, values for the unobserved parameters of the model were calibrated in the second stage. This second stage involved generating a simulated population cohort based upon assumed starting values for the unobserved model parameters, and the model parameters

[12] This involved projecting a limited grid about an identified solution, and evaluating the first order condition for the Euler maximisation problem at each point on the revised grid. If the first order condition was found to have the opposite sign to it's value at the associated limit (lower bound, for grid points below the identified solution, and upper bound otherwise) at any point on the revised grid, then the bisection algorithm was reapplied to solve the associated Euler conditions for the local maximum.

[13] This was a check that the marginal change in the value function with respect to wealth is locally increasing. Non-smoothness in the value function implies jumps in marginal rates. The interpolation routines will tend to smooth these jumps, possibly introducing an infeasible solution to the Euler equation.

estimated in the first stage (following the methods described in Section 3.5). Unconditional 'simulated moments' for employment, fertility and consumption were calculated for the simulated population, and compared against associated 'sample moments' estimated from survey data. The unobserved model parameters were then adjusted to fit the simulated moments as best we could to the sample moments.

This section begins by describing the parameters obtained in the first-stage estimation, before moving on to the second stage. In the interests of clarity, all parameter estimates for the 1953 female birth cohort are reported in Table 13. Details regarding the principal data sources considered for the calibration can be found in Appendix A. Throughout the text that follows, we use the anagram EFS to refer to pseudo panel data reported by repeated cross-sections of the Family Expenditure Survey from 1972 to 2000/01, and the Expenditure and Food Survey from 2001/02 to 2005/06.

4.1 First stage estimates for observable model parameters

Life expectancy and limits of the considered lifetime

We consider decisions by households with women aged 21 and over. This starting age was selected to capture the timing of fertility early in life as reported by survey data for the 1953 birth cohort.

The survival probabilities assumed for the current study are based upon the principal projections for female cohort life-expectancy produced by the Office for National Statistics (ONS).[14] Male probabilities of life expectancy enter the model through the probabilities that are assumed for relationship dissolution, as is discussed below. The projections for life-expectancy considered for analysis embody official estimates for the trend improvement of future mortality rates, and their use in estimating the model is consistent with our assumption of rationally behaved agents.

We assume a maximum age of life of 110 in the current analysis; $T = 110$. The official data permit annual mortality rates to be calculated to age 94. Mortality probabilities between ages 95 and 110 were exogenously specified to obtain a smooth progression from the official estimate at age 94 to a 100% probability of mortality at age 110.

The tax function and retirement annuities

The tax function, τ, considered for analysis is a stylised representation of the tax and benefits system that was applied in the United Kingdom (UK) in 2005. It is considered to depend upon labour supply, wealth, non-property income, demographic size, and age. The age dependency assumed for the tax function divides the lifetime into two periods: the working lifetime $t < t_{SPA}$, and retirement $t_{SPA} \leq t$, where $t_{SPA} = 65$ is assumed for analysis.[15]

[14] The life tables considered here are based on historical mortality rates from 1981 to 2006, and assumed calendar year mortality rates thereafter.

[15] The state pension age in 2005/06 was 60 for women and 65 for men. Current legislation implies that the state pension age for both men and women in the UK will be 65 from 6 April 2020. It is subsequently scheduled to increase from 65 to 68 between 2024 and 2046.

During the working lifetime, the tax function is specified to reflect profiles reported in the 2005 *Tax Benefit Model Tables* (TBMT) issued by the Department for Work and Pensions.[16] These profiles reflect the incidence of income taxes, National Insurance Contributions, the Child Benefit, the Working Tax Credit and the Child Tax Credit. Although this list omits a great deal of the detail of the UK tax and benefits system, it does include the principal schemes that affected healthy families with children during 2005.

The specification of the tax function during retirement, $\tau(.)$, $t \geq t_{SPA}$, is based upon the Basic State Pension (which is assumed to be received by every household), and the Pension Credit as they were applied in the UK during 2005/06. Benefits payable under the Pension Credit were means tested, being withdrawn in regard to both private assets and income in retirement. Of the various holdings that are included in the composite asset considered for analysis, $w_{i,t}$, two classes are omitted from the means tests that were applied by the Pension Credit: owner occupied housing, and the first £6,000 of additional wealth. In the current analysis this is reflected by applying an income test only, and assuming that 50% of liquid wealth is annuitised at retirement, $\eta = 0.5$ (implying that 50% of wealth is exempt from means testing).

Full details of the tax and benefit schedules considered for analysis are reported in Appendix B. Our focus on the labour market opportunities of women, however, makes the tax treatment of childcare costs a particular issue of concern, which we discuss at further length here.

In 2005/06, working parents could claim 70% of childcare costs under the (means tested) Working Tax Credit.[17] The EFS is the only data source that provides details regarding the costs of childcare for the entire time period with which we are concerned. Unfortunately, however, the data collected by the EFS in this regard are not very comprehensive, nor is the sample sufficiently large to provide precise estimates for all of the population subgroups of interest.[18] We consequently report EFS sample statistics for the costs of childcare alongside comparable statistics derived from the Family Resources Survey (FRS), which address the afore mentioned limitations of the EFS, but were only collected from 1994.[19]

Preliminary analysis of both the EFS and FRS data indicated that the costs of childcare are strongly influenced by the age of children. Three child age groups were identified: children under 5 years

[16] See http://www.dwp.gov.uk/asd/tbmt.asp. Underlying spreadsheets were provided by Sean Gibson from the Dissemination Unit, DWP.

[17] Eligibility was limited to UK residents aged 16 or over, working at least 16 hours per week (a restriction that also extended to cohabitating partners) with children under 15 years of age. The Working Tax Credit only made allowance in relation to costs incurred for officially "registered" childcare.

[18] The costs of childcare were only included as a separate item in the EFS from 1992, and were aggregated with the costs of other household domestic help (including window washers, maids, etc.) before that year.

[19] Analysis by Brewer & Shaw (2004) indicates that the Family Resources Survey tends to understate the incidence of low cost (or free) forms of childcare. Nevertheless, estimates of the average costs of childcare derived from the Family Resources Survey are very similar to those obtained from alternative data sources (Section 3.3 of Brewer & Shaw (2004)).

of age for whom childcare costs tend to be relatively high, children between 5 and 13 years of age for whom childcare costs are non-negligible but appreciably lower, and children aged 14 and over for whom childcare costs can reasonably be ignored.[20] Furthermore, we failed to find systematic evidence of economies of scale in the costs of childcare provision with respect to the number of children in a household. Figure 9 consequently reports the average childcare costs per child, distinguished by year, female relationship status, female employment status, and age of child. As for all other financial statistics reported in the remainder of this paper, the childcare costs displayed in Figure 9 are discounted by the National Accounts consumption deflator, and are expressed as proportions of the average gross weekly earnings of all full-time employees in the UK for 2005 Q4.[21]

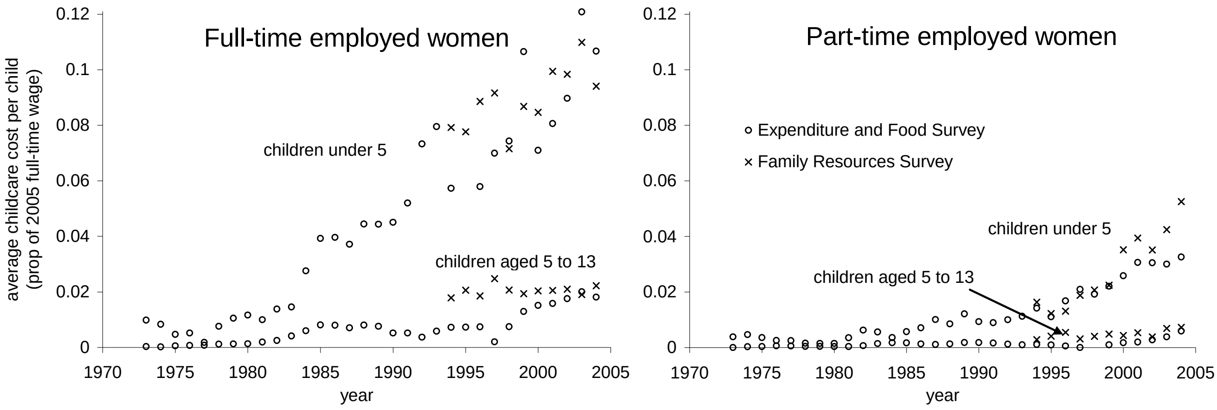
Figure 9 indicates that the average childcare costs measured by the EFS are of a similar magnitude to those estimated from FRS data, where FRS data are available. The statistics suggest that average childcare costs per child have grown substantially since the mid 1970s. Average childcare costs for children under 5 were almost six times as high as those for children between 5 and 13 years of age in 2004, excluding part-time employed women with partners for whom average childcare costs of children between 5 and 13 years of age were negligible. Furthermore, for all but full-time employed women with partners, the growth in average childcare costs described by the EFS data is approximately captured by a fixed exponential rate.

Nevertheless, the childcare costs reported by the EFS tend to understate those implied by the FRS for all but full-time employed single women with children under 5. That this is the case is of little surprise, given that the EFS makes explicit reference to childcare payments, nursery, creche, and playschool costs, but does not include reference to other forms of child-minding that are commonly taken into consideration by alternative data sources (such as after school clubs, holiday play schemes, and regular time spent with friends, or relatives). In this regard, it is of note that the EFS definition of childcare costs focusses more explicitly on forms of childcare which are eligible for claim under the Working Tax Credit than does the FRS definition. Furthermore, the real growth rates for childcare costs implied by the EFS data – which vary between and 7.3 and 14.8% per annum – appear very high, due in large part to the particularly low costs reported for the 1970's.

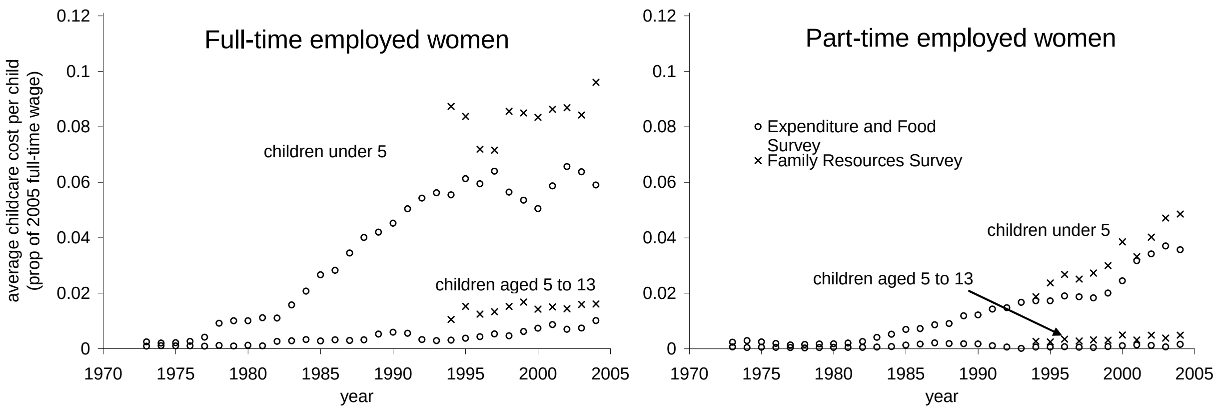
Given these observations, and the data limitations to which we are subject, we opted to base childcare costs on the statistics calculated from EFS data in the first instance, taking into account temporal variation through an exponential growth rate for all but the childcare costs incurred by full-time employed women with partners and children under 5 (for whom a constant arithmetic increase

[20] This is consistent with observations reported by Brewer & Shaw (2004), see figure 3.18.

[21] For the household sector consumption deflator, see ONS code YBFS. The average gross weekly earnings of all full-time employees in the UK for 2005 Q4 was £466 per week, as reported in the *Labour Force Survey Historical Quarterly Supplement*, Table 35 (available from the National Statistics website: http://www.statistics.gov.uk/).



Panel A: single women



Panel B: women with partners

Notes: Authors' calculations using data from Expenditure and Food Survey (EFS) and Family Resources Survey (FRS)
All statistics expressed as a proportion of average gross full-time employment income in 2005 Q4, equal to £466 per week
Childcare costs by year discounted by the National Accounts consumption deflator
EFS estimates based upon a moving pool of three years' cross-sectional data
FRS estimates based upon cross-sectional data from the relevant year only

Source: see Appendix A for details regarding the EFS and FRS data used.
price deflator data from Office for National Statistics, code YBFS

Figure 9: Childcare Costs by Year, Child Age, and Mother's Employment Status: single women and women with partners

in the average cost per child was assumed). These statistics were then adjusted as part of the model calibration that is reported in the following subsection.

An additional issue raised by the above discussion of childcare costs is the indexing that was assumed for the tax function more generally. For the current analysis, we assume that:

- tax thresholds grow at the rate of 0.6% per annum. This is the real rate of growth of the basic rate tax threshold observed between 2000/01 and 2006/07.[22]
- welfare benefits grow at a rate of 1.9% per annum, which is based upon a weighted average of the real rates of growth observed for the Child Benefit, unemployment benefits, and the Basic State Pension between 1948 and 2007.[23]

Interest rates

- The rate of return to positive holdings of net liquid wealth $\left(r^I\right)$ is assumed to be 2.9% per annum. This is based upon the average nominal interest rate of 4.9% per annum returned by banks and building societies to cash ISAs during the period between April 1999 and December 2006.[24]
- The average real interest charges applied between January 1995 and January 2006 to credit card loans, and to unsecured personal loans in excess of £10,000, were, respectively, 18.0% and 9.7% per annum.[25] The lower limit cost of debt $\left(r_l^D\right)$ assumed for analysis was consequently set to 8% per annum, and the upper limit $\left(r_u^D\right)$ to 18%.

Distinguishing the implications of alternative labour supply decisions

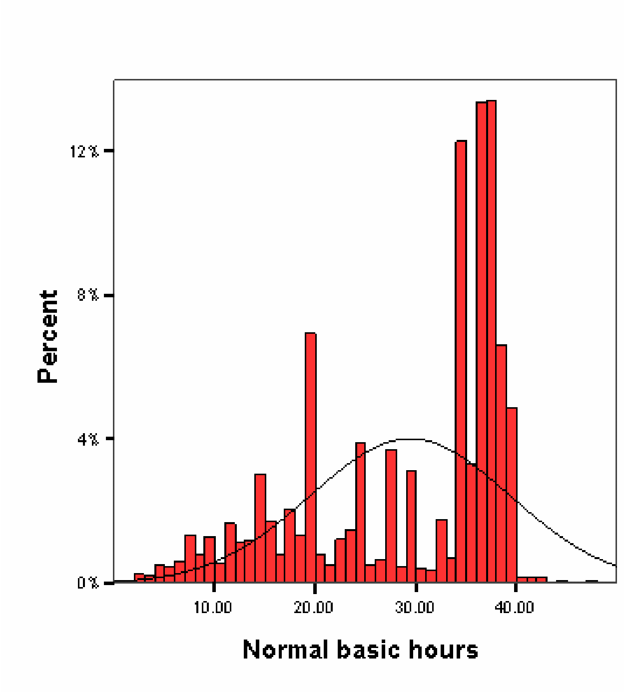
The employment categories that are considered for analysis were selected after considering the distribution of hours of employment by age. The density function of hours worked for employed women aged 32 and born between 1952 and 1954 is reported in Figure 10, which is representative of the working lifetime more generally. Figure 10 indicates a number of discrete spikes in the density function, about 20 hours for the part-time employed, and about 37-38 hours for the full-time employed. It is this observation that is a key motivation behind our decision to focus upon discrete (rather than continuous) labour alternatives.

[22] The Institute for Fiscal Studies report historical data for the tax schedule. The period of analysis considered here was selected because it exhibits stability in the underlying structure of taxation.

[23] Data reported by the Institute for Fiscal Studies indicate that the Child Benefit has grown in nominal terms by 10.4% per annum between 1977 and 2006 for the first child, and by 7.3% per annum for each subsequent child. Over that same period, the consumer price deflator grew by 4.8% per annum. Similarly, between 1948 and 2006, the nominal value of unemployment benefits rose by 6.8% per annum for single adults without children, and by 6.7% per annum for childless couples, while the consumer deflator rose by 5.5% per annum. And the Basic State Pension rose by 7.4% per annum (for both singles and couples) between 1948 and 2007. The real rate of growth of each of these benefits were weighted by their approximate years of application during the lifetime: 17 years for child related benefits, 45 years for the unemployment benefits, and 15 years for the retirement benefits. The periods considered for analysis are based upon the duration for which data were available.

[24] See Bank of England code IUMWTIS.

[25] See Bank of England, codes IUMCCTL and IUMHTPL. The rate of inflation during the period was 2.1%.



Notes: Authors' calculations using data from the New Earnings Survey

Figure 10: Density Functions of Hours of Employment for Women Aged 32 and Born in 1952-54

We equate the hours of employment for full-time and part-time work in the model to population averages by age, sex and birth cohort that are described by NES data: these are reported in Table 2. It is of note, however, that this approach to modelling labour supply fails to capture the variation in hours of work that is described by the density function reported in Figure 10. An appreciation of the scale of this issue can be gained by considering the dispersion of hours of employment that underlie the population averages reported in Table 2, which are displayed graphically in Figure 11.

Figure 11 indicates that the dispersion of hours for the full-time employed is fairly tight around the sample mean, but is wider and expands with age for the part-time employed. This variation is not captured by the simulation model considered for analysis here.

The distribution of wages for women at age 21

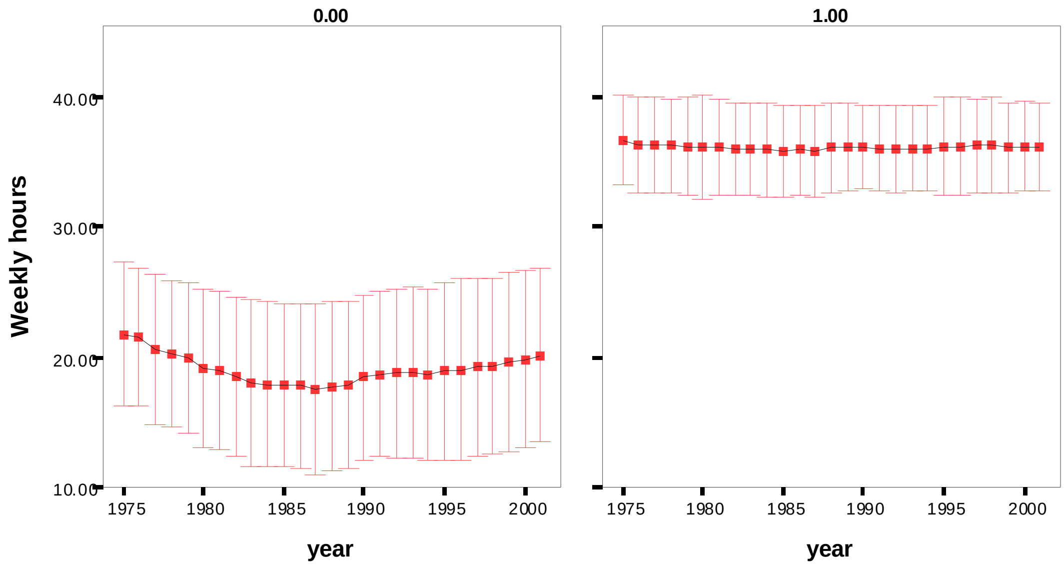
When women are first introduced into the synthetic cohorts generated by the model, they are each allocated a value for human capital that is randomly drawn from a log-normal distribution. The parameters of the log-normal distribution for the 1953 and 1963 birth cohorts were each estimated from EFS data reported for 21 year old women in the five adjacent years spanning the respective cohorts of interest. After omitting observations for the self employed, this gave a population of 549 observations for the 1953 birth cohort, and 598 observations for the 1963 cohort.[26] In both cases just over half

[26] Data for the self employed were not used to estimate the wage parameters reported here to maintain consistency with the NES data source that was used to estimate parameters for the dynamic wage processes that are discussed below.

Table 2: Average Number of Hours Worked by Age, Sex, Employment Status, and Birth Cohort

1953 birth cohort			1963 birth cohort		
women		men	women		men
full-time employed	part-time employed	all employed	full-time employed	part-time employed	all employed
37.07	22.45	39.08	37.10	19.49	38.52
36.81	21.83	38.97	37.02	19.35	38.44
36.56	21.21	38.85	36.91	19.29	38.40
36.41	20.61	38.75	36.87	19.01	38.40
36.38	20.13	38.68	36.83	18.77	38.40
36.30	19.66	38.58	36.80	18.42	38.39
36.24	19.35	38.50	36.75	18.06	38.35
36.15	18.88	38.34	36.68	17.77	38.31
36.09	18.51	38.23	36.64	17.69	38.28
36.03	18.12	38.09	36.63	17.64	38.28
35.98	17.94	38.03	36.70	17.63	38.36
35.97	17.87	38.01	36.76	17.68	38.43
35.96	17.75	38.00	36.77	17.85	38.50
36.05	17.71	38.02	36.74	18.16	38.52
36.13	17.73	38.05	36.69	18.43	38.55
36.21	17.99	38.07	36.71	18.66	38.58
36.18	18.33	38.04	36.72	18.93	38.56
36.13	18.61	38.00	36.74	19.30	38.52
36.09	18.77	37.98	36.74	19.33	38.52
36.09	18.75	38.01	36.73	19.36	38.52
36.15	18.79	38.13	36.73	19.39	38.53
36.21	18.84	38.21	36.72	19.42	38.53
36.26	19.01	38.28	36.72	19.45	38.54
36.30	19.17	38.29	36.72	19.48	38.54
36.26	19.36	38.28	36.71	19.51	38.54
36.26	19.48	38.33	36.71	19.54	38.55
36.21	19.71	38.29	36.70	19.57	38.55
36.23	19.99	38.27	36.70	19.60	38.56
36.25	20.14	38.27	36.70	19.69	38.56
36.26	20.29	38.28	36.70	19.78	38.57
36.27	20.44	38.29	36.70	19.86	38.57
36.28	20.59	38.30	36.70	19.95	38.58
36.29	20.75	38.31	36.70	20.04	38.58
36.31	20.90	38.31	36.70	20.13	38.59
36.32	21.05	38.32	36.70	20.21	38.59
36.33	21.20	38.33	36.71	20.30	38.60
36.34	21.43	38.34	36.71	20.53	38.61
36.36	21.65	38.35	36.71	20.75	38.62
36.37	21.88	38.36	36.71	20.98	38.62
36.39	22.10	38.37	36.71	21.20	38.63
36.40	22.33	38.37	36.71	21.43	38.64
36.42	22.55	38.38	36.71	21.65	38.65
36.43	22.78	38.39	36.71	21.88	38.66
36.45	23.00	38.40	36.71	22.10	38.66

Source: Authors' calculations using NES data - see the data appendix for details



Notes: Authors' calculations using data from the New Earnings Survey

Figure 11: Mean Labour Hours +/- 1 Standard Deviation, by Age and Employment Status of Women Born in 1952-1954; left hand panel describes part-time employment and right hand panel describes full-time employment

of the respective population samples were reported as being full-time employed. To control for non-random censoring, a regression procedure that adjusts for sample selection was used to undertake the estimation.[27] Regression statistics are reported in Table 3, which indicates that the mean of log full-time weekly wages for women aged 21 in 1953 was 5.186, and that the standard deviation was 0.341 (implying an average income of £189.52 per week, or 41% of average gross earnings of all full-time employees in 2005).

Male wages at time of relationship formation

In view of the data that were available for estimation, we assume that male wages at the time of relationship formation are indistinguishable from male wages of the married population more generally. Equation (8) was estimated using EFS data and a sample selection regression model. Data were omitted for any household with an adult member identified as self-employed. To mitigate small sample issues,

Furthermore, casual observation of labour income data reported by the self employed revealed substantially more – and in many cases implausible – variation than observed for employees.

[27] We used the "heckman" procedure in STATA 10.0; see Heckman (1979) for details. We also explored how far the estimates were likely to have been influenced by continued education: 15% of women born between 1952 and 1954 reported having completed their full-time education after age 20 in the 2001/02 to 2005/06 waves of the EFS. To check for selection bias in this respect, we calculated similar sample selection regression estimates to those reported here for women aged 22, 23, 24 and 25, and compared the age trend described by the estimates obtained for higher ages against the estimates reported here for age 21. As this analysis failed to reveal variation of qualitative importance we omit further discussion here.

Table 3: Estimates for the Distribution of Wages of Full-time Employed Women Aged 21, by Birth Cohort

	1953 Birth Cohort		1963 Birth Cohort	
Observations	549		598	
Censored	239		285	
Uncensored	310		313	
Variable	coef	std error	coef	std error
log wage	5.18649	0.02630	5.30416	0.03644
Selection equation				
children under 5	-2.23074	0.22775	-1.91185	0.21952
consumption	0.00112	0.00052	0.00345	0.00067
in relationship	-0.07581	0.16224	-0.48549	0.17679
constant	0.49793	0.09932	0.03070	0.09943
rho*	-0.70189	0.09125	-0.48731	0.17677
sigma**	0.34071	0.01883	0.29694	0.01797

Source: authors' calculations using EFS survey data
rho* correlation between error terms of objective and sampling functions
sigma** standard deviation of objective function error term

data for three female birth cohorts – 1952-1954 in the case of the 1953 birth cohort, and 1962-1964 for the 1963 birth cohort – were considered for estimation. Regression statistics are reported in Table 4.

The parameters reported in Table 4 indicate that the correlation between the full-time wages of cohabitating partners increased significantly from the 1953 to the 1963 female birth cohort, just as the importance of children on the relationship declined.[28] Furthermore, the estimated parameters reported for rho in Table 4 indicate that sample selection had a more pronounced influence on the parameter estimates reported for the 1953 birth cohort.

The model requires the parameters of equation (8) to be defined for all ages at which new relationships and employment are considered to be possible. Unfortunately the data that are currently available do not extend beyond age 52 for the 1953 cohort, and age 42 for the 1963 cohort. As employment is considered to be possible to age 64, it was consequently necessary to project age parameters forward for both cohorts. The coefficients reported in Table 4 for dummy variables by age describe an increasing trend, at a decreasing rate. This impression was reinforced by estimates obtained for eight alternative cohorts (not reported here). On the basis of these observations, we assumed that, for the 1953 cohort, the same age parameter applies for all women in excess of age 50. With regard to the 1963 cohort, we assumed that the age effects evolve with the same absolute changes as estimated for the 1953 birth cohort to age 50, and are flat thereafter. The parameters assumed for analysis of the 1953 birth cohort are reported in Table 13.

Wage dynamics

The specification of intertemporal wage dynamics was one of the most complex and fragile aspects of the model's specification. As noted in Section 3.3, computational limitations restricted the heterogeneity

[28] A series of specification tests failed to reveal any systematic variation with age of the correlation term between spousal wages from full-time employment.

Table 4: Estimates for Parameters of Male Wages at the Time of Relationship Formation

	1953 Birth Cohort		1963 Birth Cohort	
Observations	10521		9601	
Censored	8389		7990	
Uncensored	2132		1611	
Variable	coef	std error	coef	std error
Wage Equation				
ln(ft wage of wife)***	0.26245	0.02661	0.39952	0.04010
wife's age group				
21-25	0.06051	0.04652	0.14151	0.06785
26-30	0.18635	0.04836	0.26602	0.06757
31-35	0.27215	0.05077	0.33753	0.06810
36-40	0.35467	0.05167	0.38176	0.06941
41-45	0.38029	0.05110	0.34248	0.07347
46-50	0.45623	0.05240	-	-
51-55	0.44115	0.06173	-	-
number of children				
aged 0-4	0.10910	0.03626	-0.04558	0.03406
aged 5-13	0.05656	0.01666	-0.00173	0.02132
aged 14-17	0.07517	0.01911	-0.09904	0.03260
constant	4.29119	0.15786	3.45930	0.26916
Selection Equation				
male's age group				
21-25	1.64662	0.18979	1.86715	0.22982
26-30	1.27258	0.18769	1.83266	0.22885
31-35	1.08682	0.18842	1.62905	0.22880
36-40	0.90376	0.18874	1.50058	0.23058
41-45	0.76343	0.18817	1.32931	0.23260
46-50	0.54534	0.18764	1.15583	0.24544
51-55	0.25705	0.19059	1.33712	0.29120
56-60	-0.08123	0.22205	1.04290	0.40668
61-65	-0.86519	0.31127	-	-
66+	-1.32513	0.55004	-	-
married	3.01539	0.25610	2.82336	0.26985
number of children				
aged 0	-0.40269	0.10143	-0.03249	0.07875
aged 0-4	-0.96415	0.05991	-0.87761	0.05219
aged 5-13	-0.46688	0.02701	-0.45206	0.03038
aged 14-17	-0.16381	0.04165	-0.18409	0.06419
consumption	0.00030	0.00008	-0.00019	0.00010
wife's wage	0.00344	0.00010	0.00409	0.00013
constant	-4.66425	0.21932	-4.91562	0.21945
rho*	-0.33763	0.07563	0.10851	0.14243
sigma**	0.38903	0.00809	0.38853	0.00738

Source: authors' calculations using EFS survey data

rho* correlation between error terms of objective and sampling functions

sigma** standard deviation of objective function error term

ln(ft wage of wife)*** log of wage of wife, where wife is full time employed that is explicitly taken into account by the wage generating process. Econometric estimation of the wage generating process is consequently likely to be affected by omitted variable bias, in addition to the sample selection issues that are well recognised to affect wage equations of this type (particularly for women). We consequently calculated econometric estimates of the wage generating procedures as a starting point from which to base associated model calibration, reported in Section 4.2.

Estimation of the wage process was undertaken in two discrete stages. In the first stage, we estimated the parameters of the (sex specific) dynamic equations for employment. Parameters of the dynamic equations assumed when individuals were not employed were then estimated, given the estimates obtained in the first stage for the 'employment parameters'.

Parameter estimates for wage dynamics during periods of continuous employment were based upon the following form of the full-time and part-time elements of equation (9), with y substituted for h as defined by equation (7):

$$\ln y_{i,t}^{k} = \beta^{k} \ln y_{i,t-1}^{k} + \lambda_{1,t}^{k}.PTdum_{i,t}^{k} + \lambda_{2,t}^{k}.TimeDum_{t} + \lambda_{3,t}^{k}.PTdum_{i,t-1}^{k} + \xi_{i,t}^{1,k} \tag{10}$$

$$\begin{aligned} where &: \lambda_{1,t}^{k} = \ln \phi_{t}^{k} \\ &: \lambda_{2,t}^{k} = \ln \mu_{t}^{k} - \beta^{k} \ln \mu_{t-1}^{k} \\ &: \lambda_{3,t}^{k} = \alpha_{2,t-1}^{k} - \beta^{k} \ln \phi_{1,t-1}^{k} \end{aligned} \tag{11}$$

where $PTdum$ are dummy variables that take the value 1 if individual k from household i is part-time employed at age t, $TimeDum_t$ are dummy variables that take the value 1 at age t, $\xi_{i,t}^{1,k}$ is an error term, and all other terms are as defined previously. As the full-time / part-time employment distinction is considered only for women, the $PTdum$ terms do not appear in the regressions undertaken for men. Full details of the regression procedure adopted for analysis are reported in Appendix A.

Interpretation of the regression results reported in Tables 5 and 6 is facilitated by re-specifying the results in the form of the model parameters described by equation(9); associated statistics are reported for women in Table 7. These parameter values – which formed a starting point for the calibrations that are reported in the following subsection – indicate that the estimated model parameters do a good job of capturing the age profiles described by the geometric means of full-time employment income reported in the EFS, with a tendency for the μ's to understate the levels described by survey data. This later result is consistent with the bias that is commonly assumed to exist between the (conditional) mean described by survey data for (observed) wages, and the (unconditional) mean of the underlying distribution of human capital. The estimates for β indicate strong inter-temporal persistence of wages, particularly for the 1963 birth cohort. Similar estimates were obtained for ϕ for the two birth cohorts, with a tendency for the proportion of full-time wages earned through part-time employment to increase with age.

Table 5: Regression Estimates for Dynamic Wage Equations of the Continuously Employed

	women 1953 cohort		men 1953 cohort		women 1963 cohort		men 1963 cohort	
Variables	Coeffs	robust std. error	Coeffs	robust std. error	Coeffs	robust std. error	Coeffs	robust std. error
ln(y t-1)	0.728	0.028	0.880	0.040	0.863	0.028	0.925	0.023
PTdum2 t-1	0.333	0.135						
PTdum3 t-1	0.242	0.084						
PTdum4 t-1	0.337	0.112						
PTdum5 t-1	0.426	0.113						
PTdum6 t-1	0.294	0.079						
PTdum7 t-1	0.369	0.083						
PTdum8 t-1	0.292	0.069						
PTdum9 t-1	0.289	0.074						
PTdum10 t-1	0.273	0.075			0.714	0.197		
PTdum11 t-1	0.325	0.065						
PTdum12 t-1	0.410	0.068			0.534	0.055		
PTdum13 t-1	0.356	0.073						
PTdum14 t-1	0.352	0.053						
PTdum15 t-1	0.421	0.062			0.529	0.043		
PTdum16 t-1	0.354	0.048						
PTdum17 t-1	0.314	0.037						
PTdum18 t-1	0.275	0.046			0.496	0.034		
PTdum19 t-1	0.266	0.046						
PTdum20 t-1	0.292	0.044						
PTdum21 t-1	0.238	0.041			0.431	0.030		
PTdum22 t-1	0.282	0.040						
PTdum23 t-1	0.313	0.048						
PTdum24 t-1	0.247	0.044			0.380	0.028		
PTdum25 t-1	0.251	0.042						
PTdum26 t-1	0.338	0.049						
PTdum27 t-1	0.283	0.070			0.367	0.033		
PTdum2 t	-0.540	0.170						
PTdum3 t	-0.389	0.083						
PTdum4 t	-0.589	0.123						
PTdum5 t	-0.634	0.115						
PTdum6 t	-0.494	0.083						
PTdum7 t	-0.586	0.089						
PTdum8 t	-0.468	0.072						
PTdum9 t	-0.463	0.077						
PTdum10 t	-0.425	0.075						
PTdum11 t	-0.493	0.067			-0.595	0.063		
PTdum12 t	-0.563	0.070						
PTdum13 t	-0.522	0.073						
PTdum14 t	-0.484	0.054			-0.595	0.042		
PTdum15 t	-0.588	0.063						
PTdum16 t	-0.465	0.048						
PTdum17 t	-0.443	0.038			-0.561	0.028		
PTdum18 t	-0.415	0.047						
PTdum19 t	-0.411	0.044						
PTdum20 t	-0.427	0.046			-0.517	0.025		
PTdum21 t	-0.415	0.042						
PTdum22 t	-0.405	0.042						
PTdum23 t	-0.457	0.050			-0.424	0.022		
PTdum24 t	-0.377	0.046						
PTdum25 t	-0.394	0.044						
PTdum26 t	-0.475	0.052			-0.403	0.026		
PTdum27 t	-0.429	0.068						
TimeDum2	-0.011	0.008	0.038	0.036				
TimeDum3	-0.093	0.007	-0.051	0.033				
TimeDum4	-0.043	0.007	0.019	0.033				
TimeDum5	-0.072	0.006	-0.006	0.032				
TimeDum6	Dropped		0.048	0.030				
TimeDum7	0.015	0.007	0.039	0.027				
TimeDum8	-0.026	0.008	0.019	0.025				
TimeDum9	0.007	0.009	0.026	0.025				
TimeDum10	-0.006	0.010	0.025	0.022	0.005	0.008	Dropped	
TimeDum11	0.001	0.010	0.024	0.022	Dropped		-0.003	0.010
TimeDum12	0.032	0.011	0.043	0.020	0.027	0.007	0.020	0.010
TimeDum13	0.020	0.012	0.041	0.018	0.027	0.008	0.000	0.011
TimeDum14	0.053	0.013	0.058	0.017	0.048	0.010	0.018	0.012
TimeDum15	0.056	0.015	0.044	0.015	0.032	0.012	0.006	0.014
TimeDum16	0.057	0.016	0.047	0.014	0.019	0.014	-0.011	0.015
TimeDum17	0.051	0.016	0.032	0.012	0.011	0.015	-0.034	0.016
TimeDum18	0.056	0.017	0.036	0.011	0.000	0.016	-0.032	0.017
TimeDum19	0.047	0.018	0.027	0.011	-0.028	0.017	-0.037	0.017

Notes: Regression results split into two tables. See Table 6 for remaining data.

Table 6: Regression Estimates for Dynamic Wage Equations of the Continuously Employed (continued)

	women 1953 cohort		men 1953 cohort		women 1963 cohort		men 1963 cohort	
Variables	Coeffs	robust std. error	Coeffs	robust std. error	Coeffs	robust std. error	Coeffs	robust std. error
TimeDum20	0.045	0.019	0.021	0.010	0.000	0.018	-0.036	0.017
TimeDum21	0.031	0.019	0.009	0.010	-0.038	0.018	-0.052	0.018
TimeDum22	0.035	0.020	0.024	0.009	-0.057	0.019	-0.034	0.018
TimeDum23	0.049	0.020	0.028	0.009	-0.018	0.019	-0.026	0.019
TimeDum24	0.059	0.022	0.026	0.008	-0.021	0.021	-0.027	0.020
TimeDum25	0.070	0.022	0.020	0.008	-0.026	0.022	-0.019	0.020
TimeDum26	0.080	0.023	0.035	0.008	-0.003	0.024	-0.020	0.021
TimeDum27	0.039	0.029	Dropped		-0.073	0.028	-0.049	0.022
constant	1.506	0.146	0.709	0.249	0.807	0.148	0.508	0.124
m1 p	0.000		0.000		0.000		0.000	
m2 p	0.000		0.000		0.000		0.000	
m3 p	0.472		0.330		0.087		0.777	
Sargan p	0.002		0.073		0.586		0.016	

Notes: The dependent variable is lnyt. All estimations by System GMM. Period 2 refers to 1976, etc up to period 27, which corresponds to 2001. Some time dummies were dropped by STATA due to collinearity and are referred to as 'dropped' in the table. All coefficients on part-time dummies are significant at the 1 or 5 percent level. First-, second- and third-order serial correlation p-values are reported as m1, m2 and m3.

Instrument sets:

Women 1953 For differenced eqn - GMM-type: L(3/12).lny FT L(3/12).lny PT ; Standard: D.(PTdum) LD.(PTdum) D.(TimeDum)

For level eqn - GMM-type: L2D.lny PT L2D.lny FT ; Standard: constant

Women 1963 For differenced eqn - GMM-type: L(3/10).lny; Standard: D.(3-year PTdum) LD.(3-year PTdum) D.(TimeDum)

For level eqn - GMM-type: L2D.lny; Standard: constant

Men For differenced eqn - GMM-type: L(3/12).lny; Standard: D.(TimeDum)

For level eqn - GMM-type: L2D.lny; Standard: constant

Finally, values reported for α_2 based upon data from the 1953 birth cohort indicate a substantial amount of 'noise' in the associated econometric estimates. This noise is dampened by the three year average estimates that we consider for the 1963 cohort. The estimates obtained suggest that part-time employment does tend to have a negative influence on future wage potential, although the time profiles described by the estimates obtained for the two birth cohorts of women are quite different. The regression statistics reported above imply that part-time employment early in the simulated life tends to have a negative influence on future wage potential for the 1953 birth cohort, whereas a positive effect is identified for the 1963 cohort. By their late 30s the estimates obtained for the two female birth cohorts suggest a similar (negative) effect of that part-time employment on future wage potential. These observations can be attributed to a more pronounced influence of education on the wages earned by the 1963 female birth.

It remains to describe estimation of the $\alpha_{3,t}^k$ parameters of equation (9). Given the parameter estimates that are described above, estimates for the $\alpha_{3,t}^k$ parameters were obtained by undertaking a regression of the following specification:

$$dif_{i,t}^k = \sum_{j=1}^{Z} \nu_j^k .Gap\left(j\right)_{i,t} + \xi_{i,t}^{2,k} \tag{12}$$

$$\begin{aligned} where \quad &: \quad \widehat{\ln y_{i,t-z}^k} = \hat{\beta}^k \ln y_{i,t-z-1}^k + \hat{\lambda}_{2,t-z}^k + \hat{\lambda}_{3,t-z}^k .d_{i,t-z-1}^k \\ &: \quad dif_{i,t}^k = \ln y_{i,t}^k - \hat{\lambda}_{1,t}^k .d_{i,t}^k - \left(\hat{\beta}^k\right)^z \widehat{\ln y_{i,t-z}^k} - \sum_{j=1}^{z} \left(\beta^k\right)^{z-j} \hat{\lambda}_{2,t-z+j}^k \\ &: \quad \nu_z^k = \sum_{j=1}^{z} \left(\hat{\beta}^k\right)^{z-j} \alpha_{3,j}^k \end{aligned}$$

Table 7: Parameters of Intertemporal Wage Process Implied by Regression Estimates Reported for Continuously Employed Women

	1953 cohort				1963 cohort			
		beta	0.7280			beta	0.8635	
		std error	0.2216			std error	0.2383	
age	phi	mu	alpha(2)	mean income^	phi	mu	alpha(2)	mean income^
21					0.5517	130.30	0.0228**	183.10
22	0.5822	142.46	-0.0605**	180.64	0.5517	150.16	0.0209	199.95
23	0.6780	164.82	-0.1518	195.46	0.5516	170.57	0.0191	218.65
24	0.5550	168.79	0.0542	199.76	0.5516	194.60	0.0173	242.02
25	0.5306	180.59	-0.0023	199.34	0.5516	218.03	0.0155	273.75
26	0.6102	184.29	-0.1674	222.42	0.5579	245.64	0.0042	277.13
27	0.5563	201.02	0.0094	231.57	0.5643	268.05	0.0028	296.63
28	0.6263	217.40	-0.1351	231.27	0.5708	285.37	0.0014	300.85
29	0.6296	220.87	-0.0517	254.66	0.5791	298.64	-0.0103	308.09
30	0.6537	230.97	-0.0640	265.41	0.5877	307.26	-0.0192	324.23
31	0.6106	235.56	0.0151	248.65	0.5963	306.39	-0.0281	341.12
32	0.5698	240.66	0.0512	277.10	0.6151	314.28	-0.0392	315.54
33	0.5933	252.02	-0.0539	285.19	0.6344	309.26	-0.0361	351.99
34	0.6162	257.65	-0.0280	281.95	0.6544	299.11	-0.0329	355.71
35	0.5552	270.50	0.0690	304.22	0.6590	302.27	-0.0145	378.04
36	0.6279	281.18	-0.0743	279.74	0.6636	303.97	-0.0168	366.31
37	0.6421	289.42	-0.0251	289.89	0.6682	304.17	-0.0191	373.78
38	0.6603	293.93	-0.0480	313.91	0.6729	311.22	-0.0214	367.44
39	0.6628	298.67	-0.0365	305.47		296.04*		388.34
40	0.6525	299.34	-0.0069	325.26				
41	0.6602	299.30	-0.0732	313.26				
42	0.6671	295.15	-0.0201	343.88				
43	0.6331	293.33	0.0187	340.04				
44	0.6861	296.04	-0.0855	319.78				
45	0.6741	301.12	-0.0232	297.54				
46	0.6217	308.27	0.0512	366.03				
47	0.6511	316.84	-0.0635	360.99				
48		310.25*		353.54				

Notes: * value assumed, and used to calculate values of mu for preceding ages
** value based upon projected measure for lambda1 at age *t-1*
^ geometric means estimated from Expenditure and Food and Survey data

Table 8: Distribution of Annual Employment Gap Length by Sex and Birth Cohort

gap length	women 1953	men 1953	women 1963	men 1963
Gap1	52.46	62.38	54.95	60.74
Gap2	67.53	79.30	72.80	78.49
Gap3	75.19	86.35	80.89	86.41
Gap4	80.01	90.23	86.14	91.04
Gap5	83.46	92.55	89.75	93.88
Gap6	86.02	94.09	92.53	**96.05**
Gap7	88.31	**95.41**	94.72	97.25
Gap8	90.45	96.48	**96.40**	98.10
Gap9	92.42	97.30	97.67	98.77
Gap10	93.83	97.95	98.43	99.27
Gap11	**95.15**	98.40	99.18	99.62
Gap12	96.22	98.80	99.63	99.86
Gap13	97.17	99.03	99.83	99.92
Gap14-24	100.00	100.00	100.00	100.00

Notes: GapX denotes that X years are observed between adjacent employment observations, as described by NES data

Source: Authors' calculations based upon data from NES data; the authors' may be contacted for details

where $Gap\,(j)$ is a dummy variable that takes the value 1 when individual i has returned from a labour market gap of j years at age t, and all terms specified under 'hats' take their respective estimates from the regression of (10). Note that the form of this regression equation implies that the α_3 parameters described by equation (9) vary with the duration of the labour market absence, and not with age. This form of the regression equation was arrived at after finding no significant effect by age.

Most of the employment gaps described by NES data do not extend beyond a year for all of the population sub-groups considered for analysis, as is indicated by the distributional statistics reported in Table 8. To avoid small sample issues, regression of equation (12) was undertaken on the sub-sample of individuals with gaps less than the 95th percentiles as described in Table 8. Associated regression statistics are reported in Table 9.

As in the case of the estimated parameters for continuous employment, it is easiest to interpret the regression results reported in Table 9, by deriving the implied values for the parameters described by equation (9). These statistics are reported in Table 10. The statistics reported in Table 10 indicate that the rate of depreciation of human capital tends to rise as the duration that an individual is out of the labour market increases. As the simulation model described in Section 3 is not sufficiently flexible to reflect this, we have adopted for analysis the weighted averages that are reported at the bottom of the table. These summary statistics weight the respective period costs that are reported in Table 10 by the frequencies of observation that are reported in Table 8.

The probability of a low wage offer

The insurance effect of spousal labour supply has been found to be a potentially important factor in motivating employment amongst married women. To reflect this effect, the model is specified to account

Table 9: Regression Estimates for Dynamic Wage Equations of Individuals with Employment Gaps

gap length	women 1953	men 1953	women 1963	men 1963
Gap1	0.615***	0.206***	0.693***	0.157***
	(0.066)	(0.041)	(0.096)	(0.053)
Gap2	0.515***	0.171***	0.543***	0.111***
	(0.068)	(0.042)	(0.098)	(0.055)
Gap3	0.390***	0.132***	0.487***	0.044
	(0.070)	(0.044)	(0.101)	(0.058)
Gap4	0.341***	0.073	0.503***	-0.024
	(0.072)	(0.046)	(0.105)	(0.062)
Gap5	0.266***	-0.031	0.373***	-0.011
	(0.075)	(0.050)	(0.109)	(0.069)
Gap6	0.190**	0.004	0.332***	
	(0.078)	(0.054)	(0.117)	
Gap7	0.181**		0.077	
	(0.079)		(0.123)	
Gap8	0.016			
	(0.080)			
Gap9	0.007			
	(0.083)			
Gap10	0.109			
	(0.090)			
Constant	-0.678***	-0.239***	-0.734***	-0.164***
	(0.065)	(0.040)	(0.094)	(0.052)

Notes: Dependent variable is *dif*

***, **, * indicates that the coefficient is significantly different from 0 at the 1, 5 and 10% significance levels, respectively.

Estimations by fixed effects.

Table 10: Intercept Parameters of Intertemporal Wage Process for Employment Gaps (α_3) Implied by Regression Estimates

gap length	women 1953	men 1953	women 1963	men 1963
Gap1	-0.0635	-0.0332	-0.0407	-0.0064
Gap2	-0.1169	-0.0391	-0.1555	-0.0466
Gap3	-0.1697	-0.0468	-0.0823	-0.0714
Gap4	-0.1275	-0.0720	-0.0172	-0.0763
Gap5	-0.1667	-0.1231	-0.1619	0.0210
Gap6	-0.1885	0.0026	-0.0903	
Gap7	-0.1418		-0.3095	
Gap8	-0.2997			
Gap9	-0.1893			
Gap10	-0.0801			
wgt avgs	-0.1000	-0.0380	-0.0769	-0.0221

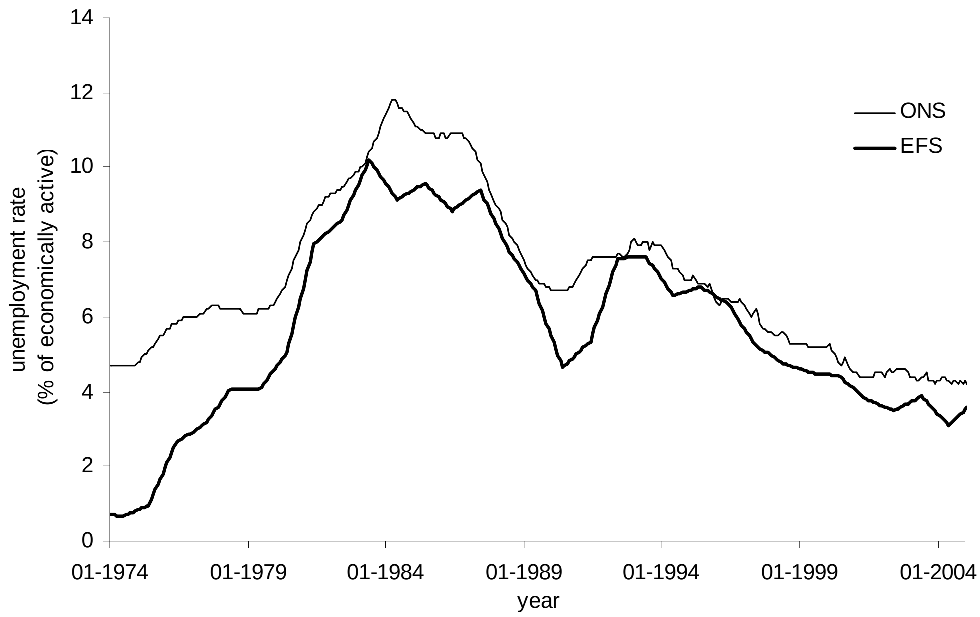
for the probability that an individual may not receive a job offer in any given year. The probabilities of not receiving a job offer that are considered for analysis are assumed to be age and sex specific, with the probability that each member in a cohabitating relationship receiving a job offer independent of the labour success of their spouse. We have based the assumed probabilities of not receiving a wage offer on temporal variation observed for rates of unemployment in the UK. Figures 12 and 13 report unemployment rates by sex observed during the period of interest.

The statistics reported in Figure 12 indicate that unemployment rates for all men peaked at values in excess of 10% during the recessions of the early 1980's and 1990's, between troughs that were as low as 3% (at the beginning of the sample period). A similar temporal trend is reported for women in Panel B of the figure, with the exception that the labour opportunities of women appear to have been less adversely affected than those of men during the recession of the early 1990's. Within this historical context, the last ten years have seen low and stable rates of unemployment for both men and women. Panels A and B of Figure 13 report unemployment rates for age groups prior to retirement. These statistics indicate that the trends in the unemployment rates for population aggregates reported in Figure 12 carry over to the age-specific subgroups, with people in younger age groups tending to experience higher unemployment rates at any given time.

Figures 12 and 13 highlight two forms of uncertainty that are associated with finding a job in practice. On the one hand, individuals cannot be sure of finding a job given the prevailing labour market conditions, and on the other any forecast of future labour market conditions is subject to error. We simplify the analysis here by ignoring forecasting error regarding the state of the labour market. By assuming away forecasting error, the model is likely to overstate the precautionary response of individuals just prior to the recessionary periods discussed above, and understate precautionary behaviour prior to favourable periods in the labour market cycle. Sensitivity to these distortions remains an issue for further research.

The statistics reported in Figures 12 and 13 indicate a close correspondence between measures of unemployment derived from the ONS and EFS data sources. The largest disparities are between the labour statistics reported for all women in Panel B of Figure 12. This is a concern, given our current focus on the labour market opportunities of women, and the fact that age specific ONS data do not extend prior to 1992. Our initial concern in relation to this issue was that, particularly during the 1970's, women in the EFS may have tended to report not being in the labour market rather than unemployed. This concern was, however, allayed by the observation that estimates of labour market participation derived from the EFS overstated by around 3% those of the ONS to 1981. Hence, the problem is not that the EFS understates the incidence of unemployment described by the ONS statistics, but that it overstates the incidence of employment. And as statistics for labour income derived from the EFS were

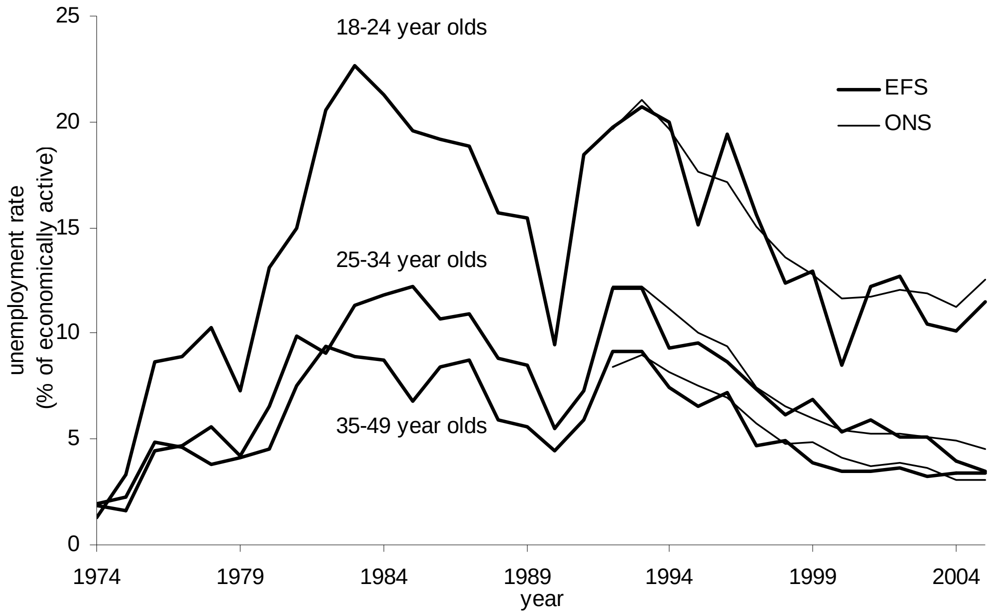
Panel A: men



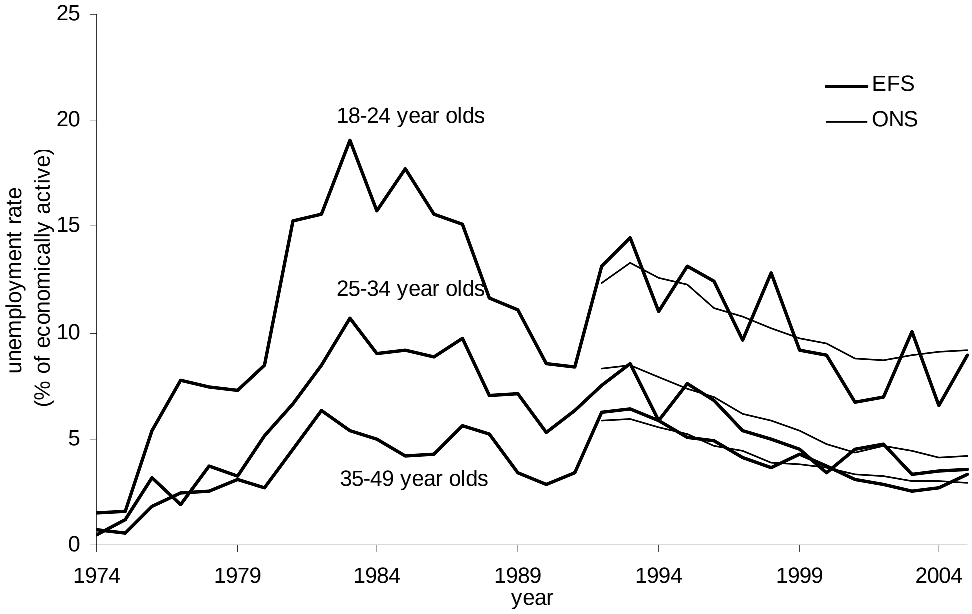
Panel B: women

Sources: ONS codes; MGSY (men), MGSZ (women)
EFS statistics described in Appendix A

Figure 12: Unemployment Rates by Sex and Year Reported for the UK



Panel A: men



Panel B: women

Notes: ONS age specific data only available to 1992

Sources: ONS codes for unemployment by age YBVO, YCGN, YCGT (men), YBVP, YCGO, YCGU (women)

ONS codes for employment by age YBTS, YBTV, YBTY (men), YBTT, YBTW, YBTZ (women)

EFS statistics described in Appendix A

Figure 13: Unemployment Rates by Age, Sex, and Year Reported for the UK

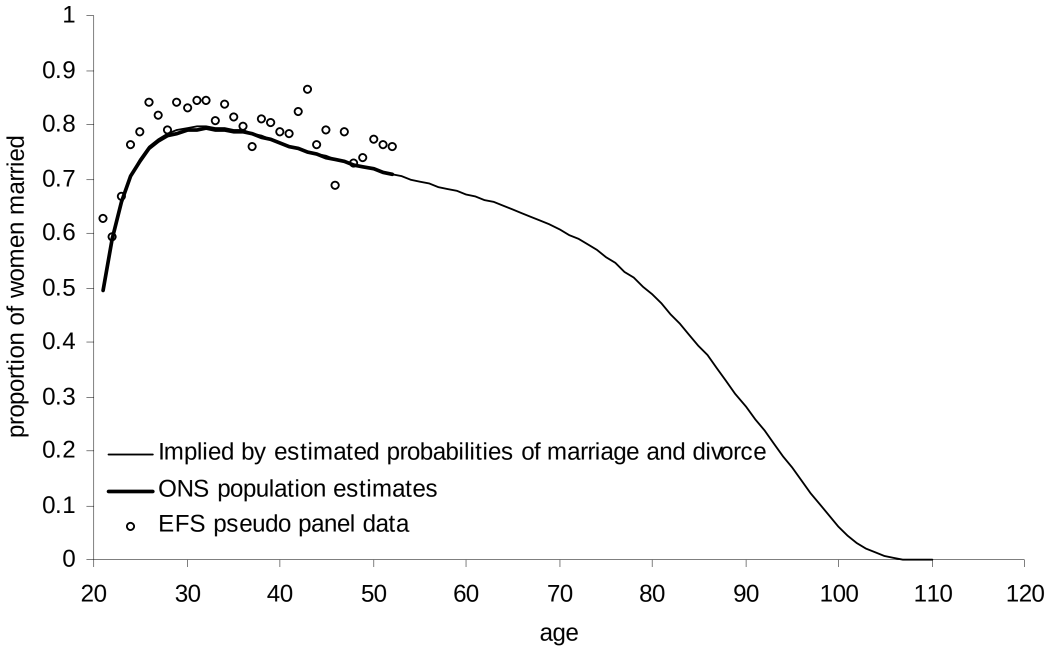
validated against statistics derived from the NES, we could find no reason to reject the EFS statistics for employment that are reported here. The EFS data were consequently used to estimate the age and sex specific probabilities that are assumed for the model.

Parameters for relationship formation and dissolution

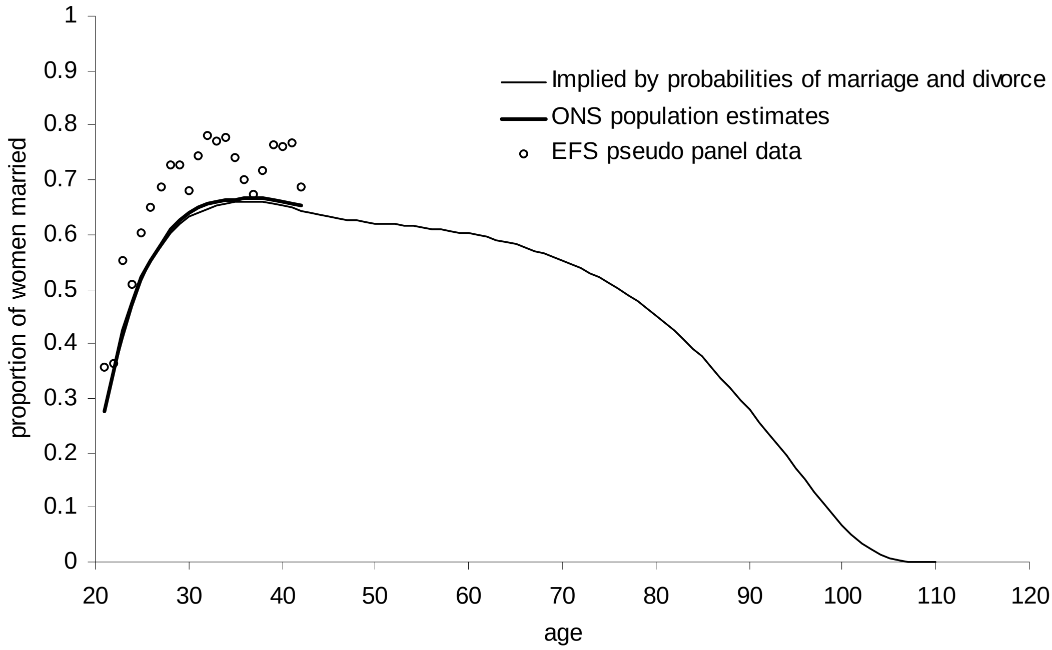
Households can be comprised of either one or two adults between ages 21 and 110, where relationship formation is stochastic and exogenous throughout. The model consequently requires age specific probabilities for relationship formation and dissolution. These probabilities were based upon ONS estimates for the total number of women by age and year, the number of marriages, the number of divorces, and the age specific probabilities of male mortality, on the assumption that marriages take place between same aged partners. Figure 14 displays the proportions of the female population married by age, as implied by three alternative data sources: ONS population projections distinguished by marital status, population projections implied by the rates of marriage and relationship dissolution considered for analysis, and population estimates calculated from the EFS pseudo panel data that are considered more generally for estimating the model.

Figure 14 is important in three respects. First, it provides an important check, confirming that the probabilities of relationship formation and dissolution calculated from population marriage, divorce, and death statistics (population flows) provide a close approximation to the associated population aggregates (stocks) produced by the ONS. Second, these population aggregates indicate substantially lower rates of marriage amongst the 1963 female birth cohort, relative to the 1953 cohort, consistent with the observations reported in Section 2. And third, the ONS statistics for marriage provide a close approximation to the statistics calculated from the EFS for the 1953 birth cohort, but understate the associated statistics for the 1963 cohort. This last observation reflects the changing nature of partner relationships in the UK, and the increasing importance of *de facto* relationships in particular.

The EFS began including cohabitation as a relationship classification from 1990, and the EFS statistics reported in Figure 14 include cohabitating relationships from that year. The two panels of Figure 1 indicate that this does not have a substantial influence on the statistics reported for the 1953 female birth cohort, but rates of cohabitation do appear to be non-trivial for women from the 1963 cohort. An adequate consideration of cohabitation in the current context is complicated by a number of factors. One is the paucity of data regarding relationship formation and dissolution where no marital contract is made. Another is empirical evidence, which suggests that it remains inappropriate to treat *de facto* relationships and formal marriages equivalently. Akerlof (1998), for example, states that “on getting married men tend to change their behaviour” (p. 290). This leads him to describe the ceremony associated with registered marital status as a rite of passage such that, “after the wedding the life of



Panel A: 1953 female birth cohort



Panel B: 1963 female birth cohort

Source: Authors' calculations based on data from repeated EFS cross-sections, and ONS population projections for England and Wales

The authors may be contacted for full details

Figure 14: Proportions of Female Population Married by Age and Birth Cohort; alternative data sources

the bride and of the groom will be changed. This can be modelled as a change in utility: with marriage the bride and the groom will have increased commitment toward each other, toward their offspring and, if religious, toward the Lord Himself." (p. 291).

In relation to this second issue, two extremes may be defined: one in which *de facto* couples are considered to act as though they are unattached in any formal respect, and another where *de facto* couples act as though they are 'registered married' in all respects. The current study adopts the first of these two extremes by focussing upon registered marital status. Sensitivity analysis with respect to the other extreme may be undertaken by adjusting the marital rates used to include all 'socially married' couples.

Fertility statistics

Fertility decisions are considered to be made at two discrete 'birth ages'. Each birth age was selected to approximately represent a 'fertility period' that included a half of all births, as described by fertility statistics for the 1953 cohort reported by the ONS, and reproduced in Table 11. Locating each birth age to the birth-weighted median of the respective fertility period involved referencing the 25th and 75th percentiles of the cumulative birth distribution reported in Table 11, resulting in the selection of ages 21 and 29 for analysis. We allow up to three children to be 'born' at each birth age, allowing for a maximum of six dependant children per household.

Calibration of the model involved matching three key sets of fertility statistics reported in Table 11 for the 1953 cohort. The first of these is the aggregate completed fertility rate, equal to 2.045 children per woman (the sum of the age specific fertility rates). The second is the timing of fertility, so that an average of 0.957 children per woman are born at the first birth age (the sum of the age specific fertility rates to age 25), and 1.088 children per woman are born at the second (the sum of age specific fertility rates from age 26). And the third is the distribution of fertility, as described in the bottom panel of Table 11.

4.2 Second stage calibration of preference parameters

The second stage calibration was concerned with the following model parameters (described in Section 3.1):

- the intertemporal elasticity of substitution (inverse of relative risk aversion), γ
- the intratemporal elasticity between consumption and leisure, ε
- the exponential rate of time discounting, δ

Table 11: Age Specific and Completed Fertility Statistics, by Year of Birth of Woman

	1953 birth cohort		1963 birth cohort	
age	fertility rate	CDF	fertility rate	CDF
17 and under	0.066	0.032	0.041	0.021
18	0.078	0.070	0.042	0.043
19	0.097	0.118	0.058	0.073
20	0.107	0.170	0.071	0.110
21	0.115	0.226	0.083	0.153
22	0.118	0.284	0.096	0.203
23	0.121	0.343	0.105	0.258
24	0.122	0.403	0.114	0.317
25	0.133	0.468	0.122	0.380
26	0.141	0.537	0.122	0.444
27	0.138	0.604	0.127	0.510
28	0.125	0.666	0.122	0.573
29	0.114	0.721	0.117	0.634
30	0.102	0.771	0.109	0.691
31	0.088	0.814	0.101	0.743
32	0.076	0.851	0.089	0.790
33	0.064	0.883	0.079	0.831
34	0.054	0.909	0.069	0.866
35	0.045	0.931	0.060	0.898
36	0.037	0.949	0.049	0.923
37	0.030	0.964	0.040	0.944
38	0.023	0.975	0.031	0.960
39	0.018	0.984	0.024	0.972
40	0.013	0.990	0.019	0.982
41	0.008	0.994	0.013	0.989
42	0.005	0.997	0.009	0.994
43	0.003	0.998	0.005	0.996
44	0.002	0.999	0.003*	0.998
45 and over	0.002	1.000	0.004*	1.000
number of children	Distributional Statistics for Completed Fertility**			
0 - childless	15		19	
1	13		13	
2	42		38	
3	20		20	
4 or more	10		10	
all	100		100	

Notes: * imputed values from 1975 cohort

** statistics for 1953 cohort imputed from statistics for 1950 and 1955 cohorts

** statistics for 1963 cohort taken to equal statistics reported for 1961 cohort

Source: Age specific fertility rates reported in Table 10.1, *Birth Statistics,* ONS

Distribution of completed fertility reported in Table 10.5, *Birth Statistics* , ONS

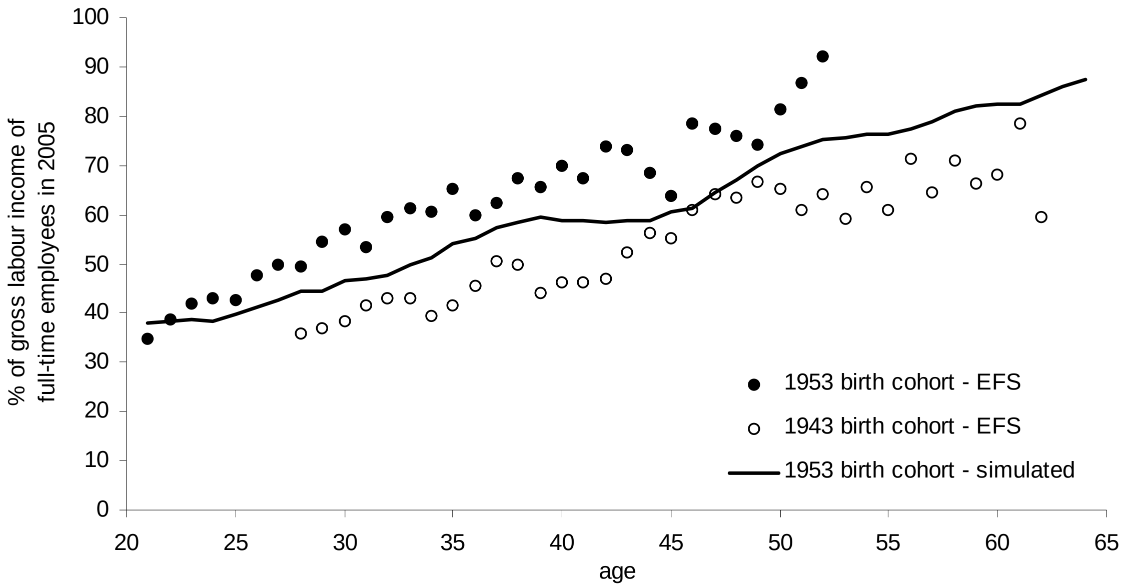
- the parameters of the function that describes the intertemporal dynamics of women's human capital
- the utility price of leisure, α
- the assumed costs of childcare
- the preference parameters for dependant children, $\alpha_c\left(n_{i,t}^c, t\right)$
- the distribution of the wealth endowment to women at age 21

For the current analysis, we set γ to 2.0, and ε to 0.4, which are broadly consistent with estimates reported in the econometric literature. δ was adjusted to reflect trend variation in the geometric mean of consumption by age. The parameters that describe female wage dynamics were adjusted to match geometric means for gross labour income by employment status and age, in view of the probable sample selection biases that are associated with the econometric estimates reported in Section 4.1. α and the costs of childcare were adjusted to match population average sample statistics for female labour supply, and the parameters α_c were adjusted to reflect statistics regarding the timing and distribution of fertility decisions. Calibration of the model was complicated by the fact that most women who were reported as being single and in their early 20's between 1972 and 1974, were also reported as living with their parents.[29] It is reasonable to suppose that these women received a measure of financial support from their parents during this period, which is not explicitly accounted for by the model described in Section 3. The wealth endowment received by women at age 21 was adjusted to reflect this support.

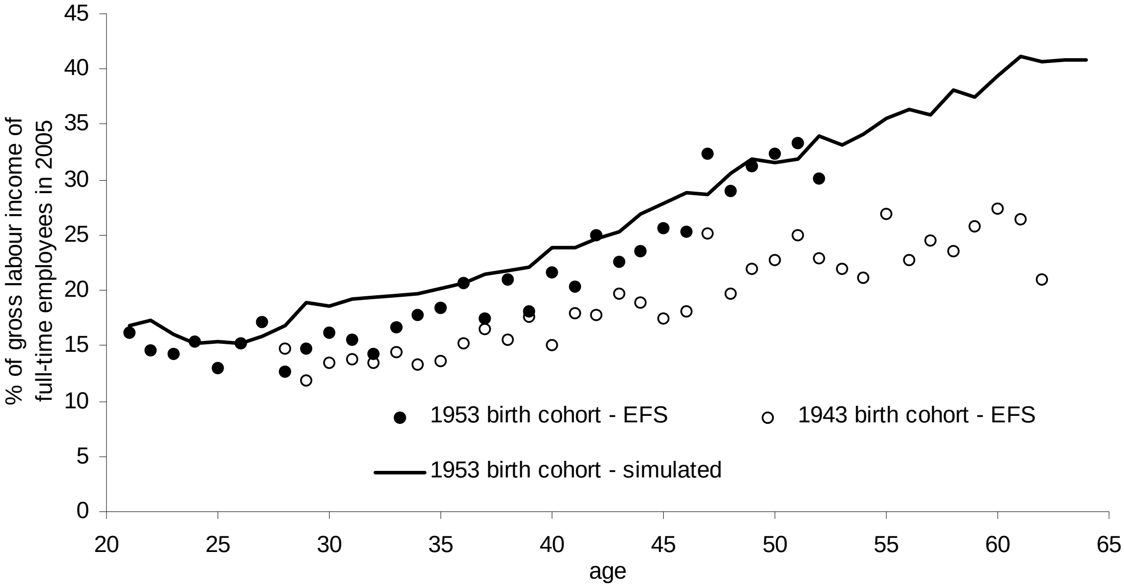
The sample moments for the 1953 female birth cohort against which the model parameters were calibrated are plotted in Figures 15 to 17 and Table 12, alongside their simulated counterparts. The calibrated model parameters considered for analysis are reported in Table 13.

The model calibration was an exercise in trial-and-error. We began with a coarse grid structure for the model, comprised of 11 points on each of the wealth, female human capital, and male human capital axes to age 64, and 151 points on each of the wealth and pension income axes from age 65. This implied 3,444,664 utility maximisations for the simulated lifetime, and the associated model solution was used to project the life history for the households of a simulated cohort of 10,000 women. To limit computation time, we also did not perform non-concavity checks in the first instance, so that each model iteration was completed in 15 minutes on an Intel Core2 X6800 processor with 4GB of RAM. We used this coarse specification of the model to obtain a broad match to survey data, which was achieved after testing 157 alternative parameter combinations. The number of grid points was then increased to 16 points on each of the wealth and human capital axes during the working lifetime, and 257 points on each of the

[29] 68% of single women between the ages of 21 and 25 were reported as living with their parents between 1972 and 1974.



Panel A: full-time employed women



Panel B: part-time employed women

Notes: Authors' calculations from various data sources

NES denotes statistics estimated using data from the New Earnings Survey

EFS denotes statistics estimated using data from the Expenditure and Food Survey

Sources: Simulated data generated by behavioural model, and preferred parameter specification – see Table 13

EFS and NES described in Appendix A

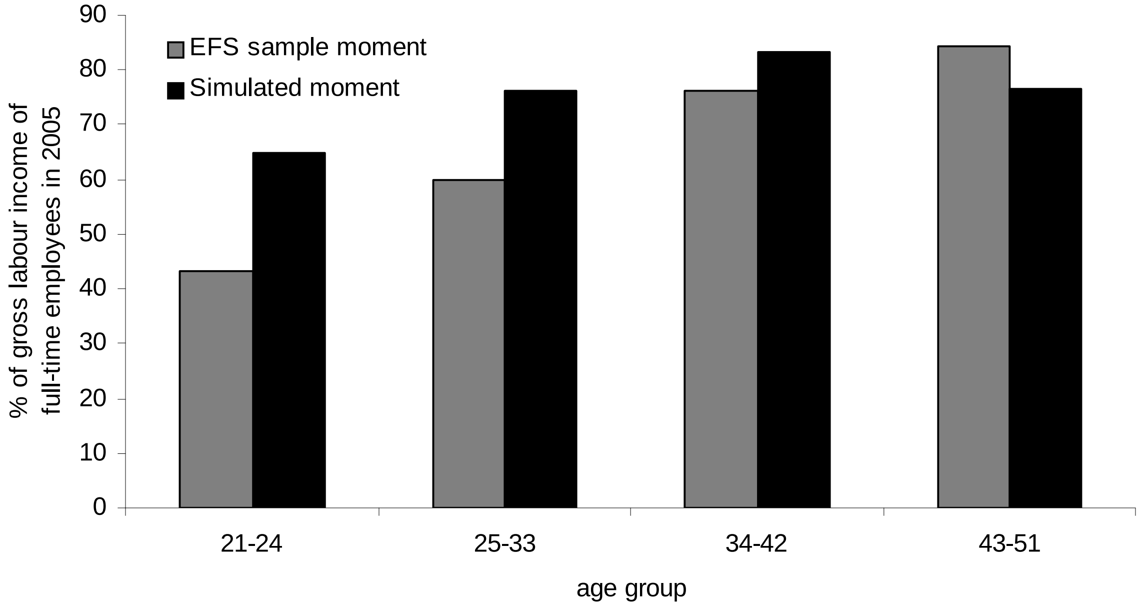
Figure 15: Simulated and Sample Statistics for Geometric Mean Female Gross Labour Incomes by Age and Birth Cohort

wealth and pension axes from age 65 (9,884,924 utility maximisations). This, in addition to undertaking non-concavity checks resulted in a model run time of just over two hours. An additional 23 parameter combinations were considered using this specification of the model. We then increased the number of grid points to 19 on each of the wealth and human capital axes (12,610,328 utility maximisations), which resulted in a model run time of just over 5 hours. This model specification was used to test five alternative parameter combinations, before settling on the preferred specification that we report here. A further test was run, using a model with 24 grid points on each of the wealth and human capital axes (19,456,508 utility maximisations undertaken in 18 hours) to check that no substantive differences in simulated behaviour were obtained at higher levels of model accuracy. The simulated statistics that are reported in the remainder of this paper are based upon model solutions using 19 points on each of the wealth and human capital axes, and the life-histories generated for a cohort of 10,000 women.

Adjustment of the model parameters focussed first upon the process considered for the evolution of women's human capital. Specifically, given the assumed values for γ and ε, we adjusted the age specific parameters that define the proportion of the full-time wage that is received by women who choose to work part-time. Although a substantial downward revision of these wage parameters was made – reported in Table 13 – we did not find it necessary to alter any other of the wage parameters from their respective estimates reported in Section 4.1. We found that the simulated moments for the mean full-time and part-time wages of women were not sensitive to the adjustment of the remaining model parameters, which facilitated calibration of other aspects of the model. Associated simulated and sample moments for the wages of women are reported in Figure 15.[30] These statistics indicate that the wage parameters adopted for analysis generate simulated moments that track the associated sample moments fairly closely, with a slight tendency to understate the wages of full-time employed women and vice versa for part-time employed women.

Having specified the wage parameters, we proceeded to adjust the exponential rate of time discounting, δ to match the time trend observed for consumption. The assumption that all households have their children at the same ages gives rise to discontinuities in consumption that are not evident in survey data. To control for these effects, we considered for calibration 9 point moving averages of consumption by age, centred about ages of fertility transition assumed for the model. Simulated and sample statistics for consumption are reported in Figure 16. This figure indicates that, although simulated measures of consumption capture the general upward trend with age described by survey data, the rate of increase is slightly understated. The obvious implication is that the rates of time discounting assumed for the model are too high. This conclusion is, however, complicated by the fact that – as is indicated in Table

[30] Associated moments for men are reported in Appendix C.



Notes: Statistics report geometric mean consumption by households with adult women in the denoted age groups
Authors' calculations using simulated data, and sample data from the EFS

Sources: Simulated data generated by behavioural model, and preferred parameter specification – see Table 13
EFS data described in Appendix A

Figure 16: Simulated and Sample Statistics for Geometric Mean Consumption by Woman's Age – 1953 Birth Cohort

13 – we reduced the rate of time discounting to just 0.5% per annum.[31]

The disparity observed for consumption can be explained principally by our assumption that all men work to age 65. Sensitivity analysis regarding this issue remains a subject for further research. Nevertheless, it is important not to read too much into the consumption statistics that are reported here. As our analysis is primarily concerned with the effects of alternative counterfactuals that are based upon the same assumptions regarding male labour supply, associated distortions are likely to be differenced out.

We found that, as a consequence of the childcare costs that were assumed for analysis, stronger preferences for leisure tended to also motivate a stronger preference for children, and vice versa. Similarly, increasing the childcare costs considered for analysis tended to reduce both the number of children that women chose to have, and the average female labour supply of households with dependant children. As a consequence, the model parameters for labour supply and fertility were jointly determined. Our calibration of these parameters started by adjusting the utility price of leisure, α_l, to broadly match rates of employment participation described by survey data. We then adjusted the child preference parameters to capture aggregate measures of completed fertility. Childcare costs were next adjusted to

[31] Although we opted not to reduce the discount rate below +0.5%, there does exist econometric evidence in support of negative rates of time discounting. See, for example, Hurd (1989).

better reflect observed rates of full-time and part-time employment. And finally, the full set of parameters were jointly fine-tuned. Simulated and sample moments are reported in Table 12 for fertility, and Figure 17 for employment.

The statistics reported in Table 12 indicate that a very close reflection was obtained by the model to both the timing of aggregate fertility, and the distribution of the number of offspring per woman. This is primarily because of the flexible specification assumed for child preferences, as described by the statistics reported for $\alpha_c(.)$ in Table 13. The calibrated parameters for α_c monotonically increase with the number of dependant children, with the rate of increase increasing to a peak at two children, and declining smoothly thereafter. We also found it necessary to apply higher child preference parameters in the period prior to the second birth age, in order to capture the timing of retirement.

Like the consumption statistics that are referred to above, the labour supply statistics by age are influenced by the discrete nature of the timing that is considered for fertility decisions in the model. As the labour supply statistics by age indicate some interesting interactions with the associated fertility statistics, we present a full set of age specific statistics in Figure 17. A number of broad trends are exhibited by the sample statistics that are reported in Figure 17. Early in the working lifetime, rates of full-time employment are relatively high, and associated rates of part-time and non employment are low. Rates of full-time employment fall to low levels during peak child rearing ages, as women move into part-time or non employment. Following peak child rearing years, women on average were observed to increase their employment participation, moving out of non-employment, and into either full-time or part-time employment. Later in the working life, the effects of retirement become evident, with rates of full-time and part-time employment declining and non-employment rising.

The simulated statistics reported in Figure 17 reveal that the model does a good job of capturing the absolute magnitudes of variation described by the alternative employment statistics against which it was calibrated, and that the underlying behavioural framework is sufficiently detailed to capture the stylised trends referred to above. Simulated rates of full-time employment are high until the second child birth age considered for analysis (29), when just over 20% of women are observed to move out of full-time employment into either part-time or non-employment. Rates of employment are then observed to pick up again slightly from age 34, as the costs of childcare for children born at the second birth age are considered to fall. The next substantive shift in simulated employment is observed about age 39, when children from the first child birth age (21) are assumed to leave the parental home. At this time, simulated households are relieved of the financial strain of supporting a child, and women are seen to move from full-time to part-time employment as a consequence. Later in the simulated working lifetime, the employment statistics generated for women describe a credible trend for their respective migration into retirement, relative to the respective sample statistics reported for the 1953 and 1943

Table 12: Simulated and Sample Statistics for Fertility – 1953 Female Birth Cohort

aggregate fertility rates	ONS statistics	simulated statistics
fertility rate to age 25	0.957	0.930
fertility rate from age 26	1.088	1.131
completed fertility rate	2.045	2.061
% of population by total number of offspring		
childless women	15	19
1 child	13	7
2 children	42	41
3 children	20	20
4 or more children	10	13

Source: ONS statistics derived from tables 10.1 and 10.5 of *Birth Statistics*

birth cohorts.

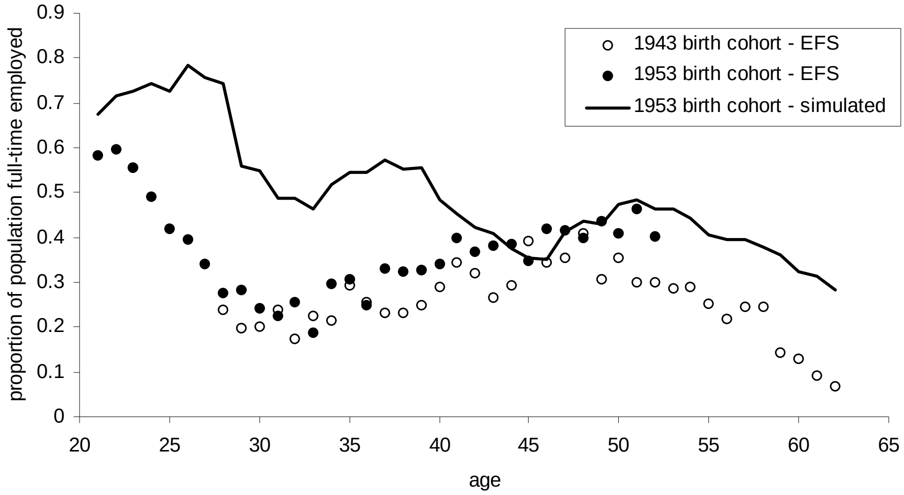
It is clear that the simulation model misses much of the detail in the evolution of female employment statistics that is described by survey data. One of the most important aspects of this is that the model fails to capture the extent of the fall in full-time employment during peak child rearing years, or the associated recovery to age 50. This mis-match can be attributed to the way in which childcare is taken into consideration by the simulation model. Our analytical model focuses upon demand side decisions, and abstracts from associated supply side effects. It is reasonable to suppose, however, that affordable childcare simply was not available to many women during the early 1970's.[32] We have made allowance for this complication by increasing the costs of childcare early in the simulated lifetime, relative to the estimate of costs derived from EFS data. Nevertheless, as the disparities between the simulated and sample statistics reported in Figure 17 make clear, the increase in childcare costs that we considered plausible (reported in Appendix C) were insufficient to account for the fall in rates of full-time employment described by survey data. This issue warrants further investigation, and remains a subject for future research.

5 Interpreting Trends in Fertility and Female Labour Supply

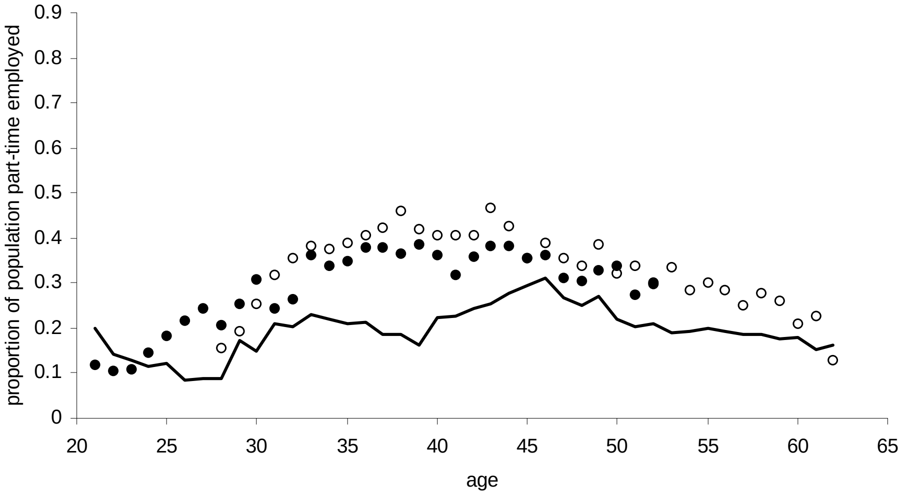
The current section is based upon data generated for a cohort of 10,000 households under three alternative environmental scenarios:

- the *1953 scenario* – using the model parameters calibrated to the 1953 female birth cohort as described in the preceding section
- the *1963-marriage scenario* – using the same stochastic innovations and model parameters as considered for the 1953 scenario, but exchanging the age specific probabilities of marriage and relationship dissolution estimated for the 1953 birth cohort with probabilities estimated for the 1963 birth cohort

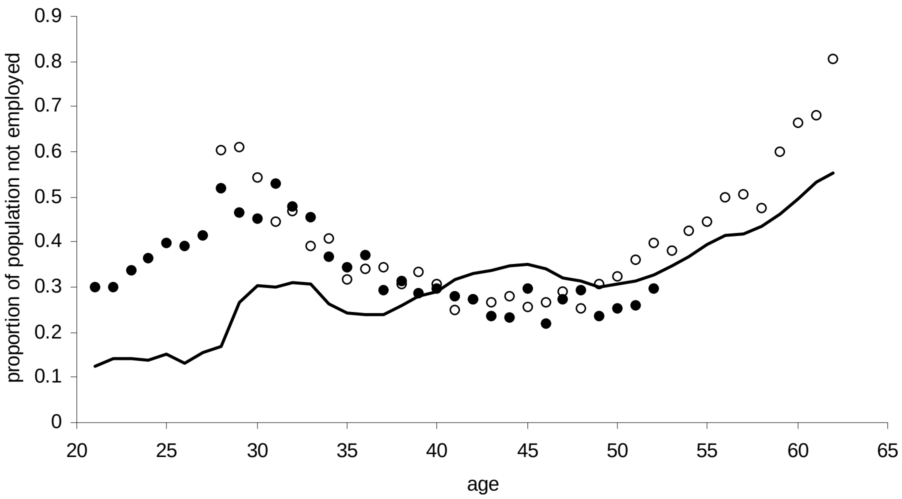
[32] As noted by Joshi (1990, p. 42), there was very little recourse to paid childcare in Britain during the period of interest.



Panel A: full-time employment



Panel B: part-time employment



Panel C: not employed

Notes: Authors' calculations using simulated data, and sample data from the EFS

Sources: Simulated data generated by behavioural model, and preferred parameter specification – see Table 13

EFS data described in Appendix A

Figure 17: Simulated and Sample Statistics for Employment Participation by Age and Birth Cohort

Table 13: Calibrated Model Parameters for 1953 Female Birth Cohort

GENERAL MODEL PARAMETERS

women married at age 21	49.35%	*wage distn women aged 21*				*max no. births*
tax threshold growth rate	0.60%	mean of logs	5.1865	1st birth age	21	3
welfare benefits growth rate	1.90%	std dev of logs	0.3407	2nd birth age	29	3
rate of return to assets	2.90%			start age	21	
min cost of debt	8.00%			max age	110	
max cost of debt	18.00%					

CHILD PREFERENCE PARAMETERS

number of children	0	1	2	3	4	5	6
ages 21-28	0.3241	0.3355	0.3545	0.3701	0.3835	0.3950	0.4052
ages 29 and over	0.2995	0.3100	0.3276	0.3420	0.3544	0.3649	0.3744

CHILD CARE COSTS (£ per week per child)

marrital status	Singles				Couples			
employment	full-time		part-time		full-time		part-time	
child age	under 5	5 to 13	under 5	5 to 13	under 5	5 to 13	under 5	5 to 13
cost in 1974	21.31	2.38	6.57	0.84	16.54	2.38	6.02	0.85
growth rate	2.85%	4.43%	3.79%	3.93%	0.58*	2.82%	4.07%	2.41%

AGE SPECIFIC PARAMETERS

age	prob marriage	prob marrital dissolution	part-time to full-time wage	unemp rate women	unemp rate men	age	female prob of death	prob marrital dissolution
21	0.2070	0.0179	0.4578	0.0211	0.0472	65	0.0037	0.0253
22	0.1991	0.0219	0.4658	0.0244	0.0421	66	0.0031	0.0253
23	0.1806	0.0235	0.4492	0.0321	0.0371	67	0.0024	0.0253
24	0.1708	0.0256	0.4438	0.0410	0.0328	68	0.0023	0.0253
25	0.1610	0.0273	0.4388	0.0475	0.0375	69	0.0021	0.0253
26	0.1488	0.0274	0.4194	0.0547	0.0439	70	0.0097	0.0170
27	0.1323	0.0266	0.4041	0.0607	0.0516	71	0.0101	0.0118
28	0.1170	0.0256	0.4056	0.0694	0.0574	72	0.0105	0.0181
29	0.1080	0.0246	0.3968	0.0763	0.0629	73	0.0110	0.0187
30	0.0996	0.0226	0.3746	0.0805	0.0685	74	0.0171	0.0256
31	0.0910	0.0227	0.3818	0.0864	0.0714	75	0.0120	0.0202
32	0.0821	0.0223	0.3857	0.0867	0.0740	76	0.0188	0.0278
33	0.0739	0.0215	0.3863	0.0858	0.0737	77	0.0196	0.0220
34	0.0699	0.0211	0.3940	0.0738	0.0697	78	0.0205	0.0303
35	0.0656	0.0204	0.3983	0.0594	0.0601	79	0.0216	0.0318
36	0.0575	0.0207	0.4041	0.0436	0.0546	80	0.0227	0.0333
37	0.0497	0.0195	0.3990	0.0382	0.0521	81	0.0317	0.0433
38	0.0469	0.0204	0.4013	0.0423	0.0577	82	0.0252	0.0366
39	0.0441	0.0216	0.3955	0.0504	0.0599	83	0.0354	0.0477
40	0.0384	0.0201	0.4124	0.0501	0.0638	84	0.0374	0.0501
41	0.0358	0.0191	0.4145	0.0431	0.0639	85	0.0396	0.0426
42	0.0349	0.0173	0.4290	0.0356	0.0643	86	0.0521	0.0667
43	0.0319	0.0162	0.4412	0.0363	0.0632	87	0.0444	0.0588
44	0.0293	0.0169	0.4527	0.0395	0.0579	88	0.0588	0.0741
45	0.0285	0.0159	0.4720	0.0405	0.0494	89	0.0741	0.0779
46	0.0262	0.0168	0.4843	0.0357	0.0395	90	0.0658	0.0822
47	0.0241	0.0161	0.4966	0.0296	0.0363	91	0.0833	0.0870
48	0.0222	0.0143	0.5054	0.0245	0.0383	92	0.0882	0.0923
49	0.0230	0.0141	0.5200	0.0190	0.0366	93	0.0938	0.1129
50	0.0217	0.0156	0.5040	0.0253	0.0366	94	0.1148	0.1186
51	0.0193	0.0149	0.5063	0.0253	0.0366	95	0.1314	0.1356
52	0.0184	0.0127	0.5087	0.0253	0.0366	96	0.1504	0.1549
53	0.0164	0.0151	0.5087	0.0253	0.0366	97	0.1722	0.1769
54	0.0140	0.0105	0.5101	0.0253	0.0366	98	0.1972	0.2022
55	0.0133	0.0133	0.5231	0.0253	0.0366	99	0.2257	0.2310
56	0.0118	0.0128	0.5315	0.0253	0.0366	100	0.2584	0.2639
57	0.0106	0.0088	0.5363	0.0253	0.0366	101	0.2959	0.3015
58	0.0088	0.0120	0.5434	0.0253	0.0366	102	0.3388	0.3444
59	0.0092	0.0119	0.5459	0.0253	0.0366	103	0.3879	0.3935
60	0.0092	0.0116	0.5476	0.0253	0.0366	104	0.4441	0.4496
61	0.0063	0.0109	0.5518	0.0253	0.0366	105	0.5084	0.5137
62	0.0055	0.0108	0.5559	0.0253	0.0366	106	0.5821	0.5869
63	0.0051	0.0108	0.5599	0.0253	0.0366	107	0.6664	0.6705
64	0.0043	0.0108	0.5641	0.0253	0.0366	108	0.7630	0.7661
						109	0.8735	0.8753
						110	1.0001	1.0000

Notes: * specified as absolute change per year in £ per week

- the *1963 scenario* – using the same stochastic innovations and model parameters as considered for the 1953 scenario, but exchanging both the wage parameters, and the age specific probabilities of marriage and relationship dissolution estimated for the 1953 birth cohort with estimates for the 1963 birth cohort

Discussion is divided into two subsections. The first subsection focuses upon differences in female labour supply and fertility generated under the 1953 and 1963-marriage scenarios. This counterfactual consequently explores how differences in the probabilities of relationship formation and dissolution between the 1953 and 1963 female birth cohorts affect the decisions generated by our behavioural model. Similarly, in the second subsection we explore differences in the simulated behaviour generated under the 1953 and 1963 scenarios, thereby extending the analysis to take into account differences in the wage rates estimated for the 1953 and 1963 birth cohorts.

5.1 Behavioural responses to the changing nature of partner relations

The probabilities of marriage and marital dissolution that were assumed for the 1953 and 1963-marriage scenarios are reported in Table 14. The statistics reported in Table 14 reflect the key observations regarding trends in formal marriages that are discussed at length in Section 2: the proportion of women identified as married at age 21 under the 1963-marriage scenario is approximately half that identified for the 1953 scenario; marital rates of women aged 50 and under are approximately 20% lower in the 1963-marriage scenario; and rates of marital dissolution are approximately 25% higher.

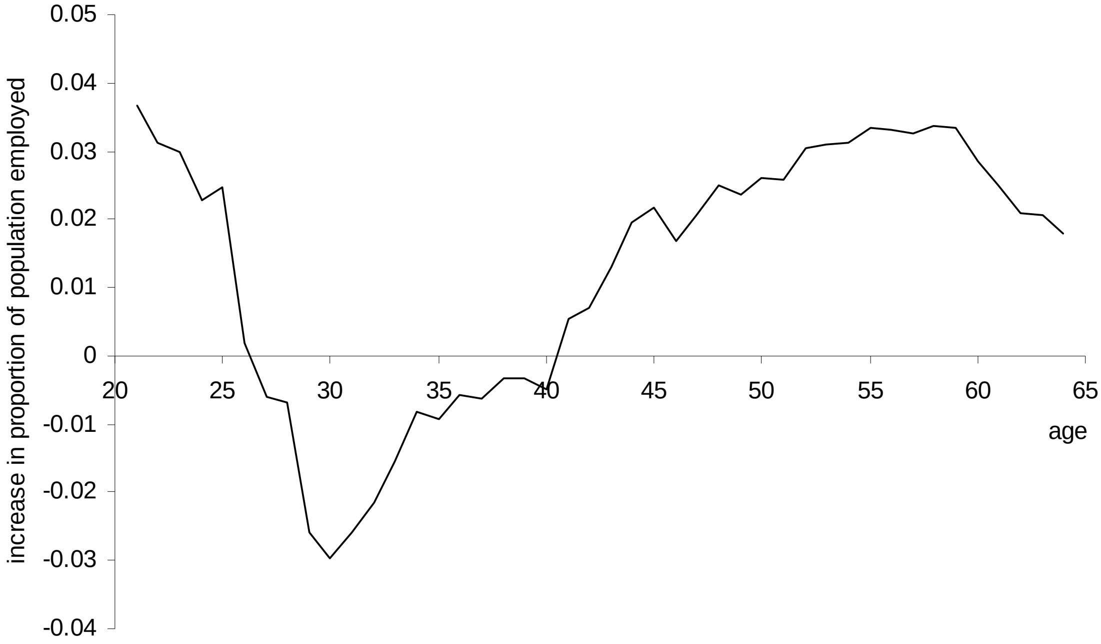
The effects on female labour supply of the changes considered to the probabilities of marriage are displayed in Figure 18. The two panels of this figure suggest that the lower probabilities of marriage associated with the 1963-marriage scenario, relative to the 1953 scenario, motivate similar labour supply responses over both the extensive and intensive margins. The 1963-marriage scenario encourages women to enter the labour market sooner, and to retire later, relative to the 1953 scenario. Furthermore, a larger proportion of women choose to work full-time at the extremes of the working lifetime under the 1963-marriage simulation. In contrast, higher rates of part-time and non-employment are generated under the 1963-marriage scenario in the middle of the working lifetime, particularly about the second child bearing age considered for analysis.

The effects on simulated fertility decisions are reported in Table 15. This table indicates that adjusting the probabilities of marriage to reflect data for the 1963 female birth cohort, and holding all other model parameters fixed at their values calibrated to the 1953 birth cohort, does a good job of capturing the stylised facts regarding recent trends in fertility that were identified in Section 2. Women choose to have fewer children, and to have those children later in their lifetimes in the context of the lower probabilities of marriage and higher probabilities of marital dissolution that were estimated for

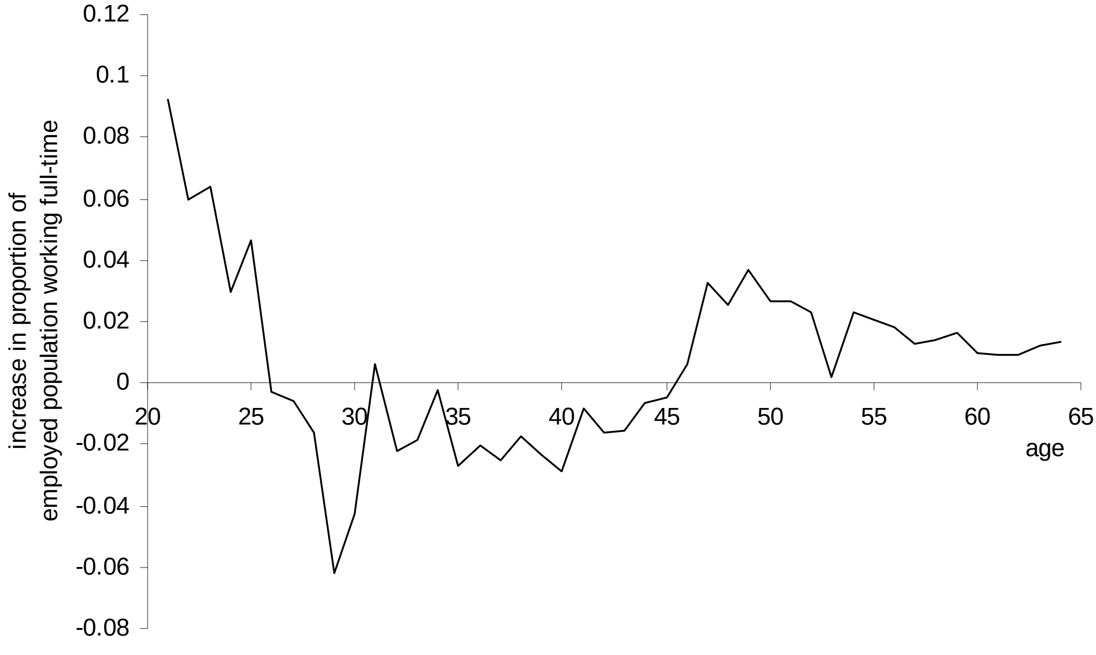
Table 14: Counterfactual Probabilities of Marriage and Divorce Estimated for the 1953 and 1963 Female Birth Cohorts in the United Kingdom

	1953 scenario		1963-marriage scenario			1953 scenario		1963-marriage scenario	
	proportion population married at age 21								
	0.4935		0.2768						
	age specific probabilites					*age specific probabilites*			
age	marriage	dissolution	marriage	dissolution	age	marriage	dissolution	marriage	dissolution
21	0.2070	0.0179	0.1123	0.0339	65	0.0037	0.0153	0.0037	0.0147
22	0.1991	0.0219	0.1165	0.0400	66	0.0031	0.0109	0.0031	0.0105
23	0.1806	0.0235	0.1200	0.0340	67	0.0024	0.0158	0.0024	0.0106
24	0.1708	0.0256	0.1156	0.0328	68	0.0023	0.0111	0.0023	0.0155
25	0.1610	0.0273	0.1105	0.0319	69	0.0021	0.0162	0.0021	0.0107
26	0.1488	0.0274	0.1034	0.0316	70	0.0017	0.0170	0.0017	0.0164
27	0.1323	0.0266	0.0937	0.0315	71	0.0013	0.0118	0.0013	0.0114
28	0.1170	0.0256	0.0882	0.0291	72	0.0011	0.0181	0.0011	0.0174
29	0.1080	0.0246	0.0836	0.0290	73	0.0009	0.0187	0.0009	0.0179
30	0.0996	0.0226	0.0753	0.0300	74	0.0008	0.0256	0.0008	0.0185
31	0.0910	0.0227	0.0676	0.0283	75	0.0007	0.0202	0.0007	0.0194
32	0.0821	0.0223	0.0628	0.0275	76	0.0006	0.0278	0.0006	0.0266
33	0.0739	0.0215	0.0586	0.0262	77	0.0004	0.0220	0.0004	0.0210
34	0.0699	0.0211	0.0567	0.0240	78	0.0003	0.0303	0.0003	0.0288
35	0.0656	0.0204	0.0499	0.0245	79	0.0004	0.0318	0.0004	0.0301
36	0.0575	0.0207	0.0443	0.0234	80	0.0003	0.0333	0.0003	0.0314
37	0.0497	0.0195	0.0403	0.0226	81	0.0002	0.0433	0.0002	0.0330
38	0.0469	0.0204	0.0376	0.0238	82	0.0001	0.0366	0.0001	0.0347
39	0.0441	0.0216	0.0375	0.0235	83	0.0001	0.0477	0.0001	0.0451
40	0.0384	0.0201	0.0343	0.0235	84	0.0002	0.0501	0.0002	0.0382
41	0.0358	0.0191	0.0302	0.0237	85	0.0000	0.0426	0.0000	0.0500
42	0.0349	0.0173	0.0286	0.0233	86	0.0000	0.0667	0.0000	0.0526
43	0.0319	0.0162	0.0291	0.0226	87	0.0000	0.0588	0.0000	0.0556
44	0.0293	0.0169	0.0275	0.0189	88	0.0000	0.0741	0.0000	0.0698
45	0.0285	0.0159	0.0257	0.0206	89	0.0000	0.0779	0.0000	0.0617
46	0.0262	0.0168	0.0253	0.0193	90	0.0000	0.0822	0.0000	0.0779
47	0.0241	0.0161	0.0237	0.0179	91	0.0000	0.0870	0.0000	0.0822
48	0.0222	0.0143	0.0237	0.0192	92	0.0000	0.0923	0.0000	0.0870
49	0.0230	0.0141	0.0231	0.0154	93	0.0000	0.1129	0.0000	0.0923
50	0.0217	0.0156	0.0206	0.0145	94	0.0000	0.1186	0.0000	0.1129
51	0.0193	0.0149	0.0193	0.0135	95	0.0000	0.1356	0.0000	0.1294
52	0.0184	0.0127	0.0178	0.0155	96	0.0000	0.1549	0.0000	0.1483
53	0.0164	0.0151	0.0164	0.0120	97	0.0000	0.1769	0.0000	0.1700
54	0.0140	0.0105	0.0140	0.0104	98	0.0000	0.2022	0.0000	0.1948
55	0.0133	0.0133	0.0133	0.0131	99	0.0000	0.2310	0.0000	0.2232
56	0.0118	0.0128	0.0118	0.0093	100	0.0000	0.2639	0.0000	0.2558
57	0.0106	0.0088	0.0106	0.0120	101	0.0000	0.3015	0.0000	0.2932
58	0.0088	0.0120	0.0088	0.0118	102	0.0000	0.3444	0.0000	0.3360
59	0.0092	0.0119	0.0092	0.0081	103	0.0000	0.3935	0.0000	0.3851
60	0.0092	0.0116	0.0092	0.0114	104	0.0000	0.4496	0.0000	0.4413
61	0.0063	0.0109	0.0063	0.0107	105	0.0000	0.5137	0.0000	0.5058
62	0.0055	0.0108	0.0055	0.0105	106	0.0000	0.5869	0.0000	0.5797
63	0.0051	0.0108	0.0051	0.0105	107	0.0000	0.6705	0.0000	0.6643
64	0.0043	0.0108	0.0043	0.0105	108	0.0000	0.7661	0.0000	0.7614
					109	0.0000	0.8753	0.0000	0.8726
					110	0.0000	1.0000	0.0000	1.0000

Notes: Authors' calculations using population projections produced by the Office for National Statistics
the authors' may be contacted for full details



Panel A: proportion of population employed



Panel B: split between full-time and part-time employment

Notes: Figure reports age specific employment rates calculated under the 1963-marriage scenario less associated statistics calculated under the 1953 scenario.

Source: Authors' calculations using simulated data for '1963-marriage' and '1953' counterfactual policy environments.

See Tables 13 and 14 for a summary of the parameters considered for analysis.

Figure 18: Effects on Simulated Female Labour Supply of Moving From Rates of Marriage and Relationship Dissolution Estimated for the 1953 Female Birth Cohort to those Estimated for the 1963 Birth Cohort

the 1963 female birth cohort. The simulated fertility responses reported in Table 15, however, tend to overstate those reported in survey data, with too few births simulated at the first birth age, too many births at the last birth age, and too few births simulated in aggregate.

We can now draw together the observations reported here for simulated labour supply and fertility responses to the probabilities of marriage estimated for the 1953 and 1963 birth cohorts. A lower proportion of women married at age 20, lower probabilities of marital formation, and higher probabilities of marital dissolution under the 1963-marriage scenario, gives young women a stronger incentive to work, relative to the 1953 scenario. It also means that women in their 20's are less well placed to meet the financial burden associated with child rearing, relative to women simulated under the 1953 scenario. Furthermore, the lower fertility rate that is generated at the first child bearing age under the 1963-marriage scenario, reduces the cost of employment to women in their early 20's, providing an added incentive to work.

Many of the women who put off having children at the first birth age under the 1963-marriage scenario, relative to the 1953 scenario, choose to increase their number of children at the second birth age. The sharply higher rates of fertility associated with the second birth age represent a disincentive to female labour supply, which motivates the coincident decline in the proportion of women moving out of full-time employment and into part-time or non-employment, relative to the 1953 scenario. After children from the second birth age exceed 4 years of age, women re-enter full-time employment at the expense of part-time and non-employment. Toward the end of the working lifetime, women in the 1963-marriage scenario are not as financially well-off as women under the 1953 scenario, and consequently choose to delay their retirement. Finally, Table 15 indicates a 4% increase in the proportion of households that choose to have the maximum number of children at the second birth age under the 1963-marriage scenario, relative to the 1953 scenario. This suggests that one of the reasons for the lower average total fertility rate generated under the 1963-marriage scenario is the associated delay in fertility.

The two scenarios that are considered here, and which differ only over the assumed probabilities of marriage and relationship dissolution, consequently do a very good job of capturing the broad empirical observations for trends in fertility that are reported in Section 2. The analysis is extended in the next subsection to take into account the incentive effects of wage growth.

5.2 The incentive effects of wage growth

The 1963 scenario is based upon the same model parameters that were assumed for the 1963-marriage scenario, but with the description of human capital adjusted to reflect survey data reported for the 1963, rather than the 1953 female birth cohort. Differences between the parameters adopted for the

Table 15: Effects on Simulated Fertility Decisions of Moving From Rates of Marriage and Relationship Dissolution Estimated for the 1953 Female Birth Cohort to those Estimated for the 1963 Birth Cohort

fertility decision	ONS stats for 1953 cohort	1953 scenario	1963-marriage scenario	effects	ONS stats for 1963 cohort
first birth age					
0 children		56.05	76.47	20.42	
1 child		5.10	4.36	-0.74	
2 children		28.68	16.87	-11.81	
3 children		10.17	2.30	-7.87	
total (%)		100.00	100.00	0.00	
average (no.)	0.957	0.930	0.450	-0.480	0.732
second birth age					
0 children		47.25	34.60	-12.65	
1 child		7.19	13.54	6.35	
2 children		30.73	33.20	2.47	
3 children		14.83	18.66	3.83	
total (%)		100.00	100.00	0.00	
average (no.)	1.088	1.131	1.359	0.228	1.192
aggregate					
0 children	15.00	18.83	23.19	4.36	19.00
1 child	13.00	7.49	8.83	1.34	13.00
2 children	42.00	40.94	38.88	-2.06	38.00
3 children	20.00	19.90	24.47	4.57	20.00
4 children	10.00*	8.77	3.06	-5.71	10.00*
5 children		2.46	0.74	-1.72	
6 children		1.61	0.83	-0.78	
total (%)		100.00	100.00	0.00	100.00
average (no.)	2.045	2.061	1.809	-0.252	1.924

Notes: * aggregate for 4 or more children

Source: Authors' calculations using simulated data for 1953 and 1963-marriage scenarios

ONS statistics reported from tables 10.1 and 10.5 of ONS publication, *Birth Statistics*

1963-marriage and 1963 scenarios are reported in Tables 2, 3, and 4 in Section 4, and Tables 16 and 17 here. In summary, the parameters that are reported in these tables indicate the extent to which wage growth observed for men and women improved the circumstances of the 1963 female birth cohort relative to the 1953 cohort.

The wages of women under the 1963 scenario start out slightly higher, and grow faster with age, relative to those of women in the 1953 / 1963-marriage scenarios. This variation in the age trend considered for wages is also described by the μ parameters that are reported for men in Table 17. The correlation between spousal wages is stronger in the 1963 scenario than the 1953 / 1963-marriage scenarios, as is the intertemporal persistence of wages (β) considered for both men and women. The strengthening of the experience effect implied by the increase in the intertemporal persistence of wages is slightly off-set by the reduction considered for the cost of non-employment, as described by the α_3 parameters in Tables 16 and 17. And the associated costs considered for part-time employment, α_2, reflect the increasing importance of education in later birth cohorts as discussed in section 4. Finally, the parameter values for ϕ that are reported in Table 16 indicate that the proportion of the full-time wage earned through part-time employment by women is lower in the 1963 scenario than the 1953 / 1963-marriage scenarios, reflecting the observation that the wages of women who were full-time employed grew faster than those of women who were part-time employed between the 1953 and 1963 female birth cohorts.

A complex interaction of incentive effects underly the behavioural responses reported here for the 1963 scenario, as the income effects of lower marital rates combine with the coincident income and substitution effects of higher wage rates, relative to the 1953 scenario. Figure 19 reports the effects on simulated female labour supply of moving from the policy environment described by the 1953 scenario to that described by the 1963 scenario, and the associated effects on fertility are reported in Table 18. To help disentangle the incentives that underly the behavioural responses that are reported here, we also include in Table 18 the fertility statistics that were obtained for the 1963-marriage scenario that are explored in the preceding subsection.

Panel A of Figure 19 indicates that, when our model is based upon marital and wage rates estimated for the 1963 female birth cohort, it suggests that women tend to start work later, with a larger proportion choosing to work between the ages of 25 and 45, relative to when the model is based upon estimates for the 1953 cohort. These projected labour supply responses closely match observations drawn from repeated cross-sections of the Expenditure and Food Survey (EFS) for the 1953 and 1963 female birth cohorts. In this regard, it is of particular note that our model also predicts that fewer women from the 1963 female birth cohort will choose to be employed beyond age 45, relative to the 1953 cohort. In the model, women choose to take retirement earlier under the 1963 scenario, relative to the 1953 scenario,

Table 16: Counterfactual Parameters of Wage Dynamics of Women, Calibrated to Data for the 1953 and 1963 Birth Cohorts in the United Kingdom

	1953 scenario					1963 scenario				
beta			0.7280					0.8635		
std dev full-time work			0.2216					0.2383		
std dev part-time work			0.3000					0.3000		
std dev not employed			0.3430					0.3348		
age	phi	mu	alpha(2)	alpha(3)	unemp rate	phi	mu	alpha(2)	alpha(3)	unemp rate
21	0.4578	143.11	-0.0524	-0.1037	0.0191	0.2928	130.30	0.0209	-0.0769	0.1634
22	0.4658	153.64	-0.0524	-0.1037	0.0191	0.3092	147.18	0.0200	-0.0769	0.1511
23	0.4492	164.16	-0.0518	-0.1037	0.0306	0.3306	173.66	0.0191	-0.0769	0.1338
24	0.4438	168.19	-0.0512	-0.1037	0.0390	0.3379	195.83	0.0154	-0.0769	0.1037
25	0.4388	179.90	-0.0498	-0.1037	0.0472	0.3363	220.43	0.0118	-0.0769	0.0891
26	0.4194	190.42	-0.0480	-0.1037	0.0526	0.3275	240.56	0.0082	-0.0769	0.0792
27	0.4041	200.84	-0.0458	-0.1037	0.0646	0.3045	260.42	0.0027	-0.0769	0.0765
28	0.4056	210.91	-0.0433	-0.1037	0.0755	0.2820	276.58	-0.0042	-0.0769	0.0722
29	0.3968	221.17	-0.0406	-0.1037	0.0877	0.2687	295.48	-0.0107	-0.0769	0.0750
30	0.3746	229.09	-0.0379	-0.1037	0.0884	0.2565	305.81	-0.0177	-0.0769	0.0831
31	0.3818	236.02	-0.0352	-0.1037	0.0866	0.2510	322.58	-0.0226	-0.0769	0.0858
32	0.3857	243.37	-0.0328	-0.1037	0.0836	0.2526	335.90	-0.0232	-0.0769	0.0835
33	0.3863	251.28	-0.0308	-0.1037	0.0829	0.2523	351.50	-0.0232	-0.0769	0.0688
34	0.3940	260.40	-0.0290	-0.1037	0.0786	0.2593	361.24	-0.0232	-0.0769	0.0577
35	0.3983	270.15	-0.0277	-0.1037	0.0633	0.2805	377.50	-0.0232	-0.0769	0.0423
36	0.4041	278.53	-0.0268	-0.1037	0.0454	0.2955	385.85	-0.0232	-0.0769	0.0467
37	0.3990	286.74	-0.0261	-0.1037	0.0339	0.3148	398.09	-0.0232	-0.0769	0.0456
38	0.4013	292.51	-0.0257	-0.1037	0.0376	0.3338	409.72	-0.0232	-0.0769	0.0447
39	0.3955	296.13	-0.0253	-0.1037	0.0484	0.3426	424.75	-0.0232	-0.0769	0.0345
40	0.4124	297.28	-0.0251	-0.1037	0.0522	0.3497	431.27	-0.0232	-0.0769	0.0348
41	0.4145	297.16	-0.0248	-0.1037	0.0491	0.3555	440.71	-0.0232	-0.0769	0.0375
42	0.4290	296.63	-0.0245	-0.1037	0.0404	0.3621	446.63	-0.0232	-0.0769	0.0440
43	0.4412	296.99	-0.0242	-0.1037	0.0381	0.3665	442.89	-0.0232	-0.0769	0.0440
44	0.4527	298.78	-0.0239	-0.1037	0.0369	0.3728	444.02	-0.0232	-0.0769	0.0440
45	0.4720	303.12	-0.0237	-0.1037	0.0388	0.3753	453.83	-0.0232	-0.0769	0.0440
46	0.4843	308.74	-0.0235	-0.1037	0.0357	0.3795	460.93	-0.0232	-0.0769	0.0440
47	0.4966	316.84	-0.0234	-0.1037	0.0301	0.3793	467.40	-0.0232	-0.0769	0.0440
48	0.5054	328.79	-0.0234	-0.1037	0.0236	0.3822	482.72	-0.0232	-0.0769	0.0440
49	0.5200	337.56	-0.0234	-0.1037	0.0187	0.3835	493.59	-0.0232	-0.0769	0.0440
50	0.5040	346.59	-0.0234	-0.1037	0.0173	0.3711	503.62	-0.0232	-0.0769	0.0440
51	0.5063	352.68	-0.0234	-0.1037	0.0172	0.3644	517.24	-0.0232	-0.0769	0.0440
52	0.5087	357.80	-0.0234	-0.1037	0.0172	0.3581	526.87	-0.0232	-0.0769	0.0440
53	0.5087	358.46	-0.0234	-0.1037	0.0172	0.3505	533.43	-0.0232	-0.0769	0.0440
54	0.5101	361.09	-0.0234	-0.1037	0.0172	0.3492	535.60	-0.0232	-0.0769	0.0440
55	0.5231	362.03	-0.0234	-0.1037	0.0172	0.3576	536.96	-0.0232	-0.0769	0.0440
56	0.5315	364.69	-0.0234	-0.1037	0.0172	0.3656	534.55	-0.0232	-0.0769	0.0440
57	0.5363	368.17	-0.0234	-0.1037	0.0172	0.3715	535.30	-0.0232	-0.0769	0.0440
58	0.5434	372.50	-0.0234	-0.1037	0.0172	0.3754	531.85	-0.0232	-0.0769	0.0440
59	0.5459	374.69	-0.0234	-0.1037	0.0172	0.3729	534.85	-0.0232	-0.0769	0.0440
60	0.5476	377.10	-0.0234	-0.1037	0.0172	0.3742	530.35	-0.0232	-0.0769	0.0440
61	0.5518	375.61	-0.0234	-0.1037	0.0172	0.3788	522.32	-0.0232	-0.0769	0.0440
62	0.5559	374.65	-0.0234	-0.1037	0.0172	0.3938	503.25	-0.0232	-0.0769	0.0440
63	0.5599	373.48	-0.0234	-0.1037	0.0172	0.4124	483.00	-0.0232	-0.0769	0.0440
64	0.5641	375.63	-0.0234	-0.1037	0.0172	0.4473	441.17	-0.0232	-0.0769	0.0440

Table 17: Counterfactual Parameters of Wage Dynamics of Men, Calibrated to Data for the 1953 and 1963 Birth Cohorts in the United Kingdom

	1953 scenario			1963 scenario		
beta		0.8803			0.9247	
std dev employed		0.2417			0.2536	
std dev not employed		0.2883			0.2832	
age	mu	alpha(3)	unemp rate	mu	alpha(3)	unemp rate
21	186.26	-0.0384	0.0443	247.45	-0.0221	0.2955
22	210.20	-0.0384	0.0443	271.01	-0.0221	0.2265
23	226.58	-0.0384	0.0443	297.03	-0.0221	0.1642
24	239.52	-0.0384	0.0443	324.33	-0.0221	0.1062
25	255.33	-0.0384	0.0443	351.49	-0.0221	0.0807
26	270.54	-0.0384	0.0457	377.60	-0.0221	0.0657
27	288.12	-0.0384	0.0476	399.04	-0.0221	0.0858
28	304.94	-0.0384	0.0514	417.25	-0.0221	0.0806
29	322.22	-0.0384	0.0606	430.40	-0.0221	0.0876
30	336.78	-0.0384	0.0721	439.45	-0.0221	0.0722
31	350.66	-0.0384	0.0796	444.40	-0.0221	0.0680
32	364.97	-0.0384	0.0793	449.05	-0.0221	0.0671
33	380.64	-0.0384	0.0780	453.99	-0.0221	0.0673
34	396.36	-0.0384	0.0767	459.55	-0.0221	0.0637
35	412.50	-0.0384	0.0697	466.43	-0.0221	0.0546
36	426.27	-0.0384	0.0573	475.93	-0.0221	0.0442
37	438.31	-0.0384	0.0483	483.38	-0.0221	0.0401
38	446.50	-0.0384	0.0544	492.33	-0.0221	0.0318
39	451.79	-0.0384	0.0593	493.23	-0.0221	0.0381
40	453.11	-0.0384	0.0631	513.58	-0.0221	0.0395
41	453.53	-0.0384	0.0669	526.19	-0.0221	0.0444
42	453.14	-0.0384	0.0664	542.70	-0.0221	0.0404
43	452.62	-0.0384	0.0643	556.72	-0.0221	0.0404
44	452.12	-0.0384	0.0516	561.67	-0.0221	0.0404
45	454.04	-0.0384	0.0473	567.99	-0.0221	0.0404
46	453.54	-0.0384	0.0391	574.35	-0.0221	0.0404
47	450.65	-0.0384	0.0407	569.42	-0.0221	0.0404
48	448.53	-0.0384	0.0427	564.31	-0.0221	0.0404
49	438.65	-0.0384	0.0419	557.05	-0.0221	0.0404
50	448.33	-0.0384	0.0419	565.28	-0.0221	0.0404
51	443.35	-0.0384	0.0419	559.68	-0.0221	0.0404
52	449.72	-0.0384	0.0419	566.84	-0.0221	0.0404
53	447.95	-0.0384	0.0419	564.85	-0.0221	0.0404
54	452.54	-0.0384	0.0419	570.01	-0.0221	0.0404
55	441.89	-0.0384	0.0419	558.04	-0.0221	0.0404
56	437.33	-0.0384	0.0419	552.91	-0.0221	0.0404
57	429.13	-0.0384	0.0419	543.68	-0.0221	0.0404
58	421.96	-0.0384	0.0419	535.62	-0.0221	0.0404
59	413.92	-0.0384	0.0419	526.59	-0.0221	0.0404
60	407.70	-0.0384	0.0419	519.59	-0.0221	0.0404
61	402.42	-0.0384	0.0419	512.00	-0.0221	0.0404
62	397.17	-0.0384	0.0419	504.42	-0.0221	0.0404
63	394.62	-0.0384	0.0419	496.84	-0.0221	0.0404
64	392.98	-0.0384	0.0419	489.25	-0.0221	0.0404

as they choose to take some of their financial advantage in the form of increased leisure. It will be interesting to observe whether this projection matches the practical reality.

Panel B of Figure 19 reveals that the simulation model over-states the incidence of part-time employment amongst the 1963 female birth cohort, relative to data described by the EFS. This reflects the fact that women under 28 years of age receive a positive return in terms of future wage potential to part-time work under the 1963 simulation. The experience effect of working part-time rather than full-time becomes negative in the 1963 scenario from age 28. This experience effect, combined with the higher full-time wages that are paid under the 1963 simulation, motivate a larger proportion of women between the ages of 28 and 40 to choose full-time employment, relative to either of the alternative counterfactuals that are considered for analysis. It also encourages a larger proportion of the employed female population to choose to work full-time, from age 28 to the end of the simulated working lifetime.

The 1963 scenario differs from the 1963-marriage scenario only insofar as the wages of men and women that are considered for the 1963 scenario tend to exceed those of the 1963-marriage scenario. The higher wages paid under the 1963 scenario relative to the 1963-marriage scenario imply off-setting income and substitution effects in relation to fertility decisions. Households with higher labour incomes are better able to afford the costs of dependant children; but – due to the proportional nature of the equivalence scale adjustment that is assumed for the preference relation – the 'price' of having children also increases with the scale of desired consumption. The statistics reported at the bottom of Table 18 for rates of completed fertility indicate that the income effects referred to here dominate the price effects, so that women under the 1963 scenario choose to have 0.1 more children on average (1.907 c.f. 1.809), relative to the marital simulation.

This finding is in direct contrast to the standard Barro-Becker analysis, in which the price effects associated with improved female labour market opportuities are considered to be a possible explaination of the general decline observed in fertility rates. The analysis that we report here suggests that focussing exclusively on women's labour market opportunities to explain fertility trends risks understating the associated income effect in the context of a coincident rise in marital instability; a form of omitted variable bias. This observation high-lights the potential difficulties associated with partial analyses of what is a complex, and highly endogenous, behavioural phenomenon.

In the preceding subsection, we observed that reducing the probabilities of marriage from estimates that reflect the 1953 female birth cohort to estimates for the 1963 birth cohort reduced the total fertility rate from 2.06 to 1.809; a fall of 0.26 that exceeds the associated empirically observed fall of 0.12. The analysis of the current section suggests that at least part of this difference can be attributed to wage growth. The simulations reported here suggest that allowing for wage growth between the 1953 and

1963 female birth cohorts obtains a fall in the total fertility rate of 0.15, which is very similar to the empirical observation.

The simulations that are reported here must, however, be treated with some caution when attempting to draw implications regarding the practical reality. The difficulties involved are made clear by digging under the aggregate measures of total fertility, and focussing upon the timing of the fertility decision. It will be recalled from the preceding subsection that, not only did the 1963-marriage scenario exaggerate the fall in the total fertility rate described by ONS data between the 1953 and 1963 female birth cohorts, but it also exaggerated the delay in fertility – average fertility at the first birth age exhibited a larger fall, and at the second birth age exhibited a larger rise than described by the survey data. The top two panels of Table 18 indicate that women under the 1963 scenario tend to delay fertility still further, a response that is driven by the stronger wage growth with age that is assumed for the 1963 scenario. It is consequently interesting to ask what aspects of the policy environment could explain the dampened responses in relation to the timing of fertility that are described by survey data, relative to the simulations that are reported here.

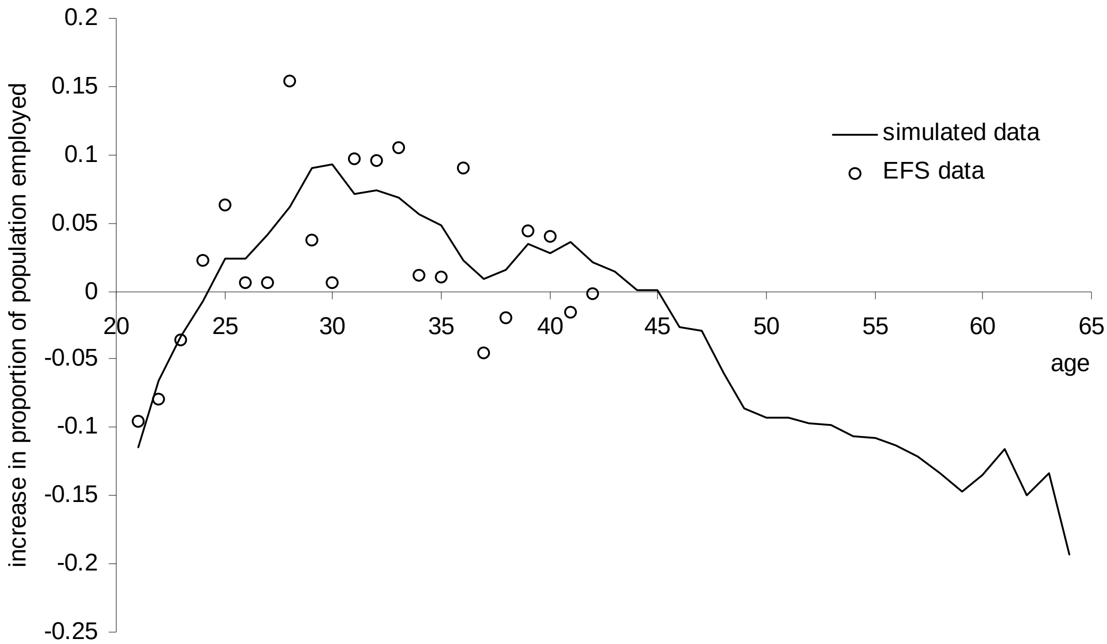
One of the key difficulties with which we have had to contend in the current analysis is the paucity of reliable estimates for the costs and availability of childcare. The allowance that we have made for childcare costs was formulated on the belief that it is preferable to adopt a simplified analytical structure when there is insufficient data to motivate a more complex specification. Nevertheless, at least some of the differences that are identified here between the simulated and sample fertility statistics could be mitigated by adopting a more complex (and potentially realistic) specification for childcare.

A related issue is the tax function that is considered for analysis. To limit heterogeneity between simulated scenarios, we have held the tax function fixed for the analysis that is presented here. This could be relaxed to recognise policy initiatives that have been undertaken to facilitate labour market participation of women. Furthermore, as previously noted, the fall in rates of formal marriages has been off-set in part by a rise in rates of informal cohabitation. Allowing for *de facto* relationships is consequently likely to dampen the behavioural responses reported in the preceding subsection, and might thereby obtain a closer reflection of reality. These issues remain subjects for further research.

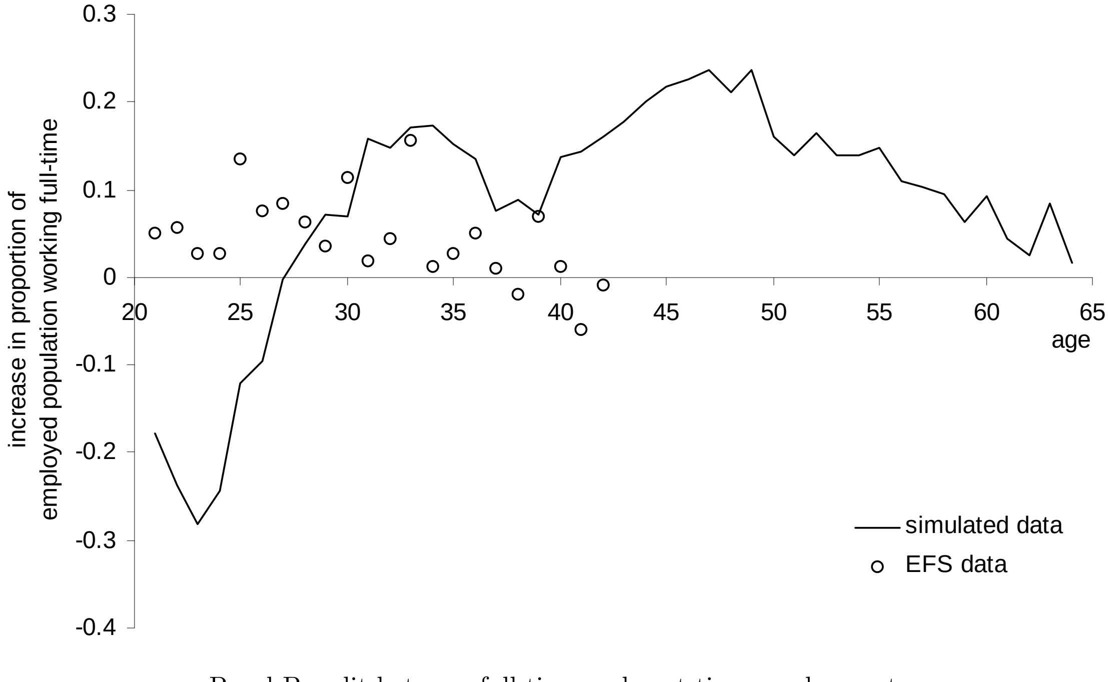
6 Behavioural Responses to Fertility Related Transfers

Many countries have considered introducing family friendly policies in response to the declining fertility rates observed during recent decades. One controversial reform that was proposed in Portugal, for example, was to inversely relate pension contributions to the number of children of an employee.[33]

[33] Described in by the then Portuguese Prime Minister José Sócrates in an interview with the *Financial Times*, published 15 May 2006. The proposal was not included as part of wider reforms to the pension system that were enacted in October of 2006.



Panel A: proportion of population employed



Panel B: split between full-time and part-time employment

Notes: Figure reports age specific employment rates calculated under the 1963 simulation scenario less associated statistics calculated under the 1953 scenario.
EFS denotes statistics estimated using data from repeated cross-sections of the Expenditure and Food Survey

Source: Authors' calculations using simulated data for '1953' and '1963' counterfactual policy environments.
EFS data described in Appendix A

Figure 19: Effects on Simulated Female Labour Supply of Replacing Wage Rates and Rates of Marriage and Relationship Dissolution Estimated for the 1953 Female Birth Cohort with Rates Estimated for the 1963 Birth Cohort

Table 18: Effects on Simulated Fertility of Replacing Wage Rates and Rates of Marriage and Relationship Dissolution Estimated for the 1953 Female Birth Cohort with Rates Estimated for the 1963 Birth Cohort

fertility decision	ONS stats for 1953 cohort	1953 scenario	1963-marriage scenario	1963 scenario	effects	ONS stats for 1963 cohort
first birth age						
0 children		56.05	76.47	70.85	14.80	
1 child		5.10	4.36	17.97	12.87	
2 children		28.68	16.87	11.18	-17.50	
3 children		10.17	2.30	0.00	-10.17	
total (%)		100.00	100.00	100.00	0.00	
average (no.)	0.957	0.930	0.450	0.403	-0.526	0.732
second birth age						
0 children		47.25	34.60	29.44	-17.81	
1 child		7.19	13.54	14.87	7.68	
2 children		30.73	33.20	31.60	0.87	
3 children		14.83	18.66	24.09	9.26	
total (%)		100.00	100.00	100.00	0.00	
average (no.)	1.088	1.131	1.359	1.503	0.372	1.192
aggregate						
0 children	15.00	18.83	23.19	18.33	-0.50	19.00
1 child	13.00	7.49	8.83	17.00	9.51	13.00
2 children	42.00	40.94	38.88	28.15	-12.79	38.00
3 children	20.00	19.90	24.47	29.35	9.45	20.00
4 children	10.00*	8.77	3.06	6.53	-2.24	10.00*
5 children		2.46	0.74	0.64	-1.82	
6 children		1.61	0.83	0.00	-1.61	
total (%)		100.00	100.00	100.00	0.00	100.00
average (no.)	2.045	2.061	1.809	1.907	-0.154	1.924

Notes: * aggregate for 4 or more children

Source: Authors' calculations using simulated data for 1953, 1963-marriage, and 1963 simulation scenarios
ONS statistics reported from tables 10.1 and 10.5 of ONS publication, *Birth Statistics*

The political rationale for such a policy reform is clear: in a society where public pensions are funded through a PAYG system, and where child rearing incurs a financial cost, people who choose to have children and thereby supply the next generation of workers have a stronger claim on public pensions than those who do not. In a similar vein, studies that explore the decline in fertility observed at the end of the 1800's have high-lighted the role played by the coincident fall in the contribution of children to family income, or the perceived relative cost of children more generally.[34] Here we explore how the cost of child rearing affects the fertility behaviour generated by our model.

Our analysis is framed in terms of a tax-free benefit of constant absolute value that is received by a woman at the time of birth, for each child to whom she gives birth. The choice to focus upon a benefit of constant absolute value per child – rather than, for example, a benefit that is proportional to the financial means of a household – was made because it is similar to other child related benefits that are currently payable in the UK.[35] An analysis of the sensitivity of the current results to the structure of benefits considered here remains an issue for further research.

[34] See Szreter (1996) for an excellent account of the British context. See also Guest & Tolnay (1983) for a study using U.S. data, and Caldwell (1978) for a wider European view.

[35] Child related benefits in relation to infants less than a year old were payable in 2005 through the (means-tested) *Child Tax Credit*. Proportional tax adjustments in respect of children are made through the *Quotient Familial* applied in France.

The parameter specification of the model that was calibrated against data for the 1953 female birth cohort, as described in Section 4, was used to conduct the analysis. This model was used to generate six population cohorts of 10,000 women, where the only environmental difference between the simulated cohorts was the value of the per child benefit considered for analysis. Discussion is divided into two subsections. In the first subsection, we focus on population aggregates, contrasting the cost of the respective benefits with the associated influence on fertility decisions. In the second subsection, we explore behavioural responses disaggregated by the financial circumstances of the household. As in the preceding section, we summarise the results that are reported here in the conclusion.

6.1 The influence of birth credits on population aggregates

The effects of the fertility payments considered for analysis on population aggregates are summarised in Table 19. One of the most striking impressions that is made by the statistics reported in Table 19 is the sensitivity of fertility decisions to fertility related transfers. In return for a once off transfer per child equal to a fifth of average annual gross full-time employment income at age 52 (the right-most column in the table) – holding all other aspects of the simulated environment fixed – households choose to have more than twice the number of children than they do in the absence of such a payment (the left-most column). Note that this does not require a child to bring in a net financial gain to their parents' household: children still impose a financial burden through the equivalence scale that is considered for analysis, and through the influence of childcare costs when mothers choose to work. All that is required is that a child provides a financial benefit to their parents over the course of their life, gross of the costs of their upbringing. This benefit could be in the form of a government transfer, or some unrequited transfer later in life.

To put the statistics reported in Table 19 into perspective, 20% of average annual gross full-time employment income is approximately equivalent to 30% of average annual disposable income of full-time employees. The analysis reported here suggests that, if a child could contribute this sum, in net present value terms, to their parents over the course of their entire lifetime, then the completed fertility rate would exceed four children per woman, thereby recovering the decline in fertility projected to have occurred during the last 150 years (reported in Figure 4). The sensitivity of simulated fertility decisions that is reported here consequently goes some way toward supporting hypotheses that attach significance to the changing economic role of children in explaining the fertility trends exhibited by survey data. Nevertheless it will be necessary to explore the robustness of the results that are reported here to the model specification, before they can be used to inform the structure of family friendly welfare payments, or be cited as part of the wider literature that is concerned with understanding observed fertility trends.

The top two panels of Table 19 indicate similar responses to the birth credits at each of the two

Table 19: The Influence on Fertility Rates of Child Related Transfers in Addition to Existing Benefits

	per child benefit (% of annual gross full-time employment income)*						
	0.0	0.4	1.0	2.1	4.1	10.3	20.6
first birth age (21)							
0 children	56.05	55.98	55.98	55.37	51.38	49.13	38.28
1 child	5.10	4.99	4.91	4.18	1.27	1.13	3.67
2 children	28.68	26.35	26.30	21.39	5.54	2.47	3.72
3 children	10.17	12.68	12.81	19.06	41.81	47.27	54.33
total (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00
average (no.)	0.930	0.957	0.959	1.041	1.378	1.479	1.741
second birth age (29)							
0 children	47.25	46.62	46.21	45.29	42.68	28.72	11.99
1 child	7.19	6.79	6.81	6.61	5.42	5.03	4.69
2 children	30.73	29.80	26.62	20.39	20.66	18.60	10.17
3 children	14.83	16.79	20.36	27.71	31.24	47.65	73.15
total (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00
average (no.)	1.131	1.168	1.211	1.305	1.405	1.852	2.445
aggregate							
0 children	18.83	18.19	18.03	16.74	11.46	2.80	0.00
1 child	7.49	7.46	7.28	6.84	4.54	2.73	0.00
2 children	40.94	39.17	38.52	33.36	23.08	15.42	1.81
3 children	19.90	21.85	22.51	28.80	44.43	54.68	49.63
4 children	8.77	8.18	6.73	2.37	1.28	3.74	8.06
5 children	2.46	2.48	3.28	6.12	2.13	3.29	9.17
6 children	1.61	2.67	3.65	5.77	13.08	17.34	31.33
total (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00
average (no.)	2.061	2.125	2.171	2.347	2.782	3.331	4.186
avg cost per woman*	0.000	0.877	2.239	4.842	11.482	34.362	86.369

Notes: * benefit specified as percentage of annual gross labour income of full-time employees in 2005 (equivalent to £466 per week)

Source: Authors' calculations using simulated data. The authors may be contacted for details

birth ages considered for analysis. As the value of the birth credit increases, there is a reasonably smooth decline in the proportion of households that choose to have no children at each of the two birth ages. Few households choose to have a single child at either of the two birth ages, regardless of the considered transfer, and the proportion of households choosing to have two children falls sharply as the birth credit increases from zero. As a residual, the proportion of households that choose to have the maximum number of children at each of the birth ages increases sharply as the birth credit increases from zero, and increases at a smooth, more gradual rate thereafter. In aggregate the bi-modal distribution of household size shifts from zero and two children per household, to three and six children as the birth credit increases. This last observation emphasises the influence that the upper bound considered for the number of births at each birth age has on the distribution of household size that is simulated by the model.

6.2 Distributional Responses

The influence of financial circumstances on simulated fertility decisions in the context of alternative birth credits is reported in Table 20. The statistics reported in left-most column of the top panel of Table 20 indicate that, in the absence of a birth credit, children tend to be concentrated at the extremes of the wealth distribution, with completed fertility rates highest amongst households in the top and bottom wealth quintiles, and lowest amongst households in the third quintile. This is an intuitive

Table 20: Effects on Completed Fertility Rates of Child Related Transfers, by Wealth Quintile at Age 30

	per child benefit (% of annual gross full-time employment income)*						
	0.0	0.4	1.0	2.1	4.1	10.3	20.6
lowest quintile	2.986	3.039	3.123	3.398	3.755	4.174	5.059
2nd quintile	1.852	1.981	2.070	2.395	3.204	3.781	4.633
3rd quintile	1.356	1.426	1.442	1.540	1.951	2.759	3.768
4th quintile	1.698	1.739	1.750	1.864	2.355	2.731	3.633
highest quintile	2.412	2.437	2.467	2.536	2.648	3.208	3.837
	*effect of benefit on completed fertility rate***						
lowest quintile		0.054	0.138	0.412	0.769	1.188	2.073
2nd quintile		0.129	0.218	0.543	1.351	1.929	2.781
3rd quintile		0.070	0.086	0.184	0.595	1.403	2.411
4th quintile		0.041	0.052	0.166	0.657	1.033	1.935
highest quintile		0.026	0.055	0.124	0.236	0.796	1.425

Notes: * benefit specified as percentage of annual gross labour income of full-time employees in 2005 (equivalent to £466 per week)

** effect of benefit = completed fertility with benefit less completed fertility with zero benefit (left-most column)

Source: Authors' calculations using simulated data. The authors may be contacted for details

observation in context of the incentives that are embodied by our behavioural model. Households in the top of the wealth distribution tend to have more children than those in the middle of the distribution because they are better able to afford the associated financial burden. Meanwhile, households at the bottom of the wealth distribution tend to have more children because associated government transfers in respect of children represent a greater share of their aggregate financial resources, relative to more affluent households. This last observation points toward the behavioural responses that were generated in response to the birth credit with which the current section is concerned.

As the statistics reported in the bottom panel of Table 20 make clear, introducing a birth credit in respect to each child to whom a woman gives birth increases fertility rates throughout the wealth distribution, with the largest responses observed amongst households in the second least wealthy quintile. The disproportionate responses of households toward the bottom of the wealth quintile is a direct consequence of the fact that the analysis focuses upon a birth credit of constant absolute value per child. As this benefit is valued more by poorer households, it is the poorer households that respond most strongly to it's introduction. That the largest increases in completed fertility are observed amongst households in the second wealth quintile, as opposed to the bottom wealth quintile is attributable to the second quintile's relatively low average fertility rate in the absence of a birth credit.

7 Conclusions

The importance of contemporary trends in fertility and female labour supply is well recognised. Women are now having fewer children than ever before, choosing to delay fertility in preference of increased labour market participation. It is difficult to overstate the social and economic importance of these trends; the changing nature of fertility is one of the key factors that underlie the aging of populations that has been observed in countries throughout the economically developed world, and women now constitute a much more important fraction of the aggregate labour force than was the case just a few decades ago. Unfortunately, our understanding of these inter-related phenomena has been hampered by the difficulties that are associated with formulating a structural model of behaviour that reflects the joint nature of the fertility and labour supply decisions in the context of an uncertain future. In this paper we describe a model that we have developed to address this analytical challenge.

Our model is based upon the premise that recent trends in fertility and female labour supply can be attributed to the changing nature of partner relations, and to the labour market opportunities available to women. The trend away from formal marital contracts during the last half century in the United Kingdom is clearly described by survey data, with rates of marriage falling, and rates of marital dissolution rising to previously unobserved levels. At the same time, the wages paid to women have grown strongly, both in absolute terms and relative to those of men. The model that we have developed is calibrated to survey data for the cohort of women born in the United Kingdom in 1953, and its out-of-sample properties are explored with reference to data reported for the cohort of women born in 1963.

Our model does a good job at capturing data reported for the 1953 female birth cohort against which it was calibrated. The out-of-sample analyses that we conduct also reflect the key stylised facts that are referred to above; adjusting our model parameters to reflect rates of marriage, marital dissolution, and wages estimated for the 1963 female birth cohort results in higher rates of full-time labour market participation, a delay in the timing of births, and a fall in completed fertility rates. In regard to labour market participation and completed fertility rates, our model obtains a close match to the trends that are described by associated survey data. In relation to the timing of fertility, however, the model exaggerates the fertility delay that has been observed in practice. We conjecture that the reflection that our model obtains to the practical reality could be improved by a number of measures. These include making a more realistic allowance for the costs and particularly the availability of childcare; an allowance for the effects of wider policy initiatives to facilitate female labour market participation; and accounting for the increasing importance of *de facto* cohabitation. These issues remain topics for further research.

We use our model to explore fertility responses to a benefit of constant absolute value that is received by a woman at the time of birth, for each child to whom she gives birth. To the extent that our behavioural model can be taken as representative of the practical reality, our findings have at least two important policy implications. First, the analysis suggests that the population average completed fertility rate can be quite sensitive to fertility related transfers: a constant absolute transfer of £250 per child measured in 2005 money generates an increase in the population average completed fertility rate simulated for the 1953 birth cohort of women of 0.11 children; and a transfer of £5000 per child generates a completed fertility rate that has not been seen since the first fertility transition at the end of the 1800's. Second, the design of birth credits can be very important in determining the incidence of behavioural responses. In the context of the constant absolute payments per child that are considered for analysis, simulated fertility responses are concentrated toward the bottom of the wealth distribution. Such a policy may obviously bring with it social concerns, that are beyond the scope of our current analysis.

References

Adsera, A. (2005), Wher are the babies? Labor market conditi0ons and fertility in Europe. IZA Discussion Paper 1576.

Akerlof, G. A. (1998), 'Men without children', *The Economic Journal* **108**, 287–309.

Arellano, M. & Bond, S. (1991), 'Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations', *Review of Economic Studies* **56**, 1–20.

Arellano, M. & Bover, O. (1995), 'Another look at the instrumental variable estimation of error-components models', *Journal of Econometrics* **68**, 29–51.

Arroyo, C. & Zhang, J. (1997), 'Dynamic microeconomic models of fertility choice: a survey', *Journal of Population Economics* **10**, 23–65.

Attanasio, O. P. & Weber, G. (1995), 'Is consumption growth consistent with intertemporal optimization?', *Journal of Political Economy* **103**, 1121–1157.

Attansio, O., Low, H. & Sanchez-Marcos, V. (2008), 'Explaining changes in female labor supply in a life-cycle model', *American Economic Review* **98**, 1517–1552.

Balcer, Y. & Sadka, E. (1986), 'Equivalence scales, horizontal equity and optimal taxation under utilitarianism', *Journal of Public Economics* **29**, 79–97.

Banks, J. & Johnson, P. (1998), How Reliable is the Family Expenditure Survey? The Institute for Fiscal Studies, London.

Becker, G. S. (1988), 'Family economics and macro behaviour', *American Economic Review* **78**, 1–13.

Berrington, A. (2004), 'Perpetual postponers? WomenŠs, menŠs and coupleŠs fertility intentions and subsequent fertility behaviour', *Population Trends* **3**, 9–19.

Blundell, R. & Bond, S. R. (1998), 'Initial conditions and moment restrictions in dynamic panel data models', *Journal of Econometrics* **87**, 115–143.

Blundell, R., Browning, M. & Meghir, C. (1994), 'Consumer demand and the life cycle allocation of household expenditure', *Review of Economic Studies* **61**, 57–80.

Boldrin, M. & Jones, L. (2002), 'Mortality, fertility and saving in a malthusian economy', *Review of Economic Dynamics* **5**, 775–814.

Bond, S. R., Hoeffler, A. & Temple, J. (2001), GMM estimation of empirical growth models. Centre for Economic Policy Research (London) Discussion Paper No. 3048.

Brewer, M. & Shaw, J. (2004), Childcare use and mothersŠ employment: a review of British data sources. Department for Work and Pensions Working Paper 16.

Bus, J. C. P. & Dekker, T. (1975), 'Two efficient algorithms with guaranteed convergence for finding a zero of a function', *ACM Trans. Math. Software* **1**, 330–345.

Caldwell, J. C. (1978), 'A theory of fertility: from high plateau to destabilization', *Popoulation and Development Review* **4**, 553–577.

Deaton, A. & Muellbauer, J. (1980), *Economics and Consumer Behavior*, Cambridge University Press, Cambridge.

Diamond, P. & Köszegi, B. (2003), 'Quasi-hyperbolic discounting and retirement', *Journal of Public Economics* **87**, 1839–1872.

Fernandez-Villaverde, J. & Krueger, D. (2006), Consumption over the life cycle: facts from Consumer Expenditure Survey Data. Working Paper, University of Pennsylvania.

Foster, K. (1996), 'A comparison of the Census characteristics of respondents and non-respondents to the 1996 FES', *ONS Survey Methodology Bulletin* **38**.

French, E. (2005), 'The effects of health, wealth, and wages on labour supply and retirement behaviour', *Review of Economic Studies* **72**, 395–427.

Guest, A. M. & Tolnay, S. E. (1983), 'Children's roles and fertility: late nineteenth-century United States', *Social Science History* **7**, 355–380.

Gustman, A. L. & Steinmeier, T. L. (2005), 'The social security early entitlement age in a structural model of retirement and wealth', *Journal of Public Economics* **89**, 441–464.

Heckman, J. (1979), 'Sample Bias as Specification Error', *Econometrica* **47**, 153–162.

Hicks, J. R. (1939), *Value and Capital*, Clarendon Press, Oxford.

Hurd, M. (1989), 'Mortality risk and bequests', *Econometrica* **57**, 779–813.

Joshi, H. (1990), 'The cash opportunity costs of childbearing: an approach to estimation using British data', *Population Studies* **44**, 41–60.

Kogel, T. (2004), 'Did the association between fertility and female employment within OECD countries really change its sign?', *Journal of Population Economics* **17**, 45–65.

Laibson, D. (1997), 'Golden eggs and hyperbolic discounting', *Quarterly Journal of Economics* **112**, 443–477.

Macunovich, D. J. (1996), Relative income and price of time: Exploring their effects on U.S. fertility and femal labor force particpation, 1963-1993. Williams College Department of Economics Working Paper 174.

Muellbauer, J. & van de Ven, J. (2004), Estimating Equivalence Scales for Tax and Benefits Systems. NIESR Working Paper, 229.

ONS (2002*a*), NESPD documentation for the 2001 Panel. Office for National Statistics, London.

ONS (2002*b*), Review of Distribution and Earnings Statistics. National Statistics Quality Review Series, Report no 14, Office for National Statistics, London.

Sefton, J. & van de Ven, J. (2004), 'Simulating household savings and labour supply: an application of dynamic programming', *National Institute Economic Review* **188**, 56–72.

Sefton, J., van de Ven, J. & Weale, M. (2008), 'Means testing retirement benefits: fostering equity or discouraging savings?', *Economic Journal* **118**, 556–590.

Szreter, S. (1996), *Fertility, Class, and Gender in Britain 1860 - 1940*, Cambridge University Press, Cambridge.

Weston, R., Qu, L., Parker, R. & Alexander, M. (2004), Its not for lack of wanting kids ... Report no. 11, Australian Institute of Family Studies, Melbourne.

A Data Appendix

The current paper uses statistics calculated from two key data sources. The New Earnings Survey (NES), and the Expenditure and Food Survey (previously the Family Expenditure Survey). It also refers sporadically to statistics calculated from the Family Resources Survey. Each of these data sources are described separately below, with particular attention paid to the variables considered for analysis.

A.1 Expenditure and Food Survey

The Expenditure and Food Survey (EFS) was introduced in 2001, as an amalgamation of the Family Expenditure Survey (FES – introduced in 1957) and the National Food Survey. The structure of the EFS is based upon the FES, and the survey reports detailed information regarding demographics, income, and expenditure for a sample of approximately 6,500 households in the United Kingdom. The basic unit in the survey is the household, with households being selected at random from the Post Office's list of addresses (for Great Britain, excluding the Scottish Isles and the Isles of Scilly; Northern Ireland is sampled through the Valuations and Lands Agency list), and participation being voluntary. The EFS defines a household as: "a group of people living at the same address with common housekeeping that is sharing household expenses such as food and bills, or sharing a living room." All individuals aged 16 and over in participating households are asked to keep a diary of expenditure covering a two week period, with children aged 7 to 15 also being asked to keep a simplified diary since 1998. Regular expenditure, demographic, and income data are recorded at a household interview, and retrospective information is collected on expenditure of selected large and infrequent purchases. The survey is collected on a continuous basis, and reported at annual intervals.

The representative nature of the EFS for the UK population is affected by a number of factors. Firstly, people in institutions – such as retirement homes, the military, or prison – are omitted from the survey. Also, people with no fixed address (the homeless) are not surveyed. Furthermore, the voluntary nature of the survey typically obtains a response rate of those initially approached in the region of 50-60 per cent, and has been found in the past to be not uniformly distributed across the population. Foster (1996) compared the characteristics of households responding to the 1991 FES with information derived from the 1991 Census, and found that response was lower than average in Greater London, higher in rural areas, and that the response rate tended to increase with the age of the household reference person. Low response rates were also found for ethnic minorities, the lower educated, self employed, and the manual social class.[36] Nevertheless, data from the EFS appear to provide a reasonably comprehensive picture of household income and expenditure in the UK, accounting for approximately 90 per cent

[36] This issue is partially corrected for by weights that are supplied with the EFS.

of income and 85 per cent of expenditure estimated in the National Accounts.[37] The EFS does not, however, adequately report income for the self-employed or from investments.

The current analysis uses FES survey data reported at annual intervals from 1972 to 2000/01, and EFS survey data from 2001/02 to 2005/06. The following text makes reference only to the EFS, though the same details apply to FES data.

Units for analysis

The EFS reports data at the household level. As implied by the definition of a household that is quoted above, this can include a group of disparate adults sharing the same residence. The model considered for analysis in this study focuses upon decisions made at the level of the family unit, and so it was necessary to adjust for this when calculating sample statistics from the EFS. We defined a family unit as a household comprised of a single adult, or partner couple, plus their dependant children. Dependant children were defined as any child under the age of 16, or any individual under the age of 18 and in full-time education. This definition is consistent with the model considered for analysis.

The EFS defines the *household reference person* as:

> the householder, i.e. the person who:
>
> a. owns the household accommodation, or
>
> b. is legally responsible for the rent of the accommodation, or
>
> c. has the household accommodation as an emolument or perquisite, or
>
> d. has the household accommodation by virtue of some relationship to the owner who is not a member of the household.
>
> If there are joint householders the household reference person will be the one with the higher income. If the income is the same, then the eldest householder is taken.

We analysed the demographics of each household reported by the EFS, and excluded from analysis any household comprised of:[38]

- family units not including the reference person, but including dependant children
- partner couples that did not include the reference person
- more than five family units

This selection reduced the sample size for the 2005/06 EFS by 2.4%, from 7473 family units to 7297.

[37] See Banks & Johnson (1998) and Foster (1996) for detailed discussion.

[38] Prior to the 2001/02 survey, reference was made to the "household head".

Consumption

One of the key reasons for consulting EFS data was to obtain sample statistics for consumption. The composite consumption variable with which the model is concerned is best interpreted as expenditure on all goods and services, including rent and mortgage interest on the family's residence, but excluding any mortgage capital repayment. The EFS reports two measures of aggregate consumption: the ONS definition, $p550tp$, and the National Accounts definition, $p560tp$. These two variables differ mainly in that the ONS definition includes expenditure on various taxes, charges, and fines (e.g. Council Tax, Stamp Duty, motoring fines), and unrequited domestic transfers that are not included in the National Accounts definition. As the taxes and charges that are included in the ONS definition are not explicitly allowed for by the model considered here (i.e. are not taken into account by the tax function considered for analysis), we have adopted the ONS definition for analysis.

Where multiple family units are identified in a household, we have allocated rental costs not attributed to individual household members on a proportional basis in relation to the number of adults sharing the common address.

Coding changes of importance

The current section provides a list of the coding changes to the EFS that are of potential importance for the current study, reported in revers chronological order:

- We focus wherever possible on usual weekly gross wages from employment. Prior to 1993, usual weekly gross wages from subsidiary employment were not reported. During the period affected, we replaced this by the associated statistic reported for the week preceding the interview.

- Prior to 1992, the costs of childcare were not reported separately from other domestic help, including housekeeping, gardening, etc. In the absence of an alternative data source, the figure reported for aggregate domestic help was interpreted as the costs of childcare for the period preceding 1992.

- Prior to 1991, the consumption code $p550tp$ was not reported. During the affected period, this was replaced in the analysis by code $p508$, which differs from $p550$ as it does not include data derived through retrospective recall. Similarly, net housing expenditure – defined by code $p536$ between 1991 and 2005/06 – was replaced by code $p367$ prior to 1991

Fertility statistics

The pseudo panel data derived from the EFS/FES are the principal basis against which the model is calibrated, and the out of sample comparisons are made. Here we report fertility statistics derived for the 1953 and 1963 female birth cohorts with which the report is principally concerned, plotted against associated data derived from Table 10.1 of the ONS publication *Birth Statistics*. The data confirm that the FES data considered for analysis provide a close match to the associated ONS data, with a slight tendency to over-state fertility rates estimated for the population in general.

A.2 New Earnings Survey[39]

The New Earnings Survey Panel Data (NESPD, commonly abbreviated to the New Earnings Survey, NES) is described at length in the "NESPD documentation for the 2001 Panel" booklet.[40] The current section uses extracts from the introduction of that publication.

> The NES is a survey of the earning of employees in employment in Great Britain carried out in April of each year by the Office for National Statistics (ONS) under the Statistics of Trade Act, 1947. The main purpose of the survey is to obtain annual information about the levels, distribution and make-up of earnings and employees in all industries and occupation. The questionnaire is directed to the employer, who completes is on the basis of payroll records for the employee. The earnings, hours of work and other information relate to a specified week in April of each year.
>
> The survey has been held in broadly the same format every year since 1970 and has changed very little since 1975 ... The NESPD contains the NES survey information in panel since 1975.

Individuals are included in the survey on the basis of their National Insurance Number.

> Since [these numbers are] issued to each individuals at minimum school leaving age, the sampling frame of the survey should be a random sample of all employees in employment, irrespective of employment status, occupation, size or type of employer or type of job. Also as there is a legal obligation on employers to complete the Survey questionnaire, and as it is based on the employer's payroll records, a high response rate and accuracy of earnings information is obtained. Moreover, should an individual not be included in the NES in any year, due for example to unemployment, temporal withdrawal of the labour force, or a failure of sample location, the sampling frame ensures that he should be located for the Survey in any future year when in employment. Consequently, absences from the survey or failures of sample location do not lead to cumulative attrition. (...).
>
> [The NES sampling frame] implies that, conditional on a 100% response rate, the NES is a 1% sample of employees in employment.

[39] We thank the ONS for making these data available.
[40] See, ONS (2002*a*).

Panel A: 1953 birth cohort

Panel B: 1963 birth cohort

Source: Pseudo panel data from EFS/FES and Table 10.1 of ONS publication "Birth Statistics"

Notes: FES data prior to 1984 do not distinguish children aged 0 from children aged 1

Fertility rate data provided by ONS publication aggregated under the assumption of zero infant mortality

Figure 20: Children Aged Under 2 Years by Age and Birth Cohort of Mother, FES and ONS data

Nevertheless, since the individuals identified by the NES sampling frame are located on the basis of their payroll records, from companies who run a PAYE scheme, it is likely to under-represent employees who are below the tax threshold or who are in firms that do not run a PAYE scheme. According to the ONS (2002*b*), this category is mostly composed of low paid jobs, which we can expect to be disproportionately weighted amongst part-time employed women. To explore the extent of this sample bias on the NES data considered for analysis, we compare the incidence of part-time employment among employed women, and associated geometric means of income as measured by the NES and EFS.

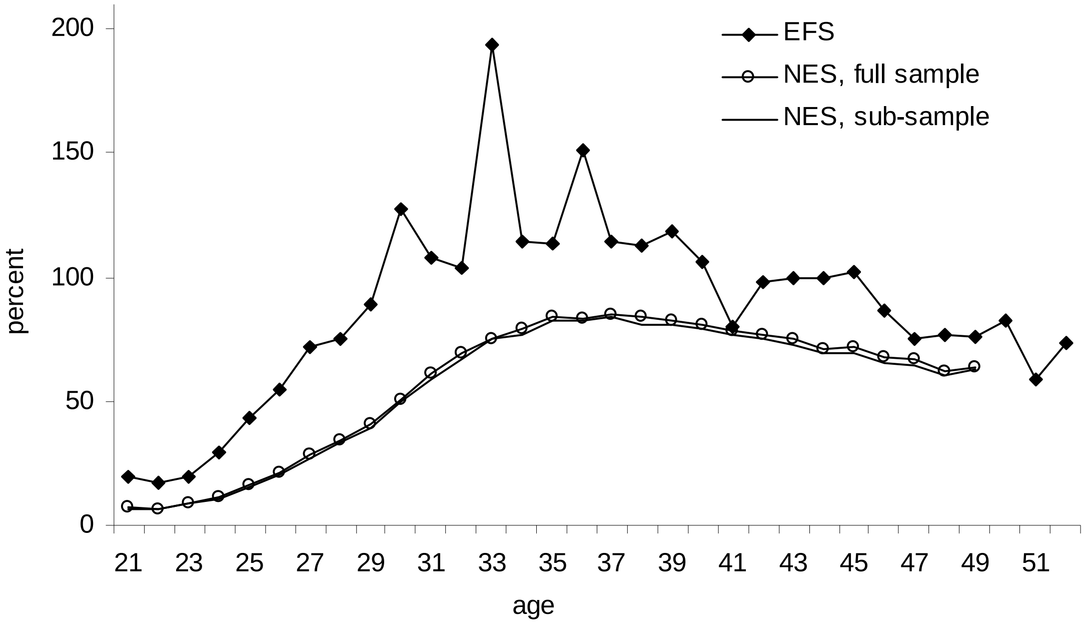
The highest point described for the EFS series in Figure 21 – with a ratio of 193.5 at age 33 – corresponds to the end of the peak out of employment period for this cohort in the EFS sample. At age 33, 45 percent of these women were not employed, 36 percent were employed part-time and 19 percent were working full-time.

While the general trends of part-time to full-time ratios reported in Figure 21 for the NES and EFS are comparable, the NES data clearly understates the incidence of part-time employment among women, consistent with our *a priori* expectations. The gap, however, seems to decline slightly over time, and is smaller on average for the 1963 cohort. Assuming the sampling of EFS households is comparable between periods, this convergence could be attributed to increased use of part-time labour amongst larger companies, which tend to run PAYE schemes. Another possibility is that bracket creep has seen more part-time workers captured by the income tax system.

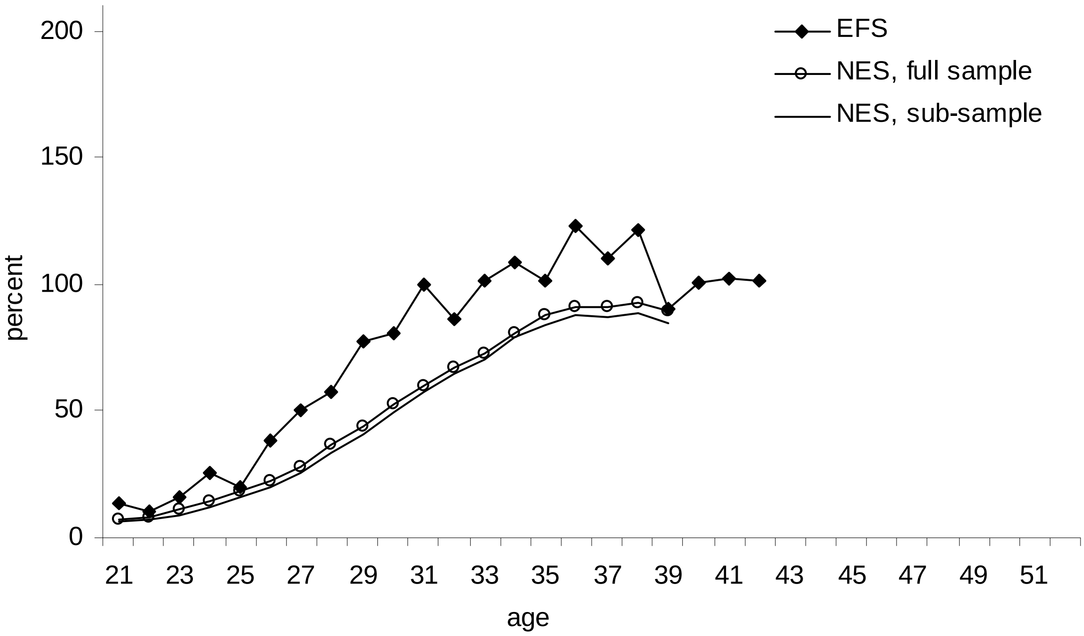
Figure 22 indicates that the NES and EFS both report very similar geometric means for the wages of full-time employed women. Consistent with the suspected biases that we describe above, however, Figure 22 indicates that the geometric mean wages of part-time workers is overstated by the NES, relative to the EFS, although the disparity is less pronounced by the end of the 1990s – i.e. after 45 in the 1953 cohort and 35 in the 1963 cohort. Hence, the data reported here suggest that the NES data are likely to be affected by sample selection bias, particularly in relation to the part-time employed. This observation highlights the need to adjust for selection bias in the regression statistics that are estimated using the NES. We undertake this adjustment in the calibration stage of the parameter specification for the model, adjusting the estimated wage parameters to match conditional sample moments calculated from EFS survey data.

A.2.1 Data preparation

In the raw NESPD dataset, a small number of individuals are coded as changing gender, and or display inconsistent shifts in age, over the period of observation. As individuals recorded as changing gender are likely to be subject to greater degrees of measurement error, they were dropped from the sample. Age was recoded for all remaining individuals according to their first observation in the sample. This



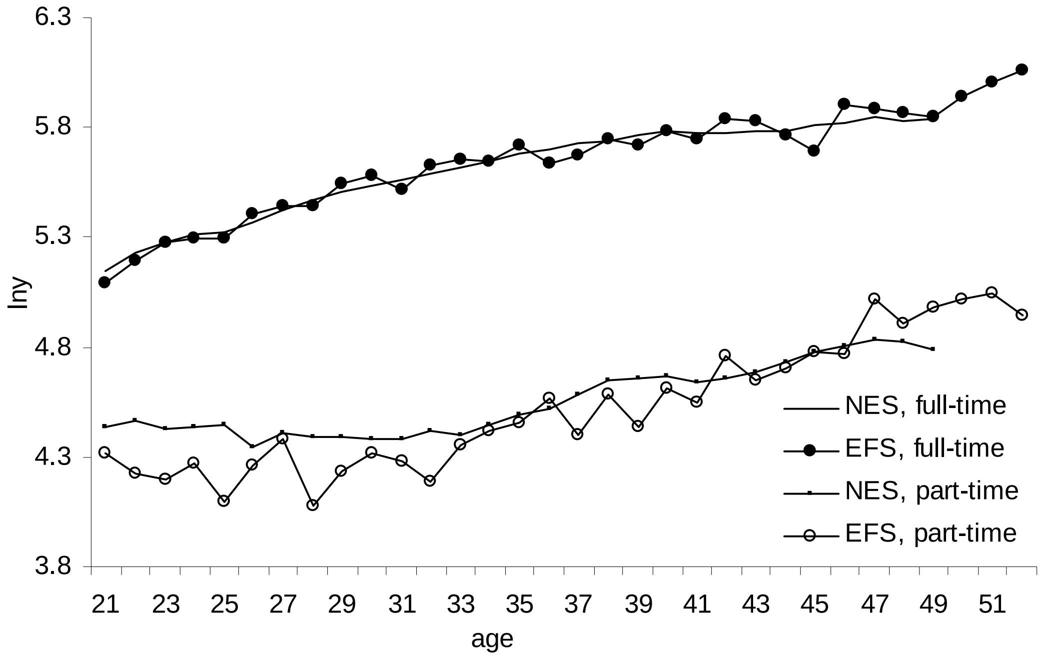
Panel A: 1953 birth cohort



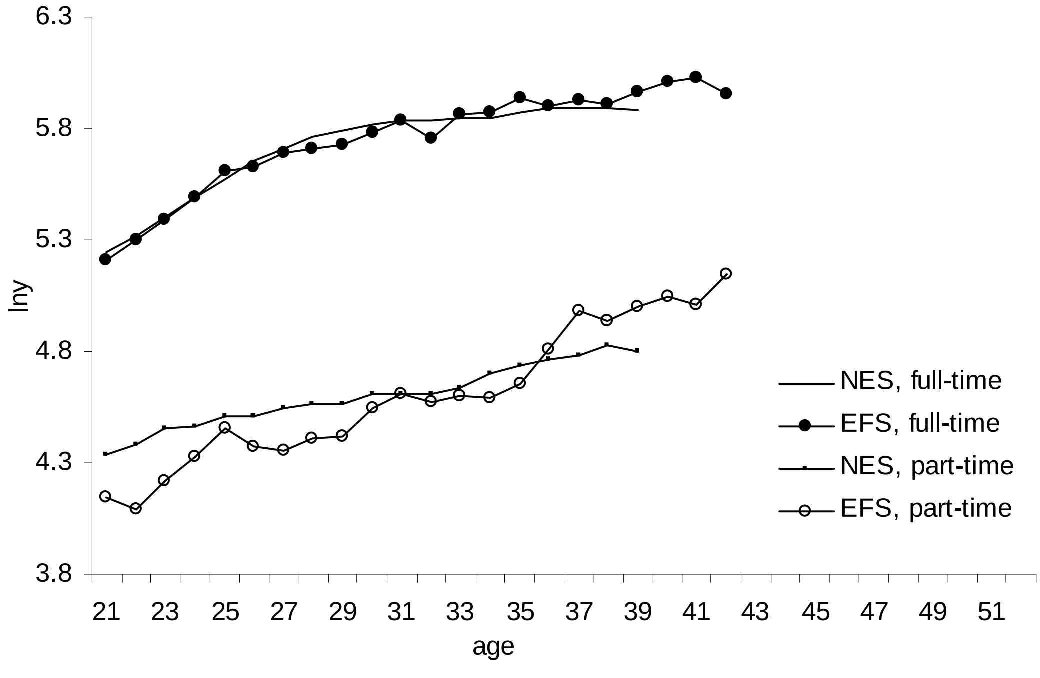
Panel B: 1963 birth cohort

Note: The 1953 cohort considered here includes women born between 1952 and 1954.
The 1963 cohort considered here includes women born between 1962 and 1964.
The difference between the full population, and population sub-samples are described in the data preparation section below

Figure 21: Part-time to Full-time Employment Ratios by Age of Women and Birth Cohort



Panel A: 1953 birth cohort



Panel B: 1963 birth cohort

Note: The 1953 cohort considered here includes women born between 1952 and 1954.

The 1963 cohort considered here includes women born between 1962 and 1964.

The difference between the full population, and population sub-samples are described in the data preparation section below

Figure 22: Mean of log Income, by Employment Status, Age Birth Cohort of Women

Table 21: Description of Data for Women, Full Sample, 1953 Birth Cohort

Description	PT	FT
Number of observations in full sample	43806	79444
Observations affected by absence	5515	6062
Observations with missing or zero wage	2157(1)	956(2)
affected by absence	2139	940
Observations with missing normal basic	7192	5178
affected by absence	2250	634
and same job marker missing	50	20
Obs with missing (or zero) wage and normal basic hours	1537(3)	204(4)
affected by absence	1529	203
Observations with missing YBAS	28(5)	

Notes:

(1) 18 obs unaffected by absence: 1 obs in 2000 and 17 obs in 2001

(2) 16 obs unaffected by absence: 16 obs in 2001

(3) 8 obs unaffected by absence: 1 obs in 2000 and 7 obs in 2001

(4) 1 obs unaffected by absence, in 2001

(5) all missing YBAS observations are found between 1996 and 2001

sample is referred to here as the full-sample. Furthermore, individuals that never appeared more than 2 subsequent years in employment were dropped from the sample, in the empirical analysis. These observations could not be used in the GMM wage estimation discussed below. Nevertheless, as these individual were mainly working part-time, eliminating them slightly reinforces the under-statement of part-timers in the sample, see Figure 22. This sample is referred to as the sub-sample.

Note that the NES cohorts considered in the analysis include people born in a 3 year band around the year of interest, that is, the 1953 cohorts include people born between 1952 and 1954 and the 1963 cohort consist of people born between 1962 and 1964.

Due to the constraints imposed by the simulation part of our analysis, we model weekly wages rather than hourly wages and only weakly control for the number of hours worked in the female wage process by including a part-time wage adjustment. Consequently, in the wage estimation analysis below, we opted for the basic weekly pay (excluding overtime pay) as our measure of weekly wage. Similarly, we consider normal basic hours, (excluding overtime), as our individual hour reference.

Observations are labelled as full-time or part-time, however, according the YBAS (Year Basis Employment Status) marker in the sample, which is filled in by the employer and is only missing in a handful number of observations; see Table 21. We chose this full-time/part-time categorisation rather a split based on the number of hours worked in a week for two reasons. First, a job can be recorded as part-time up to 30 hours worked a week while full-time job can start at 25 hours a week (e.g. teachers). Second, and importantly, the exact number of hours worked is sometimes missing, and the proportion of missing hours is greater among part-time records; see Table 21.

Nevertheless, below we consider a measure of weekly hours – based on 'normal basic hours' – where missing observations have been imputed. This measure of hours is then used in the sensitivity analysis.

Table 22: Mean Weekly Hours of Employment – women 1953 birth cohort

	Part time		Full-time	
year	Normal basic hours	hours imputed	hours imputed	hours imputed
1975	21.70	21.76	36.72	36.67
1976	21.64	21.57	36.40	36.34
1977	20.61	20.61	36.51	36.31
1978	20.34	20.29	36.46	36.27
1979	19.99	19.95	36.38	36.23
1980	19.17	19.18	36.39	36.15
1981	19.10	18.99	36.27	36.16
1982	18.66	18.47	36.18	36.05
1983	18.20	18.05	36.10	35.98
1984	18.21	17.92	36.15	35.97
1985	18.13	17.90	36.01	35.89
1986	17.91	17.79	36.07	35.97
1987	17.81	17.56	36.10	35.91
1988	17.93	17.73	36.24	36.11
1989	18.15	17.89	36.27	36.16
1990	18.71	18.43	36.30	36.19
1991	18.98	18.71	36.15	36.07
1992	19.03	18.73	36.15	36.06
1993	19.05	18.82	36.17	36.08
1994	19.02	18.70	36.30	36.10
1995	19.04	18.91	36.25	36.23
1996	19.22	19.04	36.23	36.23
1997	19.63	19.24	36.18	36.26
1998	19.48	19.32	36.36	36.36
1999	19.71	19.58	36.11	36.12
2000	19.99	19.83	36.22	36.23
2001	20.30	20.16	36.16	36.17

Similarly, the average of full-time and part-time weekly hours from imputed hour measure are used in the simulation to reflect the number of hours worked when in full-time or part-time, in all cohorts.

Hours are imputed in the following way: in the first stage, the number of hours is copied forward or backward if the individual stays with the same employer, has the same full-time or part-time status, and the year with the missing hours to be replaced is not further than one year immediately before or after the year where the number of hours is recorded. Moreover, it was imposed that hours can only be copied forward or backward if the observation of origin is not affected by absence. In the second stage, all the remaining missing observations were imputed by the average number of hours, by status and age.

As a large proportion of the part-time hours replaced in the first stage of imputation consists of low part time hours. As a result, average part-time imputed hours are slightly below the average of non-missing part-time normal basic hours especially in the main childbearing period; see Table 22.

The wage of observations affected by absence was not recorded in a systematic way; they can be reported as missing or zero, for example. For consistency, the weekly wage of observations affected by absence was set as missing but kept in the sample.

A.2.2 Wage Estimation

The wage process used in the simulation is estimated from the NESPD data in two distinct steps. First, an estimation of the evolution of weekly wage for men and women, in the 1953 and 1963 cohorts is obtained based on the 'spells' of employment in the sub-sample. In a second stage, wages are imputed over the 'gaps' using estimated coefficients from the spell estimation. The cost of being out of employment is then obtained by comparing the actual wage received by individuals at the end of the gap, with the imputed one.

As observations affected by absence have been recoded to missing but have not been dropped form the sample, they will not be included in the 'spells' estimation but will not be identified as a 'gap' out of employment either.

For the estimation of spells, the usual OLS and fixed effects estimation methods for panel data are unlikely to be appropriate in the current context. This is because omitted variable bias is likely to affect the OLS coefficient estimates, due to the presence of unobserved individual-specific effects. Although this bias can be addressed by using the fixed effects estimation technique, neither method would allow for potential endogeneity with the error term, or the influence of measurement errors. The model considered here is dynamic by construction, and it is well-known that in this context the OLS and fixed effects techniques provide biased estimates of the coefficient on the lagged dependent variable $\left(\beta^k\right)$ described in equation (9). The bias on the lagged dependent variable will typically be positive in the OLS case, as a result of the correlation between the individual effects and the lagged dependent variable. The fixed effects estimator will tend to suffer from a downward bias in finite samples (see e.g. Bond et al. (2001) for discussion). Furthermore, the coefficients of the other explanatory variables may also be biased as a consequence of their correlation with the lagged dependent variable. To address the issue of omitted variable bias and to account for endogeneity, some studies have employed the first-difference GMM technique developed notably by Arellano & Bond (1991). The differencing of the model removes the unobserved time-invariant effects, and appropriate instruments (sufficiently lagged values in levels) can then control for endogeneity and measurement error.

However, when the autoregressive parameter value is close to unity, or when the variance of the individual effect increases relative to the variance of the time varying error term, the first-differenced GMM estimator is likely to suffer from a finite sample bias, particularly when the time dimension of the sample is small. This weak instrument bias is expected to be in the direction of the fixed effect, that the estimated coefficient of the lagged dependent variable should be biased towards zero. This appears to be the case with our data.

This study consequently focuses on the system GMM estimator developed by Arellano & Bover

(1995) and Blundell & Bond (1998). The system GMM estimator can be seen as an extended version of the first-differenced GMM estimator that provides a way of retaining some of the information in the equations in levels. Provided the additional instruments used are valid, then the system GMM estimator tends to have better finite sample properties compared with the first-differenced GMM estimator, since it more efficiently exploits the time-series dimension; see e.g. Bond et al. (2001). In this context, the system GMM estimator is expected to provide more precise and less biased estimates than the first-differenced GMM estimator.

The gaps are then estimated using fixed-effects.

A.3 Family Resources Survey

The Family Resources Survey (FRS) was introduced in 1992, and reports data regarding the demographic, employment, income and financial circumstances of households in the United Kingdom (Great Britain prior to 2002). Like the EFS, data for the FRS are collected on a continuous basis from a sample of voluntary participating households that is designed to be representative of the wider United Kingdom population. The FRS sample is, however, just over 4 times as large as that of the EFS. Information is collected at both the household and individual level. Household level questions are asked of one adult (usually the household reference person / head), and individual level data are collected from all non-dependant people aged in excess of 16 years. The FRS also includes a 'benefit unit' identifier, which is very similar to the family unit identifier constructed for analysis of EFS data, and was used for calculating the associated sample statistics reported in the study.[41]

In the current study, FRS data are consulted primarily to obtain measures for the costs of childcare provision. Information regarding childcare costs have been solicited from all parents since 2003/04. Prior to that year, questions regarding childcare were only asked if one of the adults responsible for children reported being in paid work (or if it was noted that childcare was paid for on a regular basis for the 2001/02 and 2002/03 surveys). Furthermore

B Tax Treatment of Households

The tax function considered for analysis divides the lifetime into two discrete periods: the working lifetime (households under state pension age), and retirement. The treatment of taxes and benefits in each of these periods is treated separately below.

[41] The definition of a "benefit unit" reported by the FRS differs to our assumed definition of the family unit, by identifying 18 year old offspring in full-time education as dependant children.

Table 23: Tax rates and thresholds applied by analysis, specified for year 2005/06

thresholds*	tax rates (%)
income taxes	
0.0000	0
0.2020	10
0.2883	22
1.5391	40
National Insurance	
0.0000	0
0.2020	11
1.3519	1

* thresholds specified as proportions of avg full-time employment income

B.1 Tax treatment during the working lifetime

Tax treatment prior to state pensionable age, $\tau(.)$, $t < t_{SPA} = 65$ is specified to reflect income taxes, National Insurance Contributions, Income Support payments, Child Benefits, the Child Tax Credit, and the Working Tax Credit, as these schemes were applied in the UK in 2005/06.

Income Taxes and National Insurance

Income taxes and National Insurance Contributions are levied on individual incomes in the UK. The model takes this explicitly into account, separately evaluating the tax burden of each adult in a household. This is facilitated by the fact that the model separately identifies the labour income of each adult household member. Property income during the working lifetime is allocated on the assumption that household wealth is shared equally between adult members. Income taxes take a standard progressive step-wise form, comprised of four marginal rates in 2005/06. National Insurance Contributions, which are ostensibly levied to pay for a number of contributory welfare schemes (including the National Health Service), are also calculated with regard to a step-wise function, albeit one that is regressive at higher incomes. The rates and thresholds considered for analysis are reported in Table 23.

Income Support

Income support includes a number benefits that were designed specifically to provide for households with little or no private financial resources. Benefits provided under Income Support depended upon the number of adults and number of children in a household, with an additional family element payable to households with dependant children. These benefits were withdrawn £1 for £1 against any private income received by the household. Rates of Income Support benefits for 2005/06 are reported in Table 24.

Child Benefit

The Child Benefit provided a non-means tested benefit to all households with children. A higher rate of benefit was paid for the first child, and a lower fixed rate was applied for each child after the first. Table 24 reports rates of the benefit paid in 2005/06.

Child Tax Credit and the Working Tax Credit

Table 24: Benefit rates and thresholds applied by analysis, specified for year 2005/06

Benefit	Values / Thresholds*	Withdrawal Rates
Income Support		
single adult	0.12060	100.0%
couple	0.18916	100.0%
each child	0.10354	100.0%
family element	0.03455	100.0%
Child Tax Credit		
family element	0.02253	
benefit per child	0.06970	
Working Tax Credit		
base rate	0.06670	
couple / lone parent	0.06564	
30 hour element	0.02719	
Tax Credits means testing		
zero	0.00000	0.0%
threshold 1	0.21483	37.0%
threshold 2	2.05783	6.7%
Child Benefit		
first child	0.03648	NA
each additional child	0.02446	NA

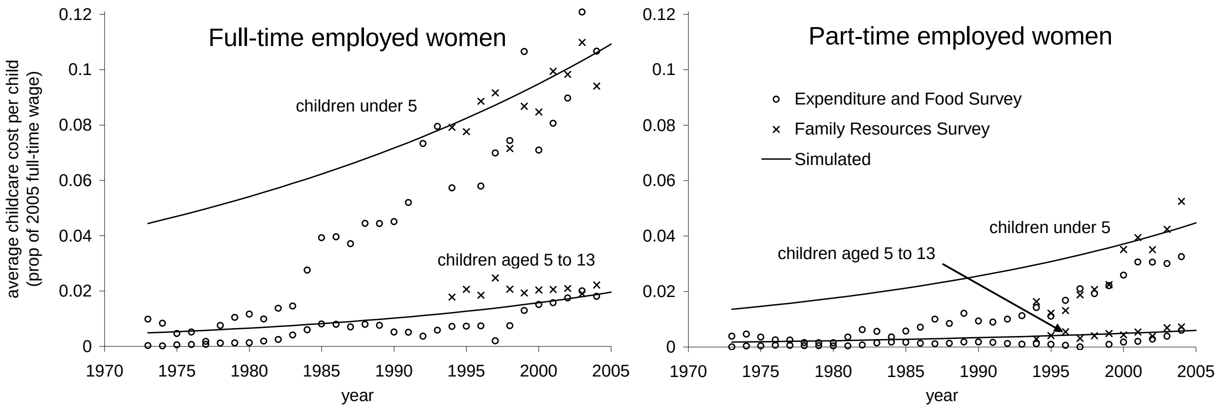
* thresholds specified as proportions of average full-time employment income, equal to £466 per week in 2005/06

The Child Tax Credit (CTC) was a benefit payable to all households with dependant children. It was comprised of two elements: a fixed benefit paid for each dependant child, and a separate family element. Working Tax Credit (WTC) was a benefit payable to low income households with some employment. Where the household included at least one dependant child, then an adult household member was required to work at least 16 hours per week to be eligible for WTC. In the absence of dependant children, an adult household member was required to work at least 30 hours per week to be eligible for the WTC. Benefits payable under the WTC were comprised of four elements: a base rate payable to all recipients, a couple / lone parent addition in relation to household demographics, a bonus where an adult household member was reported as working at least 30 hours per week, and 70% of 'registered' childcare costs.

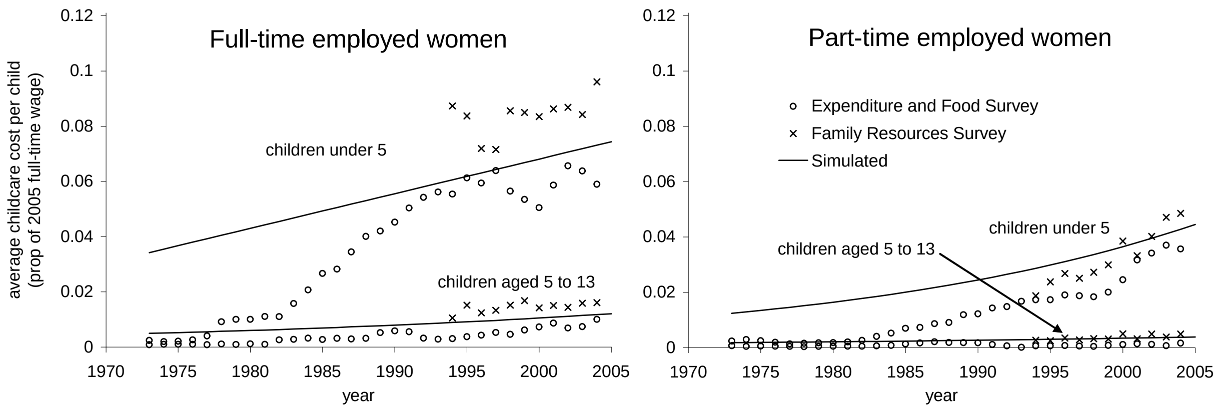
The WTC and CTC were subject to the same thresholds and rates of benefits withdrawal in response to private household income, with CTC only being reduced after any eligible benefit under the WTC had been exhausted. Furthermore, the family element of the CTC was only withdrawn after all other benefits had been exhausted, and only then in response to household private income in excess of the highest threshold rate considered for the benefits means-testing. Rates of benefits receipt, means testing thresholds, and rates of benefits withdrawal are reported in Table 24.

Childcare costs assumed for analysis

Childcare costs are adjusted as part of the second stage of the model's calibration. The relationship between the estimated costs derived from EFS / FRS survey data, and the costs obtained following the model's calibration are reported in Figure 23.



Panel A: single women



Panel B: women with partners

Notes: Authors' calculations using data from Expenditure and Food Survey (EFS) and Family Resources Survey (FRS)
All statistics expressed as a proportion of average gross full-time employment income in 2005 Q4, equal to £466 per week
Childcare costs by year discounted by the National Accounts consumption deflator
EFS estimates based upon a moving pool of three years' cross-sectional data
FRS estimates based upon cross-sectional data from the relevant year only

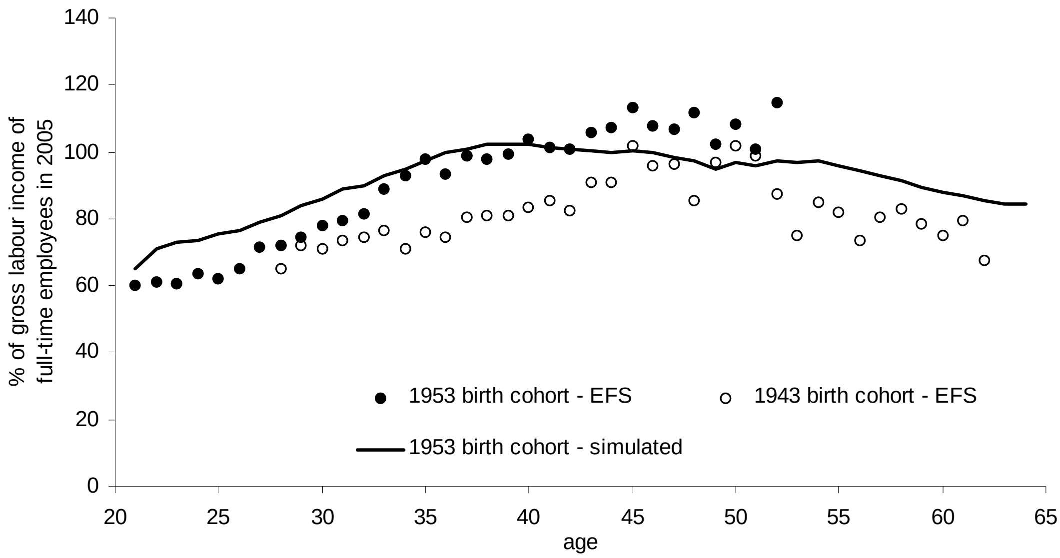
Source: see Appendix A for details regarding the EFS and FRS data used.
price deflator data from Office for National Statistics, code YBFS

Figure 23: Childcare Costs by Year, Child Age, and Mother's Employment Status: simulated and sample statistics

B.2 Tax treatment during retirement

The tax function during the retired lifetime, $\tau(.)$, $t \geq t_{SPA} = 65$, is specified to reflect the effect of income taxes, the Basic State Pension, and the Pension Credit as these schemes were applied in 2005/06. People in excess of state pension age are subject to the same income tax schedule as is described for the working lifetime above, with the notable exception that National Insurance Contributions are no longer levied. All households are considered to be eligible for the full Basic State Pension from age 65, equal to 17.6% of average gross income of full-time employees (£82.05 per week) in 2005/06 for single people, and 28.2% of gross full-time income (£131.20 per week) for couples. The Pension Credit is considered to pay a benefit equal to 5.9% of gross full-time income (£27.40 per week) to single people in 2005/06, and 7.7% of gross full-time income (£35.85 per week) to couples, and is subject to a 40% withdrawal rate on private income.[42]

C Ancillary Simulated and Sample Statistics



Notes: Authors' calculations from various data sources
NES denotes statistics estimated using data from the New Earnings Survey
EFS denotes statistics estimated using data from the Expenditure and Food Survey
Sources: Simulated data generated by behavioural model, and preferred parameter specification – see Table 13
EFS and NES described in Appendix A

Figure 24: Simulated and Sample Statistics for Male Gross Labour Incomes

[42] These figures are equal to the respective differences between the Guarantee Credit and the Savings Credit payable to singles and couples in 2005/06, and reflect the assumptions that we make regarding receipt of the Basic State Pension in the analysis.