Design and long-term effects of in-work benefits

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Abstract

In-work benefits are an increasingly popular means of transferring income towards the less well-off without compromising work incentives. In this paper, we develop an evaluation framework that includes a full characterisation of the tax system and explicitly considers the role of: (i) contemporaneous incentives to work, (ii) anticipatory effects on the value of education and (iii) future consequences for employment through human capital accumulation. We model women's decisions within a risky environment, explicitly allowing for family dynamics. We estimate our model on British BHPS data and use this to simulate recent policy changes in the UK.

1 Introduction

In-work benefits have gradually gained attention over the last 20 years. They have been introduced in a few 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.

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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. (2007) 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 experiemental 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. Our analysis is centred on women as they are more responsive to changes in working incentives and transfer mechanisms. 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. Reactions in anticipation to being directly affected by a new policy may accentuate its effects. This is the case of changes in education decisions driven by expected changes in its returns induced by the alterations in 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 the sources of change in working incentives introduced by transfer schemes: (*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. 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 6.

In what follows, section 2 discusses the model, section 3 describes the data used for estimation, section 4 discusses the two main identification problems, leaving a full description of the estimation procedure and choice of moments to Appendix B, section 5 presents estimates of the structural parameters, section 6 describes the UK transfer system and how it has changed over the past 20 years, section 7 contains a description of the experiments we run and simulated results, and finally section 8 draws some conclusions.

2 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.

2.1 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. We formalise the idiosyncratic direct monetary costs of education to depend on initial individual and parental assets. Other costs include foregone earnings and (dis)taste for education.

Upon completion of education, the woman moves into the working life. This is an absorbent 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 working, 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 is an absorbent state, arising with perfect certainty at the age of 60. 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.

Education, employment and savings decisions are optimal from the perspective of an inter-temporal problem. The decision process is embedded in a rich context characterised by contemporaneous costs and possible restrictions, contemporaneous and long-lasting returns, other dynamic elements that may affect returns, uncertainty and a detailed policy environment.

An important determinant of education and labour supply decisions is the dynamics of family composition. While generally absent from the discussion of men's education and working life, 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.

We consider two forms of income uncertainty, both affecting the returns from human capital investments. One is the stochastic process of family composition. The second source of uncertainty is described by unpredictable productivity changes capturing, say, health status. It is directly transmitted into earnings and may lead to job loss.

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. They include age, education, working experience, employment status, savings (pooled in couples) and family composition variables, all observable, as well as productivity levels and preferences for working and education, considered unverifiable by third parties.

The chances of future adversity generate precautionary behaviour and a demand for insurance. However, imperfect observability of individual characteristics and choices 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.

As should be clear by now, 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 is also an 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 increases the likelihood 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 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.

We reproduce the UK personal tax and benefits system, 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 now formally detail the elements of the model.

2.2 State Space

We split the state space into three parts. The first, X_{iat}, contains the observed idiosyncratic information for a woman i aged a at time t. The second, Ω_{iat} contains the unobserved idiosyncratic information for the same woman and time. And the third, Π_t, contains information on aggregate prices and transfer mechanisms at time t.

X contains observable information on the woman's education, experience and previous activity, presence of a partner, his education, experience and previous employment status, presence of a child and her age, family savings and parents' assets when she was 17.

Ω contains information on the woman's and man's (if present) productivity levels and preferences for working.

Π contains information on women's and men's 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 $(^m, ^k, ^p)$ to denote the man's, child's and parents' 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 for simplicity of notation. Capital letters are reserved to denote prices, vectors or matrices and functions. Greek letters are used to represent unobserved information and model parameters.

2.3 Family composition

Family composition varies exogenously over time. Two types of changes may occur: (i) arrival or departure of a 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, X_{ia}. More specifically:

$$\mathrm{P}\left(d_{ia}^k = 1 | d_{ia-1}^k = 0, X_{ia-1}\right) = \mathrm{P}\left(d_{ia}^k = 1 | d_{ia-1}^k = 0, a, s_i, d_{ia-1}^m, l_{ia-1}^m\right) \tag{1}$$

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

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 is age, s is female education, l^m is a dummy representing the partner's working status and a^k is age of the child.

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

$$a_{ia}^k = a_{ia-1}^k + 1. \tag{3}$$

The men's problem is viewed from the women's perspective and thus partly depends on her characteristics. He is characterised by three features: educational attainment, s^m, employment status, l^m, and earnings if employed w^m. The odds of a woman finding a man (s^m, l^m, w^m) depends on X:

$$
\begin{aligned}
&\mathrm{P}\left[s^m_{ia}, l^m_{ia}, w^m_{ia} \left| d^m_{ia-1} = 0, X_{ia-1}\right.\right] = \\
&\qquad \mathrm{P}\left[s^m_{ia} \left| d^m_{ia-1} = 0, X_{ia-1}\right.\right] \mathrm{P}\left[l^m_{ia} \left| d^m_{ia-1} = 0, s^m_{ia}, X_{ia-1}\right.\right] f_{w^m|.}\left(w^m_{ia} \left| d^m_{ia-1} = 0, s^m_{ia}, l^m_{ia}, X_{ia-1}\right.\right)
\end{aligned}
$$

where the first term after the equals sign 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 density of his productivity level. We further assume that the chances of finding a man of education s^m depends on the woman's age, education and whether she has a child:

$$
\mathrm{P}\left[s^m_{ia} \left| d^m_{ia-1} = 0, X_{ia-1}\right.\right] = \mathrm{P}\left[s^m_{ia} \left| d^m_{ia-1} = 0, a, s_i, d^k_{ia-1}, a^k_{ia-1}\right.\right]. \tag{4}
$$

Men are either in full time employment or unemployed, corresponding to l^m being 40 or 0 hours per week, respectively. The employment status and earnings distribution of a newly wed man depend on the characteristics of his spouse. We assume that, conditional on his education, only the woman's age is correlated with employment status and earnings,

$$
\mathrm{P}\left[l^m_{ia} = 40 \left| d^m_{ia-1} = 0, s^m_{ia}, X_{ia}\right.\right] = \mathrm{P}\left[\nu^m_{ia} > H_0\left(a, s^m_{ia}\right)\right] \tag{5}
$$

$$
\ln w^m_{ia} = \ln W^m_{s^m} + \alpha^m_{s^m} \ln(a) + \upsilon^m_{s^m ia} \tag{6}
$$

(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 his returns to experience by education s^m, and $\upsilon^m_{s^m}$ is his idiosyncratic productivity level, with a distribution that again varies with s^m.

The probability of a man leaving depends on the family's characteristics,

$$
\mathrm{P}\left[d^m_{ia} = 0 \left| d^m_{ia-1} = 1, X_{ia-1}\right.\right] = \mathrm{P}\left[d^m_{ia} = 0 \left| d^m_{ia-1} = 1, s^m_{ia-1}, a, s_i, d^k_{ia-1}, a^k_{ia-1}\right.\right]. \tag{7}
$$

2.4 Men's employment and earnings in ongoing couples

Men's employment and earnings are formalised as a reduced form selection model similar to the working selection model described for newly matched men. We allow for persistence in employment status and productivity as follows,

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

H_1 represents the explained part of the working decision, a function of previous employment status. Unobserved productivity, $\upsilon^m_{s^m}$, may be related to preferences for working, ν^m. $\upsilon^m_{s^m}$ 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.

2.5 Women's earnings

Women's earnings follow a dynamic process similar to that of men except that work experience is followed for her:

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

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.

2.6 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 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 discounted value of present and future life-time utility, β is the discount rate and U is the current flow of utility, a function of 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 hours of work 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, θ is the woman's taste type or her permanent preferences for staying out of unemployment, both in work or studying, and ν_l is the transitory taste for activity l, normalised to zero for unemployment. The function $\widetilde{U}$ is the utility cost of working as determined 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 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 R is the risk-free interest rate and y is net family income. Families are assumed to be credit constrained during their working period but borrowing is considered during education time to cover fees. Borrowing constraints are most important among low income families with high incidence of unemployment,

$$k_{ia+1} \geqslant \min\{0, Rk_{ia}\}.$$

Family income is determined by female and male employment status and earnings together with current taxes and benefits. An important source of working costs is childcare. 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. Formally,

$$\begin{aligned} y_{ia} &= l_{ia} w_{ia} + d_a^m \left[l_{ia}^m w_{ia}^m \right] \\ &- T\left(a_i, l_{ia}, w_{ia}, d_{ia}^m, l_{ia}^m, w_{ia}^m, d_{ia}^k, a_{ia}^k, C_{ia}^k\left(a_{ia}^k\right)\right) \\ &- C_{ia}^k\left(a_{ia}^k\right) \end{aligned}$$

where T is the family's tax liability (net of benefits), which is designed to reproduce closely the UK's transfer system. C^k is childcare costs, the total being proportional to the woman's working hours and a function of the child's age. The woman's earnings process is defined in equation (9). The man's working income is determined by the selection model (5)-(6) for newly matched men or (8) for men in on-going couples.

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

$$e_{ia+1} = e_{ia} + \mathbf{1}\left(l_{ia} = F\right) + \lambda_P \mathbf{1}\left(l_{ia} = P\right) - \lambda_U \mathbf{1}\left(l_{ia} = U\right) e_{ia} \tag{13}$$

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

The optimisation problem is also subject to the *dynamics of family formation* as described in equations (1), (2), (4) and (7).

Finally, the terminal condition is

$$k_{i60} \quad > \quad 0$$

while initial conditions are specified below with the educational decisions.

2.7 Women's education

We consider three levels of education, basic ($s = 1$), secondary ($s = 2$) and university ($s = 3$), completed at 16, 18 and 21 years of age respectively. Investments in education are decided upon just before the woman turns 17. Adult, independent life starts at the age of 19. In the model, this is when the young adult starts taking responsability for her costs of living. Working life starts at 19 for those not enrolling into university education, or 22 for university graduates. It is an absorbing state: the model does not contemplate the possibility of moving back into education. 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 woman turning 17. It includes parental background, measured by parental assets (k^p), individual assets (k), permanent taste type (θ), specific taste for education of level s (ϖ_s) and an idiosyncratic monetary component of assets at entrance into working life with education s, (ϵ_s).

At the moment of making her education choice, the woman is perfectly informed about its direct monetary and utility cost. She knows her level of assets at entrance into the working life, a combination of assets owned at 17, parental transfers as a function of their own assets, education investments and an idiosyncratic component ϵ_s. She also knows her preferences for studying as compared with other activities. But she has 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 is revealed once she enters the labour market, at 19 or 22 depending on education achievement.

Designate by V_s the expected value of education s. Thus,

$$V_{si}\left(k_i^p, k_{i17}, \theta_i, \varpi_{si}, \epsilon_{si}\right) = \mathrm{E}\left[V_{i19}\left(X_{i19}, \Omega_{i19}, \Pi\right)|k_i^p, k_{i17}, \theta_i, \epsilon_{si}, s_i\right] + \varpi_{si}$$

For $s = 1, 2$, 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 the working life for $s_i = s$ are,

$$\begin{aligned} k_{i19} &= K_s\left(k_i^p, k_{17}\right) + \epsilon_{si} \\ e_{i19} &= 0 \\ d_{i18}^m &= 0 \\ d_{i18}^k &= 0 \\ o_{i19} &\perp \left(\theta_i, \varpi_{si}, \epsilon_{si}\right) \\ \nu_{i19} &\perp \left(\theta_i, \varpi_{si}, \epsilon_{si}\right) \\ \upsilon_{si19} & \quad \text{correlated with } \theta \end{aligned}$$

where K_s describes the rule of assets accumulation at the start of life for an individual with education achievement s. 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) a single with no children.

For $s = 3$, the woman remains in education for another 3 years, moving into the labour market at 22. Only then will other work-related information be revealed. Before that, she will be single and with no children. Thus, the initial value function at 19 can be recursively defined as

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

where the contemporaneous utility for a student is as defined generically in (11),

$$U\left(c_{ia}, l_{ia} = S; X_{ia}, \Omega_{ia}\right) = \frac{\left(c_{ia}\right)^\mu}{\mu} \exp\left\{\widetilde{U}\left(\left(l_{ia}, d_{ia}^m, l_{ia}^m, d_{ia}^k, a_{ia}^k\right) = (S, 0, ., 0, .)\right) + \theta(l_{ia} = S)\right\}.$$

The continuation value at entrance into the labour market is defined recursively as in (14):

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

where the initial conditions at entrance in the labour market for $s_i = 3$ are

$$\begin{aligned}
k_{i22} &= K_3\left(k_i^p, k_{17}\right) - R^2 c_{i19} - R c_{i20} - c_{i21} + \epsilon_{3i} \\
e_{i22} &= 0 \\
d_{i21}^m &= 0 \\
d_{i21}^k &= 0 \\
o_{i22} &\perp \left(\theta_i, \varpi_{3i}, \epsilon_{3i}\right) \\
\nu_{i22} &\perp \left(\theta_i, \varpi_{3i}, \epsilon_{3i}\right) \\
\upsilon_{si22} & \quad \text{correlated with } \theta
\end{aligned}$$

and the state space evolves as defined in the previous section.

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

$$s_i = \underset{s}{\text{argmax}} \left\{ V_{si}\left(k_i^p, k_{i17}, \theta_i, \varpi_{si}, \epsilon_{si}\right) \text{ for } s = 1, 2, 3 \right\}.$$

3 Data

We use the first 16 annual waves of the British Household Panel Survey (BHPS), from 1991 to 2006. The BHPS is the main UK household panel survey. 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 dataset is an unbalanced panel of around 5,000 women over the 16 waves. 5% of these are observed over all 16 waves, 30% in no more than 6 waves.

4 Estimation and calibration

We follow a multi-step strategy to estimate the structural parameters in the women's life-cycle model. Two parameters are calibrated, the risk aversion coefficient, μ, and the discount factor, β. The exogeneous parts of the model, including dynamics in family composition and men's outcomes are estimated outside the structural model. All other parameters in the women's problem are estimated by indirect inference using simulated moments from auxiliary reduced form econometric models as proposed by Smith (1990), Gourieroux, Monfort and Renault (1993) Gallant and Tauchen (1996) and, more recently, Keane and Smith (2003).

We explore decisions at different stages of the life-cycle to identify the different parameters. Identification uses auxilliary parametric selection models close to the true structural model. In all, we keep notation as close as possible to that used in the structural model. We follow the rule of omitting the index t but include time variables in most econometric models.

In what follows, we discuss estimation of the main parameters in the model, describing women's earnings and preferences. Estimation of the remaining parameters is discussed in appendix 8.

4.1 Preferences and earnings dynamics

In a firsts step we disregard part-time employment. During the working life, a simplified version of the structural model is,

$$\begin{aligned} \mathrm{P}\left(l_{ia} > 0 | X_{ia}\right) &= \mathrm{P}\left(\nu_{sia} > H_s\left(X_{ia}\right)\right) \\ \ln w_{ia} &= \ln W_{st} + \alpha_s \ln(e_{ia}+1) + \upsilon_{sia} + \zeta_{sia} \\ \upsilon_{sia} &= \upsilon_{sia-1} + \epsilon_{sia} \end{aligned}$$

This is all conditional on education attainment. In the above equations, ν is a composition of preferences for working and productivity, υ is unobserved productivity and ζ is measurement error in earnings, assumed iid.

Under joint normality, the selection model of wages above can be simply estimated in first-differences to elliminate the random walk component. The earnings equation for continuously employed individuals is,

$$\Delta \ln w_{sia} = \Delta \ln W_s + \alpha_s \Delta \ln(e_{ia}+1) + \rho_s \sigma_{s\epsilon} \widehat{\lambda}_{sia} + \widetilde{\epsilon}_{sia} + \Delta\zeta_{sia}.$$

Estimation is conditional on education achievement and being in continuous employment for at least two periods. All relevant information is controlled for in the decision process: working experience, past employment status and earnings if employed, savings, presence of partner, his employment status and earnings, kids by age groups, taxes and benefits if would be unemployed.

We assume that unobserved preferences for working, θ, follow a two point discrete distribution. Its distributions is characterised by three parameters, (θ_1, θ_2, p) where $p = p(\theta = \theta_1)$. Conditional on education attainement, the distributon is characterised by $(\theta_1, \theta_2, p_s)$ with $p_s = p(\theta = \theta_1 | s)$. We use three sets of moments conditional on education to identify the distribution parameters. The moments ar all from the selection equation: the intercept — to identify the mean of θ), the coefficents associated with regressors excluded from the utility function — to identify the variance of θ, and the serial autocorrelation of the residuals — additional information to separate the variance of θ. The unconditional distribution results from the aggregation over education levels.

Heterogeneity in preferences along observed dimensions is identified by the respective coefficients in the auxilliary selection rule.

Estimates of the differenced earnings equation conditional on continuous employment spells and education reveals the returns to experience and the distribution of productivity innovations under the parametric normality assumption. As a by-product, we also estimate the distribution of the measurement error and the correlation between the innovation in productivity and unobserved preferences.

4.2 Wage rates and initial productivity

Wage rates are estimated within a reduced form selection model of education and employment decisions at 17. For the unskilled, this is

$$\begin{aligned}
\mathrm{P}\left(s_i = 1 | X_{i,17}\right) &= \mathrm{P}\left(\psi_i < H_1\left(X_{i,17}\right)\right) \\
\mathrm{P}\left(l_{i,19} > 0 | s_i = 1, X_{i,19}\right) &= \mathrm{P}\left(\nu_{i,19} > H_l\left(X_{i,19}\right)\right) \\
\ln w_{i,19} &= \ln W_1 + \upsilon_{i,19} + \zeta_{i,19}
\end{aligned}$$

where ψ measures preferences for education and working and (ν, υ, ζ) are as defined before. X contains all relevant information at 17, namely own assets, parents' assets, and the subsidies and taxes the individual would be entitled to if unemployed. Under parametric assumptions about the distribution of the error terms and using the distribution of measurement error identified before, the above selection model identifies the unskilled wage rate, W_1

Skilled wage rates are estimated as increments over unskilled wage rates. The reduced form auxilliary model is

$$\begin{aligned}
s_i^* &= H\left(X_{i,17}\right) + \psi_i \\
\mathbf{1}(s_i = s) &= \mathbf{1}\left(H_{s-1}\left(X_{i,17}\right) < \psi_i < H_s\left(X_{i,17}\right)\right) \\
l_{ia_s} &= \mathbf{1}\left(\nu_{ia_s} > G\left(X_{ia_s}\right)\right) \\
\ln w_{ia_s} &= d_1 \ln W_1 + d_2 \ln W_2 + d_3 \ln W_3 + \upsilon_{ia_s} + \zeta_{ia_s}
\end{aligned}$$

where a_s is the age at which an individual with educatin s enters the labour market. The choice of education is modeled as a ordered probit and estimates of the earnings equation will take into account the choice of education. Once more under simplifying parametric assumptions, the reduced form model provides the moment conditions to identify the wage rates of medium and high skilled labour.

Together with information on the distribution of θ, selection into education also provides the necessary moments to identify the distribution of preferences for education, ϖ, above preferences for working and education as determined by θ. Under normality, the variance of ϖ can be obtained from the X coefficients in the education selection rules.

We use a second set of moments to help identify the wage rates and distribution of initial productivity. These are based on a selection model of working at entrance in the working life. It allows for a larger number of observations to be used in estimation as it conditions on education achievement, thus requiring individuals to be followed for a shorter period.

The additional auxilliary model is

$$\begin{aligned}
\mathrm{P}\left(l_{ia_s} > 0 | X_{ia_s}\right) &= \mathrm{P}\left(\nu_{ia_s} > G\left(X_{ia_s}\right)\right) \\
\ln w_{ia_s} &= \ln W_s + \upsilon_{sia_s} + \zeta_{sia_s}.
\end{aligned} \tag{17}$$

It provides information on the following moments:

$$\left(\ln W_s + \mathrm{E}\left(\upsilon_{sa_s} | s\right), \mathrm{var}\left(\upsilon_{sa_s} | s\right), \mathrm{corr}\left(\upsilon_{sa_s}, \theta | s\right)\right).$$

Per se, these are not enough to identify any of the structural parameters. But when combined with the distribution of preferences for working identified before, these moments provide additional information about the wage rates and initial distribution of productivity, ν.

We explore the fact that complete information on idiosyncratic productivity is not available before the start of working life. Thus,

$$\mathrm{E}\left(\upsilon_{sia_s}|s\right) \;=\; p_s\mathrm{E}\left(\upsilon_{sia_s}|\theta_1\right) + \left(1-p_s\right)\mathrm{E}\left(\upsilon_{sia_s}|\theta_2\right)$$

and

$$\begin{aligned}
\operatorname{cov}\left(\upsilon_{sia_s},\theta|s\right) &= \operatorname{corr}\left(\upsilon_{sia_s},\theta|s\right)\sqrt{\operatorname{var}\left(\upsilon_{sia_s}|s\right)\operatorname{var}\left(\theta|s\right)} \\
&= \mathrm{E}\left(\upsilon_{sia_s}\theta|s\right) - \mathrm{E}\left(\upsilon_{sia_s}|s\right)\mathrm{E}\left(\theta|s\right) \\
&= p_s\theta_1\mathrm{E}\left(\upsilon_{sia_s}|\theta_1\right) + \left(1-p_s\right)\theta_2\mathrm{E}\left(\upsilon_{sia_s}|\theta_2\right) \\
&\quad - \left[p_s\mathrm{E}\left(\upsilon_{sia_s}|\theta_1\right) + \left(1-p_s\right)\mathrm{E}\left(\upsilon_{sia_s}|\theta_2\right)\right]\mathrm{E}\left(\theta|s\right).
\end{aligned}$$

All moments in the expression above are know except for $\left(\mathrm{E}\left(\upsilon_{sia_s}|\theta_1\right),\mathrm{E}\left(\upsilon_{sia_s}|\theta_2\right)\right)$. The following additional condition establishes identification of the two conditional means:

$$\mathrm{E}\left(\upsilon_{sia_s}\right) \;=\; p\mathrm{E}\left(\upsilon_{sia_s}|\theta_1\right) + \left(1-p\right)\mathrm{E}\left(\upsilon_{sia_s}|\theta_2\right) \;=\; 0$$

Furthermore, if $\left(\mathrm{E}\left(\upsilon_{sia_s}|\theta_1\right),\mathrm{E}\left(\upsilon_{sia_s}|\theta_2\right)\right)$ are known, so $\operatorname{cov}\left(\upsilon_{sia_s},\theta\right)$ can be revealed:

$$\begin{aligned}
\operatorname{cov}\left(\upsilon_{sia_s},\theta\right) &= \mathrm{E}\left(\upsilon_{sia_s}\theta\right) - \mathrm{E}\left(\upsilon_{sia_s}\right)\mathrm{E}\left(\theta\right) \\
&= p\theta_1\mathrm{E}\left(\upsilon_{sia_s}|\theta_1\right) + \left(1-p\right)\theta_2\mathrm{E}\left(\upsilon_{sia_s}|\theta_2\right),
\end{aligned}$$

Similarly for the conditional means,

$$\mathrm{E}\left(\upsilon_{sia_s}|s\right) \;=\; p_s\mathrm{E}\left(\upsilon_{sia_s}|\theta_1\right) + \left(1-p_s\right)\mathrm{E}\left(\upsilon_{sia_s}|\theta_2\right)$$

and the wage rates, W^s,

$$W_s \;=\; \left[W_s + \mathrm{E}\left(\upsilon_{sia_s}|s\right)\right] - \mathrm{E}\left(\upsilon_{sia_s}|s\right)$$

Finally, the variance of υ conditional on s is sufficient to identify the variance of υ conditional on θ under the assumption $\operatorname{var}\left(\upsilon_{sa_s}|\theta_1\right) = \operatorname{var}\left(\upsilon_{sa_s}|\theta_2\right)$:

$$\operatorname{var}\left(\upsilon_{sia_s}|s_i=s\right) \;=\; \operatorname{var}\left(\upsilon_{sia_s}\right) + p_s\left(1-p_s\right)\left[\mathrm{E}\left(\upsilon_{sia_s}|\theta_1\right)^2 + \mathrm{E}\left(\upsilon_{sia_s}|\theta_2\right)^2 - \mathrm{E}\left(\upsilon_{sia_s}|\theta_1\right)\mathrm{E}\left(\upsilon_{sia_s}|\theta_2\right)\right].$$

5 Estimation results

To be added.

6 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) and Levell et al. (2009).

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 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 beneift, 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 two main tax credits: working tax credit and child tax credit. *Working tax credit* (WTC) is an employment subsidy for low-wage workers designed 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.

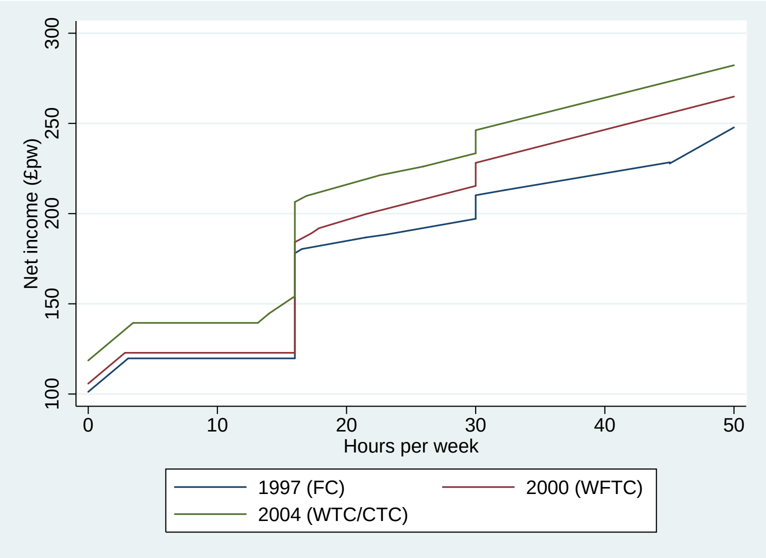
Child tax credit (CTC) is the main source of means-tested support for families with children. Awards depend on family composition and there are no employment conditions that have to be met. WTC and CTC are subject to a joint means test operating at the family level. The main taper rate is currently 39%.

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 program it replaced. The WFTC and WTC/CTC reforms both increased generosity for existing claimants as well as extending entitlement further up the income distribution (and, in the case of the WTC/CTC reform, to families without children). Figure X illustrates some of these changes, plotting example budget constraints for a lone parent (with a child aged four) who earns £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).

7 Policy experiments

To be added.

Figure 1: Lone parent budget constraints (£6ph, child aged 4)



8 Conclusions

To be added.

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Appendix A: Parameters and functions to be estimated or calibrated

Below is the list of parameters or functions that need to be precisely specified:

- Family-related:
  - probability of new child: $\mathrm{P}\left(d^k_{ia} = 1 | d^k_{ia-1} = 0, X_{ia-1}\right)$;
  - probability of new partner with education s^m: $\mathrm{P}\left(s^m_{ia} | d^m_{ia-1} = 0, X_{ia-1}\right)$;
  - probability that partner works: $\mathrm{P}\left(l^m_{ia} = 1 | d^m_{ia-1}, s^m_{ia}, X_{ia-1}\right)$;
  - distribution of men's earnings: $\alpha^m_{s^m}$, $W^m_{s^m}$, distributions of $\upsilon^m_{s^m}$ and $\varepsilon^m_{s^m}$.
- Women's employment and earnings:
  - earnings equation: α_s, distribution of ε_s, distribution of υ_{sa_s} conditional on θ;
  - accumulation of experience: λ.
- Women's entrance in labour market:
  - predictable part of transition in k by education investment: $K_s(k^P_i, k_{i17})$;
  - unpredictable innovation if assets: distribution of ϵ_s.
- Utility:
  - predictable taste for activity l: $\widetilde{U}(l, d^m, l^m, d^k, a^k)$;
  - permanent preferences for working: distribution of θ and π;
  - additional preferences for studying: distribution of ϖ_s;
  - transitory preferences for working P or F: distribution of ν_l.
- Prices and policy environment:
  - wage rates: W_s and $W^m_{s^m}$;
  - childcare costs: C^k
  - interest rate: R;
  - transfer system: B.
- Other:
  - coefficient of risk aversion: μ;
  - discount rate: β.

Appendix B: Estimation moments

In this appendix we present and discuss the estimation procedure. We start by focusing on the exogenous parts of the model, to be estimated outside the model solution, and then present the moments used to identify the remaining structural parameters.

8.1 Family composition

Since all changes in family composition are exogenous to the model, they can be readily observed from the data as a function of relevant characteristics. Transitions are specified as follows,

$$\begin{aligned} \mathrm{P}\left(d_{ia}^m = 1, s_{ia}^m \left| d_{ia-1}^m = 0, X_{ia-1}\right.\right) &= \mathrm{P}\left(Z_{ia}^1 \delta^1 + \xi_{ia}^1 > 0 \left| d_{ia-1}^m = 0\right.\right) \\ \mathrm{P}\left(d_{ia}^m = 0 \left| d_{ia-1}^m = 1, X_{ia-1}\right.\right) &= \mathrm{P}\left(Z_{ia}^0 \delta^0 + \xi_{ia}^0 > 0 \left| d_{ia-1}^m = 1\right.\right) \\ \mathrm{P}\left(d_{ia}^k = 1 \left| d_{ia-1}^k = 0, X_{ia-1}\right.\right) &= \mathrm{P}\left(Z_{ia}^k \delta^k + \xi_{ia}^k > 0 \left| d_{ia-1}^k = 0\right.\right) \end{aligned}$$

where

$$\begin{aligned} Z_{ia}^1 &= \left(a, s_i, d_{ia-1}^k, a_{ia-1}^k\right) \\ Z_{ia}^0 &= \left(a, s_i, s_{ia-1}^m, d_{ia-1}^k, a_{ia-1}^k\right) \\ Z_{ia}^k &= \left(a, s_i, d_{ia-1}^m, l_{ia-1}^m\right). \end{aligned}$$

and each of the probabilities above is modelled as a logit.

The probability that a child leaves her mother's family is deterministically set to be 0 before the age of 18, turning to 1 at that time.

8.2 Childcare costs

While young, the child needs a third-party childcare for as many hours as the mother is away working. Childcare costs are modelled on a per-hour basis as a function of the child's age, $C^k\left(a_{ia}^k\right)$, and directly estimated from the data.

8.3 Men's selection model of working and earnings

In the model, men's activity is either working full-time or unemployment. Both his activity and earnings are exogenous to the women's decision process. They are specified as a reduced form selection model of working and earnings conditional on education attainment. For each education level, two problems need to be estimated depending on whether the couple is newly formed or ongoing.

We first consider the case of a man with education s^m in a new couple. The working probability and earnings of this man are described by the selection model:

$$\begin{aligned} l_{ia}^m &= \mathbf{1}\left(Z_{ia}^0 \gamma_{s^m}^0 + \nu_{ia}^m > 0\right) \\ \ln w_{ia}^m &= \ln W_{s^m t}^m + \alpha_{s^m}^m \ln(a) + \upsilon_{s^m ia}^m + \eta_{s^m ia}^m \end{aligned} \tag{18}$$

where here Z^0 is a polynomial in a, υ^m is the productivity type of the newly matched man and η^m is classical measurement error in earnings, serially uncorrelated and iid.

The men's problem in on-going couples is very similar to (18):

$$\begin{aligned} l_{ia}^m &= \mathbf{1}\left(Z_{ia}^1 \gamma_{s^m}^1 + \nu_{ia}^m > 0\right) \\ \ln w_{ia}^m &= \ln W_{s^m t}^m + \alpha_{s^m}^m \ln(a) + \upsilon_{s^m ia}^m + \eta_{s^m ia}^m \\ \upsilon_{s^m ia}^m &= \upsilon_{s^m ia-1}^m + \varepsilon_{s^m ia}^m. \end{aligned} \tag{19}$$

where ε^m is the idd innovation in productivity. The distribution of $(\upsilon^m, \varepsilon^m)$ depends on s^m. Z^1 is a polynomial in (a, l_{a-1}^m).

Under joint normality of $\left(\nu^m, \upsilon^m | a, s^m, d_{ia-1}^m = 0\right)$ and $\left(\nu^m, \varepsilon^m | a, s^m, l_{ia-1}^m, d_{ia-1}^m = 1\right)$, the two models can be consistently estimated using the standard Heckman (1978, 1979) procedure.[1] Estimation will identify all structural parameters in the men's problem.

[1] Estimation of model (19) is in first differences in earnings under the condition of two subsequent employment periods.

8.4 Experience accumulation among women: part vs full time employment and depreciation rate

8.5 Depreciation rate

We start by disregarding the difference between part-time (PT) and full-time (FT) employment. A simplified version of the structural model including the correct rule of human capital accummulation is:

$$\begin{aligned} l_{ia} &= \mathbf{1}\left(\nu_{ia} > H\left(X_{ia}\right)\right) \\ \ln w_{ia} &= \ln W_s + \alpha_s \ln(e_{ia}) + \upsilon_{sia} + \zeta_{sia} \\ \upsilon_{sia} &= \upsilon_{sia-1} + \epsilon_{sia} \\ e_{ia} &= e_{ia-1} * (1-d)^{1-l_{ia-1}} + l_{ia-1} \end{aligned}$$

where d is the depreciation rate.

Consider an unemployment period of duration $\tau > 0$ interrupted by employment at a. Previous registered experience is $e_{i,a-\tau-1}$. The change in log experience is

$$\begin{aligned} \Delta \ln e_{ia} &= \ln\left(\frac{(e_{i,a-\tau-1}+1)(1-d)^{\tau}}{e_{i,a-\tau-1}}\right) \\ &= \ln\left((1-d)^{\tau} + \frac{(1-d)^{\tau}}{e_{i,a-\tau-1}}\right). \end{aligned}$$

For e sufficiently large,

$$\begin{aligned} \Delta \ln e_{ia} &\approxeq \ln\left((1-d)^{\tau}\right) \\ &\approxeq -d\tau \end{aligned}$$

We use observations with large experience, above 10 years, and estimate the earnings equation within selection model:

$$\begin{aligned} \Delta \ln w_{ia} &= -d\alpha_s\tau + \Delta\upsilon_{sia} \\ \upsilon_{sia} &= \upsilon_{sia-1} + \epsilon_{sia} \\ e_{ia} &= e_{ia-1} * (1-d)^{1-l_{ia-1}} + l_{ia-1} \end{aligned}$$

where Δ now measures change from last employment period to present and $\Delta \ln w$ has been stripped of systematic annual variation in wage rates by level of education.

8.6 Experience accumulation in part-time employment

We focus on individuals observed entering the labour market, for whom experience in PT and FT can be clearly measured. The auxilliary selection model is:

$$\begin{aligned} l_{ia} &= \mathbf{1}\left(\nu_{ia} > H\left(X_{ia}\right)\right) \\ \ln w_{ia} &= \ln W_s + \alpha_s^{FT} \ln(e_{ia}^{FT}) + \alpha_s^{PT} \ln(e_{ia}^{PT}) + \upsilon_{sia} + \zeta_{sia} \\ \upsilon_{sia} &= \upsilon_{sia-1} + \epsilon_{sia} \end{aligned}$$

Use $\left(\alpha_s^{FT}, \alpha_s^{PT}\right)$ as the identifying moments to separate human capital accummulation in the two working regimes.

8.7 Direct monetary university costs

Wealth data is available every 5 years. We use changes in reported assets between the age of 17 to 22 to estimate the distribution of changes and innovations leading to the distribution of assets observed among young women at 22.

Conditional on education attainment, s, the auxiliary model is simply:

$$k_{s,i,22} = X_{i,17}\gamma_s + C_s + \epsilon_{si} \tag{20}$$

where X is a polynomial in (k_{17}, k_{17}^p). The moments are the collection of coefficients γ_s, the intercept C_s and the variance of ϵ_s for $s = 1, 2, 3$. C_s is used to identify the mean cost of education s, the coefficients in (k_{17}, k_{17}^p) reveal how cost supported directly by the student vary by its initial financial circunstances, and the variance in ϵ_s reveal the variability in education costs.