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The long-term effects of in-work benefits in a life-cycle model for policy evaluation

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Abstract

This paper presents a life-cycle model of woman's labour supply, human capital formation and savings for the evaluation of welfare-to-work and tax policies. Women's decisions are formalised in a dynamic and uncertain environment. The model includes a detailed characterisation of the tax system and of the dynamics of family formation while explicitly considering the determinants of employment and education decisions: (*i*) contemporaneous incentives to work, (*ii*) future consequences for employment through human capital accumulation and (*iii*) anticipatory effects on the value of employment and education. The choice of parameters follows a careful calibration procedure, based of a large sample of data moments from the British population during the nineties using BHPS data. Many important features established in the empirical literature are reproduced in the simulation exercises, including the employment effects of the WFTC reform in the UK. The model is used to gain further insight into the responses to two recent policy changes, the October 1999 WFTC and the April 2003 WTC/CTC reforms. We find small but non-negligible anticipation effects on employment and education.

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1 Introduction

In-work benefits have gradually gained attention over the last 20 years. They have been introduced in a number of countries, including the US, Canada, the UK and France, with increasing resources being allocated to such schemes over time. At their core, in-work benefits are a means of transferring income towards low income families conditional on working. The schemes are generally designed as a subsidy to working, frequently dependent on family composition, particularly the presence of children. Commonly, the objective is to alleviate poverty whilst simultaneously mitigating some of the adverse effects other benefits have on the incentives to work.

In-work benefits target unskilled workers and families with children. These two groups are expected to face a comparatively high level of unemployment, with unemployment insurance and redistributive instruments making up for the lack of earnings. Parents of young children are particularly at risk of experiencing substantial costs of working: they may be entitled to especially generous benefits if on low income, may face high fixed costs of working in the form of childcare costs and may value highly their off-work time. They may also face very high marginal tax rates while working due to rapid phasing-out of substantial benefits (taper rates). If combined with high elasticities of labour supply, the high taper rates may lead to substantial changes in how much the individuals are willing to work and, in the limit, on whether they want to participate in the labour market at all.

Some empirical and theoretical studies have contributed to our understanding of the impacts of in-work benefits. Most of the attention has been on how they affect work incentives and labour supply. In a seminal paper, Saez (2002) showed that the optimal design of in-work benefits depends on how responsive individuals are at the intensive (hours of work) and extensive (whether to work) margins. Hotz and Scholz (2003) review the literature on the effects of the Earned Income Tax Credit, the main US transfer scheme to the (working) poor. Card and Robins (2005) 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 Klauuw (2007) assess the employment effects of the Working Families' Tax Credit reform of 1999. Most studies

find positive employment effects of in-work benefits. Some more recent studies in a special issue of the Economic Journal have looked at outcomes outside the labour market. Grogger and Karoly (2009) review the experimental evidence in North America and study the effects of in-work benefits on marriage, divorce and fertility. Francesconi, Rainer and van der Klauuw (2009) study the effects on a similar set of variables of welfare reforms in the UK. Gregg, Harkness and Smith (2009) focus on lone parents and mental and health well-being of mothers as well as children outcomes, again for the UK.

In this paper we aim to contribute to the understanding of the effects of welfare systems as a whole and in-work benefits in particular. In line with the latest literature, we acknowledge that the generosity of in-work benefits may affect life-cycle decisions other than employment. In particular, the value of education may be affected by a contemporaneous increase in the value of the outside option (being employed), the additional insurance mechanism that in-work benefits may represent, and the dynamic consequences of working and gaining experience on future employment and earnings. We also realise that dynamic links may be of great importance in welfare evaluation. Responses *in anticipation* of being (directly) affected by a policy in the future may accentuate its effects. For example, education decisions may be responsive to expected changes in returns induced by alterations to the policy environment. The insurance component of these schemes may also be substantial. It may partially protect against bad income shocks, possibly encouraging individuals to remain in work for longer and boosting labour market attachment.

We propose an evaluation model for policy analysis that accounts for how working incentives are affected by transfer mechanisms: (*i*) the contemporaneous relative values of working and education, (*ii*) the dynamic links in individual decisions, responsible for anticipatory and future changes in the relative values of working and education, and (*iii*) the role of insurance. In a parallel paper we add feedback effects to the analysis here.

Ours is a life-cycle model of education investment, labour supply and human capital formation. Decisions are taken in a risky environment by risk-averse agents. We study female decisions as they are most responsive to policy instruments given the natural course of life events affecting their cost of working and returns from education. Crucial for them, we consider changes in family composition taking place over the life-cycle, including partnering, separation and fertility. These occurrences may have great consequences for the cost of working, labour market attachment and value of future work and therefore, in retrospect, education investments. However, we do not address the consequences of in-work benefits on family formation. These are exogenously determined in our model.

We apply our model to assess the impact of UK in-work benefits and their reforms. In-work (i.e. work-contingent) benefits were first introduced in the UK in 1971 with the Family Income Supplement. Several changes have occurred over time, with the scheme being re-labeled as Family Credit in 1988 and Working Families' Tax Credit in 1999, and then split into the Child Tax Credit and Working Tax Credit in 2003 (Child Tax Credit can be claimed by those not working). Generosity has generally increased over time, with the value of awards increasing and eligibility extended to more families, at least partly through reductions in the rate at which awards were tapered away. More details of the UK tax system are given in Section 2.

The plan for the remainder of the paper after section 2 is as follows. Section 3 discusses the model; section 4 describes the data used for estimation and calibration; section 5 discusses the estimation and calibration procedures and describes the data and simulated moments for calibration as well as the calibration results; section 6 presents further evidence on the empirical relevance of the model; section 7 illustrates the use of the model for policy evaluation by an application to the 1999 WFTC and the 2002 WTC/CTC reforms of the in-work benefits operating in the UK; and finally section 8 presents some concluding remarks.

2 The UK tax and transfer system

Although simpler than in many other OECD countries, the tax and transfer system in the UK is still quite complex and involves a great number of instruments. To access the impact of tax credits within a realistic environment, we explicitly account for the most important parts of the system. Here, we briefly describe the key personal taxes and transfer programs in the UK. More detail can be found in Adam and Browne (2009), Adam, Browne, and Heady (2010) and Levell et al. (2009).[1]

There are three main personal taxes: income tax, employee national insurance and council tax. *Income tax* is calculated at the individual level, though until relatively recently some parameters did depend on family circumstances. Individuals each receive a tax–free allowance. Above that, marginal tax rates are defined over a small number of bands, generally two or three, with small changes over time. In 2008 there were two bands with marginal tax rates of 20% and 40%. *Employee National Insurance* is a payroll tax formally incident on employees (we ignore employer National Insurance, which is the payroll tax formally incident on employers). Like income tax, it is defined over a number

[1]The FORTAX microsimulation library is used to compute tax liability and benefit entitlement for each family. For details on the implementation see Shephard (2009) and Shaw (2010).

of bands; in 2008 there were three bands with marginal taxes of 0%, 11% and 1% respectively. The self-employed face a slightly different, and considerably more generous, National Insurance regime. *Council Tax* is the only significant local tax in the UK. It was introduced in April 1993, replacing the previous, and hugely unpopular, flat-rate 'poll tax'. Unlike income tax and National Insurance, council tax is levied at the household level. Tax liability varies by region and depends primarily on the valuation band of the property occupied by the household.

The UK welfare/transfer system is assessed primarily at a family level and depends on income and assets as well as family composition and needs. In addition to tax credits, we consider four other benefits: income support/income-based jobseeker's allowance, housing benefit, council tax benefit and child benefit.

Income support and *income-based jobseeker's allowance* are means-tested benefits that top family income up to a specified level based on family needs. They are basically the same benefit, except for additional job search requirements in the latter. Neither benefit can claimed by those in full time work: income support is for those not in a position to work (e.g. lone parents with young children, carers and the disabled), while jobseeker's allowance is for people actively searching for work. We ignore contribution-based jobseeker's allowance, which is a non-means-tested subsidy paid to unemployed job-seekers who meet certain contribution conditions. It is only available for up to six months, after which claimants move onto income-based jobseeker's allowance.

Housing benefit and *council tax benefit* are means-tested rebates to cover rent and council tax. They vary substantially with local conditions (e.g. local rents in the case of housing benefit) and family composition. They are tapered away at high rates: 65% for housing benefit and 20% for council tax benefit.

Child benefit is a flat rate benefit that varies by number of dependent children and their age. It is not means-tested.

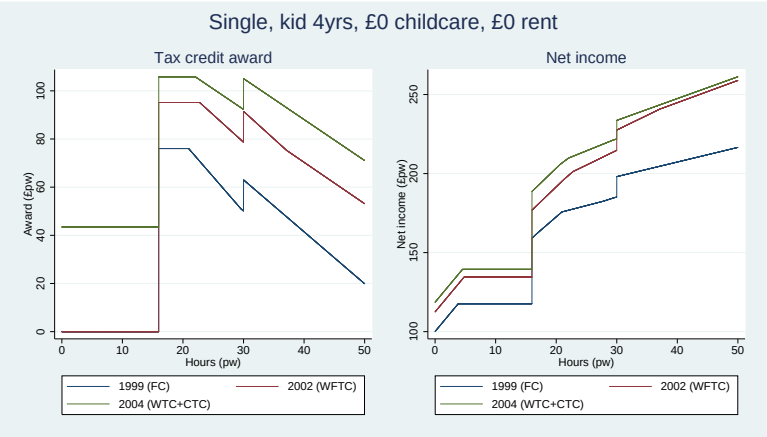
There are currently two main tax credits: working tax credit and child tax credit. *Working tax credit* (WTC) is an employment subsidy for low-wage workers designed to improve work incentives by increasing after-tax earnings. To be eligible, an hours condition needs to be satisfied: in families with children, at least one adult must work 16 hours or more; in families without children, at least one adult must work 30 or more hours a week and be aged 25 or over. WTC also includes a subsidy for formal childcare, available so long as all adults in the family work 16 hours or more a week.

Child tax credit (CTC) is the main source of means-tested support for families with children. Awards depend on family composition and there are no employment conditions that have to be met. WTC and CTC are subject to a joint means test operating at the family level. The main taper rate is currently 39%.

WTC and CTC were introduced in April 2003, replacing working families' tax credit (WFTC) as well as some other support available through the transfer system. WFTC had been introduced in October 1999 as a more generous (but otherwise similar) version of the Family Credit programme (FC). The WFTC and WTC/CTC reforms both increased generosity for existing claimants as well as extending entitlement further up the income distribution. Moreover, while the WFTC was only targeted at families with children and demanded at least one of the adults to be working, WTC/CTC extended eligibility to families without children (through the WTC, if working above 30 hours per week) and to low-income families with children independently of their working status (through CTC).

Table 1 briefly summarises the main tax credit parameters for a couple or lone parent with 1 child in April 1999, 2002 and 2004, illustrating the FC, WFTC and WTC/CTC regimes. Figure 1 illustrates how these changes act to shift the budget constraint, plotting the example of a lone parent (with a child aged four) who earns £4.6 per hour, does not rent her accommodation and does not use formal paid-for childcare. The effect of both reforms was to shift the budget constraint upwards. The gradient also increases following the WFTC reform (because the tax credit withdrawal rate was reduced).

Figure 1: Lone parent budget constraints by tax regime



Notes: Per week values. Tax credit awards and budget constraints for a lone parent of a child aged 4 not renting her accommodation and not having formal childcare costs. Female earns £4.6 per hour. Fortax simulations.

Table 1: Tax credit award: couple or lone parent with 1 child

	April 1999 (FC)	April 2002 (WFTC)	April 2004 (WTC/CTC)
Basic award	£64.95	£88.95	£131.82
30-hour premium	£11.05	£11.65	£12.31
Earnings threshold	£80.65	£94.50	£97.31 and £961.54
Taper rate	70% (net earnings)	55% (net earnings)	37% and 6.67% (gross earnings)
Help with childcare	Disregard up to £60 of childcare expenses from income	Max award increased by 70% of childcare expenses up to £135	Max award increased by 70% of childcare expenses up to £135

Notes: All values are on a per-week basis. Families with children are eligible if at least one adult works 16 or more hours per week. Help with childcare requires all adults to work more than 16 hours per week. The increase in generosity between WFTC and WTC/CTC is exaggerated because the reform also incorporated elements of other benefits.

3 The model

This section presents and discusses the life-cycle model of female education, employment and savings used to assess the effects of tax credits on education investments, working, income distribution and, ultimately, well-being.

3.1 Overview of the model

The life-cycle of females is split into three stages corresponding to education, working and retirement, all mutually exclusive activities. The decision process is modeled from the age of 17 for risk averse individuals in an uncertain environment.

Education investments are settled at the age of 17. We consider three education levels: basic, secondary and university education. We assume the individual does not bear the direct monetary cost of secondary education but pays fees for university education. Moreover, university education carries indirect costs in terms of foregone earnings with a delayed entrance in the labour market.

Upon completion of education, the woman moves into working life. This is an absorbing state, meaning that returning to education is ruled-out. In each period of her working life, the woman decides on how much to work and consume. We allow for three levels of labour supply, corresponding to unemployment, part and full time employment, respectively 0, 20 and 40 hours of work per week. A by-product of working is human capital, accumulated through learning-by-doing while employed and eroded while unemployed. Realised hourly earnings depend on education attainment, accumulated human capital and idiosyncratic persistent productivity shocks, interpreted as health shocks.

Finally, retirement arrives deterministically at the age of 60 and is also an absorbing state. To face reduced income after retirement, women accummulate savings during their working life. For simplicity it is assumed that individuals live for another 10 years after retirement.

We model education, employment and savings decisions to be optimal from an inter-temporal perspective. The decision process is determined by contemporaneous costs and restrictions, as well as contemporaneous and long-lasting uncertain returns. It is embedded in a rich context characterised by the institutional environment and the dynamics of family composition.

The discussion of family composition effects is generally absent from studies of men behaviour in the education and labour markets. In contrast, family-related considerations are empirically most relevant in the case of women. Crucial to our analysis, the effects of transfer systems will not be independent from the process of family formation and how it determines the value of human capital and working. We therefore explicitly model the dynamics of family composition, allowing for partnering, separation and the arrival of a child. For simplicity, variation in family composition is assumed exogenous to the decision process. The consideration of endogenous family formation and how it is affected by institutional features is outside the scope of this study.

Both women and their potential partners are heterogeneous with respect to a number of characteristics. These can be observable or unobservable to third parties, including the policy maker. Observable heterogeneity include ages, education, working experience, employment status, savings (pooled in couples) and family composition variables. Unobserved heterogeneity includes idiosyncratic productivity levels and preferences for working and education, considered unverifiable by third parties.

We consider two forms of income uncertainty, both affecting the returns from human capital investments. One is linked to the stochastic process of family composition and partner earnings. The other is the persistent but unpredictable productivity process capturing, say, health status. It is

directly transmitted into earnings and may lead to job loss. As result, investments in education and human capital are inherently risky. The tax and benefit system may affect their return and dispersion in different ways over the course of life, thus potentially changing the incentives to study and work over the whole life.

The chances of future adversity generate precautionary behaviour and a demand for insurance. However, imperfect observability of individual characteristics will lead to incompleteness in insurance markets. Policy instruments such as unemployment benefits or wage subsidies may provide partial insurance against income variation, while savings and human capital accumulation are forms of self-insurance that the individual may exploit.

There are several dynamic elements in the model. *First*, the life-long process of human capital formation depends of education investment at the start of life and working decisions throughout adulthood. Education equips the individual with new, different skills, with life-long consequences for the type of human capital she supplies. Working also entails investment in human capital through the accumulation of experience. The returns to human capital investments are secured in future working spells. *Second*, savings allow for a smooth consumption path and insure against periods of adversity or when working is overly costly. And *third*, family composition changes over the course of working life, with the possibility of marriage, divorce and child-bearing.

We consider the presence of credit constraints during the female's working life. Not only may credit constraints directly affect employment in the face of very high costs of working, they may retrospectively feed under-investments in education if the investment changes (increases) the odds of being constrained in the future. Public interventions may reduce the incidence of binding constraints by transferring resources across periods of life.

A final major feature of our model is the explicit inclusion of a complex transfer system resembling those typical of developed countries. Two major components of these systems are: (i) progressive tax rates, and (ii) generous means-tested benefits tapered away as income increases. Together, these two sets of policy instruments may significantly affect disposable income at different stages of the life-cycle, the returns from human capital investment and exposure to income risk. Thus, they are not fully understood without a detailed description of the individual decision process. Moreover, their effects depend on how they interact with other policy instruments in changing working and education incentives and in what margins of the distribution of workers.

For the empirical application, we reproduce the UK personal tax and benefits system of the

1990s and 2000s, including the exact schedule of income taxes, social security contributions and local taxes, unemployment insurance, income support, housing and council tax benefits, child and childcare banefits as well as tax credits. We study how major changes in the tax schedule may affect women's incentives to invest in education and work over the life-cycle.

We now formally detail the elements of the model.

3.2 State Space

We split the state space faced by woman i aged a at time t into three parts, $(X_{iat}, \Omega_{iat}, \Pi_t)$. X contains the observed idiosyncratic information, including woman's education, experience and previous activity, marital status and the characteristics of a present partner (his education, experience and previous employment status), whether a child is living in the family and her age, and family savings. Ω contains the unobserved idiosyncratic information, including the woman's and man's (if present) productivity levels and preferences for working. Π_t details information on aggregate prices and transfer mechanisms at time t, including market wage rates, childcare costs, the risk-free interest rate and current design of the tax and benefit system.

In all that follows, we use the superscripts $\left(^{m},^{k}\right)$ to denote the man's and child's information, respectively. Variables without a superscript represent either female or family information. With no loss of generality, we focus the discussion on one generation, making a and t equivalent in terms of information. We therefore omit the index t to ease notation. Capital letters are reserved to denote prices, individual observable characteristics are represented by small letters. Greek letters are used to represent unobserved information and model parameters. Functions are represented by both capital and small letters.

3.3 Family composition

Family composition varies exogenously over time. Two types of changes may occur: (i) arrival or departure of a (dependent) child; and (ii) arrival or departure of a partner.

We discuss the former first. For simplicity, we cap the maximum number of children to one per family at each moment in time. The probability of a child leaving is modeled as dependent on the age of the child only: it is zero for a child younger than 18 and jumps to one when the child turns

18 years old. The arrival rate of newborns is positive only in childless families. It is modeled as a function of the observed variables only, X_{ia}. More specifically:

$$\text{Prob}\left(d_{ia}^k = 1 | d_{ia-1}^k = 0, X_{ia-1}\right) = \text{Prob}\left(d_{ia}^k = 1 | d_{ia-1}^k = 0, a, s_i, d_{ia-1}^m\right) \quad (1)$$

$$\text{Prob}\left(d_{ia}^k = 0 | d_{ia-1}^k = 1\right) = \begin{cases} 0 & \text{if } a_{ia}^k < 18 \\ 1 & \text{if } a_{ia}^k = 18 \end{cases} \quad (2)$$

where $\left(d^k, d^m\right)$ are dummy variables representing the presence (if equal 1) or absence (if equal 0) of a child and partner, respectively, a and s are the female age and education, respectively, and a^k is age of the child.

The age of the child, a^k, evolves deterministically:

$$a_{ia}^k = a_{ia-1}^k + 1. \quad (3)$$

The man's problem is viewed from the woman's perspective and thus partly depends on her characteristics. He is characterised by three features: educational attainment, s^m, employment status, l^m, and employment earnings w^m. The odds of a woman finding a man (s^m, l^m, w^m) depends her own and her family observable characteristics, X. It is decomposed as follows:

$$\text{Prob}\left[s_{ia}^m, l_{ia}^m, w_{ia}^m \left| d_{ia-1}^m = 0, X_{ia-1}\right.\right] =$$
$$\text{Prob}\left[s_{ia}^m \left| d_{ia-1}^m = 0, X_{ia-1}\right.\right] \text{Prob}\left[l_{ia}^m \left| d_{ia-1}^m = 0, s_{ia}^m, X_{ia-1}\right.\right] f_{w^m|.}\left(w_{ia}^m \left| d_{ia-1}^m = 0, s_{ia}^m, l_{ia}^m, X_{ia-1}\right.\right)$$

where the first term after the equality represents the probability of drawing a man with education s^m for a single woman with characteristics X, the second term represents the probability that this man is working and the third term is the distribution (density) of his productivity level.

We now specify the arrival and departure probabilities of a male of type s^m and postpone the discussion of male labour supply and earnings to the next two subsections. With respect to the arrival rate of new partners to single women, its dependence on characteristics X is narrowed to:

$$\text{Prob}\left[s_{ia}^m \left| d_{ia-1}^m = 0, X_{ia-1}\right.\right] = \text{Prob}\left[s_{ia}^m \left| d_{ia-1}^m = 0, a, s_i, d_{ia-1}^k\right.\right]. \quad (4)$$

Likewise, the probability of a man of type s^m leaving is assumed to depend on the same observable characteristics,

$$\text{Prob}\left[d_{ia}^m = 0 \left| d_{ia-1}^m = 1, X_{ia-1}\right.\right] = \text{Prob}\left[d_{ia}^m = 0 \left| d_{ia-1}^m = 1, s_{ia-1}^m, a, s_i, d_{ia-1}^k\right.\right]. \quad (5)$$

3.4 Men's employment and earnings in new couples

Present men are either in full time employment or unemployed. This is consistent with empirical evidence showing men labour supply adjustments occur primarily on the extensive margin. We model fulltime employment to correspond to 40 hours of work per week, and unemployment to be 0 hours of work per week.

The employment status (l^m) and earnings (w^m) of a newly-wed man depend on the characteristics of his spouse, an implied outcome from sorting in marriage market that we leave unspecified in this study. We assume that, *conditional* on his education, only the woman's age remains correlated with his employment status and earnings. We formalise the reduced form selection model of men's earnings as follows:

$$\begin{aligned} \text{Prob}\left[l^m_{ia} = 40 \,\middle|\, d^m_{ia-1} = 0, X_{ia}\right] &= \text{Prob}\left[\nu^m_{ia} > H_0\left(a, s^m_{ia}\right)\right] \quad (6) \\ \ln w^m_{ia} &= \ln W^m_{s^m} + \alpha^m_{s^m} \ln(a) + \upsilon^m_{s^m ia} \quad (7) \end{aligned}$$

where (ν^m, H_0) are the unexplained and explained parts of the man's working selection process, respectively, $W^m_{s^m}$ is the market wage for men of education s^m, $\alpha^m_{s^m}$ measures the returns to experience to men of education s^m, and $\upsilon^m_{s^m}$ is his idiosyncratic productivity level, with a distribution that again depends on s^m.

3.5 Men's employment and earnings in ongoing couples

In ongoing couples, men's employment and earnings are formalised in much the same way as for new couples. However, the reduced form selection model now allows for persistence in employment status and productivity as follows,

$$\begin{aligned} \text{Prob}\left[l^m_{ia} = 40 \,\middle|\, d^m_{ia-1} = d^m_{ia} = 1, X_{ia}\right] &= \text{Prob}\left[\nu^m_{ia} > H_1\left(a, s^m_{ia}, l^m_{ia-1}\right)\right] \\ \ln w^m_{ia} &= \ln W^m_{s^m t} + \alpha^m_{s^m} \ln(a) + \upsilon^m_{s^m ia} \\ \upsilon^m_{s^m ia} &= \upsilon^m_{s^m ia-1} + \varepsilon^m_{s^m ia} \\ \varepsilon^m_{s^m ia} &\quad \text{iid} \end{aligned} \quad (8)$$

As before, (ν^m, H_1) represent the unexplained and explained part of the working decision, respectively, where the latter is now a function of previous employment status. Unobserved productivity, $\upsilon^m_{s^m}$, follows a random walk process with innovation $\varepsilon^m_{s^m}$, assumed serially uncorrelated and iid within education groups, but its distribution may depend on s^m.

3.6 Women's earnings

Women's earnings follow a dynamic process similar to that of men. However, working experience is endogenously considered:

$$\begin{aligned} \ln w_{ia} &= \ln W_s + \alpha_s \ln(e_{ia}+1) + \upsilon_{sia} \\ \upsilon_{sia} &= \upsilon_{sia-1} + \varepsilon_{sia} \end{aligned} \tag{9}$$

where w is earnings, a function of the market wage rate for her educational level, W_s, accumulated experience, e, and idiosyncratic unobserved productivity, υ. Unobserved productivity is a random walk with an iid innovation ε. The distributions of both υ and ε are education-specific.

3.7 Women's inter-temporal decision problem during working life

At any point a in her *working life*, the woman chooses the optimal level of consumptionn and labour supply depending on the state of her world as characterised by $(X_{ia}, \Omega_{ia}, \Pi)$. The decision involves the consideration of the present costs and benefits of her actions as well as potential future consequences. Her inter-temporal problem as viewed from age a is:

$$V_{ia}(X_{ia}, \Omega_{ia}; \Pi) = \max_{\{c,l\}_{a,\ldots A}} \mathrm{E}\left\{ \sum_{\alpha=a}^{A} \beta^{\alpha-a} U\left(c_{i\alpha}, l_{i\alpha}; X_{i\alpha}, \Omega_{i\alpha}\right) \middle| X_{ia}, \Omega_{ia}, \Pi \right\} \tag{10}$$

where V is the optimum expected value of present and future discounted utility, β is the discount rate and U is the per-period flow of utility, a function of current family consumption (c), woman's labour supply (l) and the state space. In the optimisation problem, c is a continuous decision variable while l may assume three different alternative values, 0, 20 and 40 for the number of working hours per week if the woman is unemployed, in part-time or in full-time employment, respectively.

We adopt a CRRA specification for contemporaneous utility, U,

$$U\left(c_{ia}, l_{ia}; X_{ia}, \Omega_{ia}\right) = \frac{(c_{ia}/n_{ia})^{\mu}}{\mu} \exp\left\{ \widetilde{U}\left(l_{ia}, d^m_{ia}, l^m_{ia}, d^k_{ia}, a^k_{ia}\right) + \theta_i(l_{ia}) \right\} \tag{11}$$

where n represents equivalised family dimension, μ is the risk aversion (or inter-temporal substitution) parameter, and θ is the woman's taste type or her permanent preferences for each level of labour supply. The function $\widetilde{U}$ is the utility shifter by family composition and employment status.

Optimisation is subject to a number of restrictions including the budget constraint, the dynamics of the state space and the initial and terminal conditions. We now describe each of them.

The *budget constraint* follows the typical dynamic form,

$$k_{ia+1} = R_t k_{ia} + y_{ia} - c_{ia} \tag{12}$$

where k represents accumulated assets, R is the risk-free interest rate and y is net family income. Families are assumed to be credit constrained. How severe the constraint is depends on the education decision of the woman. Individuals deciding to invest in education are entitled to a loan aimed at covering their university fees and (some) living expenses througout their extended student life. Others not investing are not entitled to this higher borrowing limit. In addition, borrowing is only allowed if it can be fully repaid before the end of the woman's working life. Thus,

$$k_{ia+1} \geqslant \underline{k}(s_i).$$

Family income is determined by the woman's and man's employment status and earnings together with current taxes and benefits. An important source of working costs are related with childcare on families with children. We assume that young children need childcare from either their parents or a third party. We explicitly consider the existence of childcare costs incurred by working mothers of children younger than 5 or full-time working mothers of children aged 5 to 10. Thus, family income can be formally described as follows,

$$\begin{aligned} y_{ia} &= l_{ia} w_{ia} + d^m_{ia} \left[l^m_{ia} w^m_{ia} \right] \\ &- T\left(a, l_{ia}, w_{ia}, d^m_{ia}, l^m_{ia}, w^m_{ia}, d^k_{ia}, a^k_{ia}, C^k_{ia}\left(a^k_{ia}, l_{ia}, d^m_{ia}, l^m_{ia}\right)\right) \\ &- C^k_{ia}\left(a^k_{ia}, l_{ia}, d^m_{ia}, l^m_{ia}\right) \end{aligned}$$

where y is net family income. $l_{ia} w_{ia}$ and $d^m_a \left[l^m_{ia} w^m_{ia} \right]$ are working earnings for the woman and partner where present, respectively. The woman's earnings process is defined in equation (9). The man's working income is determined by the selection model (6)-(7) for newly matched men or (8) for men in on-going couples. T is the family's tax liability (net of benefits), which is designed to reproduce closely the UK's transfer system, and C^k is childcare costs, the total being proportional to the woman's working hours depending on the child's age and presence and working status of a partner.

While employed, the woman accumulates experience depending on hours worked. The *rule of experience accumulation* is,

$$e_{ia+1} = e_{ia}(1 - \lambda_D) + \mathbf{1}(l_{ia} = F) + \lambda_P \mathbf{1}(l_{ia} = P) \tag{13}$$

where λ_P is the fraction of experience accumulation if in part-time as opposed to full-time employment, and λ_D is the depreciation rate.

The optimisation problem is also subject to the *dynamics of family formation* as described in equations (1), (2), (4) and (5).

Finally, the terminal condition is

$$k_{i,70} \geq 0$$

where 70 is the age 10 years after retirement, representing the end of life for purposes of savings decisions. Initial conditions are specified below together with the educational decisions.

3.8 Women's education

We consider three levels of education, basic ($s = 1$), secondary ($s = 2$) and university ($s = 3$). These correspond to leaving school after GCSEs at age 16, after A-levels at 18 and after a degree at 21. Before entering adult, independent life at the age of 19, the woman decides about her education take up. If opting for basic or secondary education, she will enter the labour market immediatly, aged 19. If deciding to continue in education and acquire an university degree, she will postpone entering the labour market for another 3 years, until she reaches 22 years of age and have completed her degree. Working life is an absorbing state, meaning that we exclude the possibility of returning to education once this state is left. We denote by a_s the age at which the woman enters the labour market depending on education attainment, s.

Education decisions depend on the information available to the young woman. It includes her initial level of assets, k, and her permanent preferences for working and studying, θ, her preferences for each education level, ϖ_s, as well as all institutional features and prices, including fees and possible loans. She makes her education choice having only partial information about her returns from the investment: she knows her productivity in each type of skill up to her preferences for working only, θ. Precise information on her initial productivity level is revealed only once she enters the labour market, at 19 or 22 depending on education investment.

Designate by V_s the expected value of education s. It is formalised as a function of the discounted value of lifetime utility at the beginning of adult life, age 19, and a idiosyncratic preference shocks:

$$V_{si}\left(k_{i19}, \theta_i, \varpi_{si}\right) = \mathrm{E}\left[V_{i19}\left(X_{i19}, \Omega_{i19}, \Pi\right) | s_i\right] + \varpi_{si}$$

For the two lowest education levels, $s = 1, 2$, the initial value function at 19 is recursively

defined as

$$V_{i19}\left(X_{i19},\Omega_{i19},\Pi|s_i\right) = \max_{c_{i19},l_{i19}}\left\{U\left(c_{i19},l_{i19};X_{i19},\Omega_{i19}\right)+\beta\mathrm{E}\left[V_{i20}\left|X_{i19},\Omega_{i19},\Pi\right.\right]\right\} \quad (14)$$

where the initial conditions at entrance into working life are,

$$\begin{aligned} k_{i19} &\quad \text{given} \\ e_{i19} &= 0 \\ d^m_{i18} &= 0 \\ d^k_{i18} &= 0 \\ \varpi_{si} &\perp (\theta_i, \upsilon_{si19}) \\ \upsilon_{si19} &\quad \text{correlated with } \theta \end{aligned}$$

The state space evolves as defined in the previous section. In particular, family composition at age 19 depends on the exogenous probabilities described before, a function of female age and education when previously (at age 18) childless and single.

For university graduates, $s = 3$, time in education extends to 3 more years delaying working life till the age of 22. Only then will other work- and family-related information be revealed. Before moving into the working life, the woman remains single and childless. The initial value function at 19 can be recursively defined as

$$\begin{aligned} &V_{i19}\left(X_{i19},\Omega_{i19},\Pi|s_i=3\right) \\ &= \max_{c_{i19},c_{i20},c_{i21}}\left\{\sum_{a=19}^{21}\beta^{a-19}U\left(c_{ia},l_{ia}=S;X_{ia},\Omega_{ia}\right)+\beta^{22-19}\mathrm{E}\left[V_{i22}\left|X_{i21},\Omega_{i21},\Pi\right.\right]\right\} \end{aligned} \quad (15)$$

subject to the conditions

$$\begin{aligned} k_{i19} &\quad \text{given} \\ k_{ia+1} &= Rk_{ia}-c_{ia} \\ e_{ia} &= 0 \\ d^m_{ia} &= 0 \\ d^k_{i18} &= 0 \\ \varpi_{si} &\perp (\theta_i, \upsilon_{si22}) \end{aligned}$$

for $a = 19, 20, 21$ and where the contemporaneous utility for a student is as defined generically in (11),

$$U\left(c_{ia},l_{ia}=S;X_{ia},\Omega_{ia}\right) = \frac{\left(c_{ia}\right)^{\mu}}{\mu}\exp\left\{\widetilde{U}\left(\left(l_{ia},d^m_{ia},l^m_{ia},d^k_{ia},a^k_{ia}\right)=(S,0,.,0,.)\right)+\theta(S)\right\}.$$

It is assumed that full-time education requires a similar effort to fulltime employment and thus we simplify $\theta(S) = \theta(FTE)$ where S and FTE stand for education and full-time employment, respectively.

The continuation value at age 22 for university graduates is defined recursively as in (14):

$$V_{i22}\left(X_{i22}, \Omega_{i22}, \Pi | s_i = 3\right) = \max_{c_{i22}, l_{i22}} \left\{U\left(c_{i22}, l_{i22}; X_{i22}, \Omega_{i22}\right) + \beta \mathrm{E}\left[V_{i23} | X_{i22}, \Omega_{i22}, \Pi\right]\right\} \quad (16)$$

where the initial conditions are

$$\begin{aligned} k_{i22} &= R^3 K_{i19} - R^2 c_{i19} - R c_{i20} - c_{i21} - T \\ e_{i22} &= 0 \\ d^m_{i21} &= 0 \\ d^k_{i21} &= 0 \\ \upsilon_{si22} & \quad \text{correlated with } \theta \end{aligned}$$

T is the university fee for a three years degree and other variables are as defined in the previous section.

The optimal choice of education can now be formalised as the argument s that maximises V_s:

$$s_i = \underset{s \in \{1,2,3\}}{\operatorname{argmax}} \left\{V_{si}\left(k_{i19}, \theta_i, \varpi_{si}\right)\right\}.$$

4 Data

Our empirical analysis is supported by the British Household Panel Survey (BHPS). This is the main UK household panel survey, by now comprising 17 annual waves covering the period from 1991 to 2007. It started with 5,500 households in 1991 and, except for panel attrition, all of these have been followed for the duration of the survey. Other individuals have been added to the sample along the way — sometimes temporarily — as they formed families with original interviewees or were born to them. Additional low-income and regional booster samples have also been created. From 2009, the BHPS forms part of the new and much larger 'Understanding Society' survey.

Interviews are conducted with all individuals in a sampled household who are aged 16 or over. Most fieldwork is conducted in the autumn and early winter. A great deal of information is collected

on demographic characteristics, educational achievement, employment, income and benefits, and some expenditures, particularly those with childcare. Information on assets is only collected once every 5 years.

Our full dataset is an unbalanced panel of around 4,400 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 the working life from education.

However, only the first 8 BHPS waves are used in the estimation and calibration procedures. These data cover the years between 1991 to 1998, a relatively stable period in terms of policy environment preceding the major 1999 reform in tax credits that we will be studying in the empirical application. Using the model fit to the pre-WFTC reform, we can then validate its specification by contrasting its predicted effect of the WFTC reform with available reduced form estimates based on data drawn after the reform.

The 8-waves working data contain observations for over 2,100 women aged between 19 and 50 and observed for at least two consecutive periods. Almost 40% of these women are observed over the 8 waves and 20% are observed entering the working life from education. Information on real earnings among working women has been de-trended as this period witnessed a systematic raise in real wages.

5 Estimation and calibration

We follow a multi-step strategy to identify the parameters of the model. The exogenous parts of the model, including the dynamics in family composition and the partner's labour supply and earnings, are estimated outside the structural model, in a reduced form framework. Details can be found in appendix A. Two parameters are calibrated using values suggested in the empirical literature: the risk aversion coefficient, μ, set to -0.56, and the discount factor, β, set to 0.98. Moreover, the interest rate, R, is set to 1.015, tuition cost of university education amounts to GBP 3,000 over three years and the credit limit for university students (and graduates throughout their life) is GBP 5,000, reflecting the university education policy of the late nineties in the UK. For everyone else, credit is constrained.

All other structural parameters in the woman's labour supply and earnings processes are calibrated using a set of data moments and their counterpart in simulated data. The production of

simulated data uses the model solution together with the initial distribution of assets for individuals aged 17 as observed in the data; the life-cycle profile of each individual is drawn 10 times. A weighting scheme is used to estimate the data moments in order to make all ages equally represented and match the distribution of age in simulated data. Otherwise, the estimation procedures applied to real and simulated data are identical. More detail on calibration moments and derived parameters is given below, keeping notation as close as possible to that used in the structural model (as before, the index t is omitted).[2]

Preferences for working Women's preferences for working depend on her family status and idiosyncratic unobservable characteristics. The latter is assumed to follow a discrete, two point distribution affecting the utility of working. The former is accounted for by family-specific utility parameters. Both the former and the latter are included as shifters to the marginal utility of equivalised (by family size) consumption. Both allow for differential effects by total labour supply, depending on whether it amounts to full- or part-time employment.

Identification of the parameters determining preferences for working relies mainly on a set of moments describing labour supply by family status and labour market transitions by past productivity. Tables 2 and 3 display the calibrated parameters and the match between data and simulated moments, respectively.

The parameters in rows (1)-(5), column (1) of table 2 represent the relative preference for full-time work among women in families of the specified type as compared to the baseline of childless women (rows (1) to (3)) or single women (rows (4) and (5)). As for all other parameters in this table, negative values signify a comparative positive preference towards full-time employment while positive values signify stronger distaste. Under the present parameterisation, mothers find it more costly to take up full-time work, particularly if the child is under 2 years of age. On the contrary, the presence of a partner, notably of a working partner, alleviates the utility cost of full-time work. The corresponding parameters for part-time employment are displayed in column (2) and should be interpreted as increments over the parameters in column (1). Rows (1)-(3) establish that mothers of dependent children have a smaller distaste for part-time than for full-time employment, but still larger than that of childless women. Likewise, women in couples have a stronger preference for full-time than for part-time work, and more so than single women.

[2]The choice of moments for calibration is is in the spirit of indirect inference, although here we do not use formal numerical procedures to find the optimum set of parameters (see Smith, 1990, Gourieroux, Monfort and Renaul, 1993 and Gallant and Tauchen, 1996, dor detail on indirect inference).

Table 2: Calibrated structural parameters: preferences for working

	Working time	
	full-time	part-time
	(1)	(2)
By family composition		
(1) Mother of dependent child	0.08	-0.01
(2) Mother of child aged 0-2	0.04	-0.02
(3) Mother of child aged 3-5	0.00	-0.01
(4) Woman in couple	-0.06	0.024
(5) Woman in couple, partner working	-0.14	0.064
Unobserved heterogeneity in preferences		
(6) type 1: $\theta = 1$	0.30	0.13
(7) type 2: $\theta = 2$	0.53	0.23
(8) % type 1 in population	0.657	

Notes: For a negative coefficient of risk aversion μ in 11, as is the case in the present parametrisation, negative (positive) preference parameters indicate relative like (dislike) for the respective type of work. Parameters in each row are as follows. Columns (1) to (5): shifters in marginal utility of consumption by family characteristics, defining function $\overline{U}$ in equation (11); parameters under 'part-time' are increments with respect to 'full-time'. Columns (6) to (8): distribution of discrete, two-point distribution of preferences for work full-time or part-time respectively.

Rows (6)-(8) in the same table display the distribution of unobserved preferences towards work, specified as a bivariate distribution. Both groups exhibit relative distaste towards working as compared to leisure, the distaste being more pronounced among type 2 women ($\theta = 2$) representing about 1/3 of the overall population.

Among the set of identification moments, those more closely affected by these preference parameters are displayed in table 3 (even though other moments will also determine the choice of preference parameters, notably the distribution of unobserved heterogeneity and its link to earnings). Rows (1) to (6) show the correspondence between data and simulated participation rates among women in different types of family; rows (7) to (9) show the correspondence of transition rates. In all cases, data and simulated moments are very close.

Table 3: Labour supply by family composition: data and simulated moments

		data moments		simulation moments	
		all work	part-time	all work	part-time
		(1)	(2)	(3)	(4)
Employment rates by family composition					
(1)	all	0.74	0.22	0.75	0.20
(2)	mothers	0.61	0.39	0.60	0.39
(3)	mothers of children aged 0-2	0.44	0.44	0.44	0.44
(4)	mothers of children aged 3-5	0.53	0.47	0.51	0.48
(5)	women in couples	0.74	0.26	0.74	0.24
(6)	women in couples, partner working	0.78	0.26	0.79	0.25
Transition rates					
(7)	U to E	0.19		0.16	
(8)	E to U	0.06		0.05	
(9)	E to U: earnings below q10	0.15		0.13	
(10)	E to U: earnings below q50	0.09		0.09	
(11)	E to U: earnings below q90	0.06		0.06	

Notes: Moments in rows (1) to (6) are employment rates over all the population (columns (1) and (3)) or part-time employment rates among employed (columns (2) and (4)). Moments in rows (7) to (11) are transition rates to (row (6)) and from (other rows) employment. 'U' stands for unemployment. 'E' stands for total employment, including part-time and full-time. q10, q50 and q90 are the 10th, 50th and 90th percentile of the distribution of observed earnings in the data, respectively.

Earnings: level and dynamics Women's earnings follow a random walk process with an idiosyncratic, education-specific initial value and a drift depending on accumulated experience. Our identification procedure uses two sets of simple regression models. The first describes the relationship between the growth rate in earnings and that of accumulated experience over the life-cycle, as well as its dispersion. The second describes earnings levels and dispersion among young adults joining the work force from education life. In addition, quantiles of the distribution of earnings at entrance in the labour market are used to pin down the distribution of productivity at entrance conditional on type (as described by working preferences, θ). The dynamics of human capital, underlying the dynamics of earnings, is more loosely identified from the profile of earnings with age. In all cases, moments are estimated/simulated by education level where, again, three levels are considered, basic, secondary and university. Tables 4 and 5 display the parameters' values and match between data and

simulated moments, respectively. Graph 2 illustrates the match between data an simulated earnings profiles among working women.

Table 4: Calibrated structural parameters: earnings and experience processes

		Education level		
		low	medium	high
		(1)	(2)	(3)
(1)	hourly wage rates (GBP, Jan05 prices)	4.15	4.60	5.40
(2)	returns to human capital (experience)	0.11	0.14	0.22
(3)	mean productivity at entrance, type 1	0.01	0.06	0.23
(4)	st. error productivity at entrance	0.32	0.33	0.43
(5)	st. error innovation in productivity	0.13	0.14	0.12
(6)	human capital accumulation while in PT work	0.30	0.30	0.00
(7)	human capital depreciation rate	0.00	0.04	0.07

Notes: Parameters in each row are as follows (for $s = 1, 2, 3$ corresponding to basic, secondary and university education, respectively). Column (1): W_s as in equation (9). Column (2): α_s in equation (9). Columns (3) and (4): $E(\upsilon_{a_s}|s, \theta = 1)$ and $\sqrt{\text{var}(\upsilon_{a_s}|s)}$ (see initial conditions under equations (14) or (16)) where a_s is the age of entrance in the labour market for an individual with education s and θ describes unobserved preferences for working (its distribution being described in table 2); υ is assumed to follow a mixed normal distribution. Column (5): $\sqrt{\text{var}(\upsilon_{a_s}|s)}$ in equation (9). Columns (6) and (7): λ_{Ps} and λ_{Us} in equation (13); PT stands for 'part-time work'.

The earnings-related parameters in table 4 show some familiar features. As compared to lower levels, university education carries a substantial wage premium (17% and 30% as compared to secondary and basic education, respectively; see row (1)), much more significant returns to experience (row (2)), and a process of human capital accumulation that depends more heavily on (long) working hours (row (6)) and is exposed to faster depreciation (row (7)). Moreover, mean differences in productivity by (unobserved) preferences for work (row (3)) and conditional (on preferences for work) dispersion in productivity (row (4)) are larger for university education than for lower education levels. The differences between basic and secondary education are not as pronounced and in the expected directions.

The analysis of moments in table 5 reveals again that simulations closely reproduce the patterns observed in data.[3] Figure 2 also shows a strong match between data and simulated earnings profiles

[3]The data dispersion parameters in rows (2) and (6), columns (1)-(3), are net of measurement error, formalised in the classic form.

Table 5: Earnings regressions: data and simulated moments

		data moments by education			simulation moments by education		
		low	medium	high	low	medium	high
		(1)	(2)	(3)	(4)	(5)	(6)
Earnings among young workers entering WL							
(1)	Level	1.49	1.60	1.88	1.48	1.59	1.87
(2)	Dispersion (se)	0.29	0.33	0.36	0.29	0.33	0.41
(3)	% below q25	0.25	0.25	0.25	0.26	0.27	0.25
(4)	% below q75	0.75	0.75	0.75	0.75	0.75	0.80
Earnings growth among workers aged 50 or less							
(5)	Experience	0.16	0.21	0.28	0.16	0.21	0.27
(6)	Dispersion (se)	0.13	0.16	0.12	0.13	0.16	0.12

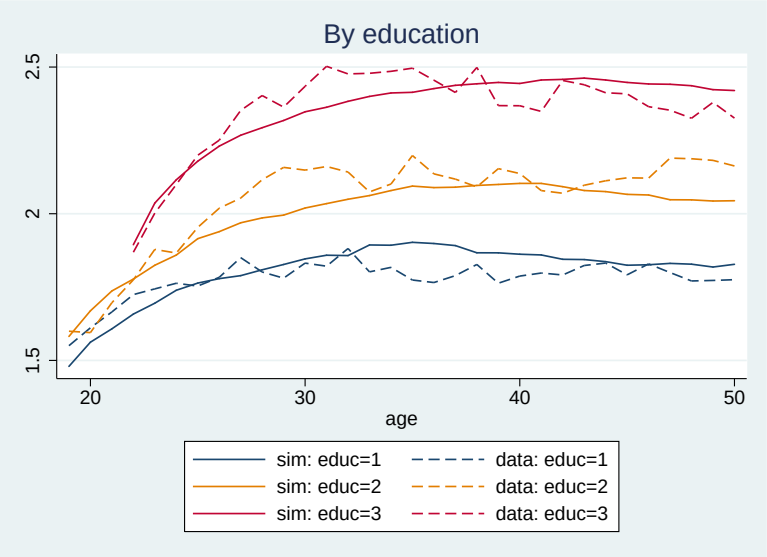
Notes: Parameters in rows (1) to (4) derived from observed (columns (1) to (3)) and simulated (columns (4) to (6)) earnings among workers during first working life period, immediately after leaving education. The dispersion parameters in row (2), columns (1) to (3), are net of classical measurement error in earnings. The parameters in rows (3) and (4) represent the proportion of working young women earning below the 25th and 75th percentiles of the (data) their observed distribution of earnings. Parameters in rows (5) and (6) derived from observed (columns (1) to (3)) and simulated (columns (4) to (6)) first differences in earnings among continuously employed women under the age of 50. Again, the dispersion parameters in row (6), columns (1) to (3), are net of classical measurement error in earnings.

among workers by education attainment.

Education The choice of education occurs at the beginning of life, before entrance in the working life. Selection is determined by the relative expected value and costs associated with each education level. In addition to the monetary and utility cost of education, present for university investment in the form of fees, foregone earnings and (dis)taste for full-time work that affects students as full-time workers alike, the relative preferences for secondary and university education are also determined by a pair of idiosyncratic shocks, $(\varpi_{s=2}, \varpi_{s=3})$ in equations (14) and (15). It is assumed that $(\varpi_{s=2}, \varpi_{s=3})$ are independent, normally distributed random variables of variance 1. Their expected value is determined by the distribution of education attainment.

The figures in rows (1) and (2) of table 6 show a good match between data and simulations in

Figure 2: Log-earnings over the life-cycle



Notes: Mean log earnings among working women by education attainment and age. In the legend, 'sim' stands for simulated data, 'data' stands for real data, 'educ=1' (or 2,3) represents basic, secondary and university education levels.

Table 6: Education attainment: moments and parameters

		Education level		
		low	medium	high
		(1)	(2)	(3)
Moments: education attainment				
(1)	real data	0.38	0.45	0.17
(2)	simulated data	0.37	0.45	0.18
Parameters: distribution of ϖ				
(3)	mean		0.32	1.05

Notes: Moments in row (1) are estimated on real data and represent the distribution of education among individuals leaving education during the observation window. Moments in row (2) represent similar moments based on simulated data. Parameters in row (3) are the centre of the distributions of taste preferences for secondary and university education.

terms of education take-up. They are partly driven by the distribution of idiosyncratic preferences for education determined by the parameters in row (3). The positive (and increasing with education level) expected values of ϖ establish a positive taste for education. However, such preference is to be cumulated with the relative distaste for working, which applies also during studying years. Overall, these parameters attenuate the utility cost of education as compared to employment.

6 Model fit and validation

The figures in the previous section show a close correspondence between data and simulated moments used in calibration. In this section we look at empirical patterns outside the calibration set, and at how the model fares in trying to reproduce some important results established in the empirical literature.

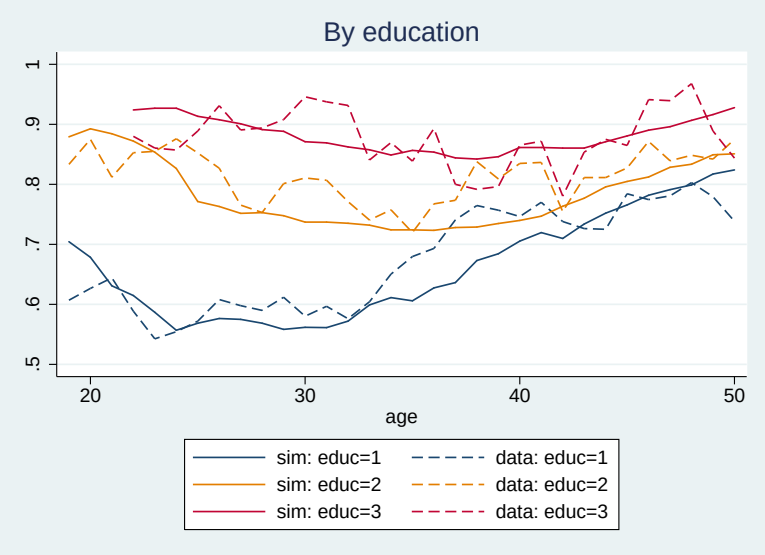
The construction of simulated data for this exercise follows a similar procedure to that described in section 5. The observed distribution of assets at the age of 17 is used to initialise simulations; ten full life cycle profiles are simulated for each individual observation. There are 562 observations of assets for 17 year olds in the BHPS being used as initial conditions. Most of the results discussed below are based on simulated data under the April 1999 policy regime, pre Working Families Tax Credit (WFTC) reform. Some parameters, like the effects of the 1999 WFTC reform presented in subsection 6.3, also demand the use of simulations under a policy regime operating after October 1999, after the WFTC reform. We use the policy regime operating in April 2002 for comparability with the empirical literature. When unexpected changes in the environment are required to produce some parameters, like the elasticities in subsection 6.2 or the WFTC effects in subsection 6.3, these are introduced as if unannounced at randomly drawn ages during the working life. Education responses are excluded in all case.

6.1 Employment

The life-cycle profile of employment rates are displayed in figures 3 and 4.

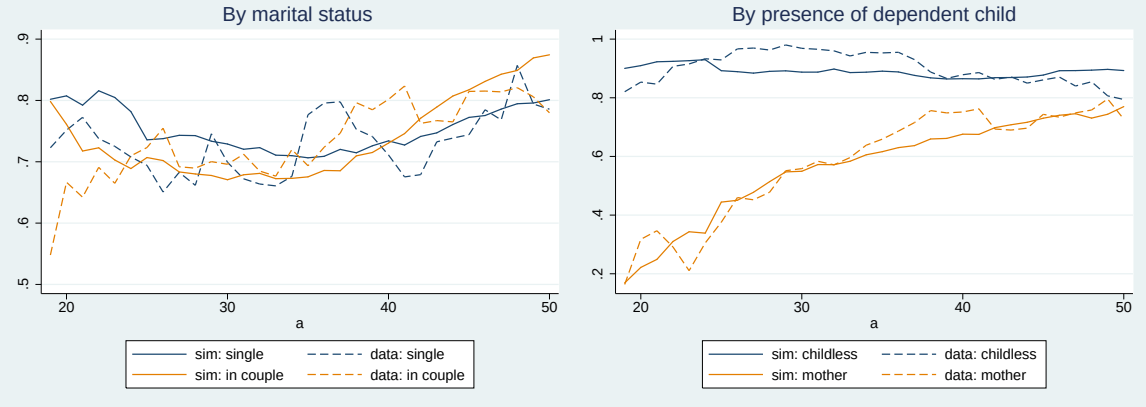
Figure 3 confirms the well known fact that employment rates increase with education. It also reveals that employment profiles are U-shaped irrespective of education, although the dip occurs earlier and is more pronounced for lower levels of education. This profile reflects the impact of child bearing on labour supply, especially during the child's early years, and the lower labour market

Figure 3: Women employment rates over the life-cycle



Notes: In the legend, 'sim' stands for simulated data, 'data' stands for real data, 'educ=1' (or 2,3) represents basic, secondary and university education levels.

Figure 4: Women employment rates over the life-cycle



Notes: In the legend, 'sim' stands for simulated data and 'data' stands for real data.

attachment among lower-educated women. There are several features of the model that formalise 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

and low-distaste-for-working 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 4. Marital status seems to have only mild effects of employment probabilities, and this is reflected in the simulated profiles. In contrast, the impact of a dependent child on labour supply is very significant and decreasing with woman's age as the average age of children increases. In the absence of a dependent child, labour supply remains constant with women's age. Both these features are reproduced in the simulations.

Table 7: Employment rates: part-time, full-time and all employment; data and simulated moments

	data moments			simulation moments		
	part-time	full-time	all	part-time	full-time	all
	(1)	(2)	(3)	(4)	(5)	(6)
By education						
(1) basic	0.19	0.49	0.67	0.19	0.45	0.65
(2) secondary	0.14	0.67	0.81	0.15	0.63	0.78
(3) university	0.09	0.78	0.88	0.05	0.83	0.88
By marital status						
(4) single	0.09	0.64	0.73	0.10	0.65	0.75
(5) in couple	0.19	0.55	0.74	0.19	0.55	0.75
By presence of child						
(6) no child	0.08	0.80	0.88	0.08	0.78	0.87
(7) dependent child	0.24	0.37	0.61	0.24	0.36	0.60
(8) all	0.16	0.57	0.74	0.15	0.59	0.75

Table 7 decomposes employment rates by working hours interacted with education level (rows (1) to (3)), marital status (row (4) and (5)) and presence of dependent child (rows 6) and (7)). Although in most cases the correspondence is close, the model overstates the choice of full-time employment against part-time employment among university graduates while understating full-time employment for lower educated woman. By family composition the match is very close.

6.2 Elasticities of labour supply

The elasticity of labour supply with respect to the wage measures the sensitivity of labour supply to small changes in incentives. It is thus an important, although insufficient, and standard parameter to understand and predict the effects of policies that alter the payoff to work. However, the concept is ambiguous as there are many alternative measures of wage elasticity of labour supply (see Blundell and MaCurdy, 1999, or Meghir and Phillips, 2010, for extensive discussions of alternative wage elasticities and their appropriateness for policy evaluation). *First*, it can be defined with respect to working hours or participation to study responses on the intensive and extensive margins, respectively (see Saez, 2002, and Brewer, Saez and Shephard, 2010). *Second*, it depends on whether inter-temporal considerations are being accounted for. And *third*, it depends on what is being held constant. In a static model, it is most common to hold constant utility (Hicksian elasticity) or non-labour income (Marshallian elasticity). In inter-temporal formulations, similar concepts could be defined depending on whether within-period or life-cycle variables are kept constant. The most frequently defined intertemporal wage elasticity of labour supply holds constant the marginal utility of wealth (Frisch elasticity), thus quantifying responses to anticipated changes in wages. This is not the most useful concept for policy evaluation in an intertemporal framework as most interventions arrive unannounced and may affect the wage profiles for some (possibly long and partly) predictable length of time. An alternative intertemporal wage elasticity quantifies the relative responses to unexpected shifts in wage profiles, adding wealth effects (from unanticipated wage changes) to the Frisch elasticity. Thus, it is expected to be smaller than the Frisch elasticity if leisure is a normal good, although the difference will depend on the duration of the shift and may depend on age.

We adopt the latter concept and simulate changes in behaviour in responses to a temporary (1 period only) and a permanent (for the rest of life) unexpected 1% increase in net wages. Simulated wage elasticities of labour supply are presented in table 8. Columns (1) and (2) show results for the transitory change during the period the wage is higher. Columns (3) to (6) show the results for the unexpected shift in life-cycle wages, first on the period the shift occurs (columns (3) and (4)) and then on all the life-cycle after the shift (columns (5) and (6)).

The simulated set of elasticities display some reasonable patterns. Results in columns (1) and (2), for the transitory change in wage, are always higher than those in columns (3) and (4), for the permanent shift, as wealth effects are more important for the latter. Participation is more elastic than hours, a result that is common in the empirical literature (see the survey of participation and hours elasticities in Meghir and Phillips, 2010). Mothers are more responsive to changes in net wages

Table 8: Wage elasticities of labour supply: simulations of unexpected changes in wages

		Effect in period wage changes				LC effect	
		transitory shift		permanent shift		permanent shift	
		participation	hours	participation	hours	participation	hours
		(1)	(2)	(3)	(4)	(5)	(6)
Single women							
(1)	all	0.62	0.06	0.39	0.05	0.54	0.05
(2)	no children	0.47	0.00	0.29	0.00	0.42	-0.03
(3)	mothers	1.04	0.31	0.69	0.25	0.93	0.38
Women in couples							
(4)	all	0.53	0.42	0.47	0.19	0.26	0.25
(5)	no children	0.40	0.28	0.40	0.11	0.16	0.19
(6)	mothers	0.71	0.70	0.57	0.36	0.47	0.40
By age when wage changes							
(7)	29 or less	0.75	0.36	0.75	0.18	0.50	0.19
(8)	30 to 39	0.69	0.30	0.48	0.20	0.26	0.21
(9)	40 to 49	0.48	0.30	0.34	0.17	0.16	0.15
(10)	50 plus	0.31	0.09	0.15	0.00	0.13	0.08
(11)	all	0.57	0.27	0.44	0.18	0.34	0.18
(12)	low educated	0.93	0.50	0.73	0.21	0.46	0.19

Notes: All values represent the percentual change in labour supply in response to a unexpected 1% increase in net earnings. Columns (1) to (4) contain the contemporaneous responses, in the period the change in wages occurs. Columns (1) and (2) refer to a transitory change, only to be happening in that period; columns (3) and (4) refer to a permanent change, to be affecting working individuals for the remaining of their life. In both cases, individuals are aware of the nature of the change. Columns (5) and (6) contain the responses during the whole life after the change occurs for a permanent shift in wages. Columns (1), (3) and (5) display participation elasticities (extensive margin) while columns (2), (4) an (6) display hours elasticities (intensive margin) where two points are considered, 20 and 40 hours per week corresponding to part- and full-time employment.

than women with no children, another typical result in the empirical literature (see Blundell, Meghir and Neves, 1993, or Blundell, Duncan and Meghir, 1998). The labour supply of younger women is more elastic than that of older, 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.

There is a vast empirical literature on wage elasticities for women reaching a wide range of results. Most of the estimates are for uncompensated (Marshallian) elasticities, relying on static models. Most intertemporal estimates are of Frisch elasticities (one notable exception being Pistaferri, 2003, but with results for males only). Frisch elasticities should be larger than the simulated elasticities in table 8 but relatively close to the values in columns (1) and (2). Estimates reported in Blundell, Meghir and Neves (1993) for the wage elasticity of hours work among married women in the UK are 0.58 and in the range of 0.8-1.22 for women with no children and mothers, respectively. These compare with our predictions of 0.28 and 0.70 (column (2), rows (5) and (6) respectively), lower but in reasonable proximity. Within a static framework, Blundell, Duncan and Meghir (1992) suggest a wage elasticity of hours work among lone mothers of 0.34 and Brewer et al. (2006) estimate the participation elasticity for lone mothers to be 1.02 (both studies on UK data). Our simulations for the more similar case of a transitory change in wages are 0.31 and 1.04 (row (3), columns (2) and (1)), very close to the empirical results.

6.3 The impact of the WFTC reform

A few empirical studies estimate the impact of the WFTC reform in 1999 on female employment rates. We now compare our simulated predictions to some of the more sound empirical estimates. Table 9 displays the results.

All parameters in the table are based on data up to 2002 and represent the impact of the reform up to 3 years after its introduction. Estimates in rows (2) and (3) are based on reduced form empirical evaluation models. Estimates in rows (3) and (4) are based on a structural static labour supply and programme participation model capable of separating the effects of WFTC from other reforms occurring around the same time. The parameters in row (4) represent the effect of the WFTC alone while the parameters in row (5) represent the combined effect of WFTC and other reforms occurring up to 2002. The latter are comparable with estimates in rows (2) and (3). Simulations in row (1) are for the 3 first years after an unexpected reform putting together the WFTC and other tax reforms introduced in the UK between 1999 and 2002.

The simulations seem to capture the impact on lone mothers quite accurately but overstate the response on married women, independently of whether the partner is working or not. As a result, our predictions are of a more pronounced negative effect of the reform on employment participation among women in couples.

Table 9: The impact of WFTC reform on employment: simulated versus empirical literature results

		lone	married mothers		
		mothers	all	partner working	partner not working
		(1)	(2)	(3)	(4)
(1)	simulations	+4.4%	-2.0%	-3.0%	+4.1%
(2)	BBS, 2005	+3.6%		-0.1%	+2.6%
(3)	FRK, 2009		+0.7%*	+0.1-0.6%*	3.1%
(4)	BDSS, 2006	+5.0%	-0.5%		
(5)	BDSS, 2006 (combined)	+3.7%	-0.4%		

Notes: BBS, 2005 stands for Blundell, Brewer and Shephard, 2005. BDSS, 2006 stands for Brewer, Duncan, Shephard and Suarez, 2006. FRK, 2009 stands for Francesconi, Rainer and Van Der Klaauw, 2009. Estimates in row (4) are for WFTC alone; estimates in row (5) are the combined effects of WFTC and other reforms occurring up to 2002. The latter are comparable with estimates in rows (2) and (3). Row (1) shows simulations based on the model discussed in this paper and effects are for first three years after unexpected change of tax regime amounting to the reforms occurring between April 199 and April 2002.

* Statistical insignificant estimate at standard levels.

7 Policy experiments

A rich structural labour supply model can be a very useful tool for policy evaluation. In this section we will use our model to gain further insight on the effects of two major tax reforms, the 1999 Working Families Tax Credit (WFTC) and the 2003 Working Tax Credit and Child Tax Credit (WTC/CTC). We simulate the entire women's life-cycle at three moments in time, April 1999, 2002 and 2004, when the tax credits regime were the Family Credit (FC), the WFTC and the WTC/CTC. As before, we use initial conditions from the BHPS. The identified effects represent long-run, life-cycle responses. In what follows, we start by describing how the policy regimes affect working incentives for some selected cases and will then discuss the simulated effects on employment, income and education decisions.

7.1 The three regimes: FC, WFTC and WTC/CTC

For the purposes of this exercise, we will be comparing three tax regimes operating in the UK in April 1999, 2002 and 2004 and representing tax credit periods under Family Credit (FC, pre October 1999), Working Family Tax Credit (WFTC, October 1999 to March 203) and the combination of

Working Tax Credit and Child Tax Credit (WTC/CTC, April 2003 onwards).[4] The three regimes are very similar, the main changes having amounted to make awards more generous, available higher up in the income distribution and to an increasing variety of families, including working families with no children (WTC) and non-working families with children (CTC).

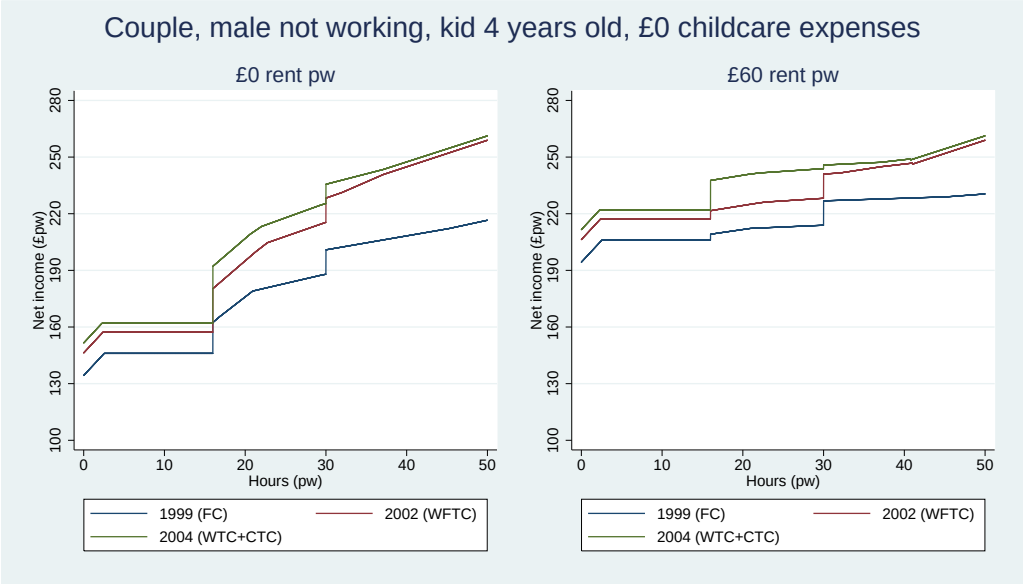
Previous studies have highlighted the heterogeneous nature of the impact of these reforms, depending in particular on family circumstances, and the possible interaction and accumulation with other existing taxes and benefits (Brewer, Saez and Shephard, 2010). In here we will pay especial attention to Housing Benefit (HB), a large means-tested rental subsidy programme potentially affecting the same families that are eligible to tax credits. HB may cover up to 100% of the cost of renting for low income families in Income Support (IS) or Job Seeker's Allowance (JSA) living in rented accommodation. Once eligibility to IS/JSA has been exhausted, the withdrawal rate is high (65% on net income). A similar means-tested benefit, the Council Tax Benefit (CTB), is available to those eligible to HB and is tapered at 20%. Eligible groups for HB/CTB face strong working disincentives that the WFTC or WTC/CTC reforms do not resolve.

To illustrate the (contemporaneous) costs of working for some groups, figure 5 plots the profiles of net weekly income by woman's working hours for a couple with a non-working man and one dependent child (woman earns £4.6 per hour). Whether or not the family rents their accommodation, the WFTC and WTC/CTC reforms significantly shift this family's budget constraint upwards, but in the case of a positive rent the profile is very flat in all regimes and has not improved over time. The discontinuity at 16 hours in 2004 may lead some otherwise unemployed individuals to move into part-time work but the large marginal tax rates imposed over extra earnings from then onwards will probably inhibit any further work. On the other hand, the increased non-labour income in both 2002 and 2004 may lead some otherwise employed individuals to drop work. By comparison, the incentives towards work of families living in non-rented accommodation have improved much more substantially over time. Not only the subsidies became gradually more generous, particularly between 1999 and 2002, the marginal tax rate for workers above 16 hours per week has also been reduced as a consequence of a drop in the tax credit taper rate. Given the wage elasticities discussed in subsection 6.2, positive participation and hours responses can be expected for this group. Lone parents face a set of very similar budget constraints.

Another group strongly affected by the HB/CTB is that of childless couples with a non-working man. Figure 6 illustrates this case. For couples renting accommodation the phasing out of HB and

[4]See section 2 and references therein for details on the tax system.

Figure 5: Net income per week by tax regime



Notes: Woman earns £4.6 per hour. Fortax simulations.

CTB removes any gains from working in 1999 or 2002 regimes. The 2004 regime extended tax credits to families with no children, introducing some positive incentive (although small for families in rented accommodation) for full-time work.

For other groups, the type of accommodation is irrelevant for the woman's working incentives. Figure 7 shows such a case, for a couple with one child where the man is working full-time. Increased generosity and enlargement of phasing out regions meant the WFTC regime reduced the gains from working and the incentive to work more hours for this group. The incentives to work were not as affected by the WTC/CTC reform, at least in what concerns to part-time work as the added generosity of this regime meant the phasing-out of tax-credits happens higher up in the distribution of income.

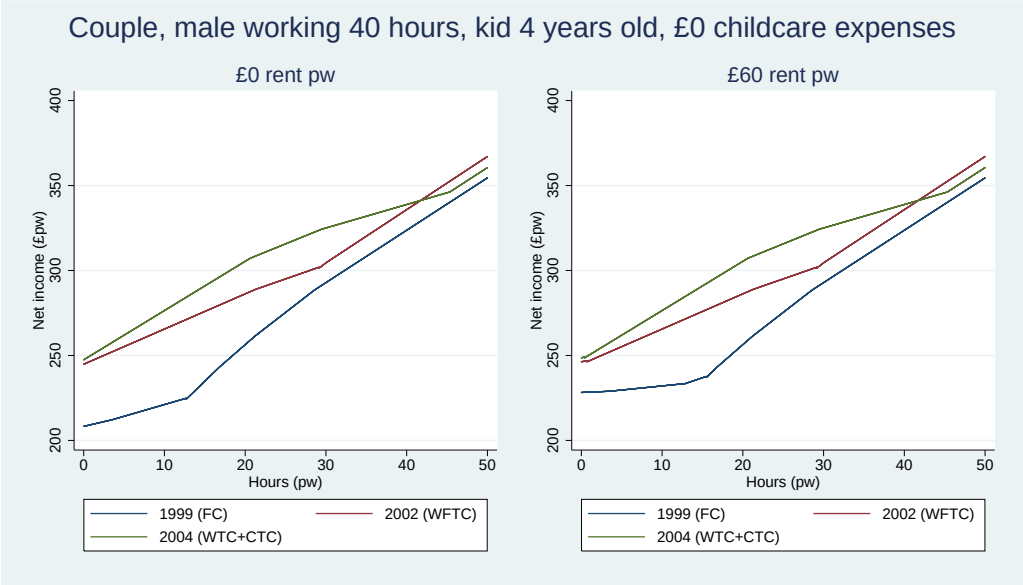
7.2 Effects on labour supply

Table 10 shows the simulated effects on employment rates of the April 2002 and April 2004 tax regimes as compared the pre-WFTC regime in April 1999 (FC). These are long-run effects, representing life-

Figure 6: Net income per week by tax regime

Notes: Woman earns £4.6 per hour. Fortax simulations.

Figure 7: Net income per week by tax regime



Notes: Man and woman both earn £4.6 per hour. Fortax simulations.

cycle changes in labour supply. Only responses in education take-up are excluded. The parameters in this table do not necessarily match those reported in table 9 (notably the impact of WFTC for single mothers), which measure employment responses in the first 3 years after an unexpected change in regime occurring at a randomly drawn age.

Table 10: The impact of the WFTC and WTC/CTC reforms on employment

		Single women		Women in couples	
		no child	1 child	no child	1 child
		(1)	(2)	(3)	(4)
Effects of WFTC reform on employment rates					
(1)	no rented accommodation	1.1%	9.6%	0.1%	-2.3%
(2)	rented accommodation	0.5%	0.6%	0.1%	-2.4%
(3)	all	1.0%	5.0%	0.1%	-2.3%
(4)	all unskilled	1.2%	4.8%	0.2%	-3.6%
Effects of WFTC reform on full-time employment rates					
(5)	all	1.0%	0.4%	0.4%	-1.4%
(6)	all unskilled	1.2%	0.2%	0.6%	-1.7%
Effects of WTC/CTC reform on employment rates					
(7)	no rented accommodation	7.8%	9.2%	0.6%	0.0%
(8)	rented accommodation	1.7%	0.0%	-0.6%	0.5%
(9)	all	5.8%	5.1%	0.5%	0.1%
(10)	all unskilled	7.5%	4.6%	0.6%	-0.4%
Effects of WTC/CTC reform on full-time employment rates					
(11)	all	5.8%	-2.8%	-0.1%	-4.5%
(12)	all unskilled	7.4%	-1.6%	-0.2%	-5.2%

Notes: All values presented and percentual point changes in employment rates (rows (1)-(4)) and full-time employment rates (rows (5), (6), (11) and (12)). Simulations in rows (1) and (7) under the assumption that no rent is paid by the family for their accommodation. Simulations in rows (3) and (8) under the assumption that the family pays £60 a week in rent. Simulations in rows (3)-(6) and (9)-(12) are weighted averages of effects per woman's education and type of accommodation for each family type; weights represent the frequency of each groups in BHPS data (waves 1991-1998).

The figures in table 10 show the large heterogeneity in responses to both policy scenarios as compared to FC. Single mothers, a major target group in the WFTC reform, increase labour supply very significantly if living in non-rented accommodation in response to the positive working incentives

introduced with the WFTC reform (column (2), row (1)). However, the phasing out of HB drains most of the positive incentives if women live in renting accommodation (column (2), row (2)). The same holds true for the WTC/CTC reform (column (2), rows (7) and (8)). The responses of unskilled women are in the same range of values as those for other education groups (column (2), rows (4) and (10)). This happens despite their response being much stronger if living in non-rented accommodation (almost 15% in both regimes), and is a consequence of the disproportionately high rate of families in rented accommodation in this group.

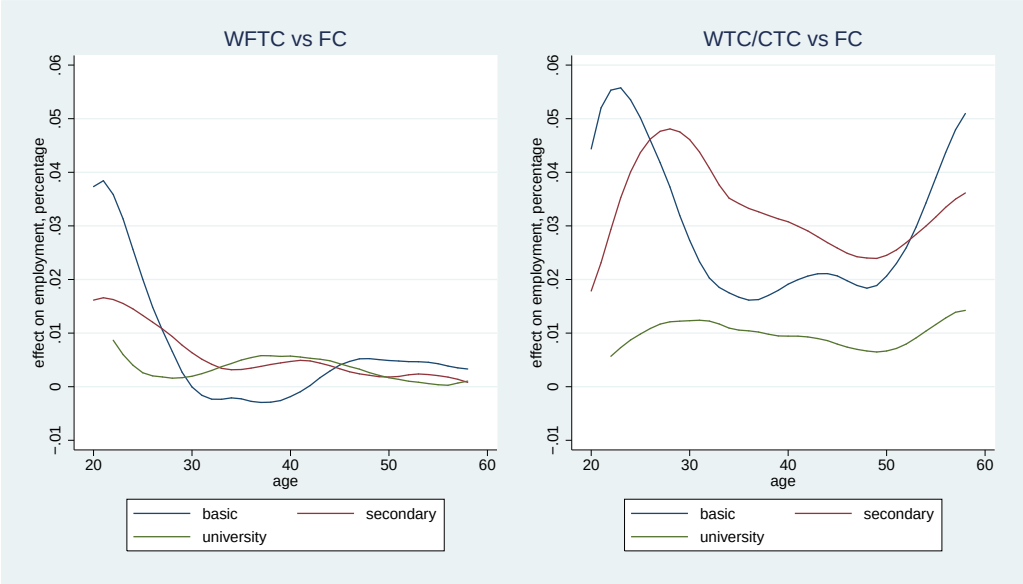
The extension of tax credits to childless families held positive labour supply returns for single women under WTC/CTC (column (1), rows (7) and (8)). On the other hand, the much smaller but positive effects of WFTC for single childless women are the consequence of two processes (column (1), rows (1)-(3)). *First*, the dynamics of human capital accumulation, leading mostly to responses in anticipation of expected future gains, when eventually becoming a mother. And *second*, some reallocation of working over time to compensate for expected higher working costs, again when eventually becoming a mother, if living in rented accommodation.

Simulated WFTC responses among married women are strongly negative (column (4), rows (1) to (3)). This result is driven by the behaviour of women in couples where the male is working, the vast majority of cases in this category, in which case the WFTC reform reduced the gains from a second working adult in the tax credit's phasing out region. As predicted by inspection of graph 7, the WTC/CTC reduced the negative impact of WFTC on employment rates (column (4), rows (7)-(9)) but had a large negative effect of full-time work (column (4), row (11)).

Figure 8 illustrates the employment responses over the life-cycle by education and policy regime (as compared to FC). Responses to the WTC/CTC regime are higher at most stages of the life-cycle among low to medium educated individuals. In both graphs, there is a large variation of average resposes over the life-cycle for this group. In particular, the lowest educated women respond little to the increased incentives during childbearing years due to their interaction with family composition and accommodation type. Responses to WTC/CTC are more consistently positive for medium educated women over life, as these are less vulnerable to the disincentives of the HB phasing-out region. As expected, higher educated women are hardly affected by any of the reforms.

Table 11 presents the simulated effects of WFTC and WTC/CTC on life-cycle employment, income and education decisions. Life-cycle changes in labour supply are modest under the WFTC regime (and this is also true conditional on housing type) suggesting most of the effects identified earlier are reallocations of labour supply across life-cycle periods in response to differential changes in

Figure 8: Changes in employment rates over the life-cycle by education



Notes: Simulations keep education investment constant across policy regimes.

incentives by age (rows (1) and (2), columns (1) to (3)). WTC/CTC yields more important life-cycle effects on employment in response to extended improved working incentives for larger parts of the life-cycle (row (1), columns (4) to (6)). Most of the changes are absorbed by part-time employment given the comparatively high payoffs to this type of work among mothers.

The small effects of WFTC and WTC/CTC on lifetime gross earned income (row (3)) are consistent with the limited impact these reforms have had in total employment, particularly on a full-time basis. On the contrary, net income has been much more importantly affected (row (4)), a consequence of the strong changes in net tax liability particularly among the less educated and reflecting a strong shift of resources towards lower income families on a lifetime perspective. Figure 9 shows how income has changed over the life-cycle by education. Clearly, the policies are also responsible for a strong relative shift of income towards the beginning of the life-cycle among the low to medium educated women, when liquidity constraints are expected to be more relevant.

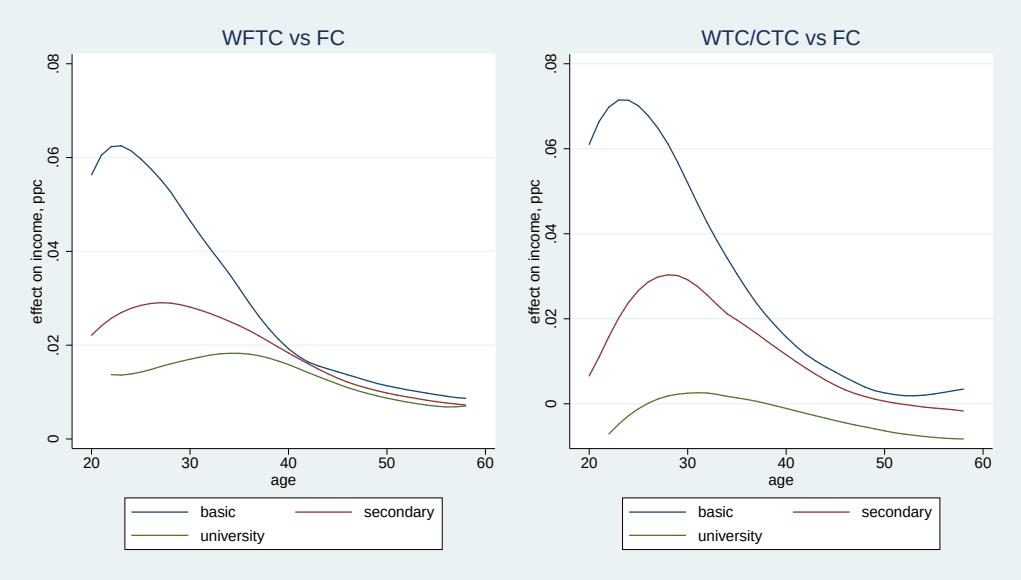
Row (6) of table 11 displays modest education responses. Notwithstanding, the simulations predict the take-up of university education to be reduced by almost 1% in response to the WTC/CTC reform. Preliminary inspection of the BHPS suggests that this result is not at odds with data on university graduation rates but this matter needs further investigation.

Table 11: The impact of the WFTC and WTC/CTC reforms on LC family income and education

	Effects of WFTC by education			Effects of WTC/CTC by education		
	basic	secondary	university	basic	secondary	university
	(1)	(2)	(3)	(4)	(5)	(6)
Effects of WFTC						
(1) LC employment	+0.8%	+0.6%	+0.3%	+3.1%	+3.2%	+1.0%
(2) LC full-time employment	+0.1%	+0.0%	+0.4%	-0.2%	+0.7%	+0.3%
(3) LC gross income	+0.1%	0.0%	+0.1%	+0.1%	+0.2%	0.0%
(4) LC net income	+2.5%	+1.6%	+1.2%	+2.2%	+0.9%	-0.3%
(5) LC tax liability	-14.1%	-5.5%	-2.8%	-12.5%	-1.9%	+1.0%
(6) education	+0.8%	-0.3%	-0.5%	+1.2%	-0.3%	-0.9%

Notes: Values in rows (3) to (5) are percentage change in cumulated LC variables when education investments are kept unaltered over policy regimes. Values in rows (1), (2) and (6) are percentual point change in education rates. LC stands for 'life-cycle'. Income and taxes are measured at the family level.

Figure 9: Changes in family net income over the life-cycle by education



Notes: Simulations keep education investment constant across policy regimes.

8 Conclusions

This model proposes a life-cycle model of women's labour supply, human capital formation and savings for policy evaluation. Decisions are taken in an uncertain dynamic environment under credit constraints. The model includes important features not yet considered together in the literature. First, the dynamic process of family formation is explicitly accounted for. And second, a detailed description of the policy environment is used to accurately determine net earnings by employment status. The model is calibrated on a large set of data moments from the nineties under a policy environment reproducing the April 1999 regime. Many important empirical features are closely reproduced, including the empirically estimated short-run effects of the WFTC reform on employment rates. Simulations are then used to study the impact of WFTC and WTC/CTC on women employment, family income and education decisions.

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Appendix A: Exogenously set parameters

Tables 12 to 16 present the exogenously determined parameters. The estimation of male's employment and earnings equations uses a parametric selection model (see Heckman, 1978 and 1979).

Table 12: Exogenously set parameters: prices and preferences

		parameter
(1)	Interest, R	1.015
(2)	Discount factor, β	0.98
(3)	Curvature in utility of consumption, μ	-0.56
(4)	University fees, T	£19.2 per week
(5)	Hourly childcare price, to determine C^k	£2.04

Notes: University fees payable for three years, parameters in row (4) thus correspond to a total fee of £3,000 for a 3-year degree.

Table 13: Exogenously set parameters: probabilities of child bearing

		Woman's education		
		basic	secondary	university
Single women				
(1)	intercept	0.174	0.032	-0.011
(2)	age	-0.045	-0.006	0.007
(3)	age squared	0.000	0.000	0.000
Married women				
(4)	intercept	-0.098	-0.412	-2.116
(5)	age	0.246	0.372	1.414
(6)	age squared	-0.051	-0.062	-0.216

Notes: parametric specification: quadratic polynomial in age. Age is divided by 10.

Table 14: Exogenously set parameters: probabilities of partnering and separation

		Partnering		Separation
		no child	child	all
(1)	intercept	0.056	0.243	0.234
(2)	age	0.025	-0.047	-0.090
(3)	age squared	-0.006	0.000	0.009

Notes: parametric specification: quadratic polynomial in age. Age is divided by 10.

Table 15: Exogenously set parameters: Distribution of man's education in new couples

		Man's education		
		basic	secondary	university
No child, by woman's education				
(1)	basic	0.58	0.39	0.03
(2)	secondary	0.34	0.51	0.15
(3)	university	0.10	0.34	0.55
Child, by woman's education				
(4)	basic	0.54	0.40	0.06
(5)	secondary	0.31	0.51	0.19
(6)	university	0.14	0.32	0.55

Table 16: Exogenously set parameters: Employment probability and earning equation of men in couples

		Man's education		
		basic	secondary	university
Employment probabilities				
(1)	new couples	0.75	0.88	0.85
(2)	ongoing couples: intercept	-0.94	-0.50	-0.25
(3)	ongoing couples: previously employed	2.71	2.47	2.37
Log wage equation				
(4)	intercept	1.72	1.83	1.79
(5)	log woman's age	0.05	0.12	0.25
(6)	dispersion productivity (new couples)	0.40	0.40	0.40
(6)	dispersion innovation in productivity (ongoing couples)	0.07	0.07	0.07

Notes: Parameters in rows (2) and (3) and coefficients from probit regression on dummy for previous man's employment status in ongoing couples.