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FEMALE LABOUR SUPPLY, HUMAN CAPITAL AND WELFARE REFORM

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ABSTRACT

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

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1 Introduction

The UK, the US and many other countries have put in place welfare programs subsidizing the wages of low earning individuals and specifically lone mothers, alongside other income support measures.[1] Empirical analysis to date has focussed on the short run employment implications of such programs and has not studied their broader long-term impact. This is an important omission because such programs have multiple effects on careers and social welfare: on the one hand they change the incentives to obtain education, to work and to accumulate human capital and savings, and on the other hand they offer potentially valuable (partial) insurance against labor market shocks. We develop an empirical framework for education and life-cycle labor supply that allows us to address these issues.

At their core, in-work benefits[2] 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. 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.[3] In addition, over their life-cycle a sizable 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 an crucial determinant of the incentives to work.[4] Indeed, a motivation for tax credits is to preserve the labour market attachment of lower skill mothers and to prevent skill depreciation.

Several empirical and theoretical studies have contributed to our understanding of the impacts of in-work benefits. Most of the attention has been on how they affect work incentives and labour supply. In a seminal paper, Saez (2002) showed that the optimal design of in-work benefits depends on how responsive individuals are at the intensive (hours of work) and extensive (whether to work) margins. Hotz and Scholz (2003) review the literature on the effects of the Earned Income Tax Credit, the main US transfer scheme to the (working)

[1]see Browne and Roantree (2012) for the UK reforms.

[2]Throughout the paper we use interchangeably the terms "benefits", "welfare" and "welfare programs" to denote government transfers to lower income individuals. We also refer to "welfare effects" or "social welfare" when discussing impacts on total utility of a group.

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

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

poor. Card and Robins (2005) and Card and Hyslop (2005) assess the effects of the Canadian Self Sufficiency Project using experimental data, again on employment outcomes. For the UK, Blundell and Hoynes (2004), Brewer et al. (2006) and Francesconi and van der Klaauw (2007) assess the employment effects of the Working Families' Tax Credit reform of 1999. Most studies find significant and sizable employment effects of in-work benefits.

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

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

The model is estimated using data from 16 waves the British Household Panel Survey (BHPS) covering the years 1991 to 2006 and uses a tax and benefit simulation model to construct in some detail household budget constraints incorporating taxes and the welfare system and the way it has changed over time.[5] We find substantial labor supply elasticities: the Frisch elasticity of labor supply is 0.9 on the extensive (participation) margin and 0.45 on the intensive one (part-time versus full-time). The elasticities are substantially higher for lower educated single mothers, who are the main target group of the tax credit program. Relatively large estimated income effects lead to lower Marshallian elasticities. We also find that tax credit, funded by increases in the basic rate of tax, have large employment effects and do reduce college education and increasing basic

[5]The micro-simulator tool is called FORTAX; see Shephard, 2009 and Shaw, 2011, for details.

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

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

Amongst others, our paper builds on a long history of dynamic labor supply models: it is related to Heckman and MaCurdy (1980) who developed the life-cycle model of female labor supply, to Eckstein and Wolpin (1989) who introduced a dynamic discrete choice model of labor supply, wages and fertility, to Keane and Wolpin (1997) who estimate a dynamic model of education, occupational choice and labor supply and to Shaw (1989), Heckman, Lochner and Taber (1998) and Imai and Keane (2004) who consider lifecycle models of labor supply and consumption with human capital accumulation. It also relates to the life-cycle consistent models of labor supply and consumption developed by MaCurdy (1983), Altonji(1986), Blundell and Walker (1986), Arellano and Meghir (1992), Blundell, Meghir and Neves (1993) and Blundell, Duncan and Meghir (1998).

The plan for the remainder of the paper is as follows. We begin the next section 2 with a description of the key features of the model. Section 3 describes the data used for estimation and the tax policy setting. Section 4 discusses the estimation procedures and results. We then go on to investigate the overall model fit, the implications for wage and employment behavior and the underlying elasticities in section 6. Section 7 We then turn to the use of the model for policy evaluation by an application to the 1999 WFTC and Income Support reforms operating in the UK; and finally section 8 presents some concluding remarks.

2 Model

We develop a life-cycle model of education choice, consumption and labor supply with on-the-job human capital accumulation. Individuals are risk-averse and face productivity shocks with a persistent stochastic structure. To account for the complex budget constraint our model embeds a detailed micro-simulation model of the UK personal tax-benefit system. We allow for changes in family composition over the life-cycle, including partnering, separation and fertility. These occurrences may have great consequences for the cost of working, labor market attachment and value of future work and therefore, in retrospect, educational investments. However, we do not address the consequences of in-work benefits on family formation. These are exogenously determined in our model.

Below, we first summarize the key features of the model, emphasizing the timing of events, and then detail its specification.

2.1 The timing of events and decisions

We start tracking women's decisions from the age of 16 with the choice of education.[6] This choice is the first step in defining a woman's career, potentially affecting future human capital accumulation as well as changing her marriage market and the chance of being a single mother.[7] Women choose between three alternatives: secondary (i.e. the compulsory level of education, completed by age 16),

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

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

high school (A-level or similar further education qualifications) and University education depending on the balance of expected benefits and realized costs, which include foregone earnings, direct financial costs representing fees and idiosyncratic (dis)taste for education.

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

Some of the features we introduce are especially important for our analysis. First, we specify human capital accumulation as an ongoing process of acquisition and depreciation. This allows us to capture the dynamic links in the earnings process of women, for whom career breaks and short working hours are frequent and may have long lasting consequences. In our model, the female rate of human capital accumulation depends on education choices made earlier in life, on persistent heterogeneity that is related to preferences for working 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 labour market leads to human capital depreciating.[8] Women's earnings are then determined by a combination of hours worked, their idiosyncratic level of human capital and the market skill-specific wage rates.

Second, we include a consumption/savings decision.[9] Ignoring savings would overstate the role that labour supply plays in achieving consumption-smoothing, and would compromise the model's ability to reproduce labour supply profiles over the life-cycle. However, we do assume that households are credit constrained: other than university loans, it is not possible to borrow when net worth is negative.

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

[8] 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.

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

data.[10]

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

Finally, public transfers constitute the other source of household income, offering minimum income floors during periods of unemployment or low income, and potentially affecting employment and education choices. We use FORTAX, a micro-simulation tax and benefit tool to draw accurate budget constraints by family circumstances, thereby describing the financial incentives to undertake work and invest in education.[11]

2.2 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) and the utility cost of working full time (θ_{FT}) or less (θ_{PT}). They also include her family arrangements and related information: the presence of a partner (m), his education ($\tilde{s}$), labour supply ($\tilde{l}$) and productivity ($\tilde{\upsilon}$), the presence of children (k), age of the youngest child (t^k) and whether she has access to free childcare (d_{cc}). We denote by X_t the state space in period t, including these two sets of variables. In all that follows, lowercase represents individual observed characteristics, the tilde denotes men's variables, uppercase is for market prices and sets of variables, and Greek letters are

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

[11]see Shephard, 2009 and Shaw, 2011, for details.

reserved for the model parameters and unobserved shocks.

We assume that utility is intertemporally separable, and that instantaneous utility depends on consumption per adult equivalent, female labour supply and preferences for work, and family circumstances like marital status, partner's employment and the presence and age of children. Using the notation defined above, her instantaneous utility, which is non-separable between consumption and leisure, is given by

$$u\left(c_t, l_t; X_t\right) = \frac{\left(c_t/n_t\right)^{\mu}}{\mu} \exp\left\{\mathbf{1}(l \neq O) \times f\left(l_t; s_t, m_t, \tilde{l}_t, k_t, t_t^k, \theta^l\right)\right\} \tag{1}$$

where $\mu < 1$, n is the equivalence scale,[12] c is total family consumption, l is female labour supply and assumes the three possible values: not-working (O), working part-time (PT) and working full-time (FT); f reflects how the marginal utility of consumption changes with full-time and part-time work, depending also on her education, family composition, whether the male works or not and on unobserved costs of work. We specify

$$\begin{aligned} f \;=\; & \theta^l + \alpha_S \times S + \alpha_F \times F + \alpha_H \times H + \alpha_k k_t + \alpha_m m_t + \alpha_{\tilde{l}} \mathbf{1}\left(\tilde{l}_t = FT\right) \\ & + \alpha_{0-2} \mathbf{1}\left(0 \leqslant t_t^k \leqslant 2\right) + \alpha_{3-5} \mathbf{1}\left(3 \leqslant t_t^k \leqslant 5\right) + \alpha_{6-10} \mathbf{1}\left(6 \leqslant t_t^k \leqslant 10\right) + \alpha_{11-18} \mathbf{1}\left(11 \leqslant t_t^k \leqslant 18\right) \end{aligned}$$

where S, F and H are mutually exclusive dummies indicating secondary schooling, further schooling and higher (college); t_t^k is the age of the youngest child. Although not shown explicitly to economize in cumbersome notation, each of the α parameters in f above depend on whether the woman works full-time or part time: we specify $\alpha_j = \alpha_{j0} + \alpha_{j1} \times \mathbf{1}(l = PT)$. Finally, θ^l is a permanent individual specific random cost of work. It is drawn from a different distribution depending on whether the woman works full-time or part-time. In practice it follows a two point discrete distribution whose points of support and probability mass are estimated alongside the remaining parameters.

As of age t_0, given earlier education choices the woman's problem can be written as:

$$V_{t_0}\left(X_{t_0}\right) = \max_{\{c_t, l_t\}_{t=t_0,\dots \bar{t}}} \mathrm{E}_{t_0}\left\{\sum_{t=t_0}^{\bar{t}} \beta^{t-t_0} u\left(c_t, l_t; X_t\right) \middle| X_{t_0}\right\}$$

where E_{t_0} is the expectation operator conditional on the available information at age t_0 over all future random events, β is the discount factor and V is the optimum value of discounted present and future utility. $\bar{t}$ is 10 years after retirement and the family lives off its savings during the retirement period.

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

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

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

$$a_{t+1} = (1+r)a_t + l_t y_t + m_t \tilde{l}_t \tilde{y}_t - T(l_t, X_t) - CC\left(t^k, l_t, \tilde{l}_t\right) - c_t \quad (2)$$

$$a_{t+1} \geqslant \underline{w}_s \quad (3)$$

where r is the risk-free interest rate, $(y, \tilde{y})$ are the wage rates of wife and husband, T is the net transfer to the public sector (taxes and welfare) and $\underline{w}_s$ represents the borrowing limit; this is either zero or the amount of the student loan borrowed (a negative number). CC are childcare costs. Pre-school children need child care for as long as both adults are away from home working; however school age children only need some childcare following the schooldays as education is publicly provided. To capture these requirements we specify

$$CC\left(t^k, l_t, \widetilde{l}_t\right) = \begin{cases} h_t * cc_h & \text{if } t^k \leqslant 5 \text{ and } \left(\widetilde{l}_t = \text{FT or } m_t = 0\right) \\ 20 * cc_h & \text{if } 5 \leqslant t^k \leqslant 10 \text{ and } l_t = \text{FT and } \left(\widetilde{l}_t = \text{FT or } m_t = 0\right) \\ 0 & \text{all other cases} \end{cases}$$

where h is female working hours (0, 20 or 40 for O, PT and FT, respectively) and cc_h is the constant per-hour rate, which we set to a number obtained from the data. Thus overall child care 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.[13] The dependence on hours reflects the way the tax credit system in particular is designed: for example eligibility requires a minimum of 16 hours.

Families are credit constrained and, except for university graduates who have access to institutional loans during their university years, are not allowed to borrow.

[13]We use X to describe the set of variables on which T depends upon and only show the dependence on female hours explicitly for notational simplicity.

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

$$\ln y_t = \ln Y_s + \gamma_s \ln(e_t + 1) + \upsilon_t + \xi_t \tag{4}$$

$$e_t = e_{t-1}(1 - \delta_s) + g_s(l_t) \tag{5}$$

$$\upsilon_t = \rho_s \upsilon_{t-1} + \zeta_t \tag{6}$$

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

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

Male employment and earnings Male employment and earnings are exogenously set to follow a simple parametric, education-specific model. We assume men in couples either work full-time ($\tilde{l} = 1$) or are unemployed ($\tilde{l} = 0$). We specify their employment process and wages as follows:

$$
\begin{aligned}
\text{Prob}\left[\tilde{l}_t = 1 \,|X_t\right] &= \begin{cases} \text{Prob}\left[\tilde{\nu}_t > h_1\left(t, \tilde{s}_t, \widetilde{l}_{t-1}\right)\right] & \text{if } m_{t-1} = 1 \\ \text{Prob}\left[\tilde{\nu^*}_t > h_0\left(t, \tilde{s}_t\right)\right] & \text{if } m_{t-1} = 0 \end{cases} && (7) \\
\ln \tilde{y}_t &= \ln \tilde{W}_{\tilde{s}} + \tilde{\gamma}_{\tilde{s}} \ln (t-18) + \widetilde{\upsilon}_t + \widetilde{\xi}_t, \quad t > 18 && (8) \\
\tilde{\upsilon}_t &= \tilde{\rho}_{\tilde{s}} \tilde{\upsilon}_{t-1} + \tilde{\zeta}_t && (9)
\end{aligned}
$$

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

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

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 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, and whether she is married. It is given by

$$
\text{Prob}\left[t^k = 0 \,\middle|\, t, s, k_{t-1}, t^k_{t-1}, m_{t-1}\right]. \tag{10}
$$

Once a child is born, she/he will live with the mother until completing 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

$$\text{Prob}\left[\tilde{s}_t \left| t, s, m_{t-1}, \tilde{s}_{t-1}, k_{t-1}\right.\right]. \tag{11}$$

Thus the model allows both for couple formation and for dissolution, all probabilities depending on a rich set of demographic circumstances.

2.3 Educational choice

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

We assume that, whatever the education choice, entry to the labor market does not take place before age 19; between the age of 17 and 18 parents are assumed to provide for their children.[14] The opportunity cost of education for this group will be captured by the estimated non-pecuniary costs of education. When entry in the labor market becomes an option, at age 19, we assume that education and labor supply are mutually exclusive activities. Entrance in the labor market is at age 19 for both secondary school ($s = 1$) and high school graduates ($s = 2$), and at age 22 for university graduates ($s = 3$). University students need to fund their consumption needs and education costs out of their assets and institutional student loans. The optimal choice of education is defined by

$$s = \underset{s\in\{1,2,3\}}{\text{argmax}} \left\{V_s\left(X_{17}\right) + \varpi_s\right\}$$

where ϖ_s is the utility cost of education s, assumed iid, and V_s is the discounted value of lifetime utility if the woman chooses education level s. It is given by

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

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

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

constraint, which includes assets at the start of working life observed in the data[15]

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

with F being the university fee for a three year degree. Any assets at age 17 are measured from the BHPS data and are presumably the result of parental and other transfers. We also assume implicitly that any costs of education are either financed by student loans or by parents, and are captured but the estimated costs of education. University students are allowed to borrow in the open market up to £5000, which can cover tuition costs of £3000 and some living expenses.

3 Data and Tax Policy Setting

3.1 The Panel Data Sample

In estimation we make use of the first 16 waves (1991 to 2006) of the British Household Panel Survey (BHPS). In this panel, 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 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 British families with one or two working-age adults other than single men. Families where the female is self-employed have also been dropped to avoid the difficulties relating to measuring their hours.[16] Our full data set is an unbalanced panel of women aged between 19 and 50 and observed over at least two consecutive periods during the years 1991 to 2006. 10% of these women are observed over the whole period, 60% in no more than 6 consecutive waves, 24% are observed entering working life from education. Some key sample descriptive statistics by education and family composition are presented in Table 2. Further details are provided in Appendix A.

[15] Initial assets are typically small or zero. We observe money in savings accounts, other assets and liabilities 3 times during the observation period. In these years we compute net wealth for those aged 17-18 and set to zero any negative values.

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

Table 1: Descriptive statistics - family demographics in 2002

	Mothers		Childless	Number of
	singles	in couples	women	observations
women aged 19-50	0.137	0.439	0.424	2073
	(0.008)	(0.011)	(0.011)	
women aged 30-45	0.165	0.582	0.253	1151
	(0.011)	(0.015)	(0.013)	
Women aged 30-45, by education				
secondary	0.213	0.571	0.216	610
	(0.017)	(0.020)	(0.017)	
further	0.144	0.612	0.244	353
	(0.019)	(0.026)	(0.023)	
higher	0.048	0.564	0.388	188
	(0.016)	(0.036)	(0.036)	

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

Our model does not deal with macroeconomic growth and fluctuations; we thus 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. In addition we remove cohort effects to avoid confounding the true life-cycle profiles with differences across generations. Individuals with wages in the top and bottom 2% of the distribution were dropped entirely.[17]

3.2 The UK Tax Policy Setting

The UK personal tax and transfer system comprises a small number of simple taxes (mostly levied at the individual level), and a complex web of welfare benefits and tax credits (usually means-tested at the family level). Our simulations in section 7 focus on reforms between April 1999 and April 2002 whose key elements we now describe.[18]

Reforms between April 1999 and April 2002 primarily affected Income Support (IS), Family Credit (FC) and Working Families Tax Credit (WFTC). Income Support (IS) is a benefit for families working less than 16 hours a week that tops family income up to a level that depends on family circumstances

[17]The censoring of the distribution from below is at £1.8 per hour in 2006 prices, well below the minimum wage.

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

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

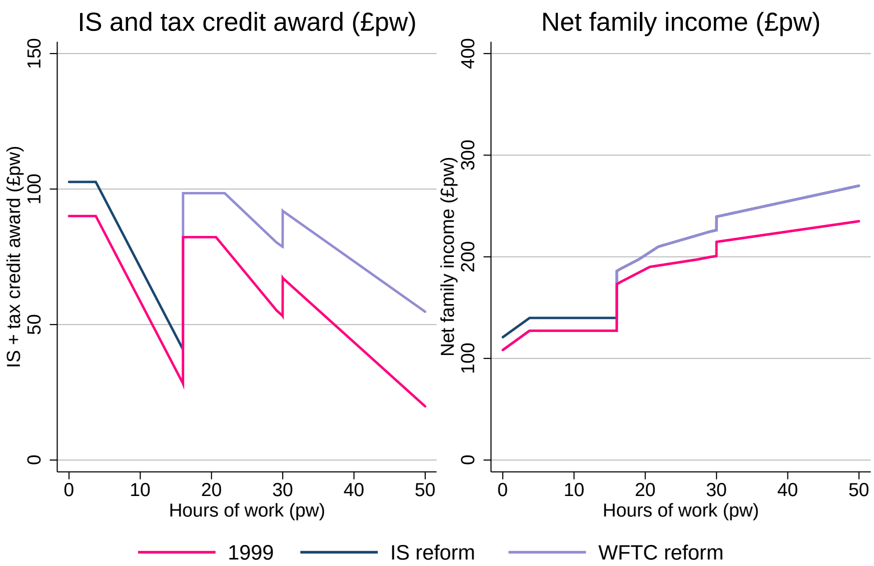
Family credit (FC) existed as part of the April 1999 system and provided means-tested support for working families with children. To be eligible, families had to have at least one adult working 16 or more hours a week and have at least one dependent child. The maximum credit depended on family circumstances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

By April 2002, FC had been replaced by WFTC. WFTC was effectively the same benefit as FC, just much more generous. This was for three main reasons: maximum awards were higher, the means-testing threshold was higher (rising in real terms by 10%) and awards were tapered away more slowly (55% rather than 70%). The increase in maximum awards was particularly large. For example, for a lone parent working 20 hours at the minimum wage with one child aged 4 and no childcare expenditure, the maximum rose by 25% in real terms. The main structural difference between FC and WFTC was the treatment of childcare. The FC childcare disregard was replaced by a childcare credit worth 70% of childcare expenditure up to a limit of £130 per week. This meant that the maximum award rose enormously for parents spending considerable amounts on childcare. The combined effect of these changes was to increase substantially awards for existing claimants and extend entitlement to new (richer) families

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

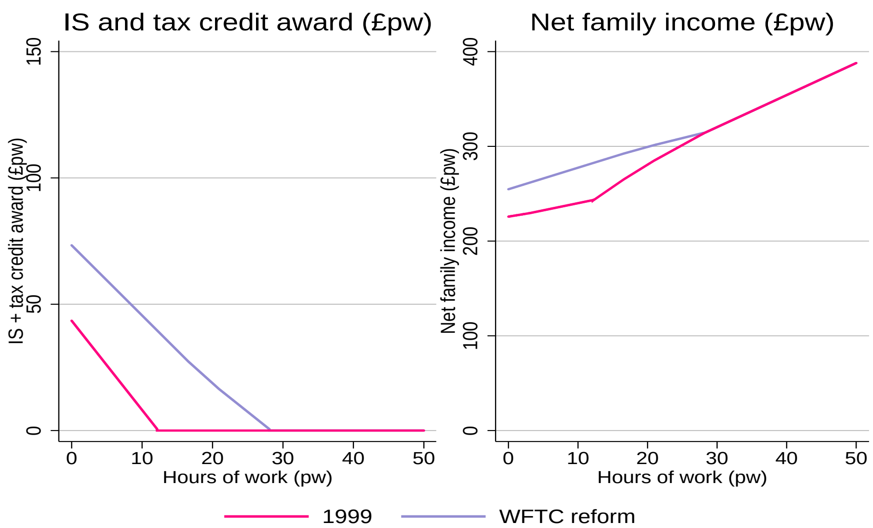
Previous studies have highlighted the heterogeneous nature of the impact of these reforms, depending in particular on family circumstances and interactions with other taxes and benefits (Brewer, Saez and Shephard, 2010). One particularly important example is Housing Benefit (HB), a large means-tested 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.

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



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

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



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.

4 Estimation

We follow a two-step procedure to recover the parameters of the model. In a first step we estimate the equations for the exogenous elements of the model, including the dynamics of marriage, divorce, fertility, male labour supply, male earnings and the cost of childcare. Details and estimates can be found in appendix B. In addition, two parameters are fixed based on pre-existing estimates: the coefficient μ is set to -0.56 giving a risk aversion coefficient of 1.56, consistent with evidence in Blundell, Browning and Meghir (1993) and Attanasio and Weber (1995); the discount factor β is set to 0.98 as for example in Attanasio, Low and Sanchez-Marcos (2008). The risk-free interest rate is set to 0.015, which is slightly lower than the discount rate thus implying that agents have some degree of impatience; tuition cost of university education is fixed to £3,000 for the three years 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 nineties in the UK. No further credit is allowed.

There are a total of 54 remaining parameters, including those determining initial female earnings, their stochastic wage process and their accumulation of experience, the distribution of preferences for working and how it varies by family circumstances, the distribution of preferences for education and the probability of facing positive childcare costs if having a child. These are estimated using the method simulated of moments in the second step (appendix C provides some detail on computational issues).[19]

Specifically, the estimation procedure is implemented as an iterative process in four steps. The first step involves solving the female life-cycle problem given a set of parameter values. We then simulate the life-cycle choices of 22,780 women in step 2, using the observed distribution of initial assets, and select an observation window for each so that the overall simulated sample reproduces the time and age structure of the observed data.[20] The simulations assume women face to up to three policy regimes over the observation window, representing the main tax and benefits systems operating during the 90s and early 00s (we adopted the 1995, the 2000 and the 2004 regimes and assumed they operated over the periods prior to 1998, 1998 to 2002 and 2003 onwards, respectively). This implies that the tax system is allowed to induce variability in behavior differently for each cohort. Individuals are assumed to have static expectations of the tax system and thus all reforms arrive unexpectedly. In step 3 we compute the moments using the simulated dataset, equivalent to those we computed from the observed data. Through this iterative process the estimated parameters $\hat{\Theta}$ solve the minimization problem

[19] 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).

[20] this is described in section 6.1

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

where the sum is over the K moments, M_{kn}^{d} denotes the k_{th} data moment estimated over n observations, $M_{s}^{m}(\Theta)$ represents the k_{th} simulated moment evaluated at parameter value Θ over s simulations. Note that we do not use the asymptotically optimal weight matrix because of its potentially poor small sample properties.[21]

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. We match in total 191 data moments. The moments we match are:[22]

- The average employment rate by family circumstances and female education;
- The average rate of part-time work by family circumstances and female education;
- Transition rates between employment and unemployment by presence of male, female education and past female wage;
- Estimates from female wage equations in first differences by education, including the correlation with experience, the autocorrelation of the residual and the variance in innovations;
- Average, variance and various percentiles of the distribution of log wage rates by education and working hours;
- Average, variance and various percentiles of the distribution of initial log wage rates by education;
- The average yearly change in wage rate by past working status and education;
- The distribution of education attainment;
- The probability of positive childcare costs among working women by education.

A full list of observed and simulated moments demonstrating the fit of the model can be found in Appendix D.

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

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

[22]The simulation reproduces any selection process in the data we observe.

5 Results

5.1 Parameter estimates

Table 2 reports the estimates for the wage process. Both the initial level and the returns to experience increase with education. Even controlling for experience, we still find strong persistence in wage shocks although not quite a unit root in this data. Productivity at entry in the labour market is found to be significantly (negatively) related with preferences for leisure.

Table 2: Estimates of the female wage equation and experience accumulation parameters

		Education attainment		
		secondary (1)	further (2)	higher (3)
(1)	hourly wage rate (0 experience): Y_s	4.49	4.88	6.29
		(0.018)	(0.022)	(0.034)
(2)	returns experience: γ_s	0.14	0.23	0.28
		(0.009)	(0.009)	(0.010)
(3)	autocorrelation coefficient: ρ_s	0.92	0.95	0.89
		(0.008)	(0.007)	(0.010)
(4)	st. error innovation in productivity: $\sqrt{\text{Var}(\zeta_s)}$	0.13	0.13	0.12
		(0.006)	(0.007)	(0.006)
(5)	mean initial productivity for type I: $\text{E}(\nu_{0s}\|\text{type I})$	0.10	0.10	0.20
		(0.013)	(0.016)	(0.015)
(6)	st. error initial productivity: $\sqrt{\text{Var}(\nu_{0s})}$	0.30	0.26	0.26
		(0.013)	(0.015)	(0.025)
(7)	human capital accumulation while in PT work: $g_s(l = PT)$	0.15	0.12	0.10
		(0.027)	(0.027)	(0.022)
(8)	human capital depreciation rate: δ_s	0.12	0.11	0.11
		(0.016)	(0.011)	(0.008)

Notes: Asymptotic standard errors in parenthesis under estimates. Type I women (row 5) are those with lower preferences for leisure. "PT" stands for part-time work.

Experience increases by one for each year of full-time work. However, experience gained while working part-time is a small fraction of this, in between 0.1 and 0.15 (row 7). Moreover, experience depreciates continuously at a rate shown in row 8, of about 11%. This is a high value as compared with others in the literature (for instance, Attanasio, Low and Sanchez Marcos find a depreciation rate for women of 7.4% using PSID data for the US). When combined with the accumulation of human capital while working part-time, these depreciation rates imply that workers may suffer losses in experience when working just part-time: while being out-of-work leads to skill depreciation, part-time work may at best just maintain the level of skills and only full-time work enhances them. We will return to this below as the part-time experience penalty turns out to be a key component of the empirical model for women in our sample.

Table 3: Estimates of preference parameters - function f in equation 1

		all employment		part-time employment	
		value	st. error	value	st. error
		(1)	(2)	(3)	(4)
(1)	Secondary education	0.41	(0.010)	-0.15	(0.023)
(2)	Further education	0.41	(0.010)	-0.16	(0.024)
(3)	Higher education	0.47	(0.007)	-0.20	(0.024)
(4)	Mother	0.05	(0.015)	-0.06	(0.026)
(5)	Mother of child aged 0-2	0.15	(0.013)	-0.05	(0.011)
(6)	Mother of child aged 3-5	0.07	(0.013)	-0.06	(0.012)
(7)	Mother of child aged 6-10	-0.02	(0.013)	0.03	(0.012)
(8)	Mother of child aged 11-18	-0.07	(0.010)	0.06	(0.009)
(9)	Woman in couple	-0.06	(0.021)	-0.02	(0.029)
(10)	Woman in couple, partner working	-0.17	(0.020)	0.09	(0.019)
(11)	Type I: utility cost of work: $\theta(l)$	-0.08	(0.004)	-0.16	(0.005)
(12)	Type I: probability	0.51	(0.004)		

Notes: The coefficients in rows 1 to 11 are shifters in the utility of consumption by family characteristics, education and working hours. Column 1 reports values for working women and column 3 reports the increment for working part-time. Row 12 reports the probability of being a type I woman, where type I women have relatively high preference for working. Columns 2 and 4 display the asymptotic standard errors in parenthesis.

In Table 3 we show the estimates of the parameters of the utility cost of working. The function f in the current period utility function (1) is simply a set of shifters in the utility of consumption for different family circumstances and education levels interacted with working hours. The parameters are incremental both over rows and columns in the table; for instance, a type I woman, mother of a two-year old with secondary education and working full time will have an argument in the exponential function of 0.41+0.05+0.15-0.08, corresponding to the sum of parameters in column 1, rows 1, 4, 5, and 11. If she is working part-time, the argument will be $(0.41 + 0.05 + 0.15 - 0.08) + (-0.15 - 0.06 - 0.05 - 0.16)$ where the first term equals the factor for full time workers and the second is the increment for part-time. Positive and larger values of the argument in the exponential function make working less attractive.

The argument in the exponential factor of the instantaneous utility is positive for all combinations of family circumstances, education attainment and working hours. So labor market participation always reduces the value of consumption (and increases its marginal value). The reduction is more pronounced for mothers of young children and less so for women in couples with working partners. The reductions are also less marked for part-time work, showing women have a comparative preference for lower working hours. Type I women are those with a relatively high preference for working; the factor for type II women is such that they average to zero over the population of adult women.

Estimates for the utility cost parameters for education and childcare are displayed in Table 4. Rows 1 to 4 show estimates for the mean and scale parameter of the distribution of preferences for high school and university education, assumed to follow extreme value distributions (the scale parameters determine the variance of the distribution). Explaining the observed proportion of women with university education given its costs and expected returns requires women to have, on average, some positive preference for it. This is in contrast to preferences for high-school education, which are more dispersed with a negative, but smaller in absolute value, mean.[23]

Table 4: Education and child-care utility cost parameters

		value (1)	st. error (2)
(1)	Utility cost of further education: mean $(\mathrm{E}(\omega_{s=2}))$	-0.28	(0.024)
(2)	Utility cost of further education: scale $(\sqrt{\mathrm{Var}(\omega_{s=2})})$	1.91	(0.060)
(3)	Utility cost of higher education: mean $(\mathrm{E}(\omega_{s=3}))$	0.47	(0.022)
(4)	Utility cost of higher education: scale $(\sqrt{\mathrm{Var}(\omega_{s=3})})$	0.99	(0.018)
(5)	Probability of positive childcare costs	0.43	(0.015)

Notes: The coefficients in rows 1 to 4 determine the distribution of preferences for high school and university education, assumed to follow extreme value distributions. Column 2 displays the asymptotic standard errors in parenthesis.

Mothers may face positive childcare costs if all adults in the household are working, in which case the cost of childcare is £2.09 per working hour for children under the age of 5 or per working hour in excess of 20 hours per week for children aged 5 to 10. The probability that this happens is estimated to be slightly below 50% (row 5).

Family transition probabilities were estimated using linear probability regressions of an arrival/departure dummy on an order 2 polynomial in female age and, in the case of child arrival, an order 2 polynomial

[23]This result is in part driven by the simplifying assumption that high school education has no direct or opportunity costs

in age of any older child and a linear interaction. Regressions were run separately for a number of different cases. For the arrival of a partner, one regression was run for each of the nine combinations of female and partner education level; for the departure of a partner, we run regressions by female education level; for child arrival, regressions were run by female education level and couple status. These specifications were chosen to be parsimonious while fitting patterns in the data well. Various age restrictions were imposed (e.g. child arrival was estimated only for women aged 42 or less) all regressions were weighted to ensure an equal number of women at each age. The resulting predicted probabilities were modified to be non-increasing or zero above a certain age and zero if negative. More details are provided in Appendix B.

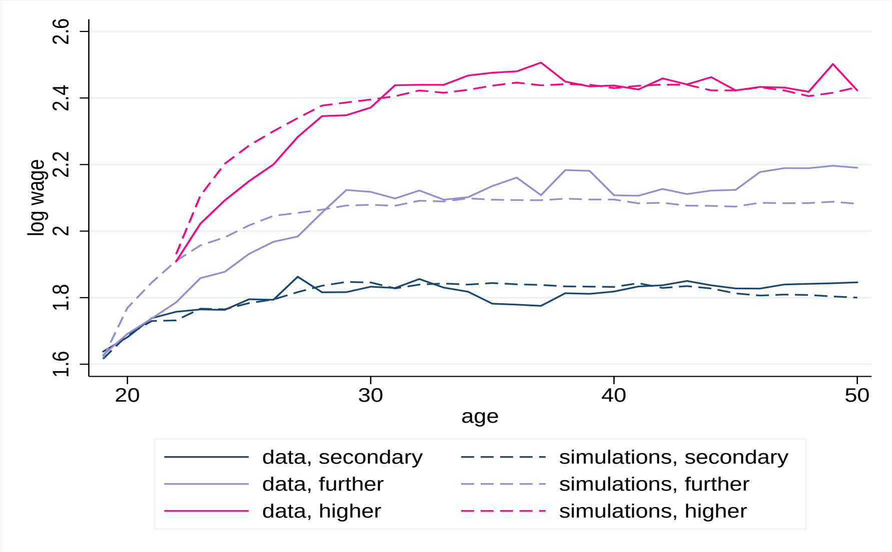
6 Implications for Behavior

6.1 Model Simulations

To assess the properties of the model we first examine its ability to reproduce the basic features of earnings and employment observed in our sample by comparing model simulations to observed data. The comparisons are based on a simulated dataset of 22,780 women, 5 times the size of the BHPS sample. We use the observed distribution of individual assets at the ages of 17 to 18 to initialize simulations. Assets are observed in the BHPS in three points in time, in the 1995, 2000 and 2005 waves; there are 562 observations of assets for 17-18 years old, from which initial conditions are drawn for each individual simulation. The initial values for unobserved preferences for work and education are drawn randomly from their estimated distributions. Based on this information, education decisions are simulated. Then, the unobserved productivity process is initialized, drawing from its estimated distribution, which is conditional on education and unobserved heterogeneity in work preferences. Finally, the full working life profiles are simulated for each individual, driven by the stochastic process for productivity.

The simulations underlying the results discussed in this section are based on changing tax and benefits systems that reproduce the reforms implemented during the observation period, between 1991 and 2006. We assume that yearly reforms arrive unexpectedly from 1992 onwards; the 1991 tax and benefits system is extended to all earlier years. Thus, the choices of women older than 17 in 1991 are simulated up to that point under the 1991 tax and benefits system. For each of the simulated life-cycle profiles we then only keep an observation window chosen to ensure that the simulated dataset reproduces the time and age structure of the observed BHPS sample.

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



Notes: BHPS versus simulated data. 2005 prices.

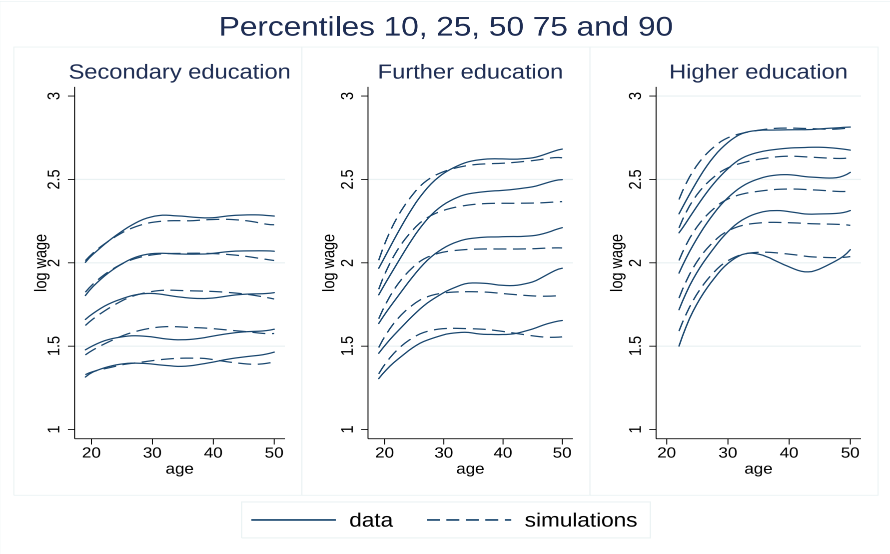
6.2 Wages and Employment

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

A key feature of the wage profiles is that they become rapidly quite flat. The flattening out in the profiles represents two opposing effects. The first being the impact of cumulative experience which leads to a continuous rise in the profile. The second being the increasing occurrence of part-time work which off-sets the growth through the part-time experience penalty. This is clearly shown in Figure 5 which displays the expected profile of the part-time penalty in wage units for women who work full-time until they are aged 30 then move in to part-time work. The severity of the penalty increases with education.

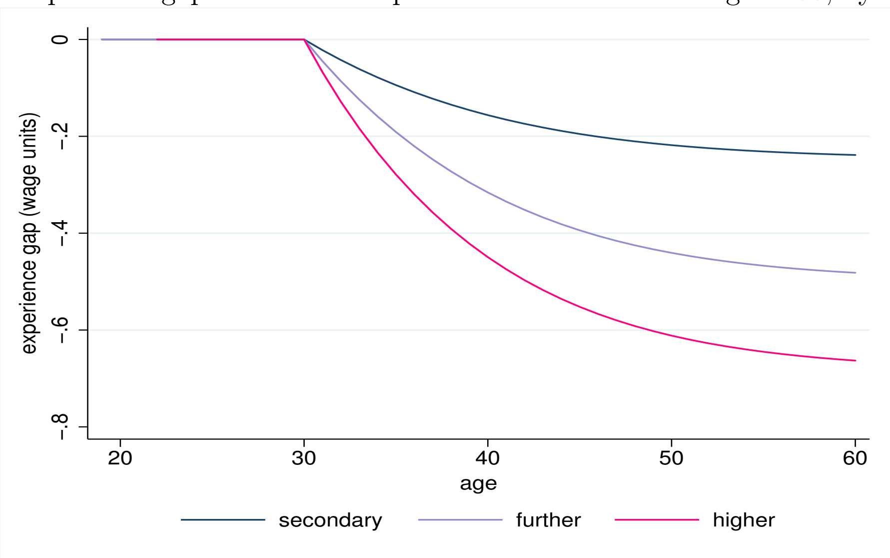
The life-cycle profile of employment rates are displayed in Figures 6 and 7. Figure 6 confirms the well known fact that employment rates increase with education. It also reveals that employment profiles are U-shaped irrespective of education, although the dip occurs earlier and is more pronounced for

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



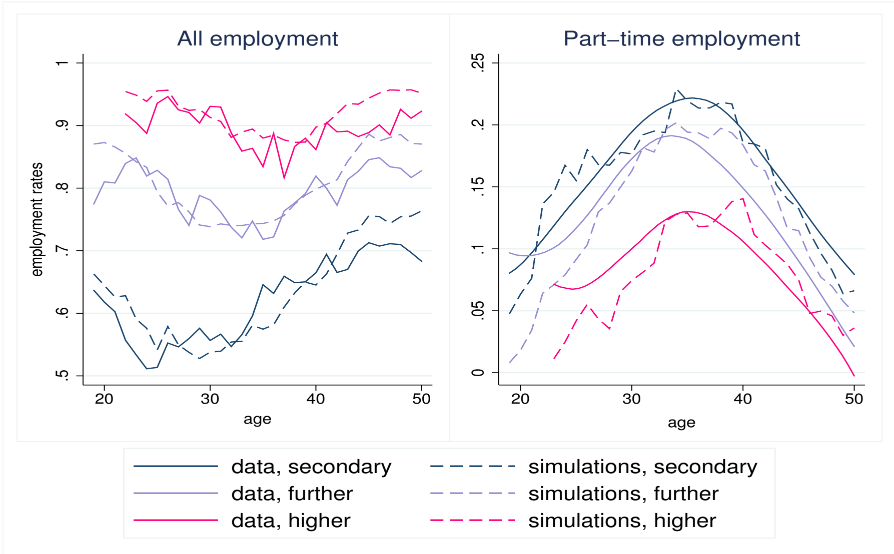
Notes: Data estimates based on BHPS data. 2005 prices. All curves smoothed using kernel weights and a bandwidth of 2 years.

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: data versus model



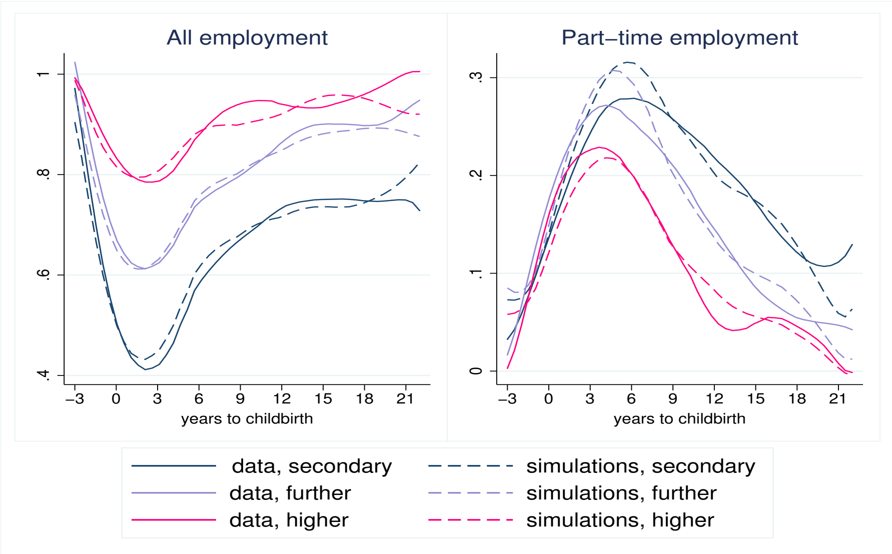
Notes: Data estimates based on BHPS data. Part-time employment data figures were smoothed using kernel weights and a bandwidth of 2 years.

lower levels of education. This profile reflects the impact of child bearing on labour supply, especially during the child's early years, and the lower labour market attachment among lower-educated women. There are several features of the model that explain the higher labour market attachment of more educated women (in addition to higher wage rates). These include higher returns to experience, higher human capital depreciation rates, and a distribution of unobserved heterogeneity leading to a disproportionately high representation of high-productivity individuals among more educated women. These factors create simulated profiles that closely resemble those from data.

The effects of family composition are displayed in Figure 7. Here we show the overall employment rates and the part-time employment rates as they evolve before and after childbirth. Again these replicate closely the patterns in the data across education groups. A full set of model comparisons with the data moments used in estimation is presented in Appendix D.

As a final validation exercise in Table 5 we emulate the differences-in-differences estimator for the full set of reforms implemented in late 1999. Given the nature of the exercise, where we are looking at immediate short-run effects, we do not allow education choices to respond. This estimator compares the employment of single mothers (the treatment group) to similar single women without children. The simulation in Table 5 produces an estimated difference in differences parameter of 3.9 percentage points increase in employment resulting from the reforms relative to the employment of single women

Figure 7: Female employment rates by years to/from childbirth



Notes: Data estimates based on BHPS data. All curves smoothed using kernel weights and a bandwidth of 2 years.

without children. In row 3 we present the closest published (matching) difference-in-differences estimator which uses the Labor Force Data (LFS) producing an estimate of 3.6 percentage points, which is very close to our model simulations.[24]

6.3 Elasticities of labour supply

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

As theory implies, Frisch elasticities are always higher than Marshallian ones, which allow for wealth effects. Participation is more elastic than hours, a result that is common in the empirical literature.[25]. Mothers are more responsive to changes in net wages than women with no children, another typical

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

[25]see the survey of participation and hours elasticities in Meghir and Phillips (2010)

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

		effect	st. error
(1)	model simulation	3.9	-
(2)	authors' estimate on LFS data	4.2	1.4
(3)	Blundell, Brewer and Shephard (2005)	3.6	0.5
(4)	Brewer, Duncan, Shephard and Suarez (2006, simulation)	3.7	

Notes: Row 1 displays the result from DID calculations of the impact of the welfare reforms implemented between 1999 and 2002 using simulated data and comparing 1999 (pre-reform) with 2002 (post-reform) employment status of lone mothers and childless single women. The reforms are assumed to be unannounced. Row 2 shows similar calculations based on data from the Labour Force Survey after matching on age. Rows 3 and 4 display similar results from the existing literature.

result in the empirical literature.[26]. The labour supply of younger women is more elastic than that of older ones, a consequence not only of changes in family composition over the life-cycle, but also of the higher returns to work at younger ages due to human capital accumulation (see Imai and Keane, 2004). Finally, less educated women are also much more responsive to incentives, particularly on the intensive margin.

The response elasticities also vary in systematic ways with age, education and family composition. This is clearly shown in figures 8 for the Marshallian elasticities at the extensive margin and life-cycle income effects, also at the extensive margin, in Figure 9.

7 Assessing the Impact of Tax Policy Reform

7.1 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.[27] 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 some features of the 1999 WFTC and IS reforms.

Table 7 shows the simulated impact of the reforms on single mothers and on mothers in married couples separately. These are revenue neutral reforms where neutrality is achieved by adjusting the

[26]see Blundell, Meghir and Neves, 1993, or Blundell, Duncan and Meghir, 1998

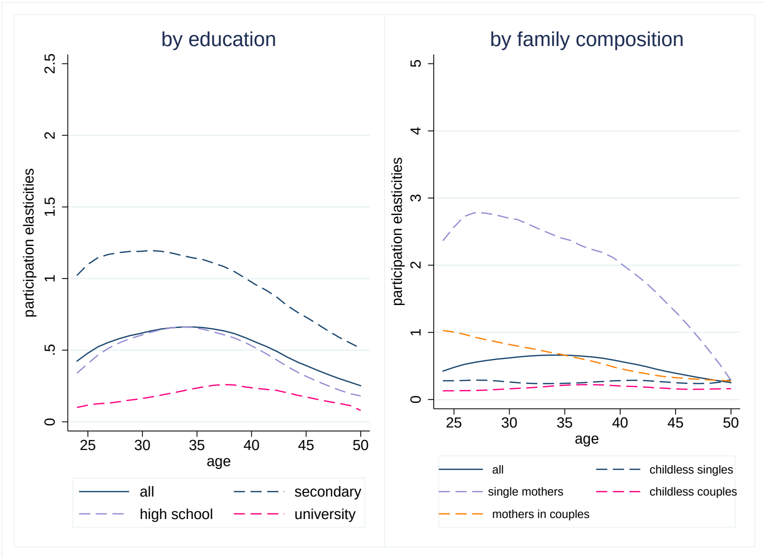
[27]The analysis is based on the simulation of 22,780 life-cycle profiles.

Table 6: Wage elasticities of labour supply and derivatives - extensive (participation) and intensive (full-time work conditional on participation)

		Frisch			Marshall		
		extensive		intensive	extensive		intensive
		elast.	deriv.	elasticity	elast.	deriv.	elasticity
		(1)	(2)	(3)	(4)	(5)	(6)
(1)	all	0.90	0.71	0.45	0.50	0.40	0.38
By education							
(2)	secondary education	1.97	1.27	0.88	0.93	0.60	0.63
(3)	further education	0.68	0.56	0.40	0.46	0.38	0.37
(4)	higher education	0.28	0.26	0.19	0.18	0.16	0.18
By family composition							
(5)	Lone mothers	4.23	2.40	0.97	1.93	1.09	0.78
(6)	Mothers in couples	0.70	0.52	0.62	0.51	0.38	0.50
(7)	Women without children	0.52	0.49	0.33	0.26	0.24	0.20

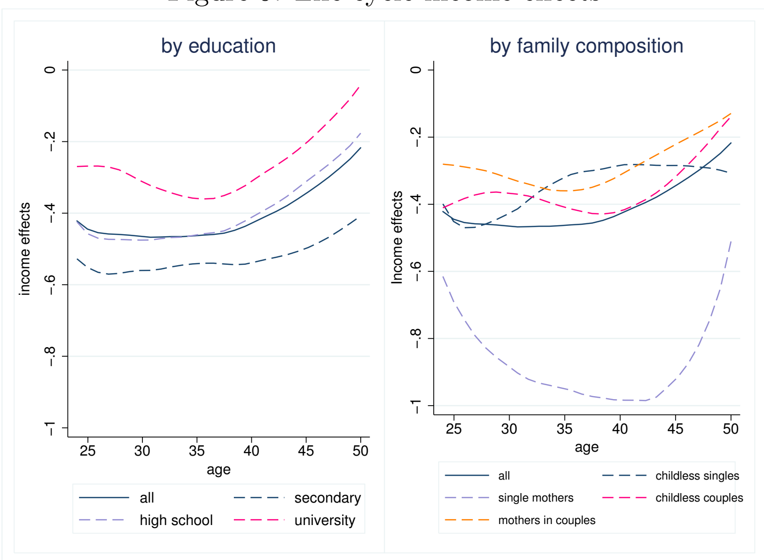
Notes: All values based on simulated data under the 1999 tax and benefits system. The elasticities in columns 1 and 4 measure the percentual change in labour supply in response to a 1% increase in net earnings. They differ from the derivatives in columns 2 and 5, which measure the percentage change in labour supply in response to a 1% increase in net earnings. The elasticities in columns 3 and 6 measure the percentual change in full-time work rates among employed women in response to a 1% increase in net earnings. The values in columns 1 to 3 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 of the change in earnings.

Figure 8: Marshallian elasticities over the life-cycle of women: permanent expected shift in net earnings



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

Figure 9: Life-cycle income effects



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

Table 7: Simulated effects of revenue neutral reforms on the employment rate of mothers (ppt)

		Single mothers by baseline educ				Mothers in couples by baseline educ			
		sec	furth	high	all	sec	furth	high	all
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Pre-reform education choice									
(1)	WFTC and child IS	3.8	3.5	1.5	2.9	-6.0	-4.4	-1.7	-4.0
(2)	WFTC	12.4	12.0	7.3	10.6	-5.2	-3.5	-1.3	-3.3
(3)	WFTC and child IS w/ 70% withdrawal	2.1	1.4	-0.6	0.9	-2.7	-2.2	-0.7	-1.9
Post-reform education choice									
(4)	WFTC and child IS	3.8	3.0	-3.6	1.0	-6.1	-4.7	-3.2	-4.7
(5)	WFTC	12.4	11.8	4.0	9.4	-5.3	-3.7	-2.2	-3.7
(6)	WFTC and child IS w/ 70% withdrawal	2.1	0.9	-4.6	-0.4	-2.8	-2.4	-1.8	-2.3

Notes: Based on simulated data. All reforms are revenue neutral, with adjustments in the basic tax rate making up for differences in the public budget relative to baseline (1999). Effects from comparisons with baseline tax and benefit system. Rows 1 and 4 show the effects of a joint reform of in-work and out-of-work benefits: (*i*) the family credit as in 1999 is replaced by the WFTC as it 2002 and (*ii*) the child component of IS as in 1999 is replace by the more generous level adopted in 2002. Rows 2 and 5 single out the effect of replacing replacing FC as in 1999 by WFTC as in 2002. Rows 3 and 6 impose the 1999 withdrawal rate (70%) on the joint reform in rows 1 and 4. Rows 1 to 3 display the effects if education is kept at pre-reform levels. Rows 4 to 6 allow for education choices to adjust to the new incentives. Columns 1 to 4 show effects for single mothers by education. Columns 5 to 8 show effects for mothers in couples. The three levels of education are secondary ('sec', columns 1 and 5), further ('furth', columns 2 and 6) and college or university ('high', columns 3 and 7).

basic rate of income tax to maintain exchequer revenue. Table 8 shows the changes in the basic tax rate required to maintain revenue neutrality.

The first panel of results in rows 1 to 3 of Table 7 show the simulated impacts holding education choices as given; in the second panel, rows 4 to 6, education is allowed to respond. The first reform we consider simulates the impact of all WFTC and the changes in the child elements of IS. For single mothers, the largest impact is for those with basic school qualifications. Employment rises by 3.8 percentage points. The impact for those completing secondary school is a little lower and, as expected, much lower for those with university level education. As we saw from the budget constraint figures earlier, this reform reduces incentives to work for women in couples where the partner works. As a results there is a large fall in employment for them.

We contrast these results to those of two simpler reforms. The first just introduces the WFTC. The second introduces the WFTC and the IS reforms but retains the 70% withdrawal rate that existed under family credit (FC) rather than moving to the lower 55% withdrawal rate of WFTC. The positive

Table 8: Basic tax rates that maintain revenue at baseline level (%)

		Education choice	
		Pre-reform	Post-reform
(1)	baseline (1999 tax and benefit system)	23.0	23.0
(2)	WFTC and child IS	24.7	25.6
(3)	WFTC	24.0	24.6
(4)	WFTC and child IS with 70% withdrawal rate	24.3	24.9

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

		Education		
		secondary	further	higher
(1)	baseline (1999 tax and benefit system)	30.4	47.5	22.1
(2)	WFTC and child IS	32.3	47.1	20.6
(3)	WFTC	31.7	47.3	21.0
(4)	WFTC and child IS with 70% withdrawal rate	31.8	47.2	21.0

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

employment impacts for single mothers are considerably enhanced in the former whereas they are scaled back in the later.

The impact of allowing education to change is shown in rows 3 to 6 of Table 7. The results are tabulated on the basis of pre-reform educational choice. Those with the minimum level of education have no incentive to increase it and of course cannot decrease it further; so for them there is no difference to the earlier results. For the other two education groups employment effects are reduced when education choices are allowed to adjust. Turning to Table 9 we see that this is accompanied by a shift towards lower education levels.

Comparing Tables 10 and 7 we see the impact of adjusting the basic tax rate to maintain revenue

Table 10: Simulated effects of *non*-revenue neutral reforms on employment rates of mothers (ppt)

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

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

neutrality. Not surprisingly there is no impact, on average, for the lower educated. But for those with higher education qualifications, the impact on employment is more positive if the reform is not revenue neutral. Similarly, the effects are decreased when we allow changes in educational investments.

7.2 Welfare and Risk

Finally, in Table 11 we turn to the impact on life-cycle earnings and welfare. Even for those with the lowest education there is a negative impact of the WFTC and IS reform on *gross* life-cycle earnings (row 1, column 1). This turns positive once transfers are accounted for (row 2, column 1), but remains negative for those with higher educational investments (row 2, columns 2 and 3). In contrast turning to overall welfare, the impact is positive and strongest for the lower educated.

Table 11: Impact of WFTC and Child IS revenue neutral reform on life-cycle earnings and welfare

		Pre-reform education choice by baseline educ				Post-reform education choice by baseline educ			
		sec	further	higher	all	sec	further	higherÂ§	all
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1)	Lifetime gross earnings	-.97	-1.02	-.70	-.89	-1.23	-1.48	-3.25	-1.99
(2)	Lifetime disposable income	.63	-.85	-1.7	-.6	.11	-1.76	-4.15	-1.93
(3)	Welfare (post-education)	2.06	.53	-1.0	.53	1.69	-.32	-1.66	-.10
(4)	Welfare (pre-education)								.16

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

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

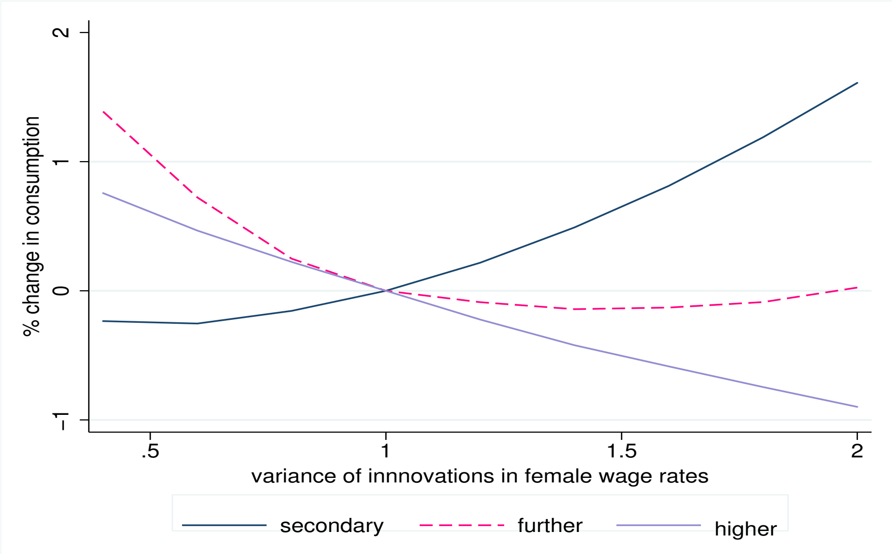
where the index 0/1 stands for the pre/post-reform solutions and the value function is evaluated at different stages in life for different rows. The equation can be solved for r, yielding:

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

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.

To understand this welfare effect it is informative to see the importance of the insurance value of the

Figure 10: Willingness to pay in consumption terms: value of risk by education



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

tax and benefit system, especially for those with lower education levels. This is examined in Figure 10, where we consider the consumption value of uncertainty in the wage rates. There we show the willingness to pay for changes in the variance of wages (risk). A positive number indicates that the individual would be willing to pay (give up consumption) for the corresponding level of uncertainty. The lines intersect at the baseline level of risk.

The key result here is that the lowest education group is so well insured by the public programs that they are willing to tolerate more uncertainty because they are protected against negative wage shocks by the tax and benefit system; on the other hand they gain from positive shocks. The middle group is also well insured following the reform, as they are indifferent between the baseline level of uncertainty and increases (although they would prefer less risk). The higher education group is unlikely to become eligible for welfare benefits, even following a negative wage shock; as a result they find increases in uncertainty costly. However, overall the reforms increased the amount of available insurance for most people in the economy, which underlies the increases in overall welfare.

Table 12: Impacts of an exogenous increase in public spending distributed through alternative routes

		Pre-reform education choice by baseline educ				Post-reform education choice by baseline educ			
		sec	further	higher	all	sec	further	higher	all
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Adjustment in basic tax rate									
(1)	Lifetime gross earnings	.29	.21	.09	.20	.63	.23	.10	.32
(2)	Lifetime disposable income	.57	.74	.90	.74	.72	.79	.95	.82
(3)	Welfare (post-education)	.40	.94	.77	.71	.42	.98	.81	.74
(4)	Welfare (pre-education)								.68
Panel B: Adjustment in tax credits maximum award									
(5)	Lifetime gross earnings	1.32	-.01	-.18	.37	.95	-.13	-1.04	-.07
(6)	Lifetime disposable income	1.66	.61	.03	.77	1.15	.30	-.57	.29
(7)	Welfare (post-education)	1.58	1.30	.21	1.03	1.11	.91	.15	.72
(8)	Welfare (pre-education)								.78
Panel C: Adjustment in IS award									
(9)	Lifetime gross earnings	-2.49	-1.34	-.38	-1.40	-2.05	-1.16	-.89	-1.36
(10)	Lifetime disposable income	-.32	-.48	-.21	-.34	-.27	-.45	-.51	-.41
(11)	Welfare (post-education)	.90	.70	.09	.56	.72	.55	.07	.45
(12)	Welfare (pre-education)								.46

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 are kept unchanged, in which case the extra spending allows for the basic tax rate to drop by 0.93pp, the IS award to increase by £4.2 per week, or the tax credits award to increase by £22.2 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 0.97pp, the IS award to increase by £3.4 per week, or the tax credits award to increase by £16.6 per week.

Rows 1 and 2 (as well as 5-6 and 9-10) display effects on pre- and post- tax lifetime income, respectively. Rows 3 and 4 (as well as 7-8 and 11-12) display effects on welfare measured by the willingness to pay in consumption terms to keep pre-reform wellbeing with the post-reform family budget. These are measured at the beginning of working life (rows 3, 7 and 11) and at the start of life (row 4, 8 and 12). See footnote to table 11 for more details.

7.3 Comparing alternative policies

Income support, tax credits and taxation are all policies that change work incentives, redistribute income and, to varying degrees, insure individuals against adverse income shocks. While we do not propose to address broader design questions, we can look at the welfare effects of marginal changes in the existing design. In Table 12 we examine the impact of distributing an unfunded increase in government expenditure equal in all cases to a 0.5% gross earnings in the economy (before any changes, for the economy under the 1999 tax and benefits system). The alternatives we consider are a decrease in the basic tax rate, an increase in the maximal tax credits award or an increase in income support, all costing exactly the same. The notes to the table give the resulting changes in the tax rate, or the tax credit or income support with and without a response of education.

The results will reflect trade-offs between incentive effects (distorting labor supply decisions) and the insurance properties of the various programs. 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 1.03% of consumption (row 7). The second preferred alternative is a tax cut with a willingness to pay of 0.71% of consumption (row 3). The least preferred program is income support with a willingness to pay of 0.56% (row 11). This continues to be the case when we allow education to adjust but the outcome is tighter in between tax credits and tax cuts, whether we look at ex-ante welfare before the education choice or ex-post. In all cases the distortionary nature of income support, with its 100% marginal tax rate, makes it the least preferable program despite its basic insurance property (it provides a strong income floor). Of course, this relates to marginal changes and the result could be very different if we were considering large changes.

Interesting insights can be obtained by looking at the willingness to pay of individual education groups: the highest education group prefers tax cuts to either tax credit changes or income support; the latter is valued close to zero by this group. The lowest group prefers an increase in tax credits, with the second best option for them being income support and tax cuts being the least preferred option. Interestingly for the middle education group (based on pre-reform classification) the relative preference between tax credits and tax cuts depends on whether education choices are allowed to adjust, with tax credits being preferred if education does not adjust and the reverse when it does. They rank increases in income support lowest, but value it much more than the highest education group. Interestingly from the perspective of one who has not yet chosen education (and hence who only knows their ability (θ^l) increases in tax credits are the most preferred policy, followed by tax cuts and the least preferable policy is an increase in income support (rows 8, 4 and 12 respectively).

The Table also reports changes in gross and net income reflecting changes in work behavior and benefit receipt as a result of the marginal increases in the benefit. These reveal large negative impacts of increases in income support on work income. On the other hand tax credits increase work income for this group. Thus tax credits seem to achieve both an increase in welfare and a decline in welfare dependency and worklessness.

8 Conclusions

While empirical work has emphasized the importance of tax and welfare on incentives to work, the longer term effects of such policies have been neglected. In particular, policies that change the return to education and work may affect the amount of human capital accumulated, with important consequences for output, employment and, ultimately, welfare. On the other hand, such welfare programs offer valuable insurance against adverse shocks and may also reduce poverty rates among both the unemployed and the low wage earners. In this paper we develop a life-cycle model of women's labour supply, human capital formation (including both education choice and work experience) and savings that allows us to consider these trade-offs and understand better the longer term effects of policy.

In our model decisions are taken in an uncertain dynamic environment under credit constraints. The model includes important features brought together for the first time. First, the dynamic process of family formation is explicitly accounted for. Second, a detailed description of the policy environment is used to accurately determine net earnings by employment status. The model is estimated on a long household panel survey for the UK. Many important empirical features are closely reproduced, including the empirically estimated short-run effects of the tax credit and income support reforms of the late 1990s. We compute intensive and extensive margin elasticities of labor supply, showing the difference between Marshallian and Frisch labor supply elasticities. We then use the model to study the impact of tax and welfare benefit reforms on employment, family income and education decisions. We also investigate the insurance value of redistributive policies.

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

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

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

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Appendix A: Data

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

We select the sample of women in all types of family arrangements observed at least for 2 consecutive years while aged 17 to 50. Our full dataset is an unbalanced panel of just over 4,100 women aged observed for some varying period during the years 1991 to 2006. 10% of these women are observed over the whole period, 60% in no more than 6 consecutive waves, 24% are observed entering the working life from education. A great deal of information is collected for them, including family demographics, their employment, working hours and earnings as well as those of a present partner, background characteristics such as age and education, demand for childcare and its cost. We also keep assets for women aged 17-18 if present (observed for 562 women).

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

Working hours refer to the usual hours in main job including overtime. We discretised labour supply using a three-point distribution: not working (0 hours per week), working part-time (1-20 hours per week) and working full-time (21 hours or more per week). The employment status and working hours observed at one point in the year are assumed to remain unaltered over the entire year.

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

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

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

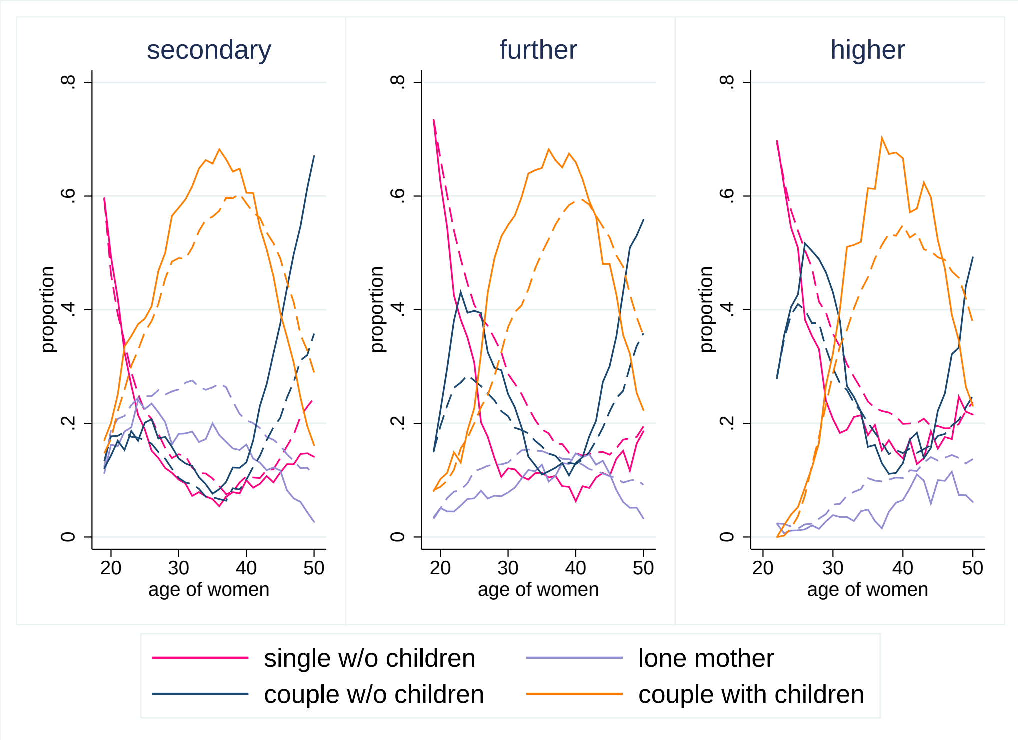
Appendix B: Externally estimated parameters

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

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

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

Figure 11: Family demographics by female age - data and simulations



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

Figure 11 shows the distribution of family composition by female age and education for both observed data and model simulations. The displayed simulated profiles are reasonably close to the observed data ones. They show that less educated women are more likely to become mothers early on and to experienced lone-motherhood than more educated women.

Male employment and earnings Table 13 reports the estimates for male working status and earnings by male education. This is relevant only when the woman lives in a couple as we do not solve the male's problem, but we use this equation to draw male income for the budget constraint and male employment status for preferences and child care costs. Rows 1 to 3 display estimates from a probit regression and show that the employment probability generally increases with education and depends strongly on past employment (row 3). Estimates for the log wage equation suggest only mild differences in wage rates by education (row 4) but strong differences in wage progression, with more educated men experiencing steeper wage profiles over time (row 5). We set the autocorrelation coefficient in the male productivity process to 0.99, close to a unit root. Estimates of the selection parameter (mills ratio in row 8) are imprecisely estimated and we assume no correlation between the residuals in the selection and wage equations.

Table 13: Exogenous parameters: married men employment and wage rates by education

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

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

Childcare costs Families with positive childcare costs when all adults in the household are working pay £2.09 (standard error is 0.04) per working hour. Childcare is required for all working hours of mothers if the child is 4 or younger, and is only necessary for oder children under the age of 10 if the mother works 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 characteristics, including initial assets, 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. The model is a finite horizon one, hence requiring the solution to be computed for each period (which we take to be a year) as a function of the entire state space (described by X at the start of section 2.2). We do this by backward recursion, starting from the end of life (age 70).

We discretize the domain of all continuous state variables to reduce the computational size of the problem. At each period of life, and for each point in the state variables' grid, the solution is computed in two steps: (1) solving the Euler equation for the optimal level of consumption conditional on labor supply and (2) choosing the labour supply that maximizes the value of present and (expected) future utility. To evaluate tomorrow's expected marginal utility of consumption (to solve for the Euler equation) and expected utility (to choose optimal labour supply) at points outside tomorrow's grid, we use linear interpolation on approximate linearizations of the expected functions on assets. These are the inverses of the marginal utility of consumption (for the expected marginal utility) and of the instantaneous utility function (for the expected continuation value). The grid in assets is finer for values closer to its lower bound as the linearizations become less precise with the increased probability of the budget constraint binding in the future. Depending on family circumstances and age, we take expectations over up to 5 unobserved variables to compute the continuation value and the expected marginal utility of consumption. These include female productivity, couple formation/dissolution, partner's education and productivity and child arrival. We use a 5-dimensional transition matrix, discretizing the domain of the continuous productivity shocks in 12 equal-probability intervals.

The estimation procedure is implemented as an iterative process in four steps. The first step involves solving the female life-cycle problem for a particular set of the estimating parameters, given the economic environment and the adopted exogenously set parameters. We then simulated the life-cycle choices of 22,780 women in step 2, using the observed distribution of initial assets, and select an observation window for each so that the overall simulated sample reproduces the time and age structure of the observed data (this is described in section 6.1). The simulations assume women are exposed to up to three policy regimes over the observation window, representing the main tax and benefits systems operating during the 90s and early 00s (we adopted the 1995, 2000 and 2004 regimes and assumed they operated over the periods prior to 1998, 1998 to 2002 and 2003 onwards, respectively). For simulation purposes, all reforms arrive unexpectedly. Step 3 computes the estimation moments using the simulated dataset and calculates the objective function (which is the sum of squared standard deviation differences between data and simulated moments). Step 4 compares the difference against a pre-established tolerance and re-optimizes (selects new set of estimation parameters) in case the convergence criterion is not met.

Appendix D: Model fit

Tables 14 to 19 display the full list of data moments used in estimation, together with their simulated counterparts an the normalized (by the data standard error) differences between the two. The estimation procedure was based on 180 moments, including employment rates in Table 14, part-time employment rates in Table 15, transition rates between employment and unemployment by level of wages in Table 16, coefficients from wage regressions, year-to-year change in wage rates by labour market activity and percentiles of the wage distribution in Table 17, moments of the initial distribution of wage rates in Table 18, and the population distribution of education and positive childcare costs in Table 19. All moments are education-specific.

Among the 180 simulated moments, 36 fall outside the 95% confidence interval for the respective data moment. We found the distribution of wage rates among part-time workers to be particularly difficult to reproduce, possibly a result of severe measurement error in working hours at the bottom of its distribution (bottom panel of Table 17). Measurement error in the distribution of hours, even if classical, results in upward biased measures of the wage rates as these are not directly observed and, instead, computed as the ratio of earned income to hours. The effect is more severe at the bottom of the distribution of hours, thus particularly affecting the distribution of wage rates among part-time workers.

Table 14: Model fit – female employment rates by family composition and education

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

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

Table 15: Model fit – female part-time employment rates for women by family composition and education

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

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

Table 16: Model fit – transition probabilities between unemployment and employment by family composition and education

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

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

Table 17: Model fit – wage regressions and the distribution of female wage rates by education

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

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

Table 18: Model fit – female initial wage rate by education

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

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

Table 19: Model fit – other moments by education

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

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