Female Labour Supply, Human Capital and Welfare Reform

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Abstract

We consider the impact of tax credits and income support programs on female education choice, employment, hours and human capital accumulation over the life-cycle. We analyze both the short run incentive effects and the longer run implications of such programs. By allowing for risk aversion and savings, we quantify the insurance value of alternative programs. We find important incentive effects on education choice and labor supply, with single mothers having the most elastic labor supply. Returns to labor market experience are found to be substantial but only for full-time employment, and especially for women with more than basic formal education. We uncover strong complementarity between formal education and human capital on-the-job. For those with lower education the welfare programs are shown to have substantial insurance value. Based on the model, marginal increases to tax credits are preferred to equally costly increases in income support and to tax cuts, except by those in the highest education group.

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1 Introduction

The UK, the US and many other countries have put in place welfare programs subsidizing the wages of low-earning individuals and especially lone mothers, alongside other income support measures. Empirical analysis to date has focussed on the short-run employment implications of such programs and has not studied their broader long-term impact. This is an important omission because such programs have multiple effects on careers and social welfare: on the one hand, they change the incentives to obtain education, to work and to accumulate human capital and savings; and on the other hand, they offer potentially valuable (partial) insurance against labor market shocks. We develop an empirical framework for education and life-cycle labor supply that allows us to address the longer-term behavioral and welfare effects of such welfare programs.

At their core, in-work benefits are a means of transferring income towards low-income families conditional on working, incentivizing work and avoiding poverty traps implied by excessive (and often above 100%) marginal tax rates.[1] The schemes are generally designed as a subsidy to working, frequently dependent on family composition and particularly on the presence of children. In the UK they are also conditional on a minimum level of hours worked. Our focus is on female careers and how they might be affected by these welfare programs because most of the associated reforms have been primarily relevant for women with children. Moreover, the consensus view is that women are most responsive to incentives.[2] In addition, over their life-cycle a sizeable proportion of women become single mothers, vulnerable to poverty (see Blundell and Hoynes, 2004, for example). For them, allowing for the effects of human capital accumulation is particularly important because of the career interruptions and the often loose labor market attachment that the programs we consider attempt to address. These features may be important sources of male-

[1] Throughout the paper we use interchangeably the terms "benefits", "subsidies", "welfare" and "welfare programs" to denote government transfers to lower income individuals. "In-work benefits" or "tax-credits" are subsidies to low-paid workers (conditional on work) and are meant to improve work incentives, while "income support" stands for unconditional (on working) income top-up transfers . We also refer to "welfare effects" or "social welfare" when discussing impacts on total utility of a group.

[2] See Blundell and MaCurdy (1999) and Meghir and Phillips (2012) for surveys of the evidence.

female wage differentials and, more importantly for the aim of our study, they may propagate the longer term effects of welfare benefits and be a crucial determinant of the incentives to work.[3] Indeed, a motivation for in-work benefits is to preserve the labour market attachment of lower-skill mothers and to prevent skill depreciation.

Several empirical and theoretical studies have contributed to our understanding of the impacts of in-work benefits. Most of the attention has been on how they affect work incentives and labour supply. In a seminal paper, Saez (2002) showed that the optimal design of in-work benefits depends on how responsive individuals are at the intensive (hours of work) and extensive (whether to work) margins. Hotz and Scholz (2003) review the literature on the effects of the Earned Income Tax Credit, the main US transfer scheme to the (working) poor. Card and Robins (2005) and Card and Hyslop (2005) assess the effects of the Canadian Self Sufficiency Project using experimental data, again on employment outcomes. For the UK, Blundell and Hoynes (2004), Brewer et al. (2006) and Francesconi and van der Klaauw (2007) assess the employment effects of the Working Families' Tax Credit reform of 1999. Most studies find significant and sizable employment effects of in-work benefits.

In this paper we extend this work by acknowledging that in-work benefits may affect life-cycle careers through a number of mechanisms beyond the period-by-period changes in employment. In particular, both the value of education and the costs of acquiring it may be affected by the presence of the subsidy; the in-work benefits will affect the incentive to accumulate assets both by providing an insurance mechanism and by reducing the needs for consumption smoothing; the accumulation of human capital may change due to its dependence on part-time and full-time work experience. We also recognize that dynamic links may be of great importance in welfare evaluation: changes in behavior will thus take place both because of actual incentives and in anticipation of future exposure. Finally, the insurance component of these schemes may also be substantial. It may partially protect against adverse income shocks, possibly encouraging individuals to remain

[3]See Shaw (1989), Imai and Keane (2004) and Heckman, Lochner and Cossa (2003)

in work for longer and boosting labour market attachment. On the other hand such programs may crowd out individual savings reducing the capacity to self-insure against shocks.

Specifically, we estimate a dynamic model of female education choice, labor supply, wages and consumption over the life-cycle. At the start of their life-cycle, women decide the level of education to be completed, taking into account the implied returns (which are affected by taxes and benefits). Once education is completed they make period-by-period employment decisions depending on wages, their preferences and their family structure (married or single and whether they have children). Importantly, wages are determined by education and experience, which accumulates or depreciates depending on whether individuals work full-time, part-time or not at all. While male income, fertility and marriage are exogenous, they are driven by stochastic processes that depend on education and age. In this sense our results are conditional on the observed status quo process of family formation.

Our data is drawn from 18 waves of the British Household Panel Survey (BHPS) covering the years 1991 to 2008. We combine these data with a tax and benefit simulation model to describe in detail the household budget constraint, incorporating taxes and the welfare system and the way it has changed over time. As well as wages, employment and household composition, the data also provides valuable information on family background and parental income.

There have been numerous reforms to the tax and welfare system over the time period we consider, with some of the most important changes taking place between 1999 and 2002. At that point there were large increases in in-work benefits, affecting particularly lone mothers. We use a reduced form difference-in-differences approach to establish that the reform did indeed increase employment substantially and significantly. Moreover in a relatively simple reduced form model of educational choice we also find evidence that the reform decreased educational attainment, which is consistent with the resulting decline in the returns to education.

The policy reforms, combined with information on parental background and parental income at

the time of education choice, constitute important sources of variation for the structural model we estimate. Specifically, we use a number of different birth cohorts each consisting of individuals with different family backgrounds. Cohorts differ in the tax and welfare system they face when they make their education choice. During their lifetime, reforms occur at different ages. We use this exogenous policy variation, to help identify the structural model. We allow for observed heterogeneity using family background variables describing conditions in the individual's parental home. These may affect education choices, wages and preferences. We also allow parental income when the woman was 16 to affect education choices, which adds further identifying information if young people face liquidity constraints for education.

We find moderate labor supply elasticities overall: the Frisch elasticity of labor supply is 0.6 on the extensive (participation) margin and 0.3 on the intensive one (part-time versus full-time). The elasticities are substantially higher for lower-educated single mothers, who are the main target group of the tax credit program. Relatively large estimated income effects lead to lower Marshallian elasticities. We also find that tax credits, funded by increases in the basic rate of tax, have large employment effects and do reduce college education and increase basic statutory schooling. Ignoring the adjustments to education that could take place in the long run leads to an increase in the estimated effects of the reforms.

Our results display large and significant returns to labor-market experience, especially for those with higher levels of formal education. Those with basic education earn little or no returns to experience. Interestingly, returns to experience are also found to be much stronger for full-time employment. Part-time employment contributes very little to experience capital. This differential between full-time and part-time experience capital, as well as the different impact of labor-market experience across education groups, is found to be central in replicating the distribution of female wages over the working life. The strong complementarity of these experience effects are also shown to be a key ingredient in understanding the responses of labour supply and human capital to tax

and welfare reform.

Other than income redistribution, benefits are designed for insurance purposes. Increases in the generosity of benefits can increase social welfare (even without a preference for redistribution) to the extent that the distortions to incentives are outweighed by the beneficial increase in insurance in a world with incomplete markets. To assess the insurance properties of the programs for different education groups we carry out two exercises. First we consider the willingness to pay for changes in labor market risk for the three education groups separately; second we estimate the willingness to pay for equally costly increases in tax credits, income support and tax cuts. We find that lower-educated women are nearly indifferent to increases in risk, demonstrating that the downside is very well insured by the current programs. On the other hand, more educated women are unwilling to accept more risk because these programs do not insure them against the uncertainty they face. We also find that the welfare of the lowest-educated women increases most with small increases in the scope of tax credits, relative to equally costly increases in income support; moreover, they have no taste for tax cuts. By contrast, highest-education individuals prefer tax cuts to equally costly increases in the generosity of welfare programs. However, from the perspective of a person *before* they make their education choice, marginal increases in tax credits are preferred to equally costly tax cuts and the lowest welfare gain is obtained by equivalent increases in the highly distortionary income support program.

Amongst others, our paper builds on a long history of dynamic labor supply models: it is related to Heckman and MaCurdy (1980) who developed the life-cycle model of female labor supply, to Eckstein and Wolpin (1989) who introduced a dynamic discrete choice model of labor supply, wages and fertility, to Keane and Wolpin (1997) who estimate a dynamic model of education, occupational choice and labor supply and to Shaw (1989), Heckman, Lochner and Taber (1998) and Imai and Keane (2004) who consider lifecycle models of labor supply and consumption with human capital accumulation. It also relates to the life-cycle consistent models of labor supply and

consumption developed by MaCurdy (1983), Altonji (1986), Blundell and Walker (1986), Arellano and Meghir (1992), Blundell, Meghir and Neves (1993) and Blundell, Duncan and Meghir (1998).

The plan for the remainder of the paper is as follows. We begin with a description of the tax and welfare policy environment. Section 3 describes the data used for estimation and the tax policy setting. We also present the quasi-experimental reduced form results. Section 4 provides a description of the main features of the model. Section 5 discusses the key sources of exogenous variation and the estimation procedures. Section 6 presents the results. We then go on to investigate the overall model fit, the implications for wage and employment behavior and the underlying elasticities in section 7. In Section 8 we turn to the use of the model for policy evaluation by an application to the 1999 WFTC and Income Support reforms operating in the UK; and finally section 9 presents some concluding remarks.

2 Tax and Welfare Policy in the UK

The UK personal tax and transfer system comprises a small number of simple taxes (mostly levied at the individual level), and a set of welfare benefits and tax credits (usually means-tested at the family level). Over the period of our data, which extends from 1991 to 2006, there have been numerous reforms to most aspects of this system and this will help us identify the model. In this section we focus on reforms between April 1999 and April 2002 which are particularly important from a policy perspective.[4]

Reforms between April 1999 and April 2002 primarily affected Income Support (IS), Family Credit (FC) and Working Families' Tax Credit (WFTC). Income Support (IS) is a benefit for families where no one is working working 16 hours or more a week (24 hours for partners) that tops

[4]For a more comprehensive discussion of UK taxes and transfers, see Browne and Roantree (2012) and Browne and Hood (2012). All taxes and transfers are modeled using the FORTAX microsimulation library; see Shephard (2009) and Shaw (2011) for more details.

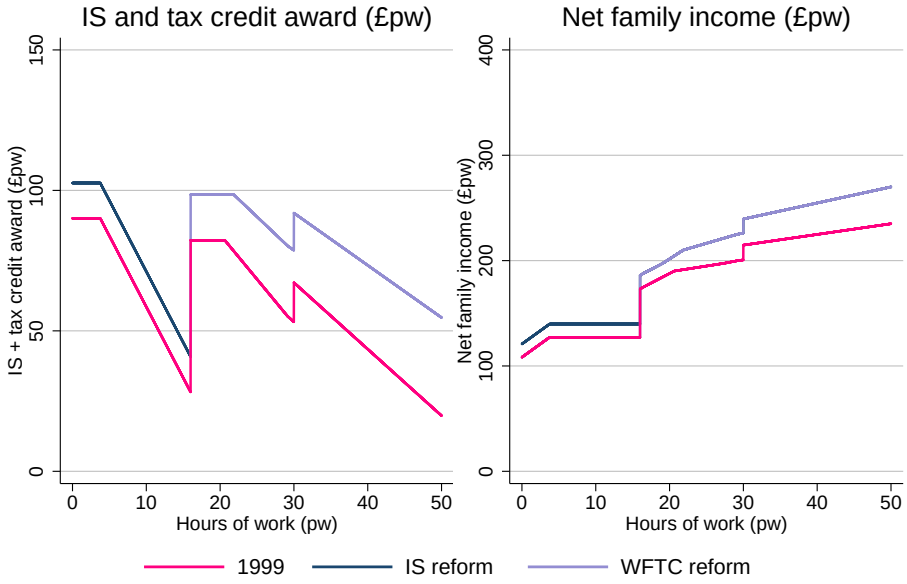
family income up to a level that depends on family circumstances such as the number and age of children. Between April 1999 and April 2002, there was a big increase in the generosity of these child additions for younger children, coinciding with the Working Families' Tax Credit (WFTC) reform (see below). Since IS is an income top-up, it implicitly creates a 100% marginal tax rate.

Family credit (FC) existed as part of the April 1999 system and provided means-tested support for working families with children. To be eligible, families had to have at least one adult working 16 or more hours a week and have at least one dependent child. The maximum credit depended on family circumstances and hours of work. Above a threshold, FC was tapered away at a rate of 70%. There was a generous childcare disregard acting to reduce net income before the taper calculation.

By April 2002, FC had been replaced by WFTC. WFTC was effectively the same benefit as FC, just much more generous. This was for three main reasons: maximum awards were higher, the means-testing threshold was higher (rising in real terms by 10%) and awards were tapered away more slowly (55% rather than 70%). The increase in maximum awards was particularly large. For example, for a lone parent working 20 hours at the minimum wage with one child aged 4 and no childcare expenditure, the maximum rose by 25% in real terms. The main structural difference between FC and WFTC was the treatment of childcare. The FC childcare disregard was replaced by a childcare credit worth 70% of childcare expenditure up to a limit of £135 per week (£200 per week for families with two or more children) by April 2002. This meant that the maximum award rose enormously for parents spending considerable amounts on childcare. The combined effect of these changes was to increase substantially awards for existing claimants and extend entitlement to new (richer) families.

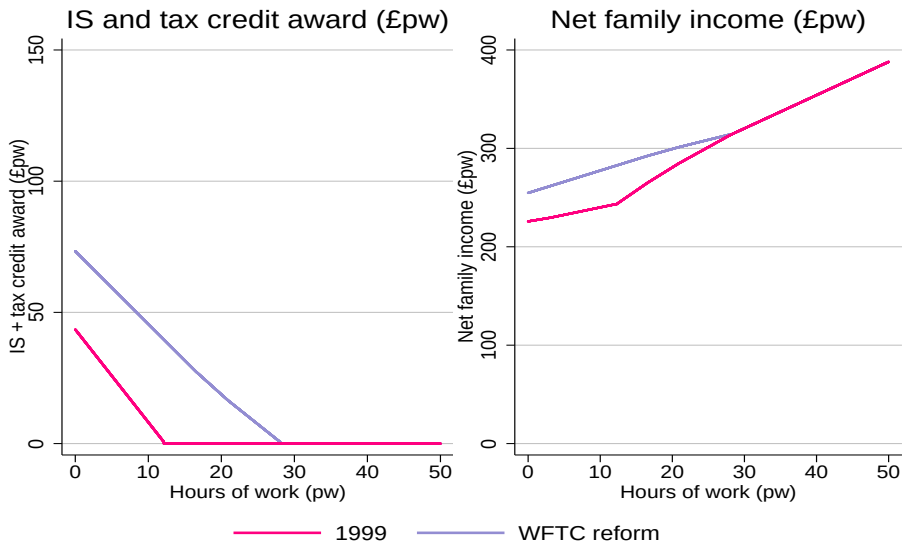
Figure 1 compares the overall generosity of the two systems for a lone parent family with one child aged 4 with no childcare expenditure. The increase in net income is not as big as the increase in maximum tax credit awards described above because tax credits count as income in the calculation

Figure 1: IS/tax credit award and budget constraint for low-wage lone parent



Notes: Lone parent earns the minimum wage (£5.05) and has one child aged 4 and no expenditure on childcare or rent. Tax system parameters uprated to April 2006 earnings levels.

Figure 2: IS/tax credit award for low-wage parent with low-wage partner working full time



Notes: Parents earn the minimum wage (£5.05) and have one child aged 4 and no expenditure on childcare or rent. Partner works 40 hours per week. Tax system parameters uprated to April 2006 earnings levels. IS reform absent from figure because family not entitled to IS.

for some other benefits. Figure 2 provides the corresponding transfers and budget constraints for a woman with same characteristics but with a partner working full time (if the partner does not work, the budget constraint is similar to that in Figure 1).

Previous studies have highlighted the heterogeneous nature of the impact of these reforms, depending in particular on family circumstances and interactions with other taxes and benefits (Brewer, Saez and Shephard, 2010). One particularly important example is Housing Benefit (HB), a large means-tested rental subsidy program potentially affecting the same families as are eligible to tax credits. HB covers up to 100% of rental costs for low-income families, but the withdrawal rate is high (65% on net income). Families eligible for HB face strong disincentives to work that the WFTC reform does not resolve. Of course our model will account for the entire tax and welfare system and hence the integration between the various programs and their impact on incentives will be fully taken into account.

Beyond the reforms described above there have been other reforms to the tax and welfare system over our observation period. From an empirical point of view these are important because they offer sources of exogenous variation, which we exploit as we explain below. In our dynamic model below the tax system acts as a state variable and consequently accounting for all possible small changes makes the problem computationally intractable without adding much to the substance. We thus construct four distinct tax and benefit regimes: the 1995 system covers the period up to 1996; the 1999 system covers 1997 to 1999; the 2002 system covers 2000 to 2002 and the 2004 system covers 2003 to 2008. These groupings represent the major reforms and abstract from minor adjustments mainly to the tax allowances and thresholds. The Appendix includes a table describing the various changes over the years.

3 Data and reduced form analysis

3.1 The Panel Data Sample

In estimation we make use of the first 18 waves (1991 to 2008) of the British Household Panel Survey (BHPS). In this panel, apart from those who are lost through attrition, all individuals in the original 1991 sample and subsequent booster samples remain in the panel from then onwards. Other individuals have been added to the sample in subsequent periods — sometimes temporarily — as they formed families with original interviewees or were born into them. All members of the household aged 16 and above are interviewed, with a large set of information being collected on demographic characteristics, educational achievement, employment and hours worked, income and benefits, and some expenditures, particularly those relating to childcare. Information on assets is collected only every 5 years.

We follow women over the observation period, so the sample represents families with one or two working-age adults other than single men. Families where the female is self-employed have also been dropped to avoid the difficulties relating to measuring their hours.[5] Our full data set is an unbalanced panel of just under 3,900 women aged between 19 and 50 observed at some point during the 1991-2008 period. Almost 60% of those are observed for at least 5 years and over 20% are observed for at least 10 years, 25% are observed entering working life from education. Some key sample descriptive statistics by education and family composition are presented in Table 12. Further details are provided in Appendix A.

Our structural model does not deal with macroeconomic growth and fluctuations; in estimating the structural model we first remove aggregate wage growth from all monetary values. The monetary parameters in the tax and welfare system (such as tax thresholds and eligibility levels)

[5]The entire histories of 2.9% of self-employed women were dropped and partial histories (from the moment they move to self employment) were dropped for another 3.1% of women

Table 1: Family demographics - women aged 19-50 in 2002

	Mothers		Childless	Number of
	singles	in couples	women	observations
all	0.10	0.44	0.46	2,096
	(0.007)	(0.011)	(0.011)	
by education				
secondary	0.15	0.49	0.36	839
	(0.012)	(0.017)	(0.017)	
high school	0.08	0.42	0.50	853
	(0.010)	(0.017)	(0.017)	
university	0.03	0.39	0.58	404
	(0.008)	(0.024)	(0.025)	

Notes: Based on BHPS data for 2002. Standard errors in parenthesis under estimates.

were similarly adjusted. Only the central 98% of the wage distribution was used in estimating the wage process.[6]

3.2 Quasi-experimental results

As already mentioned, our structural model will in part rely on the reforms for the purposes of identification. With this in mind, here we explore the effect of the 1999-2002 welfare reforms on labor supply and education choices. We also discuss further exogenous sources of variation that will help identify our model.

The WFTC reform substantially increased the maximal benefit award both directly and through increases in support for childcare. It also decreased the rate at which benefits are withdrawn when earnings increase. It thus improved the incentives for single mothers to work. The contemporaneous reform to the income support system reduced the adult related benefit, affecting all women (irrespective of children), but increased the child related benefit. This latter reform would then counteract somewhat the improved incentives of the reformed WFTC for mothers with chil-

[6]The censoring of the distribution from below is at £3.0 per hour in 2008 prices, well below the minimum wage.

dren. Both reforms reduce the returns to education and may be expected to reduce educational achievement.

We use single women without children as a comparison group to estimate the effect of the reforms on the labor supply of single mothers, using a Difference in Differences design, an approach also followed by Brewer et al (2006) and Eissa and Liebman (1996). While the effect we estimate is specific to this context, it serves to show that the reform did indeed cause increases in the labor supply of single mothers and will establish the order of magnitude that we can expect our model to replicate. It also shows that the reform is an important source of exogenous variation for the model.

The results in Table 2 show that the employment rates for the two lower education lone mothers increased by between four and six percentage points above the employment rates of similar single women, and the effects are highly significant. Those who have completed college are unaffected, as we expect, because typically their earnings will be too high to benefit from the more generous support.

Table 2: Data DiD estimates: effects of 1999-2002 reforms on the employment of lone mothers aged 22 and above

	Secondary (1)	High school (2)	University (3)
Impact on Employment	.042	.055	-.005
Standard Error	(.011)	(.015)	(.016)

Notes: DiD compares lone mothers with single women with no children (treatment and comparison groups) in 1999 and 2002 (before and after treatment). OLS estimates from a regression model with a full set of time and group dummies. Other covariates included age and age of youngest child.

The reforms may also change education choices for young people if they are perceived as permanent. This is an important dimension to consider when evaluating the longer-run effects of these reforms because it has important implications for women employment and earnings capacity over their entire working life. Before using our structural model, we investigate whether the reforms

that that took place in 1999-2002 might have affected the education choices of young women. We use two simple reduced form multinomial logit models of the three alternative levels of education (secondary, high school and university) to explore the factors that drive investments in education.

3.3 Reduced form estimates: education choice

The empirical strategy behind the regression in columns (1) and (2) of table 3 relies on the idea that, depending on their family background, the reforms around the turn of the millennium would have affected people differently. We thus include in the education choice model the two first principal components drawn from a set of family background variables.[7] Since the reforms would not have affected the education choice of those born before 1980 we also include a cohort dummy for 1980 onwards, capturing the trends in educational choice between these two groups. The causal effect of the reforms on education is then estimated as the interaction of each of these two factors with this cohort dummy, akin to a difference-in-differences design.

The family background factors will eventually be included in wages and preferences - they cannot be justified as exclusion restrictions when estimating the full structural model; exclusions will be generated by the way the tax reform affects various birth cohorts at the time of the choice. In addition we also assume that, *conditional on family background*, parental income at the time of the educational choice represents a liquidity shock that affects educational attendance of the children and can be excluded from other parts of the model (wages and preferences).

The results of the reduced form model containing all these elements are presented in the first two columns of Table 3. The first column reflects the probability of completing high school relative to the compulsory education level; the second column relates to choice of college, again relative to compulsory schooling. More of factor 1 is associated with both high school and college completion,

[7]The family background variables include education of both parents (5 levels each), dummy for no siblings, dummy for 3 or more siblings, dummy for whether subject is the first child, books in childhood home (3 levels) and dummy for whether lived with both parents when aged 16.

Table 3: Education attainment at the age of 23: multinomial logit on BHPS data

	excl parental Y		incl parental Y	
	high school	university	high school	university
	(1)	(2)	(3)	(4)
background factor 1: f1	0.335***	0.580***	0.363***	0.673***
	(0.05)	(0.09)	(0.05)	(0.08)
background factor 2: f2	0.076	0.429***	0.008	0.299***
	(0.07)	(0.10)	(0.06)	(0.07)
80s cohort	-0.161	0.171		
	(0.17)	(0.20)		
80s cohort x f1	-0.197**	-0.180		
	(0.08)	(0.12)		
80s cohort x f2	-0.081	-0.308**		
	(0.11)	(0.13)		
log parental inc	1.697***	2.942***	1.740***	2.926***
	(0.38)	(0.45)	(0.40)	(0.51)
parental inc missing	1.199**	1.328**	1.186**	1.263**
	(0.51)	(0.54)	(0.50)	(0.60)
away from parents	-0.601	-1.749*	-0.506	-1.634*
	(0.42)	(0.92)	(0.43)	(0.94)
observed after 18	0.177	0.656***	0.247	0.556**
	(0.17)	(0.21)	(0.19)	(0.23)
log E(Y_1)			-5.545**	-5.545**
			(2.35)	(2.35)
log E(Y_s)			2.107	0.019
			(2.73)	(2.06)
constant	-0.046	-1.729***	32.100	50.662**
	(0.16)	(0.22)	(22.91)	(24.03)
ll	-1091.032		-967.908	
N	1030		1030	

Notes: SE clustered by decile of distribution of f1 and generation.
Background factors are the first two principal components from a set of historical information about parental home when the woman was aged 16. parental income is measured in parents' interviews when parents and daughter are first observed together while she is 16 to 18. Lifetime (net of taxes and transfers) income (Y_s) is the structural model prediction for each woman, would she choose education level s (where s stands for secondary ($s = 1$), high school ($s = 2$) or university education($s = 3$)), under the assumption that the tax and benefit system remains unchanged over the woman's entire working life, equal to that in place when she was 17. So the tax and benefit system used in predicting lifetime income varies by year of birth but remains unchanged for each woman. The expected lifetime income by education, E(Y_s), is the simple average over 100 predictions of Y per individual, each based on a different draw of the entire sequence of shocks to income and family composition. The model in columns 3 and 4 restricts the parameter on E(Y_1) to be constant across education options.

while more of factor 2 is associated with more college. Moreover, parental income has a strong positive effect on educational attainment - consistent with the presence of liquidity constraints. More importantly there are significant interactions between the cohort dummy and the two factors, implying that the reform affected education choices. Specifically, the reform unambiguously increased the number of people dropping out of school at the compulsory level and decreased those going to college, with these impacts increasing with the value of the factors. However, people with high factor 2 and low factor 1 increased their high school completion rates, while those in the opposite cells decreased high school attendance. Hence, this suggests that the reforms over the 1999-2002 period had a heterogeneous impact depending on baseline characteristics, but overall decreased educational attendance. This is exactly what we would expect, since the reform of the in-work benefits and decreased the returns to education.[8]

The next two columns of table 3 show estimates of an alternative empirical specification that explores the finer variation in education incentives by year cohorts, while still accounting for the role of parental income in driving education choices. To do this, we use the structural model predictions of women's expected lifetime income by level of education (the model is discussed further below, in section 4). These expected income measures are a function of the information women have when deciding about education, including family background and expected returns to education. The latter are partly shaped by the tax and benefit system. We assume in simulations that women expect taxes and benefits to remain unaltered over their lives, equal to those they face when aged 17 and deciding whether to continue attending education. So variation in expected lifetime income captures changes in the returns to education by year-cohort driven by the tax

[8]This procedure cannot disentangle the effect of welfare reforms from that of other contemporaneous changes in the policy and economic environment. One concern is the reform to the funding of high education that happened in 1998, with the creation of an university fee of £1,000 per university year. Like the welfare reform, the introduction of university fees also reduces the incentives to invest in education, but unlike the welfare reform, it changes its cost rather than its return. So we would expect the impact of the new fees to work through the liquidity shocks captured by parental income, conditional on background factors. To test whether the change in education choices might have been (partly) driven by the introduction of university fees, we included an interaction between parental income and the 1980's cohort dummy in the regression model. We found no evidence of a significant effect of this interaction on education choice.

and welfare reforms. As in a random utility model of education choice, we control for expected lifetime income in the omitted category (secondary education, $E(Y_1)$) and the relevant choice ($E(Y_s)$), while restricting the coefficient on $E(Y_1)$ to be the same across education levels.

Estimates in columns 3-4 confirm our earlier results. Both background factors and parental income are important determinants of education attainment. But beyond this, an increase in the potential expected lifetime income under secondary education reduces significantly the take up of high school and university education. Since the in-work benefits reform of the 1999-2002 period increases mainly the income of low-paid workers, and low wages are more likely if women leave education at 16, then this result suggests that the reform may have reduced education attendance.

The broader conclusions from these results is that education choice depends on parental background, on available liquidity and on the institutional framework that affects the returns to education. We use these results to specify and estimate our model.

4 Model

The reduced form analysis establishes the responsiveness of important decisions to changes in taxes and transfers. However, it is not rich enough to provide a full explanation of how human capital is formed over the lifecycle and how the various decisions interact to generate an observed career path. A formal dynamic model would allow us to understand better the effects of policy on behavior and on welfare and to address important policy issues from a normative perspective as well. We now develop a framework that allows us to do precisely this.

We develop a life-cycle model of education choice, consumption and labor supply with on-the-job human capital accumulation and accounting for the budget constraint induced by welfare benefits and taxes. Below, we first summarize the key features of the model, emphasizing the timing of events, and then detail its specification.

4.1 The timing of events and decisions

We start tracking women's decisions from the age of 17 with the choice of education.[9] This choice is the first step in defining a woman's career, potentially affecting future human capital accumulation as well as changing her marriage market and the chance of being a single mother.[10] Women choose between three alternatives: secondary (the compulsory level of education, completed by age 16), high school (A-level or similar further-education qualifications) and university education (three-year degree and above) depending on the balance of expected benefits and realized costs, which include foregone earnings, direct financial costs (representing fees) and idiosyncratic (dis)taste for education.

Upon leaving education, women enter the labour market. We model annual labour supply choices – from a discrete menu of unemployment, part-time and full-time employment – and consumption. To simplify computations we assume working life ends deterministically at the age of 60, after which women are assumed to live for another 10 years when they consume their accumulated savings. This is necessary to ensure a realistic accumulation of assets throughout life, and to avoid relying excessively on labour supply as a way of smoothing consumption.

Some of the features we introduce are especially important for our analysis. First, we specify human capital accumulation as an ongoing process of acquisition and depreciation. This allows us to capture the dynamic links in the earnings process of women, for whom career breaks and short working hours are frequent and may have long-lasting consequences. In our model, the rate of female human capital accumulation depends on education choices made earlier in life, on persistent heterogeneity that is related to productivity at the start of working life, and on the level

[9]Some recent studies have added education decisions to the standard structural life-cycle model. Most have focused on men, e.g. Keane and Wolpin (1997), Lee (2005) Adda et al. (2013) and Abbot et al. (2013). Studies focussing on women include Adda et al. (2011).

[10]This is consistent with literature showing that the marriage market is responsible for substantial returns to education, e.g. van der Klaauw (1996), Francesconi (2002), Keane and Wolpin (2010), Larsen et al. (2011), Chiappori, Iyigun and Weiss (2012).

of human capital accumulated so far. Furthermore, working part-time may affect the accumulation of experience more than proportionally, and taking time out of the labour market leads to human capital depreciating.[11] Women's earnings are then determined by a combination of hours worked, their idiosyncratic level of human capital and skill-specific market wage rates.

Second, we include a consumption/savings decision.[12] Ignoring savings would overstate the role that labour supply plays in achieving consumption smoothing, and would compromise the model's ability to reproduce labour supply profiles over the life-cycle. However, we do assume that households are credit constrained: other than university loans, it is not possible to borrow when net worth is negative.

Third, family circumstances are a major determinant of female labour supply and human capital investment decisions. Their relation with labour supply has long been acknowledged in the literature on structural female life-cycle models, but their consequences for education investments has not been considered. We do not model marriage or fertility choices, but we estimate the probabilities of marriage, separation and childbirth to reproduce the dynamics of family formation observed in the data.[13]

Our focus is on modeling the life-cycle behavior of women abstracting from decisions such as marital choice and fertility. Yet being single, marrying and having children are important factors affecting choices, whether endogenous or not. Similar to Browning and Meghir (1991), our model is conditional on these other decisions; the main cost of this is that we take marriage and fertility as unchanged in counterfactual simulations, and thus cannot work through implications of changes in behavior in those dimensions. To capture the impact of marriage and fertility on preferences and on decisions as observed in the data, we characterize men by a reduced-form earnings and employment

[11] See also Huggett et al. (2011), who consider heterogeneity in wage profiles, and Adda et al. (2011), who allow for a flexible specification of human capital accumulation by working hours.

[12] See also Attanasio, Low and Sanchez-Marcos (2008) and, for men, French (2005), van der Klaauw and Wolpin (2005).

[13] Studies that endogenize marriage and fertility decisions include van der Klaauw (1996), Francesconi (2002), Keane and Wolpin (2010) and Adda et al. (2011).

model depending on education level. Men's earnings are subject to persistent shocks, adding to the uncertainty faced by women. Single women draw partners randomly with a probability that depends on her own characteristics, including her education, thus replicating the sorting patterns in the data. Likewise, childbearing and the probability of the couple separating also depend on female education. Thus this specification recognizes that the marriage market, divorce, fertility and lone-motherhood are part of the implications of education and accounted for when making choices, but are not allowed to change in counterfactual simulations.

Finally, public transfers constitute the other source of household income, offering minimum income floors during periods of unemployment or low income, and potentially affecting employment and education choices. We use FORTAX, a micro-simulation tax and benefit tool to draw accurate budget constraints by family circumstances, thereby describing the financial incentives to undertake work and invest in education.[14]

4.2 Working life

In each period of her adult life, which we take to be a year, a woman maximizes expected lifetime utility taking as given her current characteristics and economic circumstances. These are described by her age (t), education (s), accumulated assets (a), work experience (e), idiosyncratic productivity (υ), her family background (x_1, x_2) and the utility cost of working full time (θ_F) or part time (θ_P).[15] They also include her family arrangements and related information: the presence of a partner (m), his education ($\tilde{s}$), labour supply ($\tilde{l}$) and productivity ($\tilde{\upsilon}$), the presence of children (k), age of the youngest child (t^k) and whether she has access to free childcare (d_{cc}). We denote by X_t the state space in period t, including these two sets of variables. In all that follows, lowercase represents individual observed characteristics, the tilde denotes men's variables,

[14] See Shephard (2009) and Shaw (2011).

[15] To economize in the size of the state space we summarize each of the two family background factors into a binary high/low value leading to four observable types.

uppercase is for market prices and sets of variables, and Greek letters are reserved for the model parameters and unobserved shocks.

We assume that utility is intertemporally separable, and that instantaneous utility depends on consumption per adult equivalent, female labour supply, family background, family circumstances and preferences for work. Using the notation defined above, her instantaneous utility, which is non-separable between consumption and leisure, is given by

$$u\left(c_t, l_t; Z_t\right) = \frac{\left(c_t/n_t\right)^{\mu}}{\mu} \exp\left\{f_l\left(\theta_l, Z_t\right)\right\} \tag{1}$$

where $\mu < 1$, n is the equivalence scale,[16] c is total family consumption, l is female labour supply and assumes the three possible values: not working (O), working part-time (P) and working full-time (F). The function f_l reflects how the marginal utility of consumption changes with working, by the woman's education, background characteristics and family demographics. We specify

$$f_l\left(\theta_l, Z_t\right) = \begin{cases} 0 & \text{if } l_t = O \\ \theta_l + Z_t\alpha_l & \text{otherwise} \end{cases} \tag{2}$$

where $Z_t \in X_t$ is a subset of the woman's characteristics, including her family background and a set of dummies for education, education interacted with family composition (whether a mother and whether in a couple), age of the youngest child in intervals (0 to 2 years old, 3 to 5, 6 to 10 and 11 to 18) and working status of a present partner. The parameters α depend on whether the woman works full-time or part time: we specify $\alpha_{lj} = \alpha_{Fj} + \alpha_{Pj} \times \mathbf{1}(l_t = P)$ for $l_t = P, F$. Finally, θ_l is a permanent individual-specific random cost of work. It is drawn from a different distribution depending on whether the woman works full-time or part-time. In practice it follows a two point discrete distribution whose points of support and probability mass are estimated alongside the remaining parameters.

[16] n=1 for singles, 1.6 for couples 1.4 for mother with child and 2 for a couple with children.

At any age during working life, τ the woman's problem can be written as:

$$V_\tau\left(X_{tau}\right) = \max_{\{c_t,l_t\}_{t=\tau,\ldots\bar{t}}} \mathrm{E}_\tau\left\{\sum_{t=\tau}^{\bar{t}} \beta^{t-tau} u\left(c_t, l_t; Z_t\right) \middle| X_\tau\right\}$$

where E_τ is the expectation operator conditional on the available information at age τ over all future random events, β is the discount factor and V is the optimum value of discounted present and future utility. $\bar{t}$ is 10 years after retirement and the family lives off its savings during the retirement period.

Maximization must respect a number of constraints, which we now describe.

The budget constraint is described in terms of the asset evolution equation

$$a_{t+1} = (1+r)a_t + h_t y_t + m_t \tilde{h}_t \tilde{y}_t - T\left(l_t, X_t\right) - CC\left(t^k, l_t, \tilde{l}_t\right) - c_t \tag{3}$$

$$a_{t+1} \geqslant \underline{a}_s \tag{4}$$

where r is the risk-free interest rate, $(y, \tilde{y})$ are the wage rates of wife and husband, $(h, \tilde{h})$ are the working hours of wife and husband (respectively 0, 18 and 38 hours corresponding to O, P and F for women, and 0 and 40 corresponding to O and F for men), and $\underline{a}_s$ represents the borrowing limit; the latter is either zero or the amount of the student loan borrowed (a negative number). T is the net transfer to the public sector (taxes less welfare). Households face changes in this transfer system as reforms take place. These are treated as unanticipated. The age at which the reforms occur varies depending on the cohort to which individuals belong. Finally, CC are childcare costs. Pre-school children need childcare whenever both adults are away from home working; however school-age children only need childcare outside the school day as education is publicly provided.

To capture these requirements we specify

$$CC\left(t^k, h_t, \widetilde{h}_t, m_t\right) = \begin{cases} h_t * cc_h & \text{if } t^k \leqslant 5 \text{ and } \left(\widetilde{h}_t = 40 \text{ or } m_t = 0\right) \\ 18 * cc_h & \text{if } 5 < t^k \leqslant 10 \text{ and } h_t = 38 \text{ and } \left(\widetilde{h}_t = 40 \text{ or } m_t = 0\right) \\ 0 & \text{all other cases} \end{cases}$$

where cc_h is the constant per-hour rate, which we set to a number obtained from the data. Thus overall childcare costs only depend on the age of the youngest child and on male and female hours and employment respectively. This structure economizes on computational requirements by limiting the state space, while not giving up much on substance since, in practice, it is younger children who are most demanding in terms of childcare. We assume that only some women face positive childcare costs, in line with empirical information; others may have informal arrangements in place. The probability that this happens is estimated within the model.

The tax and transfer function, T, unifies the tax and welfare system, describing the total incentive structure faced by an individual at all income levels and turns out to be a complex non-concave, non-smooth and often discontinuous function of income, hours of work and family composition. The dependence on hours reflects the way the tax credit system in particular is designed: for example, eligibility requires a minimum of 16 hours of work per week.

Female human capital and earnings dynamics The female earnings process is education-specific and is determined by the following set of equations

$$\ln y_t = \ln Y_s\left(x_1, x_2\right) + \left(\gamma_{s,0} + \gamma_{s,1} x_1 + \gamma_{s,2} x_2\right) \ln\left(e_t + 1\right) + \upsilon_t + \xi_t \tag{5}$$

$$e_t = e_{t-1}\left(1 - \delta_s\right) + g_s\left(l_{t-1}\right) \tag{6}$$

$$\upsilon_t = \rho_s \upsilon_{t-1} + \zeta_t \tag{7}$$

where Y_s is the market wage rate for women with education s and background factors (x_1, x_2). The stochastic idiosyncratic productivity process, υ, follows an AR(1) process with innovations, ζ, and initial values drawn from normal distributions. Experience, e, is accumulated while working, with returns measured by parameters γ_s. This dynamic process for earnings distinguishes between endogenous state dependence, through experience effects, and heterogeneity in wage profiles, through persistent productivity which is correlated with preferences for work at the start of working life. We also allow for observed heterogeneity, through the family background variables that also enter education and labor supply decisions, to affect both the market wages and the returns to experience. The transitory wage shocks, represented by ξ, are interpreted as measurement error and do not influence choices. All unobserved components are education-specific random variables.

The process of experience accumulation is crucial for our analysis as it captures the potential cost of career interruptions and of short working hours, thus determining the earnings profiles of women. We allow for a concave profile of experience effects, with γ_s estimated to be positive but well below 1 for all s. The accumulation of experience happens on the job depending on working hours, with learning-by-doing. Function $g_s(l)$ describes this process: it equals 1 unit if the woman works full time and is estimated for part-time work (and is 0 for non-working women). Moreover, experience depreciates, at an annual rate δ_s. Thus, the profile of wages with respect to experience is concave for continuously employed women, with diminishing increments as experience increases (as in Eckstein and Wolpin, 1989). We also allow for the possibility that skills depreciate when women are working part-time, reflecting the possibly lower learning content of part-time jobs. This effect is driven by the relative size of δ_s and $g_s(l)$ for part-time workers.

Male employment and earnings Male employment and earnings are exogenously set to follow a simple parametric, education-specific model. We assume men in couples either work full-time

($\tilde{l} = F$) or are unemployed ($\tilde{l} = O$). We specify their employment process and wages as follows:

$$\text{Prob}\left[\tilde{l}_t = \text{F}\,|X_t\right] = \begin{cases} \text{Prob}\left[\tilde{\nu}_t > h_1\left(t, \tilde{s}_t, \widetilde{l}_{t-1}\right)\right] & \text{if } m_{t-1} = 1 \\ \text{Prob}\left[\tilde{\nu^*}_t > h_0\left(t, \tilde{s}_t\right)\right] & \text{if } m_{t-1} = 0 \end{cases} \tag{8}$$

$$\ln \tilde{y}_t = \ln \tilde{Y}_{\tilde{s}} + \tilde{\gamma}_{\tilde{s}} \ln\left(t - 18\right) + \widetilde{\upsilon}_t + \widetilde{\xi}_t, \quad t > 18 \tag{9}$$

$$\tilde{\upsilon}_t = \tilde{\rho}_{\tilde{s}} \tilde{\upsilon}_{t-1} + \tilde{\zeta}_t \tag{10}$$

where the earnings process is similar to that of women but instead of allowing for experience we include a concave age profile.[17] This simplifies the problem by reducing the state space without much loss since men rarely have long spells of unemployment and tend not to work part-time. However, we do allow for persistent shocks to earnings: $\tilde{\upsilon}_t$, is assumed to follow an AR(1) process with normal innovations and normal initial values, all dependent on his education, $\tilde{s}$. Transitory wage shocks ($\widetilde{\xi}$) are again interpreted as measurement error. The dependence between the earnings and employment of spouses is captured by the correlation in their education levels, as will be detailed below.

The stochastic process for male earnings is estimated separately before we estimate the main model. We estimated two separate Heckman (1979) selection models of male earnings: one in first differences for males who were present in two consecutive periods; the other for newly formed couples. We used a number of alternative employment selection equations with different combinations of instruments for selection including, in addition to age, education and past employment, family demographics potential benefits in the non-working state, and different measures of assets or of their income. In estimation we find no evidence of selection and thus assume $\tilde{\zeta}_t$, $\tilde{\nu}_t$ and $\tilde{\nu^*}_t$ are mutually independent normal random variables.

[17] In order to avoid including both male and female age in the state space and so as to allow for the fact that female and male age are highly correlated in practice, we include female age in the male earnings equation instead of male age. This simplifies the computations, while allowing age effects on male earnings, which is important in a lifecycle model.

The dynamics of family composition Family dynamics are stochastic but exogenously set to reproduce the patterns observed in the data by female education. If a child is present then $k = 1$ and t^k is her/his age. In the model only the age of the youngest child matters for preferences and costs. Hence, when a new child arrives we just reinitialize t^k to zero. The probability that a new child arrives depends on the age and education of the woman, whether she has other children and the age of the youngest child, and whether she is married. It is given by

$$\text{Prob}\left[t^k = 0 \left| t, s, k_{t-1}, t^k_{t-1}, m_{t-1}\right.\right] \tag{11}$$

Once a child is born, she/he will live with the mother until 19 years of age.

Similarly, the probability of being married to a man with education $\tilde{s}$ depends on the woman's age and education, whether she was married in the previous period – in which case it is assumed she remains in the same couple – and on the presence of children. It is given by

$$\text{Prob}\left[\tilde{s}_t \left| t, s, m_{t-1}, \tilde{s}_{t-1}, k_{t-1}\right.\right] \tag{12}$$

where $\tilde{s}_{t-1}$ is only observed if $m_{t-1} = 1$. Thus the model allows both for couple formation and for dissolution, all probabilities depending on a rich set of demographic circumstances.

4.3 Educational choice

The individual chooses education based on expected returns and realized costs at the start of active life in the model (aged 17). The choice depends on the information available at the time, which includes her initial level of assets, permanent preferences for leisure (correlated with initial productivity), utility costs of education and access to free childcare, as well as all institutional features and prices, including fees and possible loans. We denote by X_{17} the woman's information

set at 17.

We assume that, whatever the education choice, entry to the labor market does not take place before age 19; between the age of 17 and 18 parents are assumed to provide for their children.[18] The opportunity cost of education for this group will be captured by the estimated non-pecuniary costs of education. When entry in the labor market becomes an option, at age 19, we assume that education and labor supply are mutually exclusive activities. Entrance in the labor market is at age 19 for both secondary school ($s = 1$) and high school graduates ($s = 2$), and at age 22 for university graduates ($s = 3$). University students need to fund their consumption needs and education costs out of their assets and institutional student loans. The optimal choice of education is defined by

$$s = \underset{s \in \{1,2,3\}}{\operatorname{argmax}} \left\{ V_s \left(X_{17} \right) + \pi_{1s} x_1 + \pi_{2s} x_2 + \pi_{3s} y_p + \varpi_s \right\}$$

where y_p is the log of parental income at the time of decision, x_1, x_2 are the family background factors and ϖ_s is the utility cost of education s, assumed iid, and V_s is the discounted value of lifetime utility if the woman chooses education level s. It is given by

$$V_s \left(X_{17} \right) = \begin{cases} \mathrm{E} \left[V_{19} \left(X_{19} \right) | X_{17}, s \right] & \text{if } s = 1, 2 \\ \mathrm{E} \left[\max\limits_{c_{19} \ldots c_{21}} \left\{ \sum_{t=19}^{21} \beta^{t-19} u \left(c_t, l_t = F; Z_{17} \right) + \beta^{22-19} V_{22} \left(X_{22} \right) \right\} \middle| X_{17}, s \right] & \text{if } s = 3 \end{cases}$$

where it is assumed that university years carry a utility cost similar to that of full-time work, in excess of the education specific preferences described by ϖ_s. Optimization is subject to the

[18] Individuals choosing to acquire professional education, including that providing on-the-job training, are classified as students between ages 17 and 18. It is being assumed that individuals 18 and younger have loose labor market attachments, not conducive of experience accumulation.

budget constraint, which includes assets at the start of working life observed in the data[19]

$$\begin{aligned} a_{19} &= (1+r)^2 a_{17} \\ a_{22} &= (1+r)^3 a_{19} - (1+r)^2 c_{19} - (1+r) c_{20} - c_{21} - TF \quad \text{if } s = 3 \end{aligned}$$

with TF being the university fee for a three year degree. Assets at age 17 are zero. We assume implicitly that any costs of education are either financed by student loans or by parents, and are captured by the estimated costs of education. University students are allowed to borrow in the open market up to £5000, which can cover tuition costs of £3000 (for 3-year university degrees) and some living expenses.

5 Estimation

5.1 Sources of exogenous variation

At the start of the lifecycle, over and above the random unobservables, a number of observable factors differ across individuals that lead them to make different education decisions. We use these, together with the tax and benefit reforms that happened over the 1991-2008 period, to identify the model parameters.

More specifically, our data consists of many different birth cohorts, who make their choices under different policy environments. Thus, the value functions $V_s(X_{17})$ depend on the tax and welfare system that is in place at the time, which individuals assume permanent. We then allow the costs and returns to education to depend on family background, reflecting intergenerational linkages in educational attainment and possibly ability [REFERENCES], as well as different parenting

[19]Initial assets are typically small or zero. We observe money in savings accounts, other assets and liabilities three times during the observation period. In these years we compute net wealth for those aged 17-18 and set to zero any negative values.

practices [REFERENCES]. We also allow costs of education to vary by parental income at the time of the choice: in the presence of liquidity constraints the availability of parental income can make the difference between being able to attend or not.

Now consider identification of the different parts of the model. First, education is endogenous for both wages and labor supply. This endogeneity is fully taken into account by the structure of the model. Here parental income, which affects education choice but none of the other decisions, acts as an exclusion restriction, conditional on family background and the policy environment at the time of the decision. Second, the tax and benefit reforms are the source of exogenous variation used to estimate labor supply responses, as they affect women in different cohorts at different parts of their lifecycle, in ways that depend on their education and realised family circumstances. The sequence of reforms and their differential effects on the work incentives of heterogeneous women in different cohorts form natural comparison groups, very much like in the difference-in-differences framework.

To summarize, identification in our model is in part driven by variation in family background and parental income, as well as policy reforms and the way these interact. Of course these do not lead to global nonparametric identification: the implicit restrictions on the dynamics as well as the distributional assumptions also contribute to identification. We therefore also validate the specification by showing that the model matches the labor supply responses estimated using the reduced form analysis, without these having been used in estimating the structural model.

5.2 Simulated Method of Moments estimation

We follow a two-step procedure to recover the parameters of the model. In a first step we estimate the equations for the exogenous elements of the model, including the dynamics of marriage, divorce, fertility, male labour supply, male earnings and the cost of childcare. Details and estimates can be found in Appendix B. In addition, two parameters are fixed based on pre-existing estimates:

the coefficient μ is set to -0.56 giving a risk aversion coefficient of 1.56, consistent with evidence in Blundell, Browning and Meghir (1993) and Attanasio and Weber (1995); the discount factor β is set to 0.98 as for example in Attanasio, Low and Sanchez-Marcos (2008). The risk-free interest rate is set to 0.015, which is slightly lower than the discount rate thus implying that agents have some degree of impatience; tuition cost of university education is fixed to £3,000 for the three-year program and the credit limit for university students (and graduates throughout their life) is £5,000, both reflecting the university education policy of the late 1990s in the UK. No further credit is allowed.

The remaining parameters determining preferences and wages are estimated using the method simulated of moments in the second step (Appendix C provides some detail on computational issues).[20] Specifically, the estimation procedure is implemented as an iterative process in three steps. The first step involves solving the female lifecycle problem given a set of parameter values. We then simulate the lifecycle choices of 19,490 women (5 replication of the 3,898 women profiles observed in the BHPS) in step 2, using the observed distribution of initial assets. For each woman, we select an observation window so that the overall simulated sample exactly reproduces the time and age structure of the observed data.[21] The simulations assume women face to up to four policy regimes over the observation window, representing the main tax and benefits systems operating during the 1990s and early 2000s.[22] Individuals are assumed to have static expectations of the tax and benefit system, and thus all reforms arrive unexpectedly. In step 3 we compute the moments using the simulated dataset, equivalent to those computed using observed data. Through this iterative process, the estimated parameters $\hat{\Theta}$ solve the minimization problem

$$\hat{\Theta} = argmin_{\Theta}\{\Sigma_{k=1}^{K}[(M_{kn}^{d} - M_{ks}^{m}(\Theta))^2/Var(M_{kN}^{d})]\}$$

[20]Original references are Lerman and Manski (1981), McFadden (1989) and Pakes and Pollard (1989). See also Gourieroux, Monfort and Renault (1993a and 1993b) or Gallant and Tauchen (1996).

[21]This is described in section 7.1.

[22]As mentioned earlier, we adopted the 1995, the 1999, the 2002 and the 2004 regimes and assumed they operated over the periods prior to 1996, 1997 to 1999, 2000 to 2002 and 2003 onwards, respectively.

where the sum is over the K moments, M^d_{kn} denotes the k_{th} data moment estimated over n observations, $M^m_s(\Theta)$ represents the k_{th} simulated moment evaluated at parameter value Θ over s simulations. Note that we do not use the asymptotically optimal weight matrix because of its potentially poor small-sample properties.[23]

The simulation procedure controls for any initial conditions problem by starting the simulation at the start of life. Unobserved heterogeneity is allowed for in the construction of the simulated moments. The moments we match are listed in Appendix D.

We compute asymptotic standard errors following Gourieroux, Monfort and Renault (1993). This corrects for the effects of simulation noise.

6 Results

6.1 Parameter estimates

Table 4 reports the estimates for the female wage process (the full set of estimates for the wage process can be found in Appendix B, table 12). Both the wage rates at the start of the working life and the returns to experience increase with education. Human capital depreciates between 5.7% and 11% a year depending on the education group (row 8), which imposes a very large cost for time spent out of work. Importantly, though, when working part time the amount of human capital accumulated is a fraction of that accumulated in full time jobs (row 7), barely counteracting the effects of depreciation. For example, a year of part-time work is worth only 17% of a full time one in terms of acquired experience among the lowest skill group. Effectively working part time leads to almost no improvements in human capital. This result, together with the persistence of working choices, contributes to explain why in the cross section women working part-time are paid on average a lower hourly rate than those working full-time - we term this the part-time penalty.

[23] see Altonji and Segal (1996) on the small sample issue of weighted minimum distance estimators.

Table 4: Estimates of the parameters in the female wage equation and experience accumulation

		Education attainment		
		secondary	high school	university
		(1)	(2)	(3)
(1)	Mean hourly wage rates at 25	7.19	8.64	10.55
		(.050)	(.067)	(.317)
(2)	Mean returns to experience	0.16	0.25	0.31
		(.011)	(.012)	(.025)
Distribution of unobserved productivity				
(3)	autocorrelation coefficient: ρ_s	0.925	0.916	0.880
		(.009)	(.008)	(.013)
(4)	SE innovation in productivity: $\sqrt{\mathrm{V}(\zeta_s)}$	0.120	0.154	0.139
		(.007)	(.007)	(.009)
(5)	mean initial productivity for type I: $\mathrm{E}(\upsilon_{0s}\|\text{type I})$	0.150	0.121	0.306
		(.025)	(.017)	(.035)
(6)	st. error initial productivity: $\sqrt{\mathrm{Var}(\upsilon_{0s})}$	0.175	0.252	0.223
		(.015)	(.015)	(.031)
Human capital dynamics				
(7)	while in P work: $g_s(l = P)$	0.170	0.096	0.116
		(.017)	(.024)	(.023)
(8)	depreciation rate: δ_s	0.111	0.057	0.073
		(.011)	(.008)	(.011)

Notes: Mean hourly wages (row 1) are assessed at age 25 for women who worked full time since the start of their working life. Like the mean returns to educaton (row 2), they averages over the population by background factors.

A key element of the model is the stochastic process of wages. The autocorrelation coefficient, ρ_s, reported in row 9, is very high but not quite a unit root. The standard deviation of the shocks (row 10) implies a high degree of uncertainty for next period's wage rate. Finally, there is substantial payment heterogeneity at the start of life (row 12).

The remaining parameters of the model are presented in Appendix B. Here we summarise the main implications. In Table 13 we report the preference parameters determining the f function in equation 2. In reading the table note that positive and larger values of the coefficients make working less attractive. Thus children of younger ages decrease the willingness to work and more so if work is full-time. Preferences depend on education. [MORE HERE]

As in the reduced form analysis, Table 14 in Appendix B shows that family background and the presence of parents at age 16 matters for education choice as does parental income when aged 16. Over and above the observable components the unobserved random costs of education are also important in driving education choices. Mothers may face positive childcare costs if all adults in the household are working, in which case the cost of childcare is £2.60 per working hour for children under the age of 5 or per working hour in excess of 18 hours per week for children aged 5 to 10. The probability that this happens is estimated to be about 58% (row 5).

The appendix also includes details of the model for male earnings and employment as well as for the transitions of household demographic composition, including the arrival of partners and of children as well as the departure of a partner

7 Implications for Behavior

7.1 Model Simulations

To assess the properties of the model we first examine its ability to reproduce the basic features of earnings and employment observed in our sample by comparing model simulations to observed data.[24] The simulations evaluating the fit allow for the tax and benefit reforms as we did in estimation. For each of the simulated life-cycle profiles we only keep an observation window chosen to ensure that the simulated dataset reproduces the time and age structure of the BHPS sample.

[24]The comparisons are based on a simulated dataset of 19,490 women, 5 times the size of the BHPS sample, where observable background variables are drawn from their empirical distribution, while the unobservables from their estimated distributions.

7.2 Wages and Employment

The life-cycle profiles of wage rates for working women are presented in Figure 3 for each education group. These fit the observed profiles reasonably well and show the lowest education group having the most flat profile becoming steeper for higher education groups. Figure 4 shows that this pattern is replicated across the percentiles of the life-cycle wage distribution and demonstrates that the model can reproduce the dispersion of wages.[25]

The flattening out in the profiles represents a number of different effects. The first is the impact of cumulative experience which leads to a continuous rise in the profile. The second is the increasing occurrence of part-time work which off-sets the growth through the part-time experience penalty. The third is endogenous selection into full-time or part-time work. Finally there are depreciation effects. The part-time experience effect is clearly shown in Figure 5 which displays the expected profile of the part-time penalty in wage units for women who work full-time until they are aged 30 then move in to part-time work. The severity of the penalty increases with education.

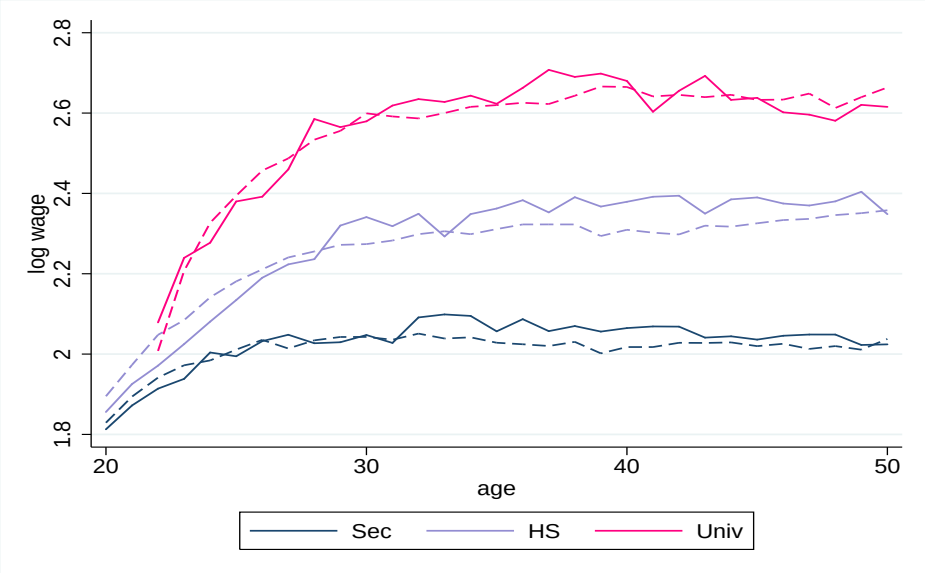
Figure 6 confirms the well known fact that employment rates increase with education and that employment profiles are U-shaped irrespective of education, although the dip occurs earlier and is more pronounced for lower levels of education, reflecting the different timing of births and the decreased labour market attachment among lower-educated women. The model explains differences in the labor market attachment by returns to experience, different human capital depreciation rates, and self-selection of higher unobserved ability women among the higher educated.[26]

As a final validation exercise in Table 5 we emulate the differences-in-differences estimator for the full set of reforms implemented in late 1999. Given the nature of the exercise, where we are looking at immediate short-run effects, we do not allow education choices to respond. This

[25]Figure 10 in the Appendix shows the fit broken down by the combination of family background factors.

[26]Figure 11 shows smoothed employment profiles relative to time at childbirth. Here we show the overall employment rates and the part-time employment rates as they evolve before and after childbirth. Again these replicate closely the patterns in the data across education groups. A full set of model comparisons with the data moments used in estimation is presented in Appendix D.

Figure 3: Mean log wage rates for working women over the life-cycle by education: data versus model



Notes: BHPS versus simulated data. 2005 prices.

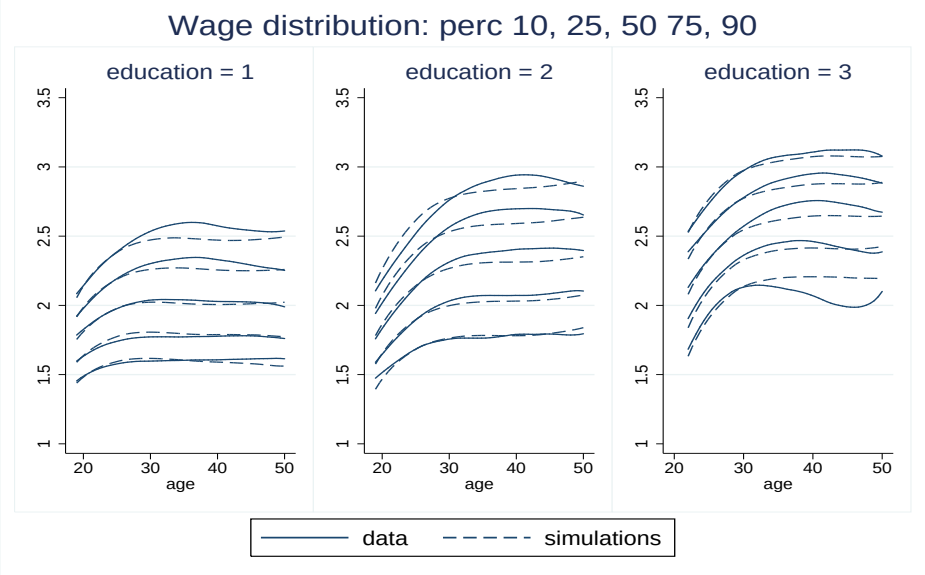
estimator compares the employment of single mothers (the treatment group) to similar single women without children. The simulation in Table 5 produces an estimated difference-in-differences parameter of 4.4 percentage points (pp) increase in employment resulting from the reforms for the lowest education group. This compares to a DiD estimate from the data of 4.2pp. For the middle education group (HS) the simulation and the estimate are 3.4pp and 5.5pp respectively: a small difference which is well within the margin of estimation error; similarly for the college group.[27]

7.3 Elasticities of labour supply

Simulated wage elasticities of labour supply are presented in Table 6. Marshallian elasticities are obtained by perturbing the entire profile of wages and comparing the outcome of the simulation

[27]see Eissa and Liebman (1996) for similar differences-in-differences estimates of the US Earned Income Tax Credit in the US.

Figure 4: Distribution of log wage rates for working women over the life-cycle by education: data versus model



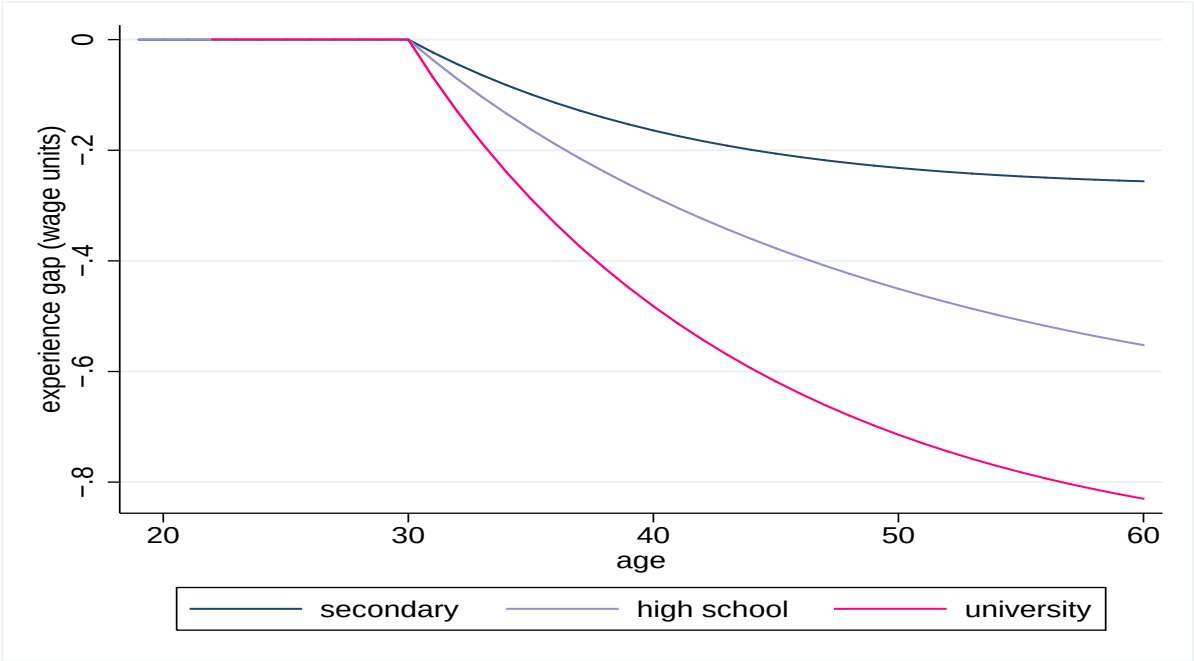
Notes: BHPS versus simulated data. 2005 prices. All curves smoothed using kernel weights and a bandwidth of 2 years.

Table 5: The impact of the reforms on the employment rates of lone mothers with secondary education - model simulations versus data estimates

	Sec.	HS	College
Model simulation	4.4	3.4	1.7
Estimates based on LFS data	4.2	5.5	-0.5
St. Error	(1.1)	(1.5)	(1.6)

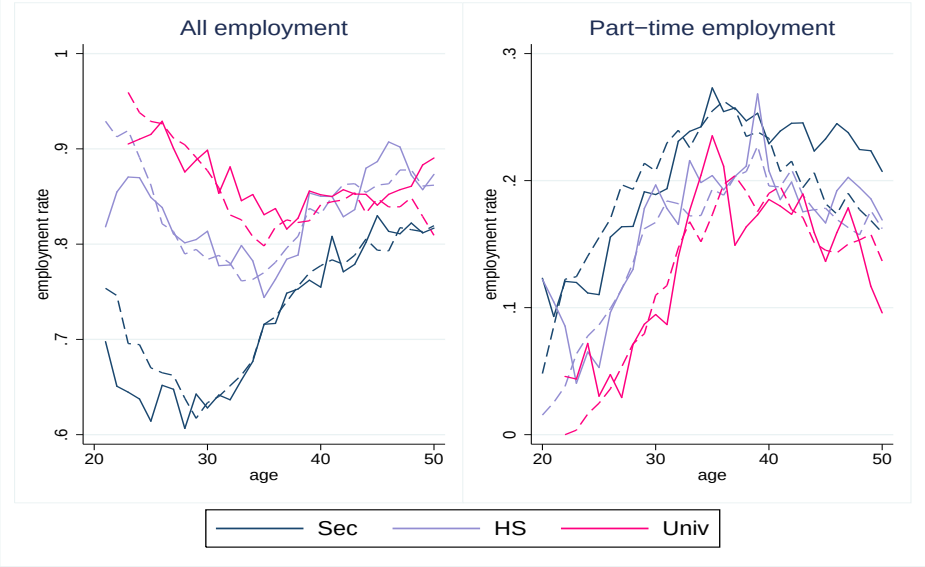
Notes: Row 1 displays the result from DID calculations of the impact of the welfare reforms implemented between 1999 and 2002 using simulated data and comparing lone mothers to childless single women. Row 2 shows similar calculations based on data from the Labour Force Survey

Figure 5: Experience gap for women in part-time work from the age of 30; by education



Notes: All values in wage units. Curves represent difference in accumulated experience between women taking part-time work from the age of 31 onwards as compared to taking full-time work over the same period, all conditional on full-time employment up to the age of 30.

Figure 6: Female employment rates over the life-cycle: data versus model



Notes: BHPS versus simulated data.

Table 6: Elasticities of labor supply

	Frisch			Marshall		
	extensive		intensive	extensive		intensive
	elast	deriv	elasticity	elast	deriv	elasticity
All women	.636	.516	.261	.468	.380	.218
By education						
Secondary	.886	.657	.383	.672	.498	.304
High school	.601	.498	.234	.434	.359	.197
University	.415	.362	.181	.301	.263	.165
By family composition						
Single women with no children	.601	.547	.186	.456	.415	.064
Lone mothers	1.871	1.097	.560	1.068	.626	.440
Women in couples, no children	.233	.214	.172	.193	.177	.171
Women in couples with children	.747	.563	.328	.581	.438	.307

Notes: Calculations based on simulated data under the 1999 tax and benefits system. The elasticities in columns 1 and 4 measure the *percentage change* in labour supply in response to a 1% increase in net earnings. The derivatives in columns 2 and 5 measure the *percentage point change* in labour supply, also in response to a 1% increase in net earnings. The elasticities in columns 3 and 6 measure the percentage change in working hours among employed women in response to a 1% increase in net earnings. The values in columns 1 to 3, Frisch calculation, are responses to expected changes in net earnings lasting for one single year, randomly selected for each woman. The values in columns 4 to 6 are responses to unexpected changes in net earnings occurring at a randomly selected year for each woman and lasting for the rest of her working life. The effects are measured in the year the change in earnings occurs.

across the original and new profile keeping education choices fixed. The Frisch elasticities are obtained by perturbing wages at one age at a time and computing the effect at each age separately. Since the perturbation in the latter case is very small there are no wealth effects; this together with the anticipated nature of the perturbation allows us to interpret this as a wealth constant or Frisch elasticity.

Frisch elasticities differ from Marshallian elasticities due to wealth effects, although with experience dynamics there is no necessity for Frisch elasticties to be larger. We find participation is more elastic than hours, a result that is common in the empirical literature.[28] Mothers are more responsive to changes in net wages than women with no children, another typical result in the empirical literature. [29] The labour supply of younger women is more elastic than that of older ones, a consequence of changes in family composition over the life-cycle that counteract the downward pressure on labour elasticities created by higher returns to work at younger ages due to human capital accumulation (see Imai and Keane, 2004). Finally, less educated women are also much more responsive to incentives, particularly on the intensive margin.

The elasticities also vary with age as illustrated for the Marshallian elasticities in Figure 7. The income elasticities on the extensive margin are about -0.4 for all education groups and decline in absolute value with age to about -0.3, with minimal variation across education groups.

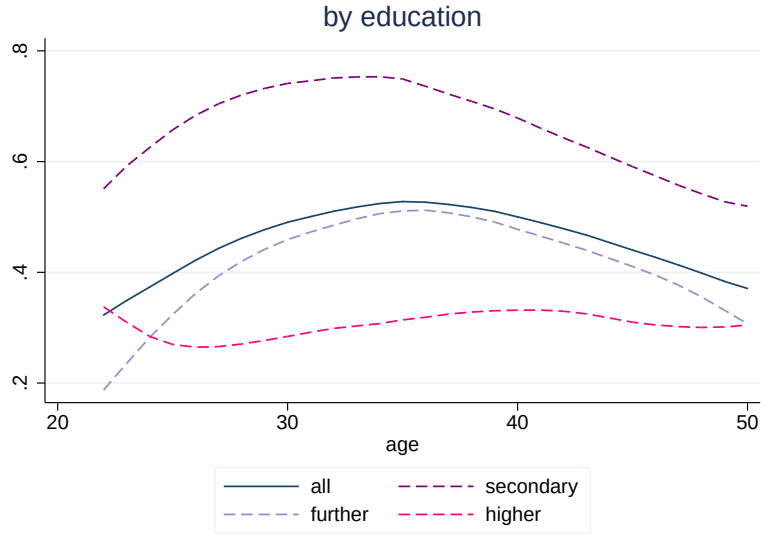
8 Assessing the Impact of Welfare Reform

8.1 Incentive effects of the Tax Credit and Income support reforms

In this section we simulate the short- and longer-run impact the 1999 Working Families' Tax Credit (WFTC) and Income Support (IS) reforms described earlier.[30] We compare the choices of

[28] see the survey of participation and hours elasticities in Meghir and Phillips (2010)
[29] see Blundell, Meghir and Neves (1993), or Blundell, Duncan and Meghir (1998)
[30] The analysis is based on the simulation of 22,780 life-cycle profiles.

Figure 7: Marshallian elasticities over the life-cycle of women: permanent expected shift in net earnings



Notes: Based on simulated data using the 1999 tax and benefit system.

women facing the baseline 1999 tax and benefits system, prior to the WFTC and IS reforms, with alternative hypothetical systems which include the 1999 WFTC and IS reforms.

Table 7 shows the simulated employment effects under revenue neutrality.[31] Rows 1 to 3 hold education choices fixed; rows 4 to 6, show results when education choice is allowed to respond. For single mothers, the largest impact is for those with basic school qualifications. Considering the WFTC reform separately the employment effects are very large: 10.7pp overall with the effect being highest among low education individuals. This is because the WFTC reform improved the work incentives substantially both by increasing the benefit and by reducing the rate at which it is withdrawn. However, when we also allow for the IS reform, where eligibility is means-tested on income only (and not on hours) carrying a 100% marginal tax rate the resulting employment effects are much more modest.[32] Finally, we consider the WFTC and IS reform combination as in

[31]The changes in the basic tax rate required to maintain neutrality are shown in Table **??** in the Appendix.
[32]Table 22 in the Appendix shows the impact of the reforms when we do not maintain revenue neutrality.

Table 7: Employment effects

		Single women				Women in couples			
		Sec	HS	Univ	all	Sec	HS	Univ	all
Mothers - Revenue Neutral and Pre-reform Education Choice									
	Employment in 1999	0.350	0.608	0.748	0.518	0.667	0.759	0.802	0.738
(1)	WFTC + childIS	0.024	0.024	0.013	0.023	-0.046	-0.030	-0.012	-0.031
(2)	WFTC	0.114	0.113	0.060	0.107	-0.037	-0.023	-0.009	-0.025
(3)	with 99 taper	0.005	0.001	-0.005	0.002	-0.019	-0.012	-0.004	-0.013
Mothers - Revenue Neutral and Post-reform Education Choice									
(4)	WFTC + childIS	0.024	0.022	-0.003	0.021	-0.046	-0.031	-0.014	-0.032
(5)	WFTC	0.114	0.112	0.054	0.106	-0.037	-0.023	-0.009	-0.025
(6)	with 99 taper	0.005	-0.000	-0.016	0.001	-0.019	-0.013	-0.005	-0.013

Notes: Based on simulated data. All reforms are revenue neutral, with adjustments in the basic tax rate making up for differences in the public budget relative to baseline (1999). Effects from comparisons with baseline tax and benefit system. Rows 1 and 4 show the effects of a joint reform of in-work and out-of-work benefits: (*i*) the family credit as in 1999 is replaced by the WFTC as it 2002 and (*ii*) the child component of IS as in 1999 is replace by the more generous level adopted in 2002. Rows 2 and 5 single out the effect of replacing replacing Family Credit as in 1999 by WFTC as in 2002. Rows 3 and 6 impose the 1999 withdrawal rate (70%) on the joint reform in rows 1 and 4. Rows 1 to 3 display the effects if education is kept at pre-reform levels. Rows 4 to 6 allow for education choices to adjust to the new incentives and classify people in the table based on their baseline educational choice.

rows 1 and 4 of the table but we keep the taper rate for WFTC at the original 70% instead of the new lower 55% withdrawal rate. The positive employment effects are reduced to zero in this case. Finally, for women living with a partner the employment effects are negative, basically because for them the increased welfare acts mostly as a disincentive to work since her earnings will be added to male earnings and will usually reduce the amount of welfare for which the household is eligible.

The impact on the employment effects of allowing education to change is shown in rows 3 to 6 of Table 7. The results are tabulated on the basis of pre-reform educational choice. Those with the minimum level of education have no incentive to increase it and of course cannot decrease it further; so for them there is no difference to the earlier results. For the other two education groups (based on pre-reform choices) employment effects are slightly reduced when education choices are allowed to adjust. Turning to Table 8 we see that the WFTC reform combined with the IS reform is accompanied by a small overall decline in educational attainment as also documented in the data earlier. Both the WFTC and the income support reforms contribute to reduce educational

Table 8: Education among women - simulated distribution by policy regime; revenue neutral reforms

	sec	HS	Uni
1999	.311	.456	.232
WFTC + childIS	.318	.454	.228
WFTC	.316	.455	.229
with 99 taper	.316	.455	.229

Notes: Based on simulated data. All reforms are revenue neutral, with adjustments in the basic tax rate making up for differences in the public budget relative to baseline (1999). Row 1 shows results for the baseline 1999 tax and benefit system. Row 2 adds WFTC and the child component of IS as in 2002. Row 3 removes the reform in the child component of IS. Row 4 imposes the 1999 withdrawal rate (70%) on the joint reform in row 2.

attainment, but most of the change is driven by the reform to in-work credits.

8.2 Welfare and Risk

One of the main reasons for having a welfare program in the first place is to provide some degree of insurance against uninsurable shocks. We now calculate the welfare implications of the WFTC and IS reforms, which are presented in Table 9.

Even for those with the lowest education there is a negative impact of the WFTC and IS reform on *gross* life-cycle earnings (row 1, column 1). This turns positive once transfers are accounted for (row 2, column 1), but remains negative for those with higher educational investments (row 2, columns 2 and 3). In contrast, turning to overall welfare, the impact is positive for the two lower education groups and strongest for the lowest one but negative for those with college education. In other words, the reform decreased welfare for college graduates because the risks insured by these programs are less relevant for them, while they bare a high proportion of the increased tax bill. Once education responses are allowed for, the welfare effect of the reforms is positive for all groups. It is quite remarkable that the lowest education group is willing to give up 1.5% of consumption for these reforms. Moreover ex-ante welfare (measured before any education choice)

increases.

Table 9: Impact of revenue neutral reform on life-cycle earnings and welfare

	Pre-reform education choice by baseline educ				Post-reform education choice by baseline educ			
	sec	further	higher	all	sec	further	higher	all
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
WFTC + child IS								
(1) Lifetime gross earnings	-0.441	-0.414	-0.323	-0.401	-0.473	-0.618	-1.017	-0.666
(2) Lifetime disposable income	0.178	-0.258	-0.733	-0.233	0.017	-0.567	-1.478	-0.597
(3) Welfare (post-education)	1.492	0.551	-0.183	0.673	1.361	0.311	0.608	0.707
(4) Welfare (pre-education)								0.612

Notes: All values measure the impact of the joint WFTC and IS child reform as compared with the baseline (1999) tax and benefit system. Reform is revenue neutral to keep the public budget at the same level as the baseline (1999). Rows 1 and 2 display effects on pre- and post- tax lifetime income, respectively. Rows 3 and 4 show effects on welfare measured by the willingness to pay in consumption terms to keep pre-reform wellbeing with post-reform family budget. These are measured at the beginning of working life (row 3) and at the start of life (row 4). The values of consumption compensation displayed in rows 3 and 4 are the solution to the equation:

$$EV_0 \quad = \quad E\sum_t \beta^{a-\underline{A}} \frac{((1-r)c_{1a}/n_{1a})^{\mu}}{\mu} \exp\{f(l_{1a}, X_{1a}) + \theta(l_{1a})\}$$

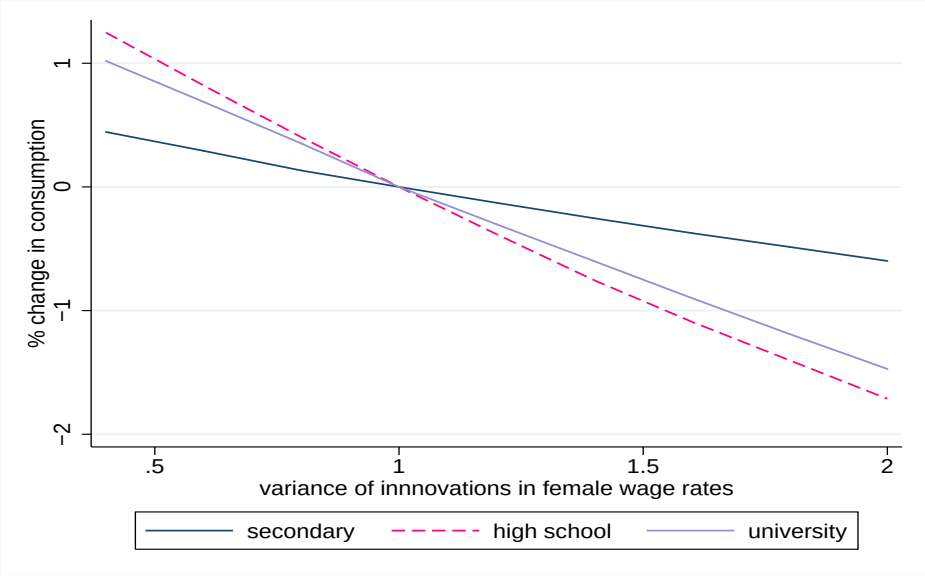
where the index 0/1 stands for the pre/post-reform solutions and the value function is evaluated at different stages in life for different rows. The equation can be solved for r, yielding:

$$r \quad = \quad 1 - \left(\frac{EV_0}{EV_1}\right)^{\frac{1}{\mu}}.$$

Columns 1 to 3 display effects if education is kept at pre-reform levels. Columns 4 to 6 allow for education choices to adjust to the new incentives, but the classification is based on pre-reform education choice.

To put these welfare effects in context, in Figure 8 we report how willingness to pay relates to increases in the variance of wages, which is the main source of uncertainty. The group that seems to value reductions in the variance of earnings least are individuals with secondary education. The other two groups are willing to forgo substantial amounts of consumption to avoid increases in risk, despite the presence of welfare programs. Thus for college graduates the income loss is too high relative to the desire for insurance, leading to a welfare loss. For women with secondary education only, insurance counteracts the loss in income. For them, a part of the loss in income is due to an endogenous decrease in labor supply (see for example the effects on married women in Table 7).

Figure 8: Willingness to pay in consumption terms: value of risk by education



Notes: Based on simulated data using the 1999 tax and benefit system. Lines show willingness to pay in consumption terms for a change in uncertainty induced by the variance of women's wage innovation changing by a varying factor (x-axis). All values computed under for families living in own accommodation. Consumption compensation calculated at entrance in working life.

Table 10: Impacts of an exogenous increase in public spending distributed through alternative routes

		Pre-reform education choice by baseline educ				Post-reform education choice by baseline educ			
		sec	further	higher	all	sec	further	higher	all
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Adjustment in basic tax rate									
(1)	Lifetime gross earnings	0.14	0.16	0.13	0.14	0.17	0.16	0.13	0.15
(2)	Lifetime disposable income	0.64	0.79	0.90	0.77	0.66	0.79	0.90	0.78
(3)	Welfare (post-education)	0.52	0.63	0.45	0.55	0.51	0.63	0.45	0.55
(4)	Welfare (pre-education)								0.78
Panel B: Adjustment in tax credits maximum award									
(5)	Lifetime gross earnings	-0.05	-0.36	-0.27	-0.24	0.01	-0.39	-0.59	-0.31
(6)	Lifetime disposable income	1.18	0.54	-0.01	0.61	1.00	0.38	-0.24	0.43
(7)	Welfare (post-education)	1.94	1.11	0.18	1.15	1.63	0.87	0.91	1.11
(8)	Welfare (pre-education)								1.24
Panel C: Adjustment in IS award									
(9)	Lifetime gross earnings	-1.30	-1.36	-0.78	-1.21	-1.25	-1.35	-0.86	-1.20
(10)	Lifetime disposable income	-0.18	-0.56	-0.49	-0.42	-0.17	-0.55	-0.55	-0.43
(11)	Welfare (post-education)	0.72	0.44	0.14	0.46	0.70	0.41	0.32	0.48
(12)	Welfare (pre-education)								0.55

Notes: The values measure the impact of exogenously increasing public spending by 0.5% of total gross earnings and distributing it through a drop in the basic tax rate (panel A), an increase in the tax credits maximum award (panel B) and an increase in the IS award (panel C). All comparisons are against the 1999 tax and benefits system.
Columns 1 to 4 display results when education choices remain at 1999 levels, in which case the extra spending allows for the basic tax rate to drop by 0.93pp, the IS award to increase by £8.1 per week, or the tax credits award to increase by £35.9 per week. Columns 5 to 8 display results when education choices can adjust to the new system, in which case the extra spending allows for the basic tax rate to drop by 0.94pp, the IS award to increase by £7.8 per week, or the tax credits award to increase by £31.1 per week.
Rows 1-2 (as well as 5-6 and 9-10) display effects on pre- and post- tax lifetime income, respectively. Rows 3-4 (as well as 7-8 and 11-12) display effects on welfare measured by the willingness to pay in consumption terms to keep pre-reform wellbeing with the post-reform family budget. These are measured at the beginning of working life (rows 3, 7 and 11) and at the start of life (row 4, 8 and 12). See footnote to table 9 for more details.

8.3 Comparing alternative policies

Taxes and the various forms of welfare have different incentive, redistributive and welfare implications. We thus evaluate the welfare implications of a small change in alternative programs all costing an exogenously funded amount equal to 0.05% of baseline earnings. We consider in turn a decrease in the basic tax rate, an increase in the maximal tax credit award an an increase in

income support respectively.

The results are in Table 10. If we do not allow education to adjust, the clear winner among the programs are tax credits where on average individuals are willing to pay 1.15% of consumption (row 7). The second preferred alternative is a tax cut with a willingness to pay of 0.55% of consumption (row 3). The least preferred program is income support with a willingness to pay of 0.46% (row 11). This continues to be the case when we allow education to adjust but the outcome is tighter in between income support and tax cuts, whether we look at ex-ante welfare before the education choice or ex-post. In all cases the distortionary nature of income support, with its 100% marginal tax rate, makes it the least preferable program despite its basic insurance property (it provides a strong income floor). Of course, this relates to marginal changes and the result could be very different if we were considering large changes.

Comparing education groups, the highest education group prefers tax cuts to either tax credit changes or income support; the latter is valued close to zero by this group. The lowest group prefers an increase in tax credits, with the second best option for them being income support and tax cuts being the least preferred option. Finally, for the middle education group, while still preferring tax credits, the second best option is a tax cut. If we allow education to adjust those who chose college education in the pre-reform world prefer tax credits to tax cuts because some of them shift to a lower education level.

The table also reports changes in gross and net income reflecting changes in work behavior and benefit receipt as a result of the marginal changes in the respective program. These reveal large negative impacts of increases in income support on work income. Tax credits also decrease gross income from work, but by much less. Thus tax credits seem to achieve an increase in welfare with a much lower effect on income.

9 Conclusions

While empirical work has emphasized the importance of tax and welfare on incentives to work, the longer-term effects of such policies have been neglected. In particular, policies that change the return to education and work may affect the amount of human capital accumulated, with important consequences for output, employment and, ultimately, welfare. On the other hand, such welfare programs offer valuable insurance against adverse shocks and may also reduce poverty rates among both the unemployed and the low wage earners.

In this paper we use reforms to the the tax and welfare system and the way they affect different demographic groups to establish that they affect both labor supply and educational decisions. We then develop a life-cycle model of women's labour supply, human capital formation (including both education choice and work experience) and savings that allows us to consider these trade-offs and understand better the longer term effects of policy.

In our model decisions are taken in an uncertain dynamic environment under credit constraints. The model includes important features brought together for the first time. First, the dynamic process of family formation is explicitly accounted for. Second, a detailed description of the policy environment is used to accurately determine net earnings by employment status.

The model is estimated on a long household panel survey for the UK. We use two sources of exogenous variation for this purpose. First, different tax and welfare systems are in place as successive cohorts start adult life. Moreover they face reforms at different ages. This induces different educational and work incentives. Second, conditional on family background (that can affect all aspects of the model) parental income at 16 is allowed to affect education choices, reflecting liquidity constraints in education choice.

Many important empirical features are closely reproduced, including the empirically estimated short-run effects of the tax credit and income support reforms of the late 1990s. We compute

intensive and extensive margin elasticities of labor supply, showing the difference between Marshallian and Frisch labor supply elasticities. We then use the model to study the impact of tax and welfare benefit reforms on employment, family income and education decisions. We also investigate the insurance value of redistributive policies.

Our results show that labor supply elasticities can be substantial both on the intensive and the extensive margins, and even more so for single mothers. As a result, tax and benefit reform has important incentive and welfare effects. We also show that there is substantial depreciation of human capital out of work and that valuable labor market experience is only gained in full-time (as opposed to part-time) work. We uncover strong complementarity between formal education and human capital on-the-job. Finally, individuals on the margin change their education choices in response to welfare reforms, such as tax credits, that change substantially the returns to education. As such policies become permanent features of the policy landscape, their benefits in terms of insurance and poverty reduction need to be weighed against changes in incentives and human capital accumulation, including education choice.

We also quantify the marginal welfare gains of tax cuts, tax credits and income support. While preferences for the alternative programs vary among education groups, overall tax credits are preferred to tax cuts and the least welfare enhancing policy (on the margin) is income support, which carries an implicit 100% marginal tax rate. Perhaps not unexpectedly the lowest education group prefers tax credits to tax cuts, while the highest education group the reverse.

While the insurance and anti-poverty value of such benefit systems is substantial, policy may need to be designed to counteract the ill-effects on education and human capital accumulation that, in itself, can have important longer term impacts in many aspects of life, including the intergenerational transmission of poverty as well as on crime.

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Appendix A: Data

Estimation is based on the first 16 yearly waves of the British Household Panel Survey (BHPS), covering the period from 1991 to 2006. Apart from those who are lost through attrition, all families in the original 1991 sample and subsequent booster samples remain in the panel from then onwards. Other individuals have been added to the sample in subsequent periods — sometimes temporarily — as they formed families with original interviewees or were born to them. All members of the household aged 16 and above are interviewed.

We select the sample of women in all types of family arrangements observed at least for 2 consecutive years while aged 17 to 50. Our full dataset is an unbalanced panel of just over 4,100 women aged observed for some varying period during the years 1991 to 2006. 10% of these women are observed over the whole period, 60% in no more than six consecutive waves and 24% are observed entering working life from education. A great deal of information is collected for them, including family demographics; employment, working hours and earnings as well as those of a present partner; and background characteristics such as age and education, demand for childcare and its cost. We also use assets for women aged 17-18 if present (observed for 562 women).

Some definitional and data preparation procedures should be mentioned for clarity. *Employment* is determined by present labour market status and excludes self-employment. Women self-employed at any point in the observation window were excluded from the sample. We consider employment choices from the age of 19 for women with compulsory and further education, and from the age of 22 for women with higher education.

Working hours refer to the usual hours in main job including overtime. We discretised labour supply using a three-point distribution: not working (0 hours per week), working part-time (1-20

hours per week) and working full-time (21 hours or more per week). The employment status and working hours observed at one point in the year are assumed to remain unaltered over the entire year.

Earnings are the usual gross weekly earnings in the main job. *(Hourly) wage rates* are the ratio of weekly earnings to weekly hours capped at 50. Only the central 96% of the earnings distribution was used for estimation, and only for women working at or above 10 hours per week to reduce the severity of measurement error in wage rates. Nominal wage rates were de-trended using the time intercepts of a regression of log wages on time dummies and log experience. The time intercepts were then used to build a nominal wage index and deflate the monetary parameters of the tax and benefit system.

Family type is classified in four groups: single women and couples without children, lone mothers and couples with children. Women are assumed to have children only after finishing education, once entering the labour market. Cumulated *work experience* is measured in years. *Individual assets* at the beginning of adult life are the total of savings and investments net of debts. They are truncated at zero, never allowed to be negative. *Education* is classified in 3 categories: secondary or compulsory (completed by the age of 16), further (corresponding to A-levels or equivalent qualifications) and higher (university or college).

Cohort effects were removed from all data moments using a fourth degree polynomial in age and cohort.

Appendix B: Model Parameters

Externally set parameters Two parameters are chosen from pre-existing estimates: the coefficient, μ, set to -0.56 giving a risk aversion coefficient of 1.56 (consistent with evidence in Blundell, Browning and Meghir, 1993, and Attanasio and Weber, 1995), and the discount factor, β, set to 0.98 (a typical value in the literature, see e.g. Attanasio, Low and Sanchez-Marcos, 2008). Moreover, the risk-free interest rate is set to 0.015, which is slightly lower than the discount rate thus implying that agents have some degree of impatience; tuition cost of university education amounts to GBP 3,000 for the three-year program and the credit limit for university students (and graduates throughout their life) is GBP 5,000, both reflecting the university education policy of the late nineties in the UK. For everyone else, credit is constrained.

Family transitions Family transition probabilities were estimated using linear probability regressions, weighted to ensure an equal number of women at each age. The probability of a partner arriving is estimated by regressing a dummy for partner arrival on age and age squared among single women aged 55 or less. This is done separately for each of the nine combinations of female and partner education level. Arrival probabilities in the first period of working life are taken directly from the data, and subsequent probabilities are restricted to be non-increasing after age 35 and zero from age 50 (or if negative). The probability of a partner leaving is estimated by regressing a dummy for partner departure on age and age squared among women aged 20–69. This is done separately for each of the three partner education levels (but not female education levels) and, up to age 45, by whether the family has any children.

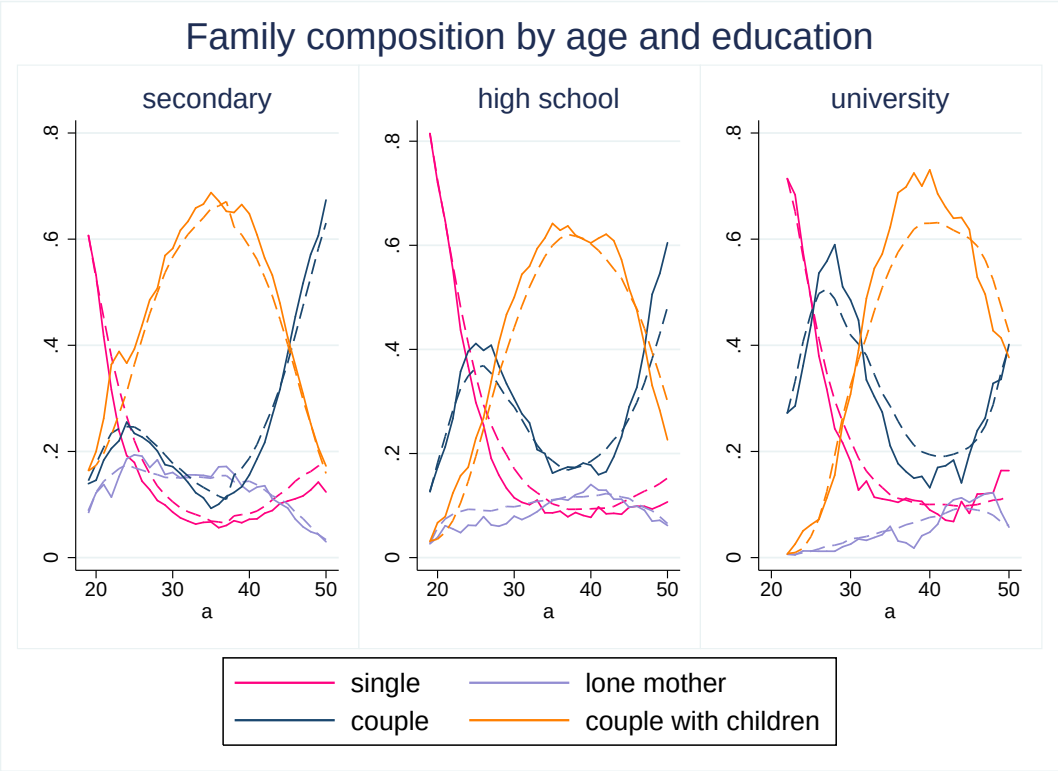
The probability of a child arriving is estimated by regressing a dummy for child arrival on an order 2 polynomial in female age and, for families with older children, an order 2 polynomial in age of next youngest child and a linear interaction with female age. This is done separately for each female education level and by couple status, and regressions only include women aged 42 or less.

Figure 9 shows the distribution of family composition by female age and education for both observed data and model simulations. The displayed simulated profiles are reasonably close to the observed data ones. They show that less educated women are more likely to become mothers early on and to experienced lone-motherhood than more educated women.

Male employment and earnings Table 11 reports the estimates for male working status and earnings by male education. This is relevant only when the woman lives in a couple as we do not solve the male's problem, but we use this equation to draw male income for the budget constraint and male employment status for preferences and child care costs. Rows 1 to 3 display estimates from a probit regression and show that the employment probability generally increases with education and depends strongly on past employment (row 3). Estimates for the log wage equation suggest only mild differences in wage rates by education (row 4) but strong differences in wage progression, with more educated men experiencing steeper wage profiles over time (row 5). We set the autocorrelation coefficient in the male productivity process to 0.99, close to a unit root. Estimates of the selection parameter (mills ratio in row 8) are imprecisely estimated and we assume no correlation between the residuals in the selection and wage equations.

Childcare costs Families with positive childcare costs when all adults in the household are

Figure 9: Family demographics by female age - data and simulations



Notes: Distribution of family types by age of woman. Data in full lines, simulations in dashed lines.

Table 11: Exogenous parameters: married men employment and wage rates by education

	Man's education		
	secondary	further	higher
Employment probabilities			
(1) new couples	0.75	0.88	0.85
	(0.03)	(0.03)	(0.06)
(2) ongoing couples: intercept	-0.94	-0.50	-0.25
	(0.05)	(0.07)	(0.13)
(3) ongoing couples: previously employed	2.71	2.47	2.37
	(0.06)	(0.08)	(0.16)
Log wage equation			
(4) log wage rates	1.72	1.83	1.79
	(0.47)	(0.18)	(0.33)
(5) log woman's age minus 18	0.05	0.12	0.25
	(0.04)	(0.04)	(0.08)
	all education groups		
(6) dispersion productivity (new couples)	0.40		
	(0.10)		
(7) dispersion innovation in productivity (ongoing couples)	0.07		
	(0.03)		
(8) mills ratio	0.25		
	(1.13)		

Notes: Standard errors in parenthesis below the estimate. Sample sizes are: 346 observations for new couples, 8461 observations for ongoing couples, 7386 observations for working married men.

working pay £2.09 (standard error is 0.04) per working hour. Childcare is required for all working hours of mothers if the child is 4 or younger, and is only necessary for older children under the age of 10 if the mother works full-time.

Model Parameters

Appendix C: Computational details on the solution and estimation of the model

The estimation and simulation exercises involve solving the life-cycle model conditional on all exogenous characteristics, including initial assets, preferences for working and education, the dy-

Table 12: Estimates of the parameters in the female wage equation and experience accumulation

		Education attainment		
		secondary	high school	university
		(1)	(2)	(3)
Hourly wage rates (0 experience) $Y_s(b_1, b_2)$				
(1)	baseline	5.40	5.55	6.94
		(.042)	(.045)	(.214)
(2)	increment: high factor 1	0.005	0.018	0.061
		(.004)	(.045)	(.183)
(3)	increment: high factor 2	0.014	-0.186	0.045
		(.057)	(.049)	(.147)
Returns to experience $\gamma_s(b_1, b_2)$				
(4)	baseline	0.15	0.23	0.31
		(.009)	(.006)	(.018)
(5)	increment: high factor 1	0.054	0.014	0.001
		(.013)	(.009)	(.013)
(6)	increment: high factor 2	-0.002	0.029	-0.006
		(.012)	(.010)	(.012)
Distribution of unobserved productivity				
(7)	autocorrelation coefficient: ρ_s	0.925	0.916	0.880
		(.009)	(.008)	(.013)
(8)	SE innovation in productivity: $\sqrt{\mathrm{V}(\zeta_s)}$	0.120	0.154	0.139
		(.007)	(.007)	(.009)
(9)	mean initial productivity for type I: $\mathrm{E}(\upsilon_{0s}\|\text{type I})$	0.150	0.121	0.306
		(.025)	(.017)	(.035)
(10)	st. error initial productivity: $\sqrt{\mathrm{Var}(\upsilon_{0s})}$	0.175	0.252	0.223
		(.015)	(.015)	(.031)
Human capital dynamics				
(11)	while in P work: $g_s(l = P)$	0.170	0.096	0.116
		(.017)	(.024)	(.023)
(12)	depreciation rate: δ_s	0.111	0.057	0.073
		(.011)	(.008)	(.011)

namics of family demographics, the random productivity processes for both women and men, and whether the woman faces positive childcare costs. The model is a finite horizon one, hence requiring the solution to be computed for each period (which we take to be a year) as a function of the entire state space (described by X at the start of section 4.2). We do this by backward recursion, starting from the end of life (age 70).

We discretize the domain of all continuous state variables to reduce the computational size of

Table 13: Estimates of preference parameters - function f in equation 1

		all employment		part-time employment	
		value	st. error	value	st. error
		(1)	(2)	(3)	(4)
(1)	Secondary education	0.344	(.011)	-0.269	(.010)
(2)	High-school education	0.412	(.011)	-0.315	(.006)
(3)	University education	0.555	(.015)	-0.382	(.008)
(4)	Mother with secondary education	0.355	(.008)	-0.151	(.002)
(5)	Mother with high-school education	0.330	(.009)	-0.152	(.007)
(6)	Mother with university education	0.372	(.014)	-0.184	(.026)
(7)	Mother of child aged 0-2	0.156	(.010)	-0.095	(.008)
(8)	Mother of child aged 3-5	0.093	(.009)	-0.067	(.007)
(9)	Mother of child aged 6-10	0.047	(.007)	-0.027	(.006)
(11)	Woman in couple: Sec	0.216	(.010)	-0.149	(.010)
(12)	Woman in couple: HS	0.222	(.012)	-0.156	(.011)
(13)	Woman in couple: Univ	0.276	(.009)	-0.180	(.010)
(14)	Mother in couple: Sec	0.226	(.011)	-0.168	(.011)
(15)	Mother in couple: HS	0.233	(.013)	-0.180	(.011)
(16)	Mother in couple: Univ	0.282	(.015)	-0.212	(.013)
(17)	Partner working	-0.077	(.010)	0.066	(.010)
(18)	High background factor 1	0.002	(.006)	0.000	(.004)
(19)	High background factor 2	0.006	(.006)	0.001	(.004)
(20)	Type I: utility cost of work: $\theta(l)$ (F/P)	-0.093	(.006)	-0.193	(.008)
(21)	Type I: probability	0.36	(.005)		

the problem. At each period of life, and for each point in the state variables' grid, the solution is computed in two steps: (1) solving the Euler equation for the optimal level of consumption conditional on labor supply and (2) choosing the labour supply that maximizes the value of present and (expected) future utility. To evaluate tomorrow's expected marginal utility of consumption (to solve for the Euler equation) and expected utility (to choose optimal labour supply) at points outside tomorrow's grid, we use linear interpolation on approximate linearizations of the expected functions on assets. These are the inverses of the marginal utility of consumption (for the expected marginal utility) and of the instantaneous utility function (for the expected continuation value). The grid in assets is finer for values closer to its lower bound as the linearizations become less precise with the increased probability of the budget constraint binding in the future. Depending on family circumstances and age, we take expectations over up to 5 unobserved variables to compute the continuation value and the expected marginal utility of consumption. These include female

Table 14: Estimates of preferences for education

		Education attainment	
		high school	university
		(1)	(2)
(1)	intercept	-0.383	-0.652
		(.046)	(.078)
(2)	background factor 1	0.157	0.283
		(.017)	(.018)
(3)	background factor 2	-0.009	0.269
		(.036)	(.020)
(4)	parental income when aged 16	0.055	0.125
		(.006)	(.006)
(5)	mother at home when aged 16	-0.008	0.456
		(.020)	(.041)
(6)	father at home when aged 16	0.088	0.336
		(.015)	(.038)
(7)	SE unobserved utility cost of education ($\sqrt{\mathrm{V}\omega_s}$)	1.579	1.015
		(.255)	(.108)
(8)	Probability of positive childcare costs	0.576	
		(.010)	

productivity, couple formation/dissolution, partner's education and productivity and child arrival. We use a 5-dimensional transition matrix, discretizing the domain of the continuous productivity shocks in 12 equal-probability intervals.

The estimation procedure is implemented as an iterative process in four steps. The first step involves solving the female life-cycle problem for a particular set of the estimating parameters, given the economic environment and the adopted exogenously set parameters. We then simulated the life-cycle choices of 22,780 women in step 2, using the observed distribution of initial assets, and select an observation window for each so that the overall simulated sample reproduces the time and age structure of the observed data (this is described in section 7.1). The simulations assume women are exposed to up to three policy regimes over the observation window, representing the main tax and benefits systems operating during the 1990s and early 2000s (we adopted the 1995, 2000 and 2004 regimes and assumed they operated over the periods prior to 1998, 1998 to 2002 and 2003 onwards, respectively). For simulation purposes, all reforms arrive unexpectedly. Step 3 computes the estimation moments using the simulated dataset and calculates the objective function (which is the sum of squared standard deviation differences between data and simulated

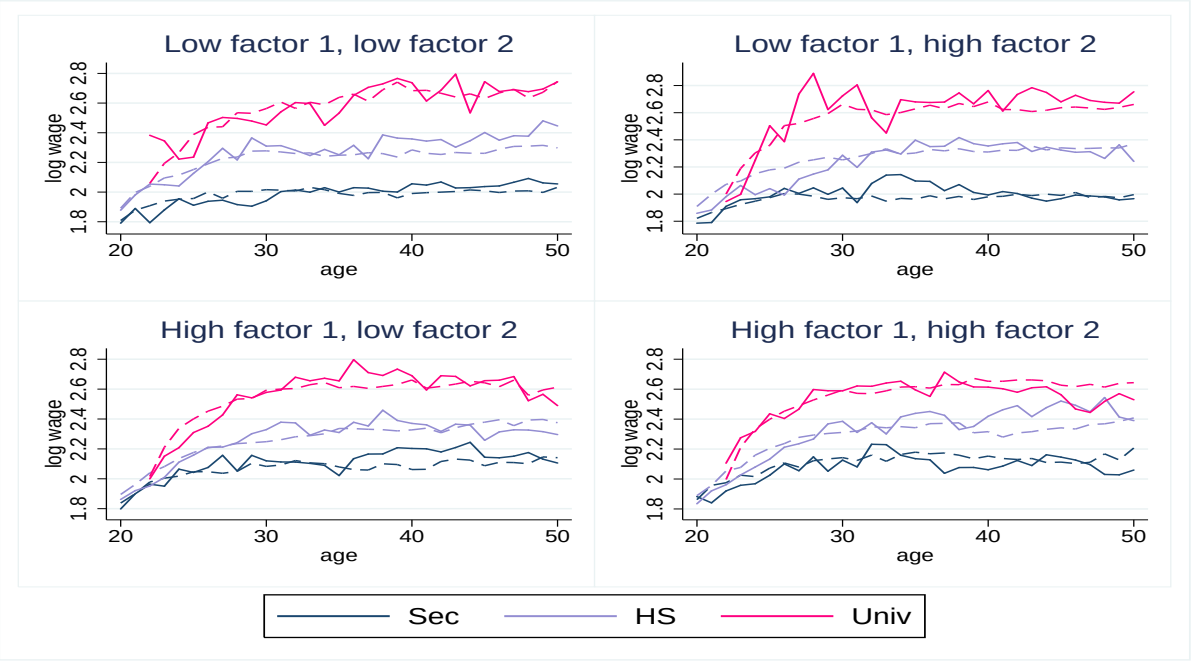
moments). Step 4 compares the difference against a pre-established tolerance and re-optimizes (selects new set of estimation parameters) in case the convergence criterion is not met.

Appendix D: Model fit and other tables

Tables 15 to 20 display the full list of data moments used in estimation, together with their simulated counterparts and the normalized (by the data standard error) differences between the two. The estimation procedure was based on 180 moments, including employment rates in Table 15, part-time employment rates in Table 16, transition rates between employment and unemployment by level of wages in Table 17, coefficients from wage regressions, year-to-year change in wage rates by labour market activity and percentiles of the wage distribution in Table 18, moments of the initial distribution of wage rates in Table 19, and the population distribution of education and positive childcare costs in Table 20. All moments are education-specific.

Among the 180 simulated moments, 36 fall outside the 95% confidence interval for the respective data moment. We found the distribution of wage rates among part-time workers to be particularly difficult to reproduce, possibly a result of severe measurement error in working hours at the bottom of its distribution (bottom panel of Table 18). Measurement error in the distribution of hours, even if classical, results in upward biased measures of the wage rates as these are not directly observed and, instead, computed as the ratio of earned income to hours. The effect is more severe at the bottom of the distribution of hours, thus particularly affecting the distribution of wage rates among part-time workers.

Figure 10: Log wage rates for working women over the life-cycle by education and family background: data versus model



Notes: Full lines are for BHPS data; dashed lines are for model predictions.

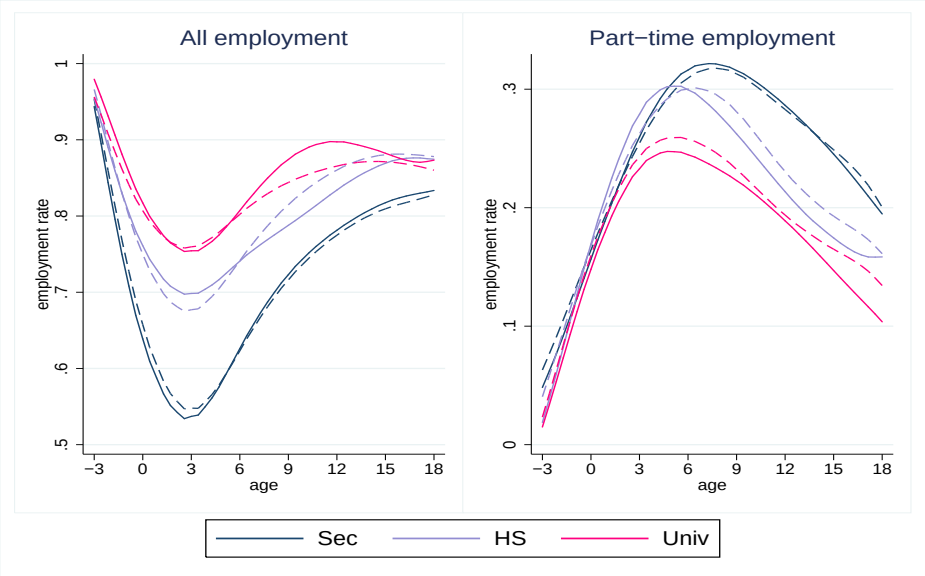
Appendix E: Tax and benefit reforms

Here we provide a brief description of the UK tax and transfer system. We focus on reforms between four systems – April 1995, April 1999, April 2002 and April 2004 – that represent four different regimes in terms of the generosity and structure of taxes and transfers. These systems are the ones we use in estimation.

Table 23 sets out the most important tax rates and thresholds for the two main personal taxes on earnings: income tax and National Insurance. Both are individual-based and operate through a system of tax-free allowances and income bands that are subject to different rates of tax.

Between April 1995 and April 1999, the main income tax and National Insurance reforms were as follows. For income tax, the personal allowance and basic rate limit rose in real terms by 11% and 4% respectively. The starting rate was cut from 20% to 10% but the starting rate limit reduced substantially (58%). Also, the basic rate was cut from 25% to 23%. For National Insurance, the 2% 'entry fee' (cliff edge) payable as soon as earnings exceeded the lower earnings limit was

Figure 11: Female employment rates by years to/from childbirth



Notes: BHPS versus simulated data. All curves smoothed using kernel weights and a bandwidth of 2 years.

abolished.

Between April 1999 and April 2002, the basic rate of income tax was further reduced from 23% to 22% and the additional allowance for couples was abolished. In addition, in National Insurance, the lower earnings limit/primary threshold and upper earnings limit rose by 27% and 10% respectively.

Between April 2002 and April 2004, the income tax personal allowance and National Insurance primary threshold both declined by 3% in real terms. Also, in National Insurance, the main rate and the rate above upper earnings limit both rose by 1%.

The system of transfers in the UK is more complex. Most transfers are strongly contingent on family circumstances and are means-tested at the family level. The main transfer programs for working-age individuals in existence at some point across the four systems of interest are as follows. Child Benefit is a universal (non-means-tested) benefit available for families with children. Income support (together with income-based jobseeker's allowance) is an out-of-work means-tested benefit that tops net family income up to a specified level based on family needs. Children's tax credit is a tax rebate available to families with children. (It actually part of the tax system but is included here because of the way it was reformed, discussed below). Family credit and working families' tax credit are means-tested benefits for working families with children. They are structurally very

Table 15: Model fit – female employment rates by family composition and education

	secondary			further			higher		
	data	sim	SE diff	data	sim	SE diff	data	sim	SE diff
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Single women									
all	0.60	0.59	0.83	0.82	0.83	0.57	0.92	0.95	2.29
mothers	0.40	0.43	1.13	0.66	0.61	1.36	0.91	0.81	2.95
mothers: child age 0-2	0.17	0.23	2.53	0.31	0.39	1.36	0.73	0.56	1.10
mothers: child age 3-5	0.31	0.39	2.58	0.57	0.57	0.15	0.76	0.78	0.11
mothers: child age 6-10	0.48	0.49	0.13	0.74	0.66	1.67	0.94	0.85	1.44
mothers: child age 11-18	0.61	0.60	0.22	0.89	0.79	2.56	0.99	0.92	3.19
Married women									
all	0.68	0.65	2.26	0.80	0.79	0.58	0.89	0.88	0.33
mothers	0.60	0.60	0.45	0.71	0.73	1.33	0.83	0.85	0.77
mothers: child age 0-2	0.40	0.35	2.20	0.58	0.54	1.64	0.77	0.75	0.60
mothers: child age 3-5	0.54	0.58	1.63	0.70	0.73	1.16	0.81	0.86	1.38
mothers: child age 6-10	0.69	0.70	0.32	0.79	0.81	1.12	0.92	0.90	0.63
mothers: child age 11-18	0.77	0.75	1.43	0.87	0.88	0.45	0.91	0.94	0.69
partner working	0.74	0.71	2.46	0.81	0.83	1.88	0.89	0.90	0.79

Notes: Values in columns 1, 4 and 7 are data moments. Columns 2, 5 and 8 report the corresponding simulated moments and columns 3, 6, and 9 report the standard error distance between the two sets of moments using the data standard errors. Statistically significant differences at the typical 5% level correspond to figures above 2 in columns 3, 6, and 9.

similar to each other. Working tax credit is a means-tested benefit for working families that is more generous for families with children but also available to childless families. Child tax credit is a means-tested benefit for families with children that is not contingent on working. Working tax credit and child tax credit are subject to a joint taper. Finally, housing benefit and council tax benefits are means-tested benefits that help low-income families meet, respectively, rent payments and council tax bills.

Table 24 sets out maximum entitlements and taper rates for transfers that were reformed across our four systems of interest. It considers six example low-wage family types to demonstrate who were the main gainers and losers from each reform. Housing benefit and council tax benefit are not included because changes to these transfer programs were relatively minor.

Between April 1995 and April 1999, the main change was the abolition of the lone parent rate of child benefit, affecting lone parents. There were also some modest increases in generosity in family credit across all low-wage families with children.

Between April 1999 and April 2002, family credit was replaced by the considerably more generous

Table 16: Model fit – female part-time employment rates for women by family composition and education

	secondary			further			higher		
	data	sim	SE diff	data	sim	SE diff	data	sim	SE diff
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Single women									
all	0.11	0.10	1.23	0.07	0.05	1.95	0.03	0.01	1.52
mothers	0.17	0.18	0.91	0.14	0.16	1.04	0.05	0.09	1.10
mothers: child age 0-2	0.12	0.16	1.66	0.11	0.17	2.08	0.16	0.11	0.42
mothers: child age 3-5	0.20	0.34	3.92	0.19	0.35	4.03	0.15	0.24	0.84
mothers: child age 6-10	0.20	0.13	3.06	0.17	0.10	1.63	0.11	0.07	0.51
mothers: child age 11-18	0.15	0.12	1.17	0.09	0.07	0.43	0.00	0.00	1.03
Married women									
all	0.18	0.19	1.12	0.15	0.16	0.60	0.11	0.11	0.21
mothers	0.23	0.23	0.47	0.22	0.21	0.50	0.17	0.15	0.91
mothers: child age 0-2	0.20	0.14	4.34	0.23	0.16	4.75	0.20	0.12	2.39
mothers: child age 3-5	0.27	0.35	4.82	0.27	0.36	3.72	0.22	0.26	1.00
mothers: child age 6-10	0.28	0.29	0.84	0.24	0.24	0.03	0.17	0.15	0.36
mothers: child age 11-18	0.20	0.17	1.91	0.12	0.11	0.53	0.06	0.08	0.34
partner working	0.20	0.21	1.06	0.15	0.16	0.97	0.11	0.11	0.05

Notes: Values in columns 1, 4 and 7 are data moments. Columns 2, 5 and 8 report the corresponding simulated moments and columns 3, 6, and 9 report the standard error distance between the two sets of moments using the data standard errors. Statistically significant differences at the typical 5% level correspond to figures above 2 in columns 3, 6, and 9.

working families' tax credit, affecting working families with children. The increase in generosity was particularly large for families with childcare costs. For example, maximum entitlement for a lone parent with one child aged 4 and no childcare costs grew by 21% compared with 93% for the same lone parent but with childcare costs of £98.80 (38 hours at pounds 2.60 per hour). This is because family credit included a childcare income disregard whereas working families' tax credit had a childcare element that contributed to the maximum award.

Between April 2002 and April 2004, child tax credit replaced children's tax credit and child elements of other benefits including in working families' tax credit. This also coincided with a modest increase in generosity. In addition, working tax credit replaced working families' tax credit and extended entitlement to families without children.

Differences in eligibility and interactions across transfer programs make it hard to use Table 24 to deduce the size of the overall gain or loss across years. Therefore, Table 25 sets out the net family income for the same six low-wage family types across the four tax and transfer systems. In

Table 17: Model fit – transition probabilities between unemployment and employment by family composition and education

	secondary			further			higher		
	data	sim	SE diff	data	sim	SE diff	data	sim	SE diff
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Single women									
U to E	0.13	0.17	4.18	0.23	0.22	0.26	0.53	0.33	2.19
E to U	0.07	0.07	0.76	0.04	0.02	3.45	0.02	0.01	1.90
E to U: $w_{t-1} < \mathrm{p}_{10}$	0.13	0.10	1.52	0.10	0.07	1.06	0.01	0.05	9.91
E to U: $w_{t-1} < \mathrm{p}_{50}$	0.09	0.08	0.59	0.07	0.04	2.93	0.04	0.03	0.67
E to U: $w_{t-1} < \mathrm{p}_{90}$	0.07	0.07	0.15	0.04	0.03	3.18	0.02	0.01	1.57
Married women									
U to E	0.14	0.14	0.28	0.18	0.17	0.82	0.24	0.22	0.48
E to U	0.06	0.08	7.21	0.04	0.05	0.55	0.03	0.03	0.55
E to U: $w_{t-1} < \mathrm{p}_{10}$	0.12	0.15	1.57	0.12	0.14	0.62	0.05	0.20	1.10
E to U: $w_{t-1} < \mathrm{p}_{50}$	0.06	0.10	4.52	0.06	0.08	2.72	0.04	0.09	3.28
E to U: $w_{t-1} < \mathrm{p}_{90}$	0.05	0.08	5.03	0.04	0.05	1.64	0.03	0.04	0.79

Notes: Women only. Values in columns 1, 4 and 7 are data moments. Columns 2, 5 and 8 report the corresponding simulated moments and columns 3, 6, and 9 report the standard error distance between the two sets of moments using the data standard errors. Statistically significant differences at the typical 5% level correspond to figures above 2 in columns 3, 6, and 9. U stands for unemployment, E for employment, w_{t-1} is the female wage rate in period $t-1$, and p_q is the qth quantile of the distribution of female wage rates.

each case, results are shown for three different hours of work: zero, part-time (18 hours per week) and full-time (38 hours per week). In each case, the wage is assumed to be equal to the April 2004 minimum wage of £4.50, uprated for inflation. In cases involving childcare costs, childcare is assumed to be required to cover every hour of work at a rate of £2.60 per hour. A partner, if present, is assumed to work 40 hours per week, also at the April 2004 minimum wage.

Table 18: Model fit – wage regressions and the distribution of female wage rates by education

	secondary			further			higher		
	data	sim	SE diff	data	sim	SE diff	data	sim	SE diff
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log wage regression in first differences									
log experience	0.10	0.11	0.46	0.12	0.19	4.54	0.17	0.21	1.68
autocorr of residuals	0.96	0.92	1.81	0.95	0.94	0.64	0.92	0.89	1.11
var of innovation	0.01	0.01	0.73	0.01	0.01	0.06	0.01	0.01	0.42
Annual change in log earnings by past employment status									
full-time employment	0.02	0.01	1.26	0.02	0.01	1.78	0.03	0.01	2.37
part-time employment	-0.03	-0.00	3.32	-0.06	-0.01	5.95	-0.01	-0.01	0.74
unemployment	-0.02	-0.01	0.27	-0.04	-0.03	1.14	-0.05	-0.03	1.19
Distribution of log wage rates among full-time working women									
mean	1.85	1.84	1.28	2.07	2.08	0.91	2.36	2.40	1.37
proportion below p_{10}	0.10	0.11	1.57	0.10	0.08	1.69	0.10	0.05	6.08
proportion below p_{25}	0.25	0.25	0.12	0.25	0.24	0.47	0.25	0.20	1.90
proportion below p_{50}	0.50	0.51	0.30	0.50	0.49	0.04	0.50	0.49	0.15
proportion below p_{75}	0.75	0.75	0.16	0.75	0.76	0.29	0.75	0.75	0.14
proportion below p_{90}	0.90	0.90	0.14	0.90	0.89	0.11	0.90	0.89	0.15
Distribution of log wage rates among part-time working women									
mean	1.69	1.69	0.00	1.95	1.81	5.49	2.27	2.10	4.18
proportion below p_{10}	0.10	0.08	1.80	0.10	0.10	1.24	0.10	0.05	5.38
proportion below p_{25}	0.25	0.20	2.39	0.25	0.26	0.62	0.25	0.32	4.02
proportion below p_{50}	0.50	0.43	1.78	0.50	0.64	4.27	0.50	0.78	7.92
proportion below p_{75}	0.75	0.76	0.31	0.75	0.91	3.15	0.75	0.96	3.99
proportion below p_{90}	0.90	0.94	0.75	0.90	0.98	1.37	0.90	0.99	1.37

Notes: Values in columns 1, 4 and 7 are data moments. Columns 2, 5 and 8 report the corresponding simulated moments and columns 3, 6, and 9 report the standard error distance between the two sets of moments using the data standard errors. Statistically significant differences at the typical 5% level correspond to figures above 2 in columns 3, 6, and 9. qth quantile of the distribution of female wage rates.

Table 19: Model fit – female initial wage rate by education

	secondary			further			higher		
	data	sim	SE diff	data	sim	SE diff	data	sim	SE diff
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Distribution of log wage rates among full-time working women									
mean	1.63	1.61	1.30	1.62	1.61	0.47	1.89	1.93	1.49
variance	0.08	0.06	2.89	0.07	0.06	1.23	0.11	0.09	1.33
proportion below p_{25}	0.25	0.31	2.30	0.25	0.27	1.35	0.25	0.21	1.43
proportion below p_{75}	0.75	0.73	0.64	0.75	0.83	3.83	0.75	0.79	1.78

Notes: Values in columns 1, 4 and 7 are data moments. Columns 2, 5 and 8 report the corresponding simulated moments and columns 3, 6, and 9 report the standard error distance between the two sets of moments using the data standard errors. Statistically significant differences at the typical 5% level correspond to figures above 2 in columns 3, 6, and 9. p_q is the qth quantile of the distribution of female wage rates.

Table 20: Model fit – other moments by education

	secondary			further			higher		
	data	sim	SE diff	data	sim	SE diff	data	sim	SE diff
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
distribution of education	0.30	0.30	0.01	0.47	0.47	0.00	0.21	0.21	0.00
prob positive CC cost	0.29	0.30	0.44	0.40	0.37	1.21	0.41	0.40	0.26

Notes: Women only. Values in columns 1, 4 and 7 are data moments. Columns 2, 5 and 8 report the corresponding simulated moments and columns 3, 6, and 9 report the standard error distance between the two sets of moments using the data standard errors. Statistically significant differences at the typical 5% level correspond to figures above 2 in columns 3, 6, and 9. *CC* stands for childcare.

Table 21: Basic tax rates to maintain revenue at baseline level (%)

	1999 educ	post-reform educ
1999	23.0%	23.0%
WFTC + childIS	+.73	+.98
WFTC	+.40	+.57
with 99 taper	+.59	+.76

Notes: Based on simulated data. Basic tax rate required to keep public budget at the same level as baseline (1999). Row 1 shows the basic tax rate for the baseline system (1999). Row 2 adds WFTC and the child component of IS as in 2002. Row 3 elliminates the reform in the child component of IS. Row 4 imposes the 1999 withdrawal rate (70%) on the joint reform in row 2. Column 1 displays results if education is kept at pre-reform levels. Column 2 allows for education choices to adjust to the new incentives.

Table 22: Simulated effects of *non*-revenue neutral reforms on employment rates of mothers (ppt)

	Single mothers by baseline educ				Mothers in couples by baseline educ			
	sec	furth	high	all	sec	furth	high	all
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Pre-reform education choice								
(1) WFTC and child IS	3.8	3.6	1.6	3.0	-5.9	-4.3	-1.7	-4.0
(2) WFTC	12.4	12.0	7.3	10.6	-5.1	-3.5	-1.3	-3.3
(3) WFTC and child IS w/ 70% withdrawal	2.1	1.4	-0.4	1.0	-2.6	-2.2	-0.8	-1.9
Post-reform education choice								
(4) WFTC and child IS	3.8	3.3	-2.8	1.4	-5.9	-4.5	-3.0	-4.4
(5) WFTC	12.4	11.8	4.3	9.5	-5.1	-3.6	-2.1	-3.6
(6) WFTC and child IS w/ 70% withdrawal	2.1	1.1	-3.6	-0.1	-2.6	-2.3	-1.7	-2.2

Notes: Based on simulated data. Reforms are *not* revenue neutral. Effects from comparisons with baseline tax and benefit system. Rows 1 and 4 show the effects of a joint reform of in-work and out-of-work benefits: (*i*) the family credit as in 1999 is replaced by the WFTC as it 2002 and (*ii*) the child component of IS as in 1999 is replace by the more generous level adopted in 2002. Rows 2 and 5 single out the effect of replacing replacing FC as in 1999 by WFTC as in 2002. Rows 3 and 6 impose the 1999 withdrawal rate (70%) on the joint reform in rows 1 and 4. Rows 1 to 3 display the effects if education is kept at pre-reform levels. Rows 4 to 6 allow for education choices to adjust to the new incentives. Columns 1 to 4 show effects for single mothers by education. Columns 5 to 8 show effects for mothers in couples. The three levels of education are secondary ('sec', columns 1 and 5), further ('furth', columns 2 and 6) and college or university ('high', columns 3 and 7).

Table 23: Tax rates and thresholds under different tax and transfer systems

	April 1995	April 1999	April 2002	April 2004
Income tax				
Personal allowance	95.45	105.87	105.97	103.09
Allowance for couples	6.99	4.81	0.00	0.00
Starting rate	20%	10%	10%	10%
Starting rate limit	86.65	36.63	44.09	43.89
Basic rate	25%	23%	22%	22%
Basic rate limit	657.99	683.83	686.6	682.21
Higher rate	40%	40%	40%	40%
National insurance				
Lower earnings limit/primary threshold	81.67	83.82	106.27	102.81
Entry fee	2%	0%	0%	0%
Main rate	10%	10%	10%	11%
Upper earnings limit	619.54	634.99	698.54	689.17
Rate above upper earnings limit	0%	0%	0%	1%

Notes: Amounts expressed in weekly terms and uprated to January 2008 prices using RPI. Allowance for couples is the married couple allowance and additional personal allowance.

Table 24: Maximum entitlements and taper rates for example families for selected benefits and tax credits under different tax and transfer systems

	April 1995	April 1999	April 2002	April 2004
Childless single				
Child benefit	0.00	0.00	0.00	0.00
Income support	65.47	65.28	64.42	62.87
Children's tax credit	–	–	0.00	–
Tax credits	0.00	0.00	0.00	48.02
Lone parent with one child aged 4 and no childcare costs				
Child benefit	23.51	18.29	18.81	18.64
Income support	109.69	108.58	122.04	62.87
Children's tax credit	–	–	12.15	–
Tax credits	93.64	96.52	117.14	162.84
Lone parent with one child aged 4 and with childcare costs				
Child benefit	23.51	18.29	18.81	18.64
Income support	109.69	108.58	122.04	62.87
Children's tax credit	–	–	12.15	–
Tax credits	93.64	96.52	186.30	232.00
Childless couple				
Child benefit	0.00	0.00	0.00	0.00
Income support	102.79	102.42	101.08	98.63
Children's tax credit	–	–	0.00	–
Tax credits	0.00	0.00	0.00	115.69
Couple parents with one child aged 4 and no childcare costs				
Child benefit	14.64	18.29	18.81	18.64
Income support	139.68	145.73	158.69	98.63
Children's tax credit	–	–	12.15	–
Tax credits	93.64	96.52	117.14	162.84
Couple parents with one child aged 4 and with childcare costs				
Child benefit	14.64	18.29	18.81	18.64
Income support	139.68	145.73	158.69	98.63
Children's tax credit	–	–	12.15	–
Tax credits	93.64	96.52	186.30	232.00
Taper rates (all family types)				
Income support	100%	100%	100%	100%
Children's tax credit	–	–	6.67%	–
Tax credits	70%	70%	55%	37%

Notes: Amounts expressed in weekly terms and uprated to January 2008 prices using RPI. Amounts ignore disability-related supplements and transition rules. Note that it doesn't make sense to sum across maximum entitlements for all benefits and tax credits because some cannot be received together. April 1995 child benefit amount includes one parent benefit (later combined with child benefit) Income support calculated assuming adults are aged 25+. Child-related components of income support became part of tax credits in April 2004 system. The children's tax credit is an income tax rebate so is only received if income tax is paid. It became part of tax credits in the April 2004 system. Tax credits include family credit, working families' tax credit, working tax credit and child tax credit. Tax credit maximum amounts calculated assuming entitlement to full-time premium and, where relevant, childcare support for 38 hours per week at 2.60 per hour. Tax credit maximum amount in April 1995 includes full-time premium that was introduced in July 1995. The way childcare was treated for tax credits changed between the April 1999 and April 2002 systems so the maximum tax credit awards are not directly comparable before and after these dates. Tax credits under the April 2004 system additionally incorporate child-related support previously delivered through income support and the children's tax credit. The 37% tax credit taper rate in April 2004 is roughly equivalent to the 55% taper rate in April 2002 because the former operates against gross income and the latter against net income. Also note that under the April 2004 system there was a second taper of 6.67%.

Table 25: Net income for example families under different tax and transfer systems

Hours of work	April 1995	April 1999	April 2002	April 2004
Childless single				
0 (not working)	65.47	65.28	64.42	62.87
18 (part-time)	85.62	86.92	87.29	86.91
38 (full-time)	148.16	152.51	154.01	167.15
Lone parent with one child aged 4 and no childcare costs				
0 (not working)	109.69	108.58	122.04	128.66
18 (part-time)	184.32	181.28	201.22	213.83
38 (full-time)	227.14	223.61	263.65	266.51
Lone parent with one child aged 4 and with childcare costs				
0 (not working)	109.69	108.58	122.04	128.66
18 (part-time)	191.96	190.64	236.78	249.39
38 (full-time)	267.80	275.35	332.81	337.14
Childless couple				
0 (not working)	162.49	165.87	164.62	202.47
18 (part-time)	246.60	250.08	246.90	255.17
38 (full-time)	318.01	326.27	325.99	319.20
Couple parents with one child aged 4 and no childcare costs				
0 (not working)	219.49	226.55	263.60	268.25
18 (part-time)	261.24	268.36	302.41	320.96
38 (full-time)	332.65	344.55	356.95	360.52
Couple parents with one child aged 4 and with childcare costs				
0 (not working)	219.49	226.55	263.60	268.25
18 (part-time)	276.39	283.58	335.17	353.72
38 (full-time)	332.65	344.55	407.16	429.68

Notes: Amounts expressed in weekly terms and uprated to January 2008 prices using RPI. Amounts ignore disability-related supplements and transition rules. Calculated assuming a wage equal to the April 2004 minimum wage (£4.50) uprated in line with RPI. A partner, if present, is assumed to work 40 hours per week at the April 2004 minimum wage. Childcare costs calculated as £2.60 per hour for the number of hours worked listed in the table.