FEMALE LABOR SUPPLY, HUMAN CAPITAL AND WELFARE REFORM

By

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Female Labor Supply, Human Capital and Welfare Reform

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Abstract

We estimate a dynamic model of employment, human capital accumulation - including education, and savings for women in the UK, exploiting policy changes. We analyze both the incentive effects and the welfare implications of tax credits and income support programs and we account for their insurance value. We find important incentive effects on education choice and labor supply, with single mothers having the most elastic labor supply. Returns to experience increase with education, but experience only accumulates when in full-time employment. Finally, marginal increases in tax credits are preferred to equally costly income support or to tax cuts.

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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. 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, life-cycle labor supply and savings 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-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

[1] Throughout the paper we use interchangeably the terms "benefits", "subsidies", "transfers", "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.

determinant of the incentives to work.[3] Indeed, a motivation for in-work benefits is to preserve the labor-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. With the notable exception of Keane and Wolpin (2007, 2010) most of the attention of empirical studies has been on how they affect work incentives and labor 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, which we also consider here.

In this paper we extend this work by acknowledging that in-work benefits and the other components of the tax and welfare system, may affect life-cycle careers through a number of channels beyond the period-by-period changes in employment. These include educational choice because the returns and indeed the risk properties of alternative choices are affected; human capital accumulation through work experience because of changes in labor supply behavior; asset accumulation because welfare benefits and taxes provide partial insurance against income shocks when markets are incomplete; and of course, all these channels are interrelated, reinforcing or mitigating the effects of each other for various outcomes over the lifecycle, resulting in complex behavioral and welfare effects.

To obtain a better understanding of the effects of in work benefits and more generally of taxes and welfare, we estimate a dynamic model of female education choice, labor supply, wages and consumption/savings over the life-cycle. At the start of their life-cycle, women decide how much to invest in education. They choose between three possible levels (secondary, high school and university), taking into account the implied costs as well as the expected returns and volatility

[3] See Goldin (2007 and 2014), Shaw (1989), Imai and Keane (2004) and Heckman, Lochner and Cossa (2003).

associated with each choice, both of which are affected by taxes and benefits. Once education is completed they make period-by-period employment decisions depending on wages, preferences and 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 study addresses a number of important research questions. First, we study the effects of incentives on the labor supply of women. Second, we also look at how individuals make decisions on education and, more generally, at how human capital evolves over the lifecycle depending on the interaction between education, employment and working hours. Third, by developing a framework that can explain the labor supply and education responses to incentives and their long-term effects for earnings capacity and savings, we also contribute to the understanding of the broader impact of taxes and welfare benefits and their role in redistribution, insurance and incentives. Within this context our empirical results are directly relevant for the design of optimal income tax and human capital policies, which balance incentives and insurance as developed by Stantcheva (2015). Clearly, modeling the way individuals save is central to these aims. And finally, we incorporate the use of quasi-experimental policy variation in the estimation of the dynamic model. We show in a difference-in differences setup that these reforms affect both employment and education choices.

The closest model to ours is that of Keane and Wolpin (2007, 2010) who use NLSY data to estimate a dynamic model of schooling and human capital accumulation (through work experience), labor supply, fertility, marriage and welfare participation and to analyze the effects of welfare on these of outcomes. The key distinguishing feature of our model specification is that we allow for savings, a central ingredient given the motivation of our paper. On the other hand, we simplify the fertility and marriage processes by allowing them to depend on education but not modeling them as choices that can be affected by policy. We focus on savings because in an economy with incomplete insurance and credit markets assets are the main channel for (self) insurance. Savings will be affected by the structure and generosity of the welfare programs. Moreover, when choosing education individuals will take into account the varying degrees of return and risk associated with each choice and the resulting paths of asset accumulation, leading to different possibilities for self-insurance against adverse shocks. Assets are also important because this study relates to the entire population - not just a very low skill and poor subgroup. Indeed we document that holding assets is to varying degrees relevant for all education groups, particularly once we account for housing. Finally, counterfactual simulations that change public insurance programs would give an incomplete picture of the welfare effects if they did not allow individuals to change their savings behavior because they would ignore the change in insurance value.[4] Despite our focus on insurance and savings, we do acknowledge that fertility can respond to welfare reform. Fertility responses may be especially relevant during adolescent years, when even small effects may have sizable consequences for education, female labor supply, earnings capacity and family wellbeing in the long run. We briefly document the impact of the reforms we consider on fertility but we leave a more complete treatment of this interesting issue to future research because of the formidable computational demands that it entails.

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 provide 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

[4]Beyond this the studies have many other differences. For example, we use the exact description of the personal taxes and benefits operating in each year of our observation window to obtain a realistic representation of the work incentives faced by women and how they change over time. Our identification strategy also differs from that adopted in Keane and Wolpin (2010) by drawing heavily on quasi-experimental variation in the incentives to work and study due to tax and welfare reforms.

use a reduced form difference-in-differences approach to establish that the reforms 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 single mothers with secondary education only, who are the main target group of the tax credit program.[5] 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 university 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 women who completed a 3-year university degree or more. Those with secondary 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 expe-

[5] Our elasticities are somewhat lower than those estimated by Keane and Wolpin (2010) but exhibit similar variation with education and family demographics.

rience 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 labor 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 secondary 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 sufficiently against the uncertainty they face. We also find that the welfare of the secondary 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, university-educated 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 in section 2. Section 3 describes the data used for estimation and presents 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 estimated parameters. We then 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. 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 2008, 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. Appendix F sets out the changes over the whole period of our data in more detail.[6]

Reforms between April 1999 and April 2002 primarily affected Income Support (IS), Family Credit (FC) and Working Families' Tax Credit (WFTC). IS is a benefit for families where

[6]For a more comprehensive discussion of UK taxes and transfers, see Browne and Roantree (2012) and Browne and Hood (2012).

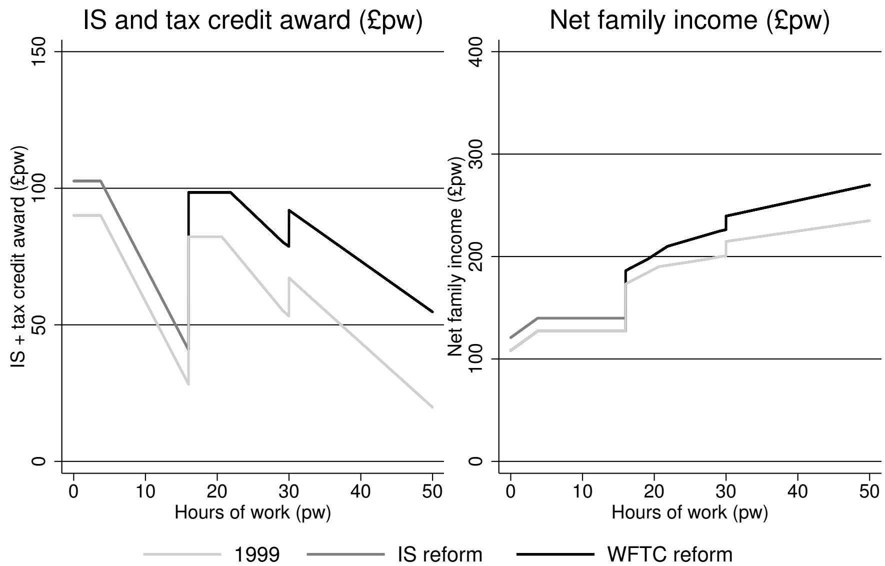
no one is working working 16 hours or more a week (24 hours for partners) that tops family income up to a level that depends on family circumstances including the the number and age of children, and the number and age of adults (under 18, 18-24 or 25 and older). An asset test limits eligibility; in 2002, only families holding assets (excluding housing) below £9,730 (2008 prices) were entitled to IS.[7] 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. Eligibility was conditional on the same asset test as IS, but this rule was abolished in 2004. 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, with a similar but more generous design in three main ways: 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)

[7]This changed little over the period. For the majority of families, particularly for those of low educated women who are more likely to be on IS, this rule is unlikely to bind.

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



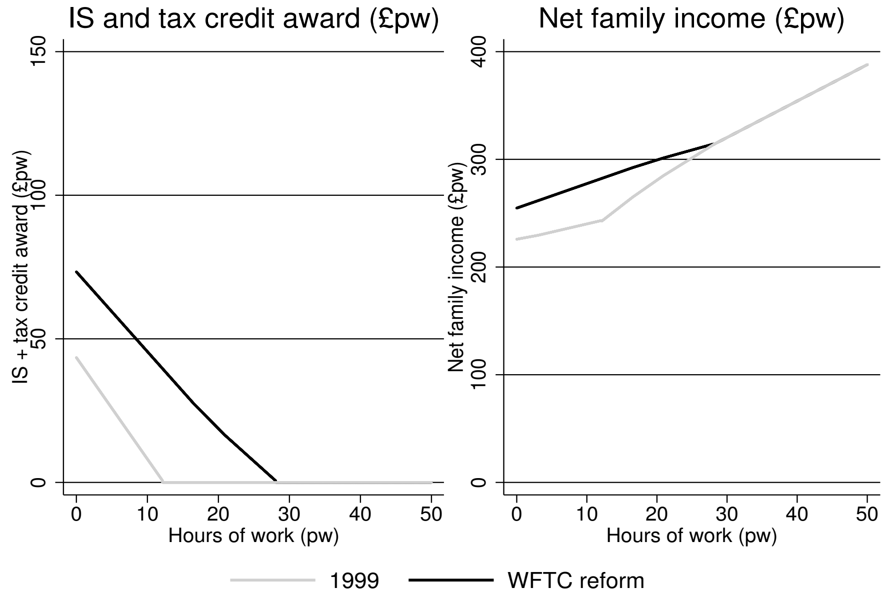
Notes: Lone parent earns the minimum wage (£5.05) and has one child aged 4 and no expenditure on childcare or rent. Tax system parameters uprated to April 2006 earnings levels.

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 award described above because tax credits count as income in the calculation 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. Our model will account for the entire tax

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.

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. Appendix F includes tables describing the various changes over these years.

3 Data and reduced form analysis

3.1 The Panel Data Sample

In estimation we make use of 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. Families where the female is self-employed have also been dropped to avoid the difficulties relating to measuring their hours.[8] 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 1. Further details are provided in Appendix A.

One important element of our model is accounting for savings behavior. Table 2 shows that assets are important, to varying degrees, for all education groups. This is particularly true when we account for housing, which is by far the most important asset held by individuals. Moreover, since the choice of different education levels leads to different earnings trajectories, labor market attachment and welfare benefit utilization we would expect different asset trajectories. The same table confirms that higher educated individuals hold on average over the lifecycle more

[8]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.

assets. Taken together this means that it is important to allow for savings if we are to understand the welfare effects of social programs and the overall level of insurance that individuals enjoy.

Table 2: Assets by Education

	Financial Assets			Housing		
	Proportion	Net assets (£1,000)		Proportion	For owners (£1,000)	
Education	positive	average	[p10,p90]	Owners	Value	[p10,p90]
Secondary	0.58	3.0	[-1.9 , 8.3]	0.69	127.4	[51.9 , 225,6]
High-school	0.74	4.9	[-2.9 , 16.1]	0.74	158.7	[57.0 , 287.7]
University	0.82	9.9	[-5.1 , 28.2]	0.85	206.2	[75.0 , 379.1]

Notes: Values in 1,000s British pounds, 2008 prices. Excludes private and public pension wealth. Housing value is gross: information on mortgages not available. Financial assets net of debts, includes zeros. [p10,p90] in columns 3 and 6 stands for inter-decile range.

Our structural model does not deal with macroeconomic growth and fluctuations; in estimating the 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) were similarly adjusted. To limit the importance of measurement error in earnings and especially working hours, the wage distribution was trimmed at percentiles 2 and 99 from below and above, respectively.[9]

[9]The censoring of the distribution from below is at £3.4 per hour in 2008 prices, well below the minimum wage.

3.2 Reduced-form estimates: labor supply

As already mentioned, estimation of the 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 maximum 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 (IS) system reduced the adult related benefit, affecting all women (irrespective of children), but increased the child related benefit. This latter reform counteracted somewhat the improved incentives for mothers with children due to the WFTC reform. 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 WFTC and IS reforms on the labor supply of single mothers, using a difference-in-differences design, an approach first used to estimate the effects of EITC on labor supply by Eissa and Liebman (1996) and also used in the UK by Brewer et al. (2006). While the effect we estimate is specific to this institutional context, it serves to show that the combined reforms did indeed cause increases in the labor supply of single mothers and establishes the order of magnitude that we can expect our model to replicate. It also shows that the reforms are an important source of exogenous variation for the model.

Table 3 shows results by education groups, using the same categories as will later be considered in the structural model: secondary (compulsory level, completed by age 16), high school (A-level or similar further-education qualifications) and university education (three-year degree and above). The results indicate that the employment rates for secondary and high school educated 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 university are unaffected, as we expect, because typically their earnings will be too high to benefit from the more generous support.

Table 3: Difference-in-differences 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)
N	24,225	8,911	5,749

Notes: Estimates on data from the Labour Force Survey. Difference-in-differences 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 time, group and time x group dummies. Other covariates include age and age of youngest child.

3.3 Reduced form estimates: education choice

The WFTC and IS 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 implications for women's employment and earnings capacity over their entire working life. Before using our structural model, we investigate whether the 1999-2002 reforms 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.

The empirical strategy behind the regression in columns (1) and (2) of Table 4 relies on the idea that, depending on their family background, the WFTC and IS reforms 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.[10] Since the reforms would not have affected the

[10]Family background variables summarize information on the education of both parents (five levels each), number of siblings and sibling order (dummies for no siblings, three or more siblings, and whether respondent is the first child), books in childhood home (three levels) and whether lived with both parents when aged 16. The first two principal components account for 17% and 10% of the data variability. The first factor is associated with more educated parents, fewer siblings, being the eldest child and more books at home. Factor 2 is also

Table 4: Educational attainment at the age of 23: multinomial logit on BHPS data

	cohort x background		lifetime income	
	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 income	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 lifetime income (sec)			-5.545**	
			(2.35)	
log lifetime income (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)
Log likelihood	-1091.0		-967.9	
N	1030		1030	

Notes: Standard errors clustered by decile of distribution of f1 and generation.
Background factors are the first two principal components from a set of historical information about the parental home when the woman was aged 16. Parental income measured in parents' interviews when parents and daughter are first observed together while she is 16 to 18. Variables "parental inc missing", "away from parents" and "observed after 18" account for missing information on parental income due to non-response, respondent not living with parents at 16 or not observed at 16; overall, parental income is observed for about half of the sample. Lifetime (net of taxes and transfers) income is the structural model prediction of each woman's present value income up to age 60. It is evaluated at each alternative education option under the assumption that she expects the tax and benefit system that she faces when deciding about education to be permanent. Hence 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 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 expected lifetime income were the woman to leave school after secondary education to be constant across education options. It also controls for expected lifetime income in the woman's preferred education level if $s = 2$ (high school) or $s = 3$ (university).

education choice of those born before 1980 we also include a cohort dummy for 1980 onwards, capturing the time trends in educational choice. The causal effect of the reforms on education

associated with more educated parents but of larger families, not being the eldest and living with both parents when aged 16.

is then estimated as the interaction between each of these two factors and the cohort dummy, akin to a difference-in-differences design.

When estimating the model, the family background factors will also 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 that reforms to the tax and benefit system over the entire observation period (1991 to 2008) affect various birth cohorts at the time of the educational choice. In addition we also assume that, *conditional on family background*, parental income at the time when the woman is deciding about education investments represents a liquidity shock that affects educational attendance but can be excluded from other parts of the model (wages and preferences).

The results of the reduced form multinomial logit model containing all these elements are presented in the first two columns of Table 4. The first column reflects the probability of completing high school relative to the compulsory education level; the second column relates to the choice of university, again relative to compulsory schooling. More of factor 1 is associated with both high school and university completion, while more of factor 2 is associated with more university. 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 WFTC and IS reforms affected education choices. Specifically, women with higher values of factor 1 became comparatively less likely to complete high-school education, while women with higher values of factor 2 became comparatively less likely to complete university. Hence, this suggests that the reforms over the 1999-2002 period had a heterogeneous impact depending on baseline characteristics. Moreover, the reforms seem to have affected education choices at both the secondary to high-school and the high-school to university margins.[11]

[11]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 higher education that happened in 1998, with the introduction of a university fee of £1,000 per 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 the cost rather than the return. So we could 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

To gain further insight into how the reforms affected education choice, we construct expected lifetime disposable income under each possible education option, predicted using the structural model described in section 4. These expected income measures are a function of the tax and welfare system in place at the time, which they assume to be permanent. So variation in expected lifetime income captures changes in the returns to education by cohort driven by the tax and welfare reforms. As in a random utility model of education choice, we control for expected lifetime income in the omitted category (secondary education) and the relevant choice ($s = 2, 3$ for high-school and university educated women, respectively), while restricting the coefficient on the former to be the same across education levels. This approach, which is a step closer (but much simpler) than the full model quantifies the role of changing expected income by education in shaping educational choices. However, it is not complete because it ignores the insurance value of education and how this interacts with the various tax and welfare systems.

The estimates are shown in columns (3) and (4) of Table 4. In line with the previous results, both background factors and parental income are important determinants of education attainment. But beyond this, we can now see that an increase in expected lifetime income under secondary education significantly reduces the take up of high school and university education. Since the in-work benefits reform of the 1999-2002 period increases the income of low-paid workers, and since low wages are more likely if women leave education at 16, then this result suggests that overall the reform decreased educational attendance.[12] This is exactly what we would expect, since the reform to in-work benefits decreased the returns to education.

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.

an interaction between parental income and the 1980 cohort dummy in the regression model. We found no evidence of a significant effect of this interaction on education choice.

[12]Model simulations indeed indicate that the WFTC and IS reforms increased on average by about 1% the expected lifetime income were women to complete only secondary or high-school education, and has no significant impact on expected lifetime income if women graduate from university.

Fertility Our study focuses on human capital accumulation and for practical reasons we have not extended it to fertility choices. However, we have carried out some reduced form analysis on this subject using exactly the same specification as that for education choice but with an indicator for being a mother by ages 18, 19 and 20 as dependent variables respectively. About 27% of women with no high school degree (by the age of 23) are mothers by the age of 19. For high school and university graduates at the same age the numbers are 8% and 0%, respectively. The effect of the reforms was to decrease the proportion of women who had a birth by the age of 18 by 0.34 percentage points (p-value 0.0002) and to increase the proportion of those who had a birth by the ages of 19 and 20 by 0.11 and 0.23 pp respectively (p-values 0.31 and 0.06 respectively). These are interesting effects, which we leave for further analysis in future work. Practically this means that our counterfactual simulations condition on the fertility patterns estimated from the data over this period.

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 a detailed characterization of the budget constraint induced by welfare benefits and taxes. We do not allow for general equilibrium effects. 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.[13] This choice is the first step in defining a woman's career, potentially affecting future human capital accumulation as well as the chances of marrying an educated man and of being a single mother.[14] Women choose between the three alternatives described before: secondary (compulsory, completed by age 16), high school (A-levels, completed at 18) and university education (three-year degree and above, completed at 21) 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 labor market. We model annual labor 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 labor 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 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 labor market

[13] 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 Keane and Wolpin (2007, 2010), Adda et al. (2011).

[14] 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).

leads to human capital depreciating.[15] 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.[16] Ignoring savings would overstate the role that labor supply plays in achieving consumption smoothing, and would compromise the model's ability to reproduce labor 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 labor supply and human capital investment decisions. Their relation with labor supply have long been acknowledged in the literature on structural female life-cycle models, but their consequences for education investments have 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.[17]

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 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

[15] 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.

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

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

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 tax and benefit micro-simulation tool to draw accurate budget constraints by family circumstances, thereby describing the financial incentives to undertake work and invest in education.[18]

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 an unobserved factor characterising her preferences for working full time (θ_F) or part time (θ_P).[19] They also include her family circumstances and related information: the presence of a partner (m), his education ($\tilde{s}$), labor 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 letters represent individual observed characteristics, the tilde denotes men's variables, uppercase letters are for market prices and sets of variables, and Greek letters are reserved for the model parameters and unobserved shocks. Except for unobserved preferences for work and productivity, all other shocks and random components of the model are independent of each other.[20]

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

[19] 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.

[20] To be clear, the random components of the model are the female preferences for work, whether she has access to free childcare when working, her productivity, the arrival of a child, the arrival and departure of a partner, and his education and productivity.

We assume that utility is intertemporally separable, and that instantaneous utility depends on consumption per adult equivalent, female labor supply, family background, family circumstances and preferences for work. Her instantaneous utility is non-separable between consumption and leisure. It is given by

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

where n is the equivalence scale,[21] c is total family consumption, l is female labor supply and assumes the three possible values: not working (O), working part-time (P) and working full-time (F). The function f reflects how the marginal utility of consumption changes with working, by the woman's education, background characteristics and family demographics; it is normalised to zero if the woman is not working. Finally, μ is the curvature parameter determining both risk aversion and the elasticity of intertemporal substitution. We use $\mu < 0$ in line with empirical evidence on these measures. A positive f for $l = P, F$ implies that working reduces the utility of consumption and that consumption and labor supply are complements as indeed is the case in Blundell, Browning and Meghir (1994), who use consumption data from the UK.[22] f is specified as follows

$$f\left(l_t, \theta, Z_t\right) = \begin{cases} 0 & \text{if } l_t = O \\ \theta_l + Z_t \alpha_{l,s} & \text{if } l_t = l \neq O \end{cases} \tag{2}$$

where $Z_t \in X_t$ is a subset of the woman's characteristics, including whether she is single or with a partner, and whether she is a mother; these are interacted with a dummy for the three education levels (secondary, high school or university). It also includes a dummy for the age of the youngest child (0-2, 3-5, 6-10 or 11+), a dummy for the partner working or not and two variable reflecting the background factors derived from principal component analysis of the parental background variables. To economize in the size of the state space these are summarized by two dummy variables indicating whether the respective factor is above or below the median for this person. The parameters α_l depend on whether the woman works full-time or part time:

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

[22] For more evidence on this see Ziliak and Kniesner (2005) and Shaw (1989).

we specify $\alpha_l = \alpha_F + \alpha_P \times \mathbf{1}(l = P)$ for $l = P, F$. Finally, $\theta_{l,s}$ is the permanent individual-specific random cost of work if she has education s, which we model as being drawn from a two point discrete distribution whose points of support and probability mass both depend on whether the woman works part time or full time. The parameters of this distribution are estimated alongside the other parameters of the model.

At any age t during working life, the woman's problem can be written as:

$$V_t\left(X_t\right) = \max_{\{c_\tau, l_\tau\}_{\tau=t,\ldots\bar{t}}} \mathrm{E}\left\{ \sum_{\tau=t}^{\bar{t}} \beta^{\tau-t} u\left(c_\tau, l_\tau; \theta, Z_\tau\right) \middle| X_t \right\}$$

where E is the expectation operator conditional on the available information at age t over all future random events, β is the discount factor and V_t 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.[23]

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

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

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

$$a_{t+1} \geqslant \underline{a}_s \quad (4)$$

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) that depend on demographic characteristics, household income, female earnings, all reflected in the state space

[23] This ensures that individuals save towards retirement above their social security contributions, which in the UK only replaces a small proportion of their working earnings.

X_t, as well as on labor supply because of the way tax credits operate in the UK.[24] 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.

[24] T includes income tax, social security contributions, and the main subsidies for working-age families, namely income support, job-seekers allowance, tax credits, housing benefit, council tax benefit, child benefit. These are described in appendix F, together with the main reforms over 90s and 00s.

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

$$\ln y_t^m = \ln Y_s(x_1, x_2) + (\gamma_{s,0} + \gamma_{s,1}x_1 + \gamma_{s,2}x_2)\ln(e_t + 1) + \upsilon_t + \xi_t \quad (5)$$

$$\ln y_t = \ln y_t^m - \xi_t \quad (6)$$

$$e_t = e_{t-1}(1 - \delta_s) + g_s(l_{t-1}) \quad (7)$$

$$\upsilon_t = \rho_s \upsilon_{t-1} + \zeta_t \quad (8)$$

where $\ln y_t^m$ is the observed hourly wage rate[25], $\ln y_t$ is the wage rate on which individual decisions are based and ξ is assumed to be iid Normal measurement error.[26] $Y_s(x_1, x_2)$ 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. We allow for the initial productivity shock to be related with preferences for working (type θ) by assuming it is distributed as a mixture of two normals with type-specific means; the innovations ζ follow a normal distribution with mean zero. 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. All unobserved components in the wage equation are education-specific random variables, and all parameters in these distributions left unspecified above are estimated alongside the parameters of the model.

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

[25]This is the ratio of usual weekly earnings by usual weekly hours, the latter being capped at 70.
[26]In other words we attribute the entire transitory shock to measurement error.

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 and wages as follows:

$$\begin{aligned}
\text{Prob}\left[\tilde{l}_t = \text{F}\,|X_t\right] &= \begin{cases} \text{Prob}\left[\tilde{\nu}_{1t} > b_1\left(t, \tilde{s}_t, \tilde{l}_{t-1}\right)\right] & \text{if } m_{t-1} = 1 \\ \text{Prob}\left[\tilde{\nu}_{0t} > b_0\left(t, \tilde{s}_t\right)\right] & \text{if } m_{t-1} = 0 \end{cases} && (9) \\
\ln \tilde{y}_t^m &= \ln \tilde{Y}_{\tilde{s}} + \tilde{\gamma}_{\tilde{s}} \ln(t-18) + \tilde{\upsilon}_t + \tilde{\xi}_t, \quad t > 18 && (10) \\
\ln \tilde{y}_t &= \ln \tilde{y}_t^m - \tilde{\xi}_t && (11) \\
\tilde{\upsilon}_t &= \tilde{\rho}_{\tilde{s}} \tilde{\upsilon}_{t-1} + \tilde{\zeta}_t && (12)
\end{aligned}$$

where $\ln \tilde{y}_t^m$ is measured earnings, $\ln \tilde{y}_t$ is the earnings that matter for decisions and $\tilde{\xi}$ is a transitory wage shock that is interpreted as iid normal measurement error. The earnings process in equations (10)-(12) is similar to that of women but simpler, where instead of controlling for working experience we include a concave age profile.[27] 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

[27] 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.

to follow an AR(1) process with normal innovations and normal initial values, all dependent on his education, $\tilde{s}$. The dependence between the earnings and employment of spouses is captured by the correlation in their education levels, as will be detailed below.

Male employment and wages are estimated separately, prior to the estimation of the main model. We assumed joint normality of the unobserved terms $(\tilde{\nu}_{0t}, \tilde{\nu}_{0t}, \tilde{\upsilon}_t)$ and estimated two separate Heckman (1979) selection models: one in first differences for men who were present in two consecutive periods; the other in levels for men in newly formed couples. Despite using 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, family income if the man is not working (the latter being a function of the tax and benefit system), different measures of assets and of asset income, the selection correction term was never significant. We therefore assumed independence between the unobservables in employment and wages, $(\tilde{\nu}_{0t}, \tilde{\nu}_{1t})$ and $\tilde{\upsilon}_t$, and adopted the simple specification of men's employment described in equation (9).

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

$$\text{Prob}\left[t^k = 0 \,\middle|\, t, s, k_{t-1}, t^k_{t-1}, m_{t-1}\right] \tag{13}$$

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

$$\text{Prob}\left[\tilde{s}_t \left| t, s, m_{t-1}, \tilde{s}_{t-1}, k_{t-1} \right.\right] \tag{14}$$

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.[28]

4.3 Educational choice

Investments in education are decided at the start of active life, when the woman is aged 17, based on the balance of realized costs and expected returns to education. The choice is conditional on the current available information, denoted by X_{17}. It includes family background (which determines both the costs of and the returns to education), current parental income (representing liquidity shocks driving the cost of education), permanent preferences for leisure (correlated with initial productivity), utility costs of education and access to free childcare.

Whatever the education choice, entry to the labor market does not happen before age 19 in the model; parents are assumed to provide for their children between ages 17 to 18.[29] The opportunity cost of education for those aged 17-18 is captured by the estimated non-pecuniary costs of education. Education and labor supply are assumed to be mutually exclusive activities once employment becomes an option. 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 ($s = 3$).

The optimal choice of education is defined by

$$s = \underset{s \in \{1,2,3\}}{\text{argmax}} \left\{ W_s\left(X_{17}\right) - q_s\left(X_{17}\right) \right\}$$

[28]As specified, fertility, marriage and the type of spouse depend on education but not on other choices such as labor supply, and does not depend on experience. This simplification allows us to estimate these processes outside the full dynamic model, simplifying considerably the computations.

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

where q_s measures the utility costs of the investment, defined as

$$q_s(X_{17}) = \pi_{1s}x_1 + \pi_{2s}x_2 + \pi_{3s}y_p + \varpi_s.$$

y_p is (log) parental income at the time of the decision, (x_1, x_2) are the family background factors and ϖ_s is the unobserved utility cost of education s, assumed to be normally distributed with variances σ_s^2. W_s is the discounted expected value of lifetime utility if the woman chooses education level s. It is given by

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

where Z_{17} summarises the relevant information for the instantaneous utility (as in equation (1)) and it is assumed that university years carry an utility cost similar to that of full-time work in excess of the education specific preferences described by ϖ_s.

University students need to fund their consumption needs and education costs out of their institutional student loans; they 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. Optimization is therefore subject to the budget constraint

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

with D being the university fee for a three year university degree. In practice, we set initial assets a_{17} to zero, consistently with the (limited) information we have on assets for women of this age.[30]

[30] BHPS data shows that that savings are zero in two thirds of the cases, and otherwise small.

5 Estimation

5.1 Sources of exogenous variation

In our model, education and working experience are endogenous for both wages and labor supply. As is typical of structural approaches, this endogeneity is fully taken into account by the model; in addition, we use exclusion restrictions to help identify the structural parameters driving the returns to education and experience. Exogenous variation is given by a number of observed factors that differ across individuals and lead them to make different education decisions, as well as the tax and benefit reforms that happened over the 1991-2008 period and affect the values of education and experience.

More specifically, our data consists of many different birth cohorts, who make their education and employment choices under different policy environments. The expected value function for education s at the start of active life $(W_s(X_{17}))$ and of labour supply l in period t, $(V_t(X_t \mid l_t))$, depend on the current tax and benefit system, which individuals assume permanent. We then allow the costs and returns to education and working hours to depend on family background, reflecting intergenerational linkages in educational attainment, preferences for working and ability, as well as different parenting practices[31]. Finally, 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 how exogenous variation affects the model. First parental income, which affects education choice but none of the other decisions or wages, acts as an exclusion restriction in driving education choice, conditional on family background and the policy environment at the time of the decision. These choices are also driven by the tax and benefit reforms because they affect the value functions corresponding to each education level. The reforms also affect labor supply, as they affect women in different cohorts at different parts of their lifecycle, in ways that depend on their education and realized family circumstances. The sequence of reforms

[31]For intergenerational links in Human Capital see for example Black and Deveraux (2011) and Lindahl et al. (2015).

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 our model by showing that it 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 labor 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 (1994) and Attanasio and Weber (1995), while 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. The tuition cost of university education is set 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).[32] Specifically, the estimation procedure in this second step is implemented as an iterative process where each iteration itself involves a number of computation steps. We start

[32] 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).

by solving the female lifecycle problem given a set of parameter values. We then simulate the lifecycle choices of 19,490 women (5 replications of the 3,898 women profiles observed in the BHPS) using the observed distribution of family background and parental income. 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. The simulations assume women face up to four policy regimes over the observation window, representing the main tax and benefits systems operating during the 1990s and early 2000s.[33] Individuals are assumed to have static expectations of the tax and benefit system, and thus all reforms arrive unexpectedly. Finally, we compute the moments using the simulated dataset, equivalent to those computed using observed data. These moments feed the objective criterion used in estimating the parameters $\hat{\Theta}$ by an iterative numerical minimization routine[34]

$$\hat{\Theta} = argmin_{\Theta}\{\Sigma_{k=1}^{K}[(M_{kn}^{d} - M_{ks}^{m}(\Theta))^2/Var(M_{kN}^{d})]\} \tag{15}$$

where the sum is over the K moments, M_{kn}^{d} denotes the k_{th} data moment estimated over n observations, $M_{ks}^{m}(\Theta)$ represents the kth 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.[35]

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.[36]

[33] 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.

[34] We use the Bound Optimization By Quadratic Approximation implemented by the Numerical Algorithms Group (Nag, see Powell, 2009).

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

[36] Estimation of the standard errors of the structural parameters takes the parameters estimated in the first estimation stage as fixed. Allowing for the variation in first stage to be accounted in estimating second-stage standard errors is prohibitively demanding in terms of computation time.

6 Parameter estimates

Table 5 reports the estimates for the female wage process. Both the wage rates at the start of the working life and the returns to experience increase with education. The former is summarised in row 4, which shows the mean wage rates by education for 25 years old women who have continuously worked full-time; the latter is clear from the mean returns to experience by education reported in row 8, and demonstrates the complementarily between returns to experience capital and education level. Human capital depreciates between 5.7% and 11% a year depending on the education group (row 14), 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 13), 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 explaining 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.

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 and there is substantial heterogeneity in wages at the start of life (row 12). Finally, the family background factors have only a limited effect on wage levels and growth.

In Table 6 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 because utility is negative (i.e, the parameter driving risk aversion, μ in equation (1), is negative). Moreover the coefficients in column (3) on part time work are incremental to those in full time work and reflect the difference of part-time from full-time work.

The parameters in column (1) of Table 6 imply that f for full time work is always positive,

Table 5: Estimates of the parameters in the female wage equation and experience accumulation

		Education	
	secondary	high school	university
	(1)	(2)	(3)
Hourly wage rates (0 experience) $Y_s(x_1, x_2)$			
(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)
(4) Mean hourly wage rate at 25	7.19	8.64	10.55
	(.050)	(.067)	(.317)
Returns to experience $(\gamma_s, \gamma_{s,1}, \gamma_{s,2})$			
(5) baseline	0.15	0.23	0.31
	(.009)	(.006)	(.018)
(6) increment: high factor 1	0.054	0.014	0.001
	(.013)	(.009)	(.013)
(7) increment: high factor 2	-0.002	0.029	-0.006
	(.012)	(.010)	(.012)
(8) Mean value of the coefficient	0.16	0.25	0.31
	(.011)	(.012)	(.025)
Distribution of unobserved productivity			
(9) autocorrelation coefficient: ρ_s	0.925	0.916	0.880
	(.009)	(.008)	(.013)
(10) st. error innovation in productivity: $\sqrt{\mathrm{V}(\zeta_s)}$	0.120	0.154	0.139
	(.007)	(.007)	(.009)
(11) mean initial productivity for type I: $\mathrm{E}(\upsilon_{0s}\|\text{type I})$	0.150	0.121	0.306
	(.025)	(.017)	(.035)
(12) st. error initial productivity: $\sqrt{\mathrm{Var}(\upsilon_{0s})}$	0.175	0.252	0.223
	(.015)	(.015)	(.031)
Human capital dynamics			
(13) while in P work: $g_s(l = P)$	0.170	0.096	0.116
	(.017)	(.024)	(.023)
(14) depreciation rate: δ_s	0.111	0.057	0.073
	(.011)	(.008)	(.011)

Notes: Standard errors in parenthesis under estimates. Mean hourly wages (row 4) are assessed at age 25 for women who worked full time since the start of their working life. This and the mean value of the coefficient on returns to experience (row 8) are averages over the population, conditional on education. The mean initial productivity in row 11 is for individuals with high preferences for working (type I). The (population) mean initial productivity is zero.

meaning that working carries a utility cost for all groups. The parameters in column (3) are negative but smaller in absolute terms than the ones in column (1), implying part-time work yields a lower disutility than full-time work. The utility cost of working is higher for

Table 6: Estimates of preference parameters – function f_l in equation (1)

		all employment		part-time employment	
		value	st. error	value	st. error
		(1)	(2)	(3)	(4)
Women with no children					
(1)	Singles: Sec	0.344	(.011)	-0.269	(.010)
(2)	Singles: HS	0.412	(.011)	-0.315	(.006)
(3)	Singles: Univ	0.555	(.015)	-0.382	(.008)
(4)	In couples: Sec	0.216	(.010)	-0.149	(.010)
(5)	In couples: HS	0.222	(.012)	-0.156	(.011)
(6)	In couples: Univ	0.276	(.009)	-0.180	(.010)
Mothers					
(7)	Singles: Sec	0.355	(.008)	-0.151	(.002)
(8)	Singles: HS	0.330	(.009)	-0.152	(.007)
(9)	Singles: Univ	0.372	(.014)	-0.184	(.026)
(10)	In couples: Sec	0.226	(.011)	-0.168	(.011)
(11)	In couples: HS	0.233	(.013)	-0.180	(.011)
(12)	In couples: Univ	0.282	(.015)	-0.212	(.013)
(13)	Child aged 0-2	0.156	(.010)	-0.095	(.008)
(14)	Child aged 3-5	0.093	(.009)	-0.067	(.007)
(15)	Child aged 6-10	0.047	(.007)	-0.027	(.006)
(16)	Partner working	-0.077	(.010)	0.066	(.010)
(17)	High background factor 1	0.002	(.006)	0.000	(.004)
(18)	High background factor 2	0.006	(.006)	0.001	(.004)
(19)	Type I: utility cost of work: θ_l ($l = F/P$)	-0.093	(.006)	-0.193	(.008)
(20)	Type I: probability	0.36	(.005)		

Notes: The utility costs of working full-time and part-time for women of preference type II is set such that the averages over the population of the utility parameters $\theta(F)$ and $\theta(P)$ are zero. The utility function is $\frac{c^{\mu}}{\mu}e^{f(x)}$, where x are the characteristics in the table. Note that the level of utility is negative because $\mu = -0.56$. This means that a positive f decreases utility and consequently any factor that increases f increases the disutility from work. Also this specification implies that consumption and leisure are substitutes.

single women than for women in couples, conditionally on the different monetary incentives to work that each group faces. These results are consistent with similar employment rates across marital status for women without children and lower employment rates among uneducated single mothers than among their married counterparts. Children, particularly of pre-school age, increase the utility costs of working and more so for full-time. Preferences depend on education, particularly amongst singles. Indeed to rationalize the data given the budget constraint, the single university graduates are attributed a higher disutility from full-time work. We also find that the presence of a working partner (row (16)) further reduces the cost of working, implying some complementarity between the labour supply of partners (as in Blundell, Pistaferri, and Saporta-Eksten, 2012). It is interesting that family background does not affect preferences.

Table 7: Estimates of preferences for education and probability of positive childcare costs if working

		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)	st. error unobserved utility cost of education ($\sqrt{V\varpi_s}$)	1.579	1.015
		(.255)	(.108)
(8)	Probability of positive childcare costs	0.576	
		(.010)	

Notes: Standard errors in parenthesis under estimates. The indicators for living with parents when aged 16 included to scale

As in the reduced form analysis, Table 7 shows that family background and the presence of parents at age 16 matters for education choice as does parental income when aged 16. Thus background primarily operates through educational attainment and moreover, liquidity at the time of education choice matters, over and above the longer term family factors. Beyond this, 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 of Table 7), meaning that the rest have informal sources of childcare.

Appendix B includes estimates of the model for male earnings and employment as well as of the transitions in household composition, including the arrival of partners and of children as well as the departure of a partner.

7 Implications for Behavior

7.1 Wages and Employment

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.[37] 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.

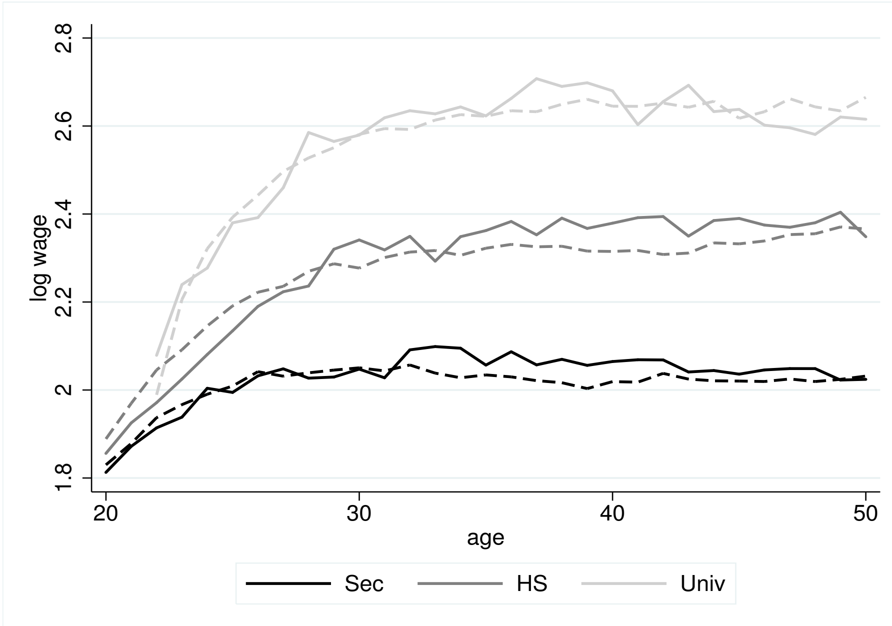
The life-cycle profiles of wage rates for working women are presented in Figure 3 for each education group. These fit the observed profiles reasonably well and show the lowest education group having the most flat profile becoming steeper for higher education groups. Figure 4 shows that this pattern is replicated across the percentiles of the life-cycle wage distribution and demonstrates that the model can reproduce the dispersion of wages.[38]

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

[37] 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.

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

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



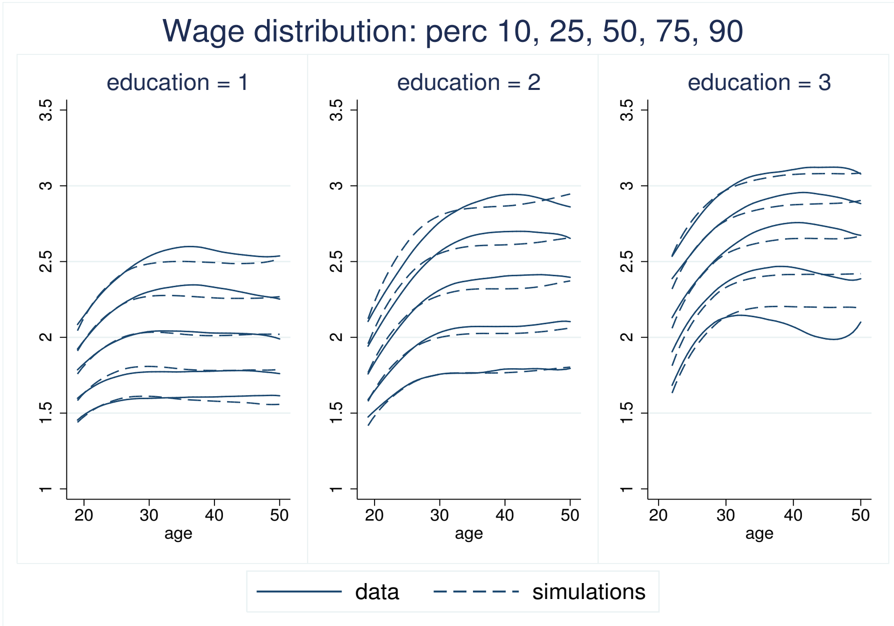
Notes: BHPS versus simulated data, in solid and dashed lines respectively. 2008 prices.

full-time until they are aged 30 then move in to part-time work. The severity of the penalty increases with education.

The top panel of Figure 6 confirms 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 labor-market attachment among secondary 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 university educated. In the bottom panel of the same figure we compare the model predictions to smoothed employment profiles obtained from the data for each education group relative to years from childbirth. Again these replicate closely the patterns in the data. A full set of model comparisons with the data moments used in estimation is presented in Appendix D.

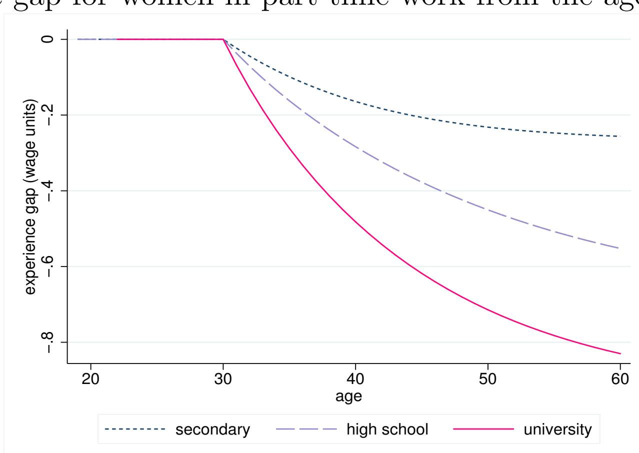
As a final validation exercise in Table 8 we emulate the differences-in-differences estimator

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



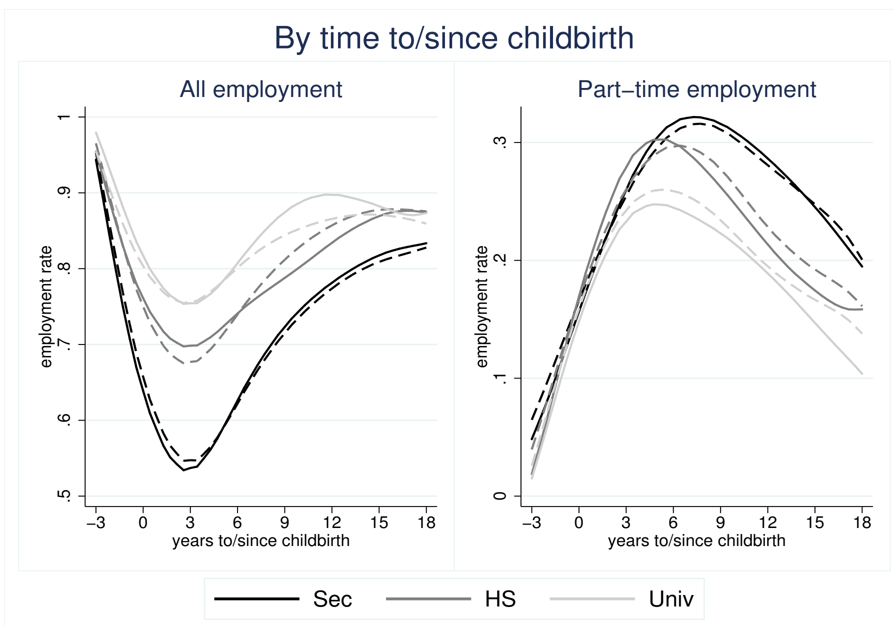
Notes: BHPS versus simulated data. 2008 prices. All curves smoothed using kernel weights and a bandwidth of 2 years.

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 and by time to/since childbirth: data versus model



Notes: BHPS versus simulated data, in solid and dashed lines respectively. Lines by time to/since childbirth in the bottom panel are smoothed using kernel weights and a bandwidth of 2 years.

Table 8: The impact of the reforms on the employment rates of lone mothers – model simulations versus data estimates

		Secondary	High school	University
(1)	Estimates based on LFS data	4.2	5.5	-0.5
	St. Error	(1.1)	(1.5)	(1.6)
(2)	Model simulation	4.4	3.4	1.7

Notes: Row 2 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 1 shows similar calculations based on data from the Labour Force Survey.

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 estimator compares the employment of single mothers (the treatment group) to similar single women without children. The simulation in Table 8 produces an estimated difference-in-differences parameter of 4.4 percentage points (pp) increase in employment resulting from the reforms for the secondary education group. This compares to a DiD estimate from the data of 4.2pp. For high school graduates 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 university group.[39]

7.2 Elasticities of labor supply

Simulated wage elasticities of labor supply are presented in Table 9. Marshallian elasticities are obtained by perturbing the entire profile of wages and comparing the outcome of the simulation 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 expe-

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

Table 9: 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

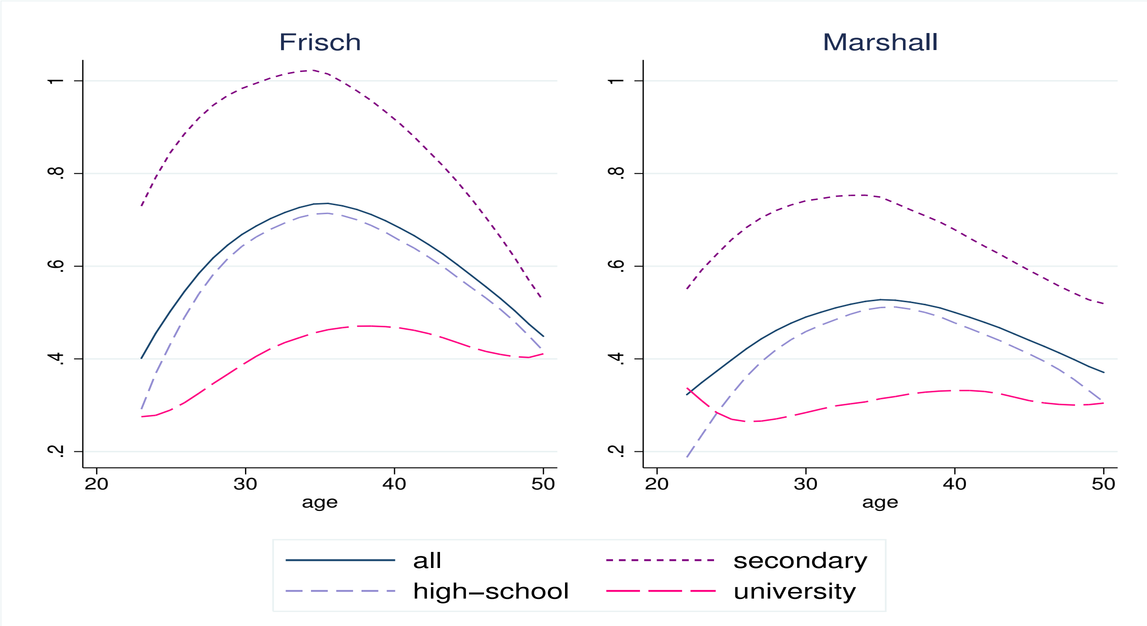
Notes: Calculations based on simulated data under the 1999 tax and benefits system. The elasticities in columns 1 and 4 measure the *percentage change* in labor supply in response to a 1% increase in net earnings. The derivatives in columns 2 and 5 measure the *percentage point change* in labor supply, 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.

rience dynamics there is no necessity for Frisch elasticities to be larger. We find participation is more elastic than hours, a result that is common in the empirical literature.[40] Mothers are more responsive to changes in net wages than women with no children, another typical result in the empirical literature. [41] The labor 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 labor elasticities created by higher returns to work at younger ages due to human capital accumulation (see Imai and Keane, 2004). Finally, secondary educated women are also much more responsive to incentives, particularly on the intensive margin.

The elasticities also vary with age as illustrated for both the Frisch and the Marshallian elasticities in Figure 7. In all cases, elasticities are low at the start of the lifecycle and peak at about age 35, when family formation and childrearing are important. They then decline again gradually to the levels they were at the start of the lifecycle. It is however remarkable that for college graduates the elasticities are always low and only the Frisch elasticities show some

[40]See the survey of participation and hours elasticities in Meghir and Phillips (2010)
[41]See Blundell, Meghir and Neves (1993), or Blundell, Duncan and Meghir (1998)

Figure 7: Frisch and Marshallian elasticities over the life-cycle of women by education



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

(although much milder) age pattern. 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.

7.3 Education choice

To validate the model predictions on education, we use the reduced-form specification of education choice in columns (1) and (2) of Table 4 to calculate the average effects of the 1999-2002 reforms on education attainment and compare these effects to similar estimates on simulated data. To calculate the effects we compare the individual-level post-reform probabilities of investing in each education level with what these probabilities would have been had the reform had no differential impact by background factors. We than take the average over the generation born during the 80s. The first row of Table 10 shows the BHPS estimates of these average effects on the treated , while row (2) shows comparable estimates based on simulated data. The BHPS estimates show that the reform seems to have had no impact on the probability of

Table 10: The impact of the reforms on education attainment – model simulations versus data estimates

		High school	University
(1)	Estimates based on BHPS data	-0.1	-1.3
	St. Error	(0.5)	(0.4)
(2)	Model simulation	-0.2	-1.1

Notes: Row 1 displays the data estimates of the average impact of the 1999-2002 reforms on education attainment. Calculations based on the regression estimates in columns (1) and (2) of Table 4. Given the logistic specification, the effect for education level s is estimated as

$$\frac{1}{n_{80}} \sum_{i=1,\ldots,n_{80}} \left(\frac{\exp\left[x_i\beta + \alpha_1 \left(f_{1i} \times g_{80,i}\right) + \alpha_2 \left(f_{2i} \times g_{80,i}\right)\right]}{1 + \exp\left[x_i\beta + \alpha_1 \left(f_{1i} \times g_{80,i}\right) + \alpha_2 \left(f_{2i} \times g_{80,i}\right)\right]} - \frac{\exp\left(x_i\beta\right)}{1 + \exp\left(x_i\beta\right)} \right).$$

where there are n_{80} observations in the generation born in the 80s (for whom $g_{80,i} = 1$, hence making education choices post-reform), (f_1, f_2) are the first and second family background factors and x includes all other covariates in the regression model. Standard errors calculated with the delta method. Row 2 shows similar calculations, from a similar regression model on simulated data.

graduating from high-school but reduced those graduating from university by 1.3 pp. Although the estimates of Table 4 show that the reform affected education choices at both the high school and university margins, the heterogenous effects on high school completion average out and the only statistically significant effects are on university graduation. Estimates based on simulated data are very similar, and well within the confidence region for the BHPS estimates.

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.[42] We compare the choices of 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 11 shows the simulated effects on the employment of mothers under revenue neutrality.[43]

[42] We only consider the reform in one of the components of IS, namely the one targeted at families with children. The analysis is based on the simulation of 19,490 life-cycle profiles.

[43] The changes in the basic tax rate required to maintain neutrality are shown in Table 25 in the Appendix E.

Rows 2 to 4 hold education choices fixed at pre-reform levels, while rows 5 to 7 show results when education choice is allowed to respond. Row 1 reports the the pre-reform employment rates. For single mothers, the largest impact is for those with secondary qualifications. Considering the WFTC reform in isolation, 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.[44] When we consider the WFTC and IS reform combination as in 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. Finally, for mothers in couples 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 4 to 6 of Table 11. 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 12 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 attainment, but most of the change is driven by the reform to in-work credits. Finally, note that the effects in Table 12 are smaller than those shown when simulating the model to fit the actual data (Table 10) for two reasons: in the data the reforms are not revenue neutral while here they are, and in the data there are more policy

[44] Table 26 in Appendix E shows the impact of the reforms when we do not maintain revenue neutrality.

Table 11: Effects on employment rates of mothers under revenue neutrality

		Single mothers				Mothers in couples			
		Sec	HS	Univ	all	Sec	HS	Univ	all
(1)	Employment in 1999	0.350	0.608	0.748	0.518	0.667	0.759	0.802	0.738
Pre-reform Education Choice									
(2)	WFTC + IS	0.024	0.024	0.013	0.023	-0.046	-0.030	-0.012	-0.031
(3)	WFTC	0.114	0.113	0.060	0.107	-0.037	-0.023	-0.009	-0.025
(4)	with 99 taper	0.005	0.001	-0.005	0.002	-0.019	-0.012	-0.004	-0.013
Post-reform Education Choice									
(5)	WFTC + IS	0.024	0.022	-0.003	0.021	-0.046	-0.031	-0.014	-0.032
(6)	WFTC	0.114	0.112	0.054	0.106	-0.037	-0.023	-0.009	-0.025
(7)	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 2 and 5 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 components of IS as in 1999 are replaced by the more generous level adopted in 2002. Rows 3 and 6 single out the effect of replacing replacing Family Credit as in 1999 by WFTC as in 2002. Rows 4 and 7 impose the 1999 withdrawal rate (70%) on the joint reform in rows 2 and 5. Rows 2 to 4 display the effects if education is kept at pre-reform levels. Rows 5 to 7 allow for education choices to adjust to the new incentives and classify people in the table based on their baseline educational choice.

changes, while here we are isolating just the reforms of WFTC and IS for families with children. So the magnitude of the education effects can indeed be large and will depend on how reforms are actually implemented and what other taxes are raised to fund them.

Table 12: Education among women – simulated distribution by policy regime; revenue neutral reforms

	Sec	HS	Univ
1999	.311	.456	.232
WFTC + IS	.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 components of IS as in 2002. Row 3 removes the reform to the child components of IS. Row 4 imposes the 1999 withdrawal rate (70%) on the joint reform in row 2.

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 13. Rows (1) and (2) show the percentage change in lifetime gross earnings and disposable income, while rows (3) and (4) show the effects of the reform on welfare as measured by the willingness to pay for it expressed as a percentage of consumption (i.e., the percentage change in consumption required to keep wellbeing at pre-reform levels with the post-reform family budget).

Even for those with the secondary 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 university education. In other words, the reform decreased welfare for university 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.

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. Despite this, the welfare loss from the reforms is highest for university graduates because the income loss is too high relative to the amount of insurance their design can provide to them. For women with secondary education only, insurance counteracts the loss in income. For them, a part of the loss in income

Table 13: Effects of WFTC and child IS reforms on lifecycle earnings and welfare under revenue neutrality

		Pre-reform education choice by baseline educ				Post-reform education choice by baseline educ			
		Sec	HS	Univ	All	Sec	HS	Univ	All
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1)	Lifetime gross earnings	-0.44	-0.41	-0.32	-0.40	-0.47	-0.62	-1.02	-0.67
(2)	Lifetime disposable income	0.18	-0.26	-0.73	-0.23	0.02	-0.57	-1.48	-0.60
(3)	Welfare (post-education)	1.49	0.55	-0.18	0.67	1.36	0.31	0.61	0.71
(4)	Welfare (pre-education)								0.61

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 show the percentage change in lifetime gross earnings and disposable income, respectively. Rows 3 and 4 show effects on welfare measured by the willingness to pay as a percentage of consumption 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:

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

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.

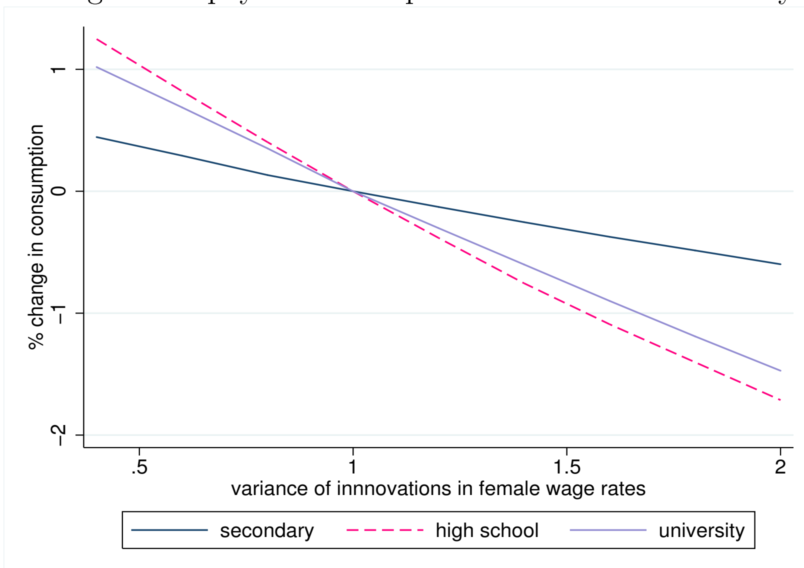
is due to an endogenous decrease in labor supply (see for example the effects on married women in Table 11).

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 0.5% 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 14. 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, col 4). The second preferred alternative is a tax cut with a willingness to pay of 0.55% of

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 for families living in own accommodation. Consumption compensation calculated at start of working life.

consumption (row 3, col 4). The least preferred program is income support with a willingness to pay of 0.46% (row 11, col 4). This continues to be the case when we allow education to adjust, 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 different if we were considering large changes.

Comparing education groups, the university graduates strongly prefer tax cuts to either tax credit changes or income support. Secondary educated women prefer an increase in tax credits, with the second best option for them being income support and tax cuts being the least preferred option. Finally, the preferred option for high-school graduates is also an increase in tax credits, but their second best option is a tax cut. If we allow education to adjust, those who choose university education in the pre-reform world prefer tax credits to tax cuts because some of them shift to a lower education level.

Table 14: 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	HS	Univ	All	Sec	HS	Univ	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 £8.10 per week, or the tax credits award to increase by £35.90 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 £7.80 per week, or the tax credits award to increase by £31.10 per week.
Rows 1-2 (as well as 5-6 and 9-10) display percentage 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 as a percentage of consumption 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 13 for more details.

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 programs. 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 incentive and welfare effects of such policies have received less attention. 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 labor supply, human capital formation (including both education choice and work experience) and savings, allowing for family formation, that allows us to consider these trade-offs and understand better the longer-term effects of policy. We pay particular attention in the detailed modeling of the tax and welfare system and they it was reformed.

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 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. Moreover, the least welfare enhancing policy on the margin is income support, which carries an implicit 100% marginal tax rate. Perhaps not unexpectedly, secondary educated women prefer tax credits to tax cuts, while university graduates prefer tax cuts.

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 all 18 yearly waves of the British Household Panel Survey (BHPS), covering the period from 1991 to 2008. 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 while aged 19 to 50. Our full dataset is an unbalanced panel of just under 3,900 women observed for some varying period during the years 1991 to 2008. Almost 60% of these women were observed for at least 5 years and just over 20% were observed for at least 10 years; 25% are observed entering working life from education and for 18% parental earnings when the respondent was aged 16-17 is observed. 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, women's demographics such as age and education, demand for childcare and its cost. Moreover, historical data provides information on the characteristics of their parental home when they were aged 16, including whether lived with parents, parent's education, employment status, number of siblings and sibling order, books at home.

Some definitional and data preparation procedures should be mentioned for clarity. *Employment* is determined by present labor-market status and excludes self-employment. The paths of women who report being self-employed are deleted from that moment onwards. Only women working 5 or more hours per week are classified as employed. We consider employment choices from the age of 19 for women with secondary and high school education, and from the age of 22 for women with university 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 to 4 hours per week, modelled as 0 hours), working part-time (5 to 20 hours per week, modelled as 18 hours) and working full-time (21 hours or more per week, modelled as 38 hours). 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 70. The wage distribution is trimmed at percentiles 2 and 99 from below and above, respectively, and only for women working at or above 5 hours per week to reduce the severity of measurement error in wage rates. Wage rates are de-trended using the aggregate wage index (for both men and women of all education levels), and all other monetary parameters in the model, including all monetary values in the annual sequence of tax and benefit systems, were deflated using the same index.

Family type includes 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 labor 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), high school or equivalent (corresponding to A-levels or equivalent qualifications) and university (3-year degrees and above).

Appendix B: Parameters estimated outside the structural model

Externally set parameters

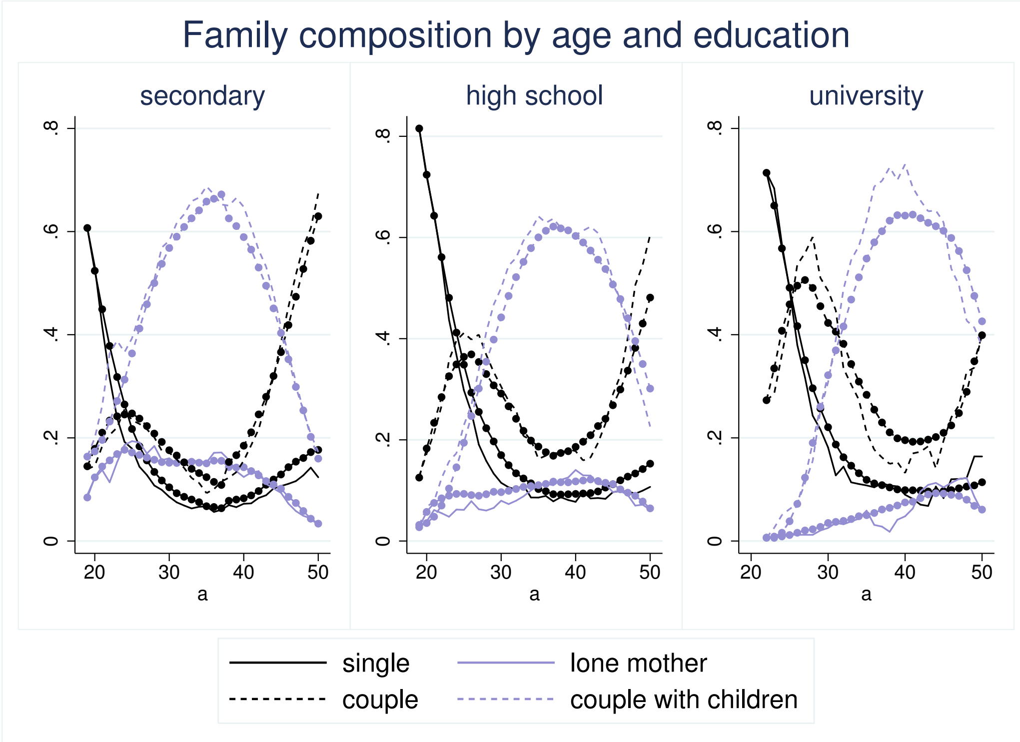
Two parameters are chosen from pre-existing estimates: the coefficient, μ, set to -0.56, giving a risk aversion coefficient of 1.56 (consistent with evidence in Blundell, Browning and Meghir, 1994, and Attanasio and Weber, 1995). This choice implies that the utility is always negative, and so the higher is the argument in the exponential - f_s in equation (1) - the lower is overall utility. Hence, positive and larger values of the parameters in f make working less attractive. The discount factor, β, is 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 costs of university education amount to £3,000 (uprated to 2008 prices) for the three-year program and the credit limit for university students (and graduates throughout their life) is £5,000 (also uprated to 2008 prices), both reflecting the university education policy of the late 1990s 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 a fourth order polynomial in female age 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 are set to zero after 55. The probability of a partner leaving is also described by a fourth order polynomial

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



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

in female age, estimated on all women aged 20–69. This is done separately by spouses' education and presence of children.

The probability of a child arriving is estimated by regressing a dummy for child arrival on a second order polynomial in female age and, for families with children, a second order 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. The probability of a child arriving is set to zero from when the woman reaches 43 onwards.

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 secondary educated women are more likely to become mothers early on and to experienced lone-motherhood than high school and university graduates.

Male employment and earnings

Table 15 reports the estimates for male working status and earnings by his education. This is relevant only for women in couples as we do not seek to solve the men's problem. However, the partner's employment and income changes the family budget constraint and the work incentives of women in couples.

Rows 1 to 3 display estimates from a probit regression and show that the employment probability generally increases with education and is very persistent (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. Having tried several alternative exclusion restrictions within a Heckman selection model of male employment and earnings, we found no evidence of statistically significant selection. Hence, we assume that the residuals in the employment and wage equations are uncorrelated.

Table 15: Exogenous parameters: married men employment and wage rates by education

		Man's education		
		secondary	further	higher
Employment probabilities				
(1)	new couples	0.74	0.87	0.83
		(0.02)	(0.02)	(0.03)
(2)	ongoing couples: intercept	0.05	0.37	0.58
		(0.02)	(0.02)	(0.04)
(3)	ongoing couples: previously employed	1.52	1.40	1.28
		(0.03)	(0.03)	(0.06)
Log wage equation				
(4)	log wage rates	1.94	2.07	2.05
		(0.07)	(0.08)	(0.15)
(5)	log woman's age minus 18	0.09	0.18	0.35
		(0.04)	(0.03)	(0.07)
(6)	dispersion productivity (new couples)	0.37	0.36	0.39
		(0.12)	(0.13)	(0.18)
(7)	dispersion innov in productivity (ongoing couples)	0.12	0.10	0.10
	(0.04)	(0.03)	(0.5)	

Notes: Standard errors in parenthesis below the estimate. Sample sizes are: 665 observations for new couples, 31,946 observations for all couples and 16,318 for continuously employed men.

Families with positive childcare costs pay £2.60 (standard error 0.04) per working hour. Childcare is required for every hour when all adults in the household are working if the child is 5 or younger, and is only necessary for older children under the age of 10 if all adults work full-time.

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 individual characteristics, including family background, parental income, preferences for working and education, the dynamics of family demographics, the random productivity processes for both women and men, and whether the woman faces positive childcare costs. This is a life-cycle model (finite horizon), 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 dimensionality of the problem to a manageable computational size. The continuous state variables are assets, experience, and the productivity shocks of the woman and present partner, $(a, e, \upsilon, \tilde{\upsilon})$. We use a grid of 6 points in each of the variables $(a, e, \tilde{\upsilon})$, but use 12 points in υ to ensure that the domain of uncertainty in future wages, a key determinant of future labor supply, is well covered. A good representation of uncertainty is crucial in ensuring that the approximated future expected value functions are smooth and concave when one of the decisions variables - labor supply - is discrete. The grid points in the productivity shocks are the mid points (median) of the equal probability adjacent intervals of their entire support. The grid points in assets and experience are more concentrated towards the bottom of the domain of each variable, where the problem is more non-linear. The support of the discrete state variables is fully represented in the solution. During working life, the discrete state variables include the woman's age, family background, education, and preferences for working, whether kids are present and the age of the youngest, whether she faces childcare costs as a mother of a young child, the presence of a partner his education and employment status, respectively $(t, x_1, x_2, s, \theta, k, t^k, d_{cc}, m, \tilde{s}, \tilde{l})$.

The solution of the problem at any point of the woman's working life requires knowledge of two continuation functions: the expected value of the stream of utilities from tomorrow onwards and the expected marginal utility of consumption tomorrow. These are functions of the information available today and of assets and experience tomorrow, which are deterministic functions of the savings and employment choices to be made today. Expectations are taken with respect to all random components of the model (family composition, productivity of both spouses and employment status of a present husband). We use the model transition rules to integrate future uncertainty; specifically for the productivity shocks, which are modelled as

AR(1) processes, we calculate the probabilities of moving from each point in today's grid to the interval corresponding to each grid point tomorrow.

Once her continuation functions for age $a+1$ are known, the solution for age a is computed in two steps. The first step involves solving the optimality condition (Euler equation) for the optimal level of consumption at each possible labor supply choice. To evaluate tomorrow's expected marginal utility of consumption at points in experience and assets outside the grid at which its value is explicitly calculated, we use linear interpolation on a approximate linearization in assets of the expected marginal utility, where the transformation is the inverse marginal utility of consumption. This is in the spirit of Carroll (2006) endogenous grid point method, but we do not endogenously select the grid. Instead, the root of the Euler equation is calculated as the solution to a linear equation on a pre-determined grid in assets – that is finer for values closer to its lower bound where the linearization becomes less precise with the increased probability of the budget constraint binding in the future. This procedure proved to be computationally efficient and showed in early experiments to compare well with methods based on richer approximations of the marginal utility function (as, for instance, shape preserving splines).

The second step in the solution procedure amounts to choosing the woman's labor supply point that maximizes the value of present and (expected) future utility. This is done at the conditional (on labor supply) optimal savings calculated in step one. Again, we use an approximate linearization of the expected value function to facilitate interpolation on the two dimensions, experience and assets, where the transformation is the inverse instantaneous utility function.

Simulations are based on initial conditions for family background and parental income observed in the data, together with random draws of the entire profile of unobserved shocks. Given this information, individual optimal choices are calculated starting from the beginning of active life, age 17, and moving forward. As for the solution, the optimum is computed at each age in two steps, first by solving the Euler equation to calculate optimal savings at each labor supply point, then by selecting the labor supply that achieves maximum total utility. In doing so, however, the problem must now be evaluated outside the grid chosen for solution. In practice, this means that the continuation functions need to be interpolated over up to four dimensions: future assets and experience as before, along with present productivity shocks (for both spouses if women are married). We do this by linear interpolation.

The estimation procedure is implemented in two steps. The first step estimates all the exogenous parts of the model. This include the dynamics of family formation (marriage, divorce, fertility, male labor supply and earnings, and the cost of childcare. I addition, two parameters are exogenously set: the coefficient of risk aversion and the discount rate.

The second step implements an iterative procedure to estimate the preferences and wages of women within the structural model. In each iteration, we start by 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 simulate 5 replications of the life-cycle choices of 3,898 women observed in the data, conditional on observed family background and parental income. We use the same sequences of lifetime shocks in all iterations in the estimation procedure to avoid changes in the optimising function due to changes in the random draws. For each woman, we select an observation window such that the overall simulated sample exactly reproduces the time and age structure of the observed data. The simulations assume women face up to four policy regimes over the observation window, representing the main tax and benefits systems operating during the 11991-2008 period. We adopted the 1995, 1999, 2002 and 2004 regimes and assumed they operated over the periods prior to 1996, 1997 to 1999, 2000 to 2002 and 2003 onwards, respectively. Women into their active life over the entire period will experience all of these regimes at different stages of their lives. Younger and older women, who either enter or leave active life within our observation window, will experience only some of these policy regimes during the life period that we are modelling. It is assumed that women expect the tax and benefit system they face in each period to be permanent, so all reforms arrive unexpectedly. Finally, we calculate the simulated moments using the simulated dataset and the objective function. We use 222 moments to estimate 89 parameters.

The parameters are selected to minimise the distance between sample and simulated moments, where the weights are the inverse variances of the data moments as described in equation (15) in the main text. The procedure described above calculates the value of the criterion function in each iteration of the optimization routine. Given the discrete choice of labor supply, our criterion may not be a smooth function of the model parameters everywhere in their domain (McFadden, 1989). We therefore use an optimisation routine that does not rely on derivatives. Specifically, we choose to use the Bound Optimization By Quadratic Approximation, which generates, in each iteration, a quadratic approximation of the criterion function that matches the criterion in a set of interpolation points (see Powell, 2009; implementation by Nag).

Appendix D: Model fit

Tables 16 to 24 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 222 moments, including education distribution and regressions (table 16), employment rates (table 17), transition rates into and out of work (tables 18 and 19), coefficients from log wage regressions, percentiles of the distribution of log wages and year-to-year changes in wage rates by past working hours, age and years of work (tables 20 to 23), and the probability of positive childcare costs (table 24). All moments are education-specific. Among the 222 simulated moments, 47 fall outside the 95% confidence interval for the respective data moment, but many amongst these are very similar to their BHPS counterparts. Finally, figure 10 displays the lifecycle profiles of wage rates by education and family background in the model and data; the fit is close.

Table 16: Educational attainment

Moment	Data	Simulated	SE data	No. SE diff
Education distribution				
secondary	0.246	0.255	0.021	0.429
high school	0.473	0.462	0.023	0.465
university	0.281	0.283	0.022	0.077
Education regressions: high school				
constant	0.437	0.532	0.155	0.612
cohort 80+	-0.035	-0.032	0.047	0.068
family bkg: factor 1	0.008	0.009	0.020	0.045
family bkg: factor 2	-0.048	-0.037	0.023	0.483
cohort 80+ x factor 1	-0.018	-0.005	0.022	0.591
cohort 80+ x factor 2	0.012	0.020	0.022	0.385
log parental income	0.003	0.015	0.011	1.093
mum present (at 16)	-0.010	-0.134	0.146	0.848
dad present (at 16)	0.029	-0.026	0.061	0.909
Education regressions: university				
constant	-0.129	-0.107	0.076	0.295
cohort 80+	0.024	-0.005	0.041	0.700
family bkg: factor 1	0.064	0.056	0.017	0.498
family bkg: factor 2	0.078	0.061	0.016	1.044
cohort 80+ x factor 1	0.002	0.002	0.024	0.013
cohort 80+ x factor 2	-0.043	-0.009	0.020	1.699
log parental income	0.025	0.023	0.008	0.282
mum present (at 16)	0.151	0.170	0.062	0.313
dad present (at 16)	0.073	0.067	0.032	0.178

Table 17: Employment by education

	secondary				high school				university			
Moment	Data	Sim	SE data	SE diff	Data	Sim	SE data	SE diff	Data	Sim	SE data	SE diff
All employment												
all	0.719	0.729	0.005	1.922	0.825	0.832	0.005	1.336	0.868	0.869	0.006	0.247
single women, no child	0.913	0.882	0.008	3.911	0.911	0.919	0.009	0.843	0.940	0.957	0.008	2.171
married women, no child	0.884	0.887	0.006	0.445	0.950	0.940	0.005	2.079	0.948	0.929	0.007	2.647
lone mothers	0.452	0.437	0.016	0.922	0.672	0.666	0.021	0.276	0.817	0.773	0.032	1.384
married mothers	0.637	0.626	0.007	1.542	0.723	0.730	0.008	0.817	0.770	0.757	0.011	1.217
partner working	0.758	0.742	0.006	2.720	0.823	0.833	0.005	2.052	0.848	0.845	0.007	0.397
youngest kid 0-2	0.413	0.398	0.011	1.345	0.596	0.594	0.015	0.141	0.699	0.673	0.018	1.455
youngest kid 3-5	0.522	0.508	0.014	1.012	0.709	0.671	0.017	2.218	0.736	0.760	0.025	0.976
youngest kid 6-10	0.707	0.685	0.011	1.971	0.774	0.799	0.015	1.690	0.864	0.826	0.017	2.262
youngest kid 11+	0.806	0.784	0.010	2.177	0.855	0.873	0.014	1.318	0.875	0.864	0.019	0.576
family bkg: factor 1	0.745	0.739	0.007	0.923	0.819	0.836	0.006	2.831	0.868	0.870	0.006	0.370
family bkg: factor 2	0.713	0.720	0.007	1.057	0.824	0.826	0.006	0.269	0.865	0.861	0.008	0.500
Part-time employment												
all	0.206	0.197	0.004	2.295	0.160	0.151	0.004	2.135	0.123	0.119	0.005	0.757
single women, no child	0.055	0.048	0.007	0.960	0.053	0.037	0.006	2.612	0.039	0.035	0.007	0.625
married women, no child	0.125	0.113	0.007	1.721	0.060	0.052	0.005	1.503	0.034	0.035	0.005	0.200
lone mothers	0.181	0.191	0.011	0.945	0.167	0.187	0.014	1.462	0.092	0.104	0.025	0.499
married mothers	0.297	0.289	0.006	1.346	0.280	0.271	0.008	1.169	0.243	0.251	0.011	0.684
partner working	0.248	0.235	0.005	2.502	0.191	0.188	0.005	0.519	0.148	0.158	0.007	1.420
youngest kid 0-2	0.217	0.231	0.009	1.601	0.255	0.260	0.013	0.365	0.244	0.250	0.017	0.364
youngest kid 3-5	0.299	0.273	0.013	1.963	0.317	0.281	0.018	1.977	0.254	0.279	0.023	1.081
youngest kid 6-10	0.331	0.336	0.012	0.398	0.284	0.296	0.014	0.848	0.235	0.241	0.024	0.259
youngest kid 11+	0.274	0.238	0.013	2.737	0.196	0.180	0.015	1.041	0.163	0.157	0.022	0.281
family bkg: factor 1	0.171	0.174	0.006	0.480	0.153	0.143	0.005	2.100	0.126	0.119	0.006	1.231
family bkg: factor 2	0.203	0.199	0.005	0.798	0.172	0.142	0.006	4.969	0.111	0.124	0.007	1.876

Table 18: Transition rates from out of work into work

Moment	Data	Simulated	SE data	No. SE diff
Secondary education				
all	0.180	0.194	0.008	1.744
women with no children	0.272	0.301	0.026	1.129
lone mothers	0.114	0.124	0.014	0.691
married mothers	0.183	0.192	0.010	0.893
High school				
all	0.255	0.244	0.013	0.874
women with no children	0.503	0.347	0.038	4.096
lone mothers	0.186	0.203	0.031	0.548
married mothers	0.210	0.222	0.015	0.790
University				
all	0.276	0.198	0.023	3.380
women with no children	0.585	0.249	0.054	6.226
lone mothers	0.294	0.187	0.111	0.968
married mothers	0.188	0.181	0.023	0.294

Table 19: Mean transition rates from employment to out of work

Moment	Data	Simulated	SE data	No. SE diff
Secondary education				
all	0.064	0.068	0.003	1.403
single women with no children	0.037	0.035	0.006	0.283
married women with no children	0.031	0.039	0.004	2.104
lone mothers	0.147	0.135	0.016	0.753
married mothers	0.085	0.087	0.005	0.440
past wage in bottom decile ($y_{t-1} < Q10$)	0.112	0.114	0.010	0.162
$y_{t-1} < Q50$	0.073	0.080	0.004	1.848
$y_{t-1} < Q90$	0.063	0.069	0.003	1.950
High school				
all	0.056	0.051	0.003	1.675
single women with no children	0.047	0.027	0.006	3.400
married women with no children	0.021	0.027	0.003	1.911
lone mothers	0.092	0.088	0.017	0.225
married mothers	0.086	0.075	0.006	1.813
$y_{t-1} < Q10$	0.135	0.118	0.010	1.705
$y_{t-1} < Q50$	0.078	0.073	0.004	1.254
$y_{t-1} < Q90$	0.056	0.054	0.003	0.504
University				
all	0.041	0.037	0.004	1.124
single women with no children	0.030	0.015	0.007	2.121
married women with no children	0.023	0.021	0.005	0.316
lone mothers	0.045	0.058	0.020	0.649
married mothers	0.063	0.063	0.007	0.015
$y_{t-1} < Q10$	0.091	0.109	0.010	1.791
$y_{t-1} < Q50$	0.083	0.063	0.004	4.989
$y_{t-1} < Q90$	0.046	0.044	0.003	0.730

Table 20: Log wages ($\ln y$) at entrance in working life

Moment	Data	Simulated	SE data	No. SE diff
Secondary education				
mean	1.841	1.839	0.018	0.128
st. deviation	0.272	0.275	0.012	0.262
wage: bottom quartile ($y_t < Q25$))	0.250	0.258	0.026	0.306
$y_t < Q50$	0.500	0.531	0.032	0.981
$y_t < Q75$	0.750	0.734	0.026	0.625
High school				
mean	1.893	1.917	0.017	1.382
st. deviation	0.294	0.341	0.013	3.550
$y_t < Q25$)	0.250	0.260	0.025	0.402
$y_t < Q50$	0.500	0.459	0.026	1.564
$y_t < Q75$	0.750	0.680	0.023	3.016
University				
mean	2.254	2.204	0.023	2.154
st. deviation	0.344	0.369	0.013	1.907
$y_t < Q25$)	0.250	0.321	0.025	2.817
$y_t < Q50$	0.500	0.577	0.033	2.321
$y_t < Q75$	0.750	0.759	0.029	0.308

Notes: Statistics in this table are for 19 to 22 years old women in the two lowest education levels, or 22 to 25 years old university graduates.

Table 21: Log wage ($\ln y$) regressions on cumulated experience and lagged wages

Moment	Data	Simulated	SE data	No. SE diff
Secondary education				
constant	0.433	0.462	0.037	0.775
family bkg: factor 1	0.029	0.036	0.006	1.100
family bkg: factor 2	-0.006	0.001	0.006	1.172
$\ln y_{t-1}$	0.745	0.735	0.011	0.944
log cumulated working years	0.072	0.115	0.078	0.552
lagged log cumulated working years	-0.039	-0.090	0.069	0.743
Variance of residuals	0.050	0.051	0.002	0.541
1st order autocorrelation of residuals	-0.010	-0.011	0.002	0.325
High school				
constant	0.372	0.336	0.033	1.097
family bkg: factor 1	0.009	0.007	0.006	0.316
family bkg: factor 2	0.002	0.008	0.006	0.970
$\ln y_{t-1}$	0.799	0.813	0.009	1.540
log cumulated working years	0.191	0.208	0.060	0.289
lagged log cumulated working years	-0.153	-0.176	0.052	0.450
Variance of residuals	0.050	0.053	0.002	1.389
1st order autocorrelation of residuals	-0.010	-0.010	0.002	0.021
University				
constant	0.602	0.579	0.051	0.458
family bkg: factor 1	-0.008	-0.004	0.009	0.499
family bkg: factor 2	0.001	-0.004	0.008	0.660
$\ln y_{t-1}$	0.761	0.752	0.016	0.556
log cumulated working years	0.087	0.179	0.072	1.277
lagged log cumulated working years	-0.068	-0.151	0.061	1.354
Variance of residuals	0.043	0.047	0.002	1.801
1st order autocorrelation of residuals	-0.007	-0.008	0.002	0.508

Table 22: Distribution of log wages during working life

	Secondary				High school				University			
Moment	Data	Sim	SE data	SE diff	Data	Sim	SE data	SE diff	Data	Sim	SE data	SE diff
Full-time workers												
Mean	2.084	2.054	0.014	2.167	2.298	2.286	0.015	0.787	2.556	2.558	0.021	0.099
wage: bottom dec ($y_t < Q10$)	0.100	0.129	0.007	4.082	0.100	0.112	0.008	1.517	0.100	0.101	0.012	0.096
$y_t < Q25$	0.250	0.265	0.012	1.290	0.250	0.270	0.012	1.649	0.250	0.255	0.018	0.257
$y_t < Q50$	0.500	0.519	0.015	1.264	0.500	0.515	0.014	1.092	0.500	0.510	0.023	0.418
$y_t < Q75$	0.750	0.767	0.015	1.158	0.750	0.759	0.015	0.586	0.750	0.762	0.021	0.562
$y_t < Q90$	0.900	0.918	0.010	1.797	0.900	0.894	0.010	0.605	0.900	0.890	0.015	0.668
Part-time workers												
Mean	1.902	1.883	0.015	1.298	2.089	2.096	0.022	0.302	2.476	2.411	0.040	1.627
$y_t < Q10$	0.100	0.113	0.008	1.686	0.100	0.067	0.010	3.305	0.100	0.019	0.020	4.026
$y_t < Q25$	0.250	0.247	0.016	0.209	0.250	0.182	0.018	3.754	0.250	0.215	0.030	1.177
$y_t < Q50$	0.500	0.441	0.020	2.963	0.500	0.447	0.023	2.296	0.500	0.651	0.037	4.086
$y_t < Q75$	0.750	0.756	0.018	0.343	0.750	0.769	0.021	0.927	0.750	0.897	0.042	3.508
$y_t < Q90$	0.900	0.947	0.012	3.939	0.900	0.955	0.013	4.227	0.900	0.982	0.035	2.333

Table 23: Other moments in log wages

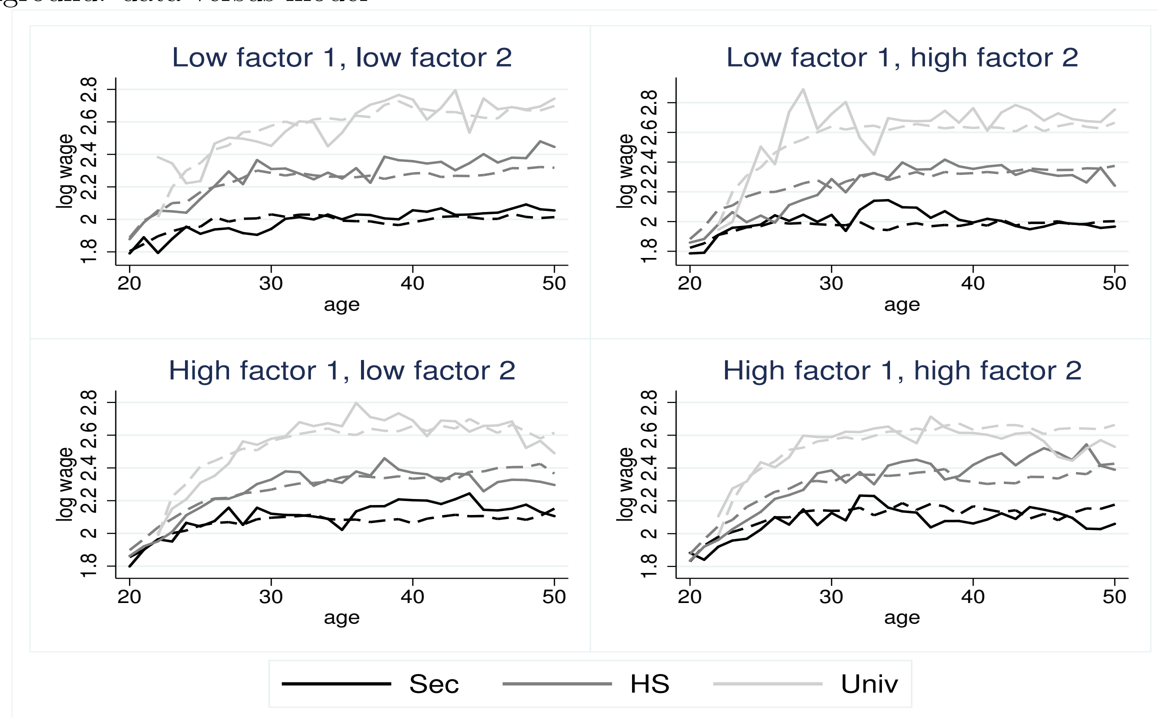
Moment	Data	Simulated	SE data	No. SE diff
Panel A				
Coefficients from regression of log wages on age$\times 10^{-1}$				
Secondary education	0.051	0.037	0.007	1.964
High school	0.107	0.101	0.008	0.777
University	0.179	0.145	0.015	2.268
Panel B				
Coefficients from regression of log wages on log experience, 1st differences				
Secondary education	0.110	0.142	0.027	1.169
High school	0.198	0.234	0.021	1.706
University	0.231	0.263	0.024	1.345
Panel C				
Mean yearly change in log wages if working full-time at $t-1$				
Secondary education	0.026	0.013	0.004	3.180
High school	0.041	0.023	0.005	3.636
University	0.042	0.032	0.007	1.443
Panel D				
Mean yearly change in log wages if working part-time time at $t-1$				
Secondary education	0.000	0.009	0.007	1.303
High school	-0.007	0.013	0.009	2.276
University	0.012	0.011	0.016	0.082
Panel E				
Mean yearly change in log wages if not working at $t-1$				
Secondary education	0.005	-0.005	0.010	1.048
High school	0.003	0.000	0.013	0.210
University	-0.014	0.012	0.024	1.091

Notes: Experience in panel B is number of years worked in the past.

Table 24: Positive childcare costs costs among working mothers of kids 10 or younger

Moment	Data	Simulated	SE data	No. SE diff
Secondary education	0.250	0.319	0.016	4.2859
High school	0.396	0.386	0.020	0.5060
University	0.632	0.441	0.028	6.8141

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



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

Appendix E: Other model results

Table 25: Basic tax rates to maintain revenue at baseline level (%)

	1999 educ	post-reform educ
1999	23.0%	23.0%
WFTC + IS	+.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 26: Simulated effects of *non*-revenue neutral reforms on employment rates of mothers (ppt)

		Single mothers				Mothers in couples			
		Sec	HS	Uni	all	Sec	HS	Uni	all
Pre-reform education choice									
(1)	Empl in 1999	0.350	0.608	0.748	0.518	0.667	0.759	0.802	0.738
(2)	WFTC + IS	0.024	0.024	0.014	0.023	-0.046	-0.030	-0.013	-0.032
(3)	WFTC	0.114	0.113	0.060	0.107	-0.037	-0.023	-0.010	-0.025
(4)	with 99 taper	0.004	0.001	-0.003	0.001	-0.020	-0.013	-0.005	-0.013
Post-reform education choice									
(5)	Empl in 1999	0.350	0.608	0.748	0.518	0.667	0.759	0.802	0.738
(6)	WFTC + IS	0.024	0.022	-0.002	0.020	-0.046	-0.031	-0.015	-0.032
(7)	WFTC	0.114	0.111	0.054	0.106	-0.037	-0.023	-0.010	-0.025
(8)	with 99 taper	0.004	-0.000	-0.014	0.000	-0.020	-0.013	-0.006	-0.014

Notes: Based on simulated data. Reforms are *not* revenue neutral. Effects from comparisons with baseline tax and benefit system. Rows 2 and 6 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 3 and 7 single out the effect of replacing replacing FC as in 1999 by WFTC as in 2002. Rows 4 and 8 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 5-8 allow for education choices to adjust to the new incentives, while rows 1-4 display results conditional on pre-reform education attainment.

Appendix F: Tax and benefit reforms

Here we provide a brief description of the UK tax and transfer system.[45] 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 27 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.

Table 27: 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.

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 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

[45] For a more comprehensive discussion of UK taxes and transfers, see Browne and Roantree (2012) and Browne and Hood (2012).

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 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 28 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 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 28 to deduce the size of the overall gain or loss across years. Therefore, Table 29 sets out the net family income for the same six low-wage family types across the four tax and transfer systems. In 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.

Childless singles and childless couples were largely unaffected by the reforms, except for the changes between April 2002 and April 2004. Childless singles working full time and childless couples with one working partner saw substantial increases in generosity (9% and 23% respectively). This was due to the Working Tax Credit reforms, which extended entitlement to families without children.

Lone parents with no childcare costs saw the largest gains between April 1999 and April 2002, particularly if they worked full time. This is a consequence of the Working Families Tax Credit reform. There were smaller gains across all hours of work between April 2002 and April 2004, due to the Working Tax Credit and Child Tax Credit reforms. Lone parents with childcare costs were affected in much the same way, though many of the gains were larger. There was also an increase in generosity for full-time work between April 1995 and April 1999.

Turning to couple parents, the patterns are similar: the biggest gains were felt between April 1999 and April 2002, coinciding with the Working Families' Tax Credit reform. There were also gains between April 1995 and April 1999 particularly for full-time workers and between April 2002 and April 2004 for part- and full-time workers.

Table 28: 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 29: 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.