Equilibrium Search and Tax Credit Reform

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May 13, 2016

Abstract

A multi-sector empirical equilibrium job search model with wage posting is developed to analyse the labour market impact of UK tax reforms and to explore tax credit design. The model allows for a rich characterization of the labour market, with hours responses, accurate representations of the tax and transfer system, and both worker and firm heterogeneity. The model is estimated with pre-reform longitudinal survey data using a semi-nonparametric technique, and the impact of actual tax reform policies is simulated. The British Working Families' Tax Credit and contemporaneous reforms are predicted to increase employment, with equilibrium effects found to be relatively modest. The model is used to assess the impact of alternative policies, and equilibrium effects are shown to become important as the generosity of tax credits is increased. They also bear an important influence when the optimal design of tax credits is considered.

Keywords: Labour market equilibrium, empirical job search, wage dispersion, monopsony, incidence, tax credits, optimal design

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1 Introduction

Over the past two decades earned income tax credit programs have grown substantially in the UK, US and many other countries.[1] These programs are typically motivated by a desire from policy makers to increase labour market participation among target groups, and to alleviate in-work poverty. While the effect of these policies on labour supply has been studied extensively, much less is known regarding the equilibrium impact of these policies.[2] The objective of this paper is to develop an empirical equilibrium job search model that provides us with an appropriate framework to consider these issues. We first apply it in our analysis of a series of UK tax reforms that included the Working Families' Tax Credit (WFTC) reform, which considerably increased the generosity of in-work support for families with children (see Brewer, 2001), and then in our analysis of tax credit design more generally.

This paper contributes to the literature on the impact and design of tax credit policies, but starts from the premise that labour markets may be characterized by considerable search frictions (see for example, van den Berg and Ridder, 2003).[3] The presence of labour market frictions may have important equilibrium implications for our understanding of programmes like WFTC. In particular, if firms set wages then these frictions bestow them with some degree of monopsony power. If labour supply were to increase following such reforms, firms may respond by lowering wage offers, in which case the effective transfer to eligible families is reduced, whilst non-eligible families may become worse off if they are competing within the same labour market. Conversely, the increased labour supply may induce firms to increase their recruiting intensity. In terms of both evaluation, and program design, an understanding of the quantitative importance of these equilibrium effects is essential.

The equilibrium job search literature allows us to capture these and other effects in a dynamic and imperfectly competitive economy that is characterized by search frictions.

[1] See Hotz and Scholz (2003) for EITC in the US, and Blundell and Hoynes (2004) for the British WFTC and its predecessors.

[2] Recent studies by Azmat (2006), Leigh (2010), and Rothstein (2008, 2009) have examined the economic incidence of tax credit programmes, and provide evidence that suggests that as tax credit entitlement is expanded, gross wages are reduced.

[3] Blundell, Francesconi and van der Klaauw (2011) study the same tax reforms that we focus upon in this paper. They present evidence of important announcement effects on the employment decisions of single parents (employment increasing between the announcement and implementation of the programme), which is consistent with the presence of significant labour market frictions existing for this group. We describe other evaluations of WFTC in Section 5.3.

Competition between firms is the fundamental determinant of wages, with the extent of this competition limited by the presence of search frictions. In the spirit of Burdett and Mortensen (1998), we consider a model with ex-ante wage posting: firms set wages before meeting potential workers, which workers then either accept or reject.[4] We advance this literature in several dimensions, with the model developed here designed to reflect some key features of the UK labour market and to allow for the possibility of rich equilibrium effects following reforms such as WFTC. At a methodological level, this paper contributes to the empirical equilibrium job search literature by developing a wage-posting model with wage-hours packages, accurate representations of the tax and transfer system, and both observed and unobserved worker and firm heterogeneity. The paper most closely related is the on-the-job search model presented in Bontemps, Robin and van den Berg (1999), which this paper builds upon. As in their model, we allow for continuous distributions of firm productivity and worker leisure flows, but make an important methodological contribution by relaxing the assumption that the arrival rate of job offers is independent of employment status. While conceptually simple, relaxing this assumption in models with both unobserved worker and firm heterogeneity has previously been considered intractable in the literature (see for example, van den Berg, 1999).[5] As will become clear, allowing for heterogeneity in worker leisure flows is important as it provides the main mechanism through which policies such as tax reforms induce non-degenerate labour supply responses.

To allow for the possibility of richer equilibrium responses we additionally allow firms to choose a level of recruiting intensity so as to increase their meeting rate with workers independent of the posted wage. This provides a framework which then allows the job offer arrival rates to be endogenized at the macroeconomic level by comple-

[4]Manning (2003) argues that while wage posting is not always appropriate, it provides a good characterization of wage determination in many settings. This is likely to be particularly true when focusing on low-skilled labour markets, as in this paper. Hall and Krueger (2008) present recent US survey evidence which suggests that while other forms of wage formation are also important, wage posting is much more prevalent in less skilled occupations (see also the discussion in Manning, 2003, chapter 5). Other papers have examined the impact of similar policies with alternative forms of wage determination; Lise, Seitz and Smith (2005) simulate the effect of a wide scale implementation of the Canadian Self-Sufficiency Project in a model with ex-post worker-firm bargaining.

[5]As we shall see in Section 3, the over-identifying restriction in Bontemps, Robin and van den Berg (1999) simplifies the analysis as it implies that the optimal strategy of non-employed workers is independent of the equilibrium wage offer distribution. This restriction led to a poor fit of the duration data in their application, as empirically job offer arrival rates for non-employed workers are often estimated to exceed that of the employed. Furthermore, under this over-identifying restriction they found that the dispersion in leisure flows was not an important determinant of the variation in individual wages. These findings contrast with our later results.

menting the model with aggregate matching functions. We then prove a new important theoretical invariance result regarding the extent to which certain assumptions on the recruiting cost function actually matter for our counterfactual simulations.

As we describe in the following section, both WFTC and its predecessor were only available to families with children. To investigate possible differential impacts to the tax reforms, and to also explain differences in labour market outcomes, we make a further methodological contribution by incorporating further dimensions of worker heterogeneity. Both the tax and transfer system, and the key worker parameters, may all potentially vary with observable demographic characteristics, and we demonstrate how the type of semi-parametric estimation procedure used in simpler job search models can be extended to this much richer environment. In contrast to the segmented markets approach adopted by van den Berg and Ridder (1998), we will allow workers of all types to operate within the same labour market. It is this feature that allows workers who are not eligible for tax credits to be indirectly affected by them through changes in the optimal strategies of firms.

The UK labour market has a high prevalence of part-time work, particularly among women with children. As noted above, the presence of children is a central eligibility requirement for receipt of tax credits. These features motivate us to incorporate hours of work into the model. While the use of the canonical labour supply model may be pervasive, there is a body of empirical work that challenges the view that individuals are able to freely choose their hours of work at a fixed hourly wage.[6] We allow for both part-time and full-time jobs by developing a multi-sector model, and throughout this paper maintain the assumption that jobs sequentially arrive as wage-hours packages.

The level of generality here means that the model is analytically intractable. Nonetheless, we show that the model remains empirically tractable by demonstrating how the type of three step semi-nonparametric estimation technique proposed by Bontemps, Robin and van den Berg (1999, 2000) in the context of much simpler environments can be adapted to the considerably richer multi-sector framework that we consider here. We estimate the model using UK Labour Force Survey data shortly before WFTC was introduced. We show that the estimated model is successful in explaining pre-reform differences in employment states, distributions of wages, as well as labour market transitions. Using the estimated parameters we then simulate the impact of actual tax reforms and

[6] See, for example, Altonji and Paxson (1988) and Dickens and Lundberg (1993). Blundell, Brewer and Francesconi (2008) studied the impact of a series of in-work benefit reforms in the UK during the 1990s, and found that the positive effect on hours worked was largely driven by women who changed their job.

later compare our results to post-reform data. We find that the introduction of WFTC, together with the contemporaneous changes to the tax and transfer system, increased employment for most groups, with single parents experiencing the largest employment increase. Our main simulations suggest that while equilibrium considerations do play a role in these reforms, the changes in labour market outcomes are dominated by the direct effect of changing job acceptance behaviour.

Our estimated model is shown to reproduce the most important features of the data, and to provides labour supply reform responses that are consistent with numerous studies. This performance provides the basis for a series of exercises that are concerned with the design of tax credits. First, we consider the impact of extending the generosity of WFTC, and demonstrate that as maximal tax credit awards are increased, equilibrium effects become much more important. Second, we develop a framework for considering the optimal design of tax credits under a revenue constraint. We focus on practically implementable reforms, that completely nest the actual UK tax, transfer, and tax credit systems. Our analysis points towards a reformed tax credit system, with tax credit entitlement extended further up the income distribution. Again, we show the importance of equilibrium considerations.

The remainder of the paper proceeds as follows. In the next section we describe the WFTC reform, as well as the contemporaneous changes to the UK tax and transfer system. In Section 3 we outline the theoretical model that we use to study tax reforms and describe the optimal strategies of firms and workers. Section 4 introduces our data, discusses identification and the estimation procedure, and presents the main estimation results. In Section 5 we then use our estimated model to simulate the impact of actual tax reforms, while Section 6 is concerned with the design of tax credits. Finally, Section 7 concludes.

2 UK Tax Credit Reform

As in the US, the UK has a long history of in-work benefits, starting with the introduction of Family Income Supplement in 1971. Over the years, these programs became more generous, and in October 1999, Working Families' Tax Credit was introduced, replacing a similar but less generous tax credit program called Family Credit (FC). Both WFTC and FC were only available to families with children and shared a similar eligibility structure, requiring recipients work for at least 16 hours per week, and with the credit

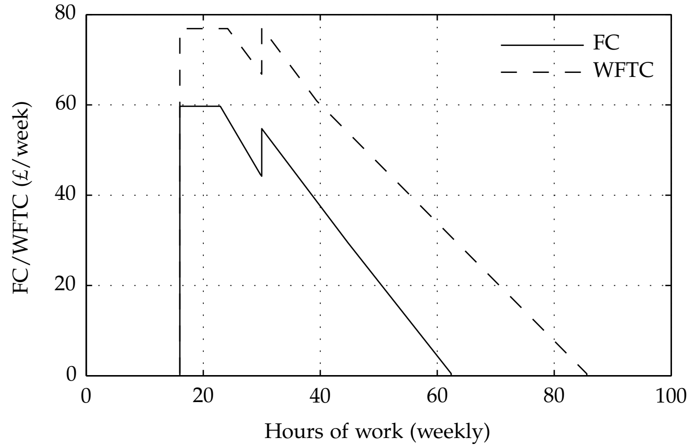


Figure 1: Tax Credit awards under FC and WFTC. FC refers to Family Credit as of April 1997. WFTC refers to Working Families' Tax Credit as of April 2002. Figure assumes a single parent with a single child aged 10, and a constant hourly wage rate of £3.50. All incomes expressed in pounds per week in April 1997 prices.

tapered away with household earnings above a threshold. Both also offered a further credit when recipients worked at least 30 hours a week. WFTC increased the level of in-work support by offering higher credits, increasing the threshold so that families can earn more before it was phased out, and by reducing the withdrawal rate.[7] In Figure 1 we illustrate how this reform changed tax credit awards for a single parent family. Note that the expanded eligibility increases marginal effective tax rates for those newly eligible families.

When analysing low income support it is important to take an integrated view of the tax system. This is because tax credit awards in the UK are counted as income when calculating entitlements to other benefits. Families in receipt of these benefits would gain less from WFTC than otherwise equivalent families not receiving such benefits. There were also other important changes to the tax system affecting families with children that coincided with the expansion of in-work tax credits, and which make the potential labour market impact considerably more complex. In particular, there were increases in the generosity of Child Benefit (a cash benefit available to all families with children regardless of income), as well as notable increases in the child additions in Income Support (a welfare benefit for low income families working less than 16 hours a week). There were also other changes to the tax and transfer system that affected families both with

[7]WFTC also provided more support for formal childcare costs and allowed all child maintenance payments to be disregarded from income when calculating tax credit entitlement.

and without dependent children: a new 10% starting rate of income tax was introduced, the basic rate of income tax was reduced from 23% to 22%, and there was a real rise in the point at which National Insurance (payroll tax) becomes payable. In Appendix A we illustrate the influence of all these changes on the budget constraint for a single parent family.[8]

3 The Model

In the model that we outline here and develop fully in the Appendices, workers receive job offers when both employed and unemployed. Job offers are characterised by both an hours of work requirement and an hourly wage, and workers may choose to either accept or reject any given job offer they receive. Workers differ in both observed and unobserved dimensions, and this generates differences in job acceptance behaviour across workers. Reforms to the tax system, as we investigate here, will change the value to workers from holding different jobs and therefore induce behavioural responses in the form of changes in job acceptance behaviour. For example, a wage subsidy may enlarge the set of wages that workers are willing to accept. Firms are not passive in this model and may respond should workers change their behaviour in this way. More specifically, following any tax-induced change in worker behaviour, firms (which differ in their productivity levels) may respond by adjusting the wage that they offer (which changes the profit per-worker and workforce size), as well as their recruiting intensity decision (which changes the rate at which they meet with prospective employees). These changes will determine both the wage offer distribution and the aggregate rate of job offer arrivals, and feedback into the behaviour of workers until a new equilibrium emerges.

3.1 Environment

The economy consists of a continuum of infinitely lived individuals with a population size normalized to unity. Individuals firstly differ by their observable demographic characteristics that are finite in number and indexed by $i \leq I$. The fraction of such workers is denoted n_i with $\sum_i n_i = 1$. Individuals also differ in their unobserved leisure flow b

[8]Our analysis does not consider the non-tax related changes that occurred during this period. Various "New Deal" active labour market policies were introduced which aimed to improve both the incentives and the ability of the long-term unemployed to obtain employment (see Blundell et al., 2004). Furthermore, a national minimum wage was introduced (see Metcalf, 2008).

(as in Albrecht and Axell, 1984), which includes any search costs but not unemployment benefit and other transfers. As will become clear, heterogeneity in leisure flows translates into heterogeneity in job acceptance behaviour, so that tax reforms may introduce non-trivial labour supply effects on this margin. The cumulative distribution function of leisure flows in the population of type i workers is denoted H_i, which is assumed continuous on its support $[\underline{b}_i, \overline{b}_i]$. To simplify some of the subsequent exposition we assume that $\underline{b}_i$ is sufficiently low such that in equilibrium all firms are active in the labour market.[9] Time is continuous and all individuals have the constant discount rate $\rho > 0$. There is no saving or borrowing technology.

Jobs are characterized by a wage rate w and required hours of work h. We allow for part-time jobs (hours h_0) and full-time jobs (hours $h_1 > h_0$), with workers subject to a monetary hours disutility C_i^h.[10] Mirroring the actual conditioning performed by the UK tax authorities, the tax schedule is a function of demographics, hours, and earnings, with $T_i^h(wh)$ denoting the potentially negative net taxes paid (and transfers received) by an employed worker.[11] We assume that this tax schedule is continuously differentiable in labour earnings. The net transfer paid to an non-employed worker is given by $-T_i^u$. Utility flows are linear in income, so that in the presence of a tax and transfer system and hours responses these are given by:

$$\begin{array}{ll} wh - T_i^h(wh) - C_i^h & \text{if employed} \\ b - T_i^u & \text{if unemployed.} \end{array}$$

From the outset we impose the location normalization $C_i^0 = 0$ for all $i \leq I$.

[9]While this can be relaxed, this assumption ensures that (absent restrictions on the set of permissible wages), there will always exist a wage rate such that even very low productivity firms will earn strictly positive profits. This allows us to equate the set of potential firms with the set of active firms. A similar assumption is made in Bontemps, Robin and van den Berg (1999).

[10]This may also reflect any differences in search costs for full-time and part-time workers. The inclusion of work hours is rare in the empirical search literature (for an exception see, for example, Blau, 1991). The analytical framework we develop generalizes to more than two hours choices, and can also be applied in the context of other non-wage amenities. See also Hwang, Mortensen and Reed (1998) for an analysis of non-wage amenities in an equilibrium search framework.

[11]We impose the condition that marginal tax rates, conditional on hours of work, are always (strictly) less than 100%. This is a necessary and sufficient condition for reservation wages to be strictly increasing in the worker leisure flow b. See also Robin and Roux (2002) for an analysis of progressive income taxation in the Burdett and Mortensen (1998) framework.

3.2 Worker Search

Individuals (or workers) are either employed or unemployed.[12] Both search for jobs. Job offer arrivals are exogenous to the worker: a type i worker accrues hours h offers at the constant rate λ_{ji}^{h} with $j \in \{u, e\}$ indexing the current worker state of unemployment or employment. To maintain focus on the decision of workers, we postpone any discussion concerning how these arrival rates may depend upon the overall state (or tightness) of the labour market until Section 3.6.[13] Employment spells end at rate δ_i regardless of whether individuals are employed in part-time or full-time jobs, and we define $\kappa_{ji}^{h} = \lambda_{ji}^{h}/\delta_i$ as the ratio of the arrival rates to this destruction rate.[14] We place no restrictions on the relative magnitude of these parameters.

Regardless of their observed or unobserved type, workers sample sector h wages from the wage offer distribution F_h which has support $[\underline{w}_h, \overline{w}_h]$. Wages are constant throughout an individual's employment spell within a given firm and we additionally define the survival functions $\overline{F}_h \equiv 1 - F_h$. For now, we treat these distributions as given and will later describe how they emerge as an equilibrium outcome from the wage posting game. The assumption that all workers sample offers from common distributions implies that, while the government may be able to condition taxes and transfers on demographic characteristics, firms are unable to do so. This assumption can be justified by the presence of anti-discrimination laws, such as the Equal Pay Act 1970, Sex Discrimination Act 1975,

[12]We make no distinction between unemployment and non-participation, and use the terms unemployment and non-employment interchangeably. Individuals with high values of the leisure flow b are effectively non-participants in the labour market.

[13]We do not allow the search effort of workers to vary with their current wage or to respond to any changes in the tax system. A richer specification would endogenize the job offer arrival rates at the micro-level by relating them directly to an endogenously determined worker search effort, as in Christensen et al. (2005). While characterising the worker problem is straightforward in this case, the *aggregation* over workers with heterogeneous reservation wages greatly complicates the characterisation of the labour market equilibrium, and is left as an extension for future research. See Gentry and Hubbard (2004) for US evidence on the impact of tax rates on job mobility.

[14]As emphasized by van den Berg and Ridder (2003), the parameters κ_{ei}^{h} and κ_{ui}^{h} can be thought of as labour market friction parameters. In particular, κ_{ei}^{h} is the number of sector h job offers a type i individual can expect to receive when employed, before exiting to unemployment. The assumption here that both the job destruction rate and job offer arrival rates when employed are independent of whether individuals are currently engaged in part-time or full-time work simplifies the subsequent analysis. Without this assumption it is necessary to track workers once employed in order to characterise the distribution of reservation wages amongst the unemployed, which then results in the loss of certain analytical aggregation properties of the model. See Appendix C for more details. In our empirical application, only women sample part-time job offers. For women without children, the empirical annual transition rates from full-time work to non-employment are very similar to those from part-time work to unemployment (respectively, 0.036 and 0.041). For women with children, the transition rate from full-time work to unemployment is slightly lower then from part-time work (respectively, 0.048 and 0.074).

and various Employment Equality Regulations, which outlaw such practices. It implies that workers who are not targeted by a tax reform may be indirectly affected through changes in the optimal strategy of firms. We explore alternative assumptions regarding market segmentation in Section 5.6.

3.3 Worker Strategies

The behaviour of workers can be described by two objects. The first is a function $q_i(w)$ that describes how workers value part-time versus full-time work, and which we refer to as the *indifference condition*. This is defined such that the value to a type i individual holding a full-time job paying wage w is the same as the value of a part-time job paying wage $q_i(w)$. Knowledge of this allows us to describe when workers will accept a job in an alternative sector. As we show in Appendix B, this function does not depend upon the unobserved type b and may be obtained simply by comparing the instantaneous utility flows across hours sectors. The second object is the usual reservation wage equation that defines the lowest wage that workers will accept to exit the non-employment state. The reservation wage for a full time job $\phi_i(b)$ takes a similar form to the standard reservation wage equation with on-the-job search (see Mortensen and Neumann, 1988), but is here modified both by the presence of taxes (which discount future earnings by the net-of-tax rate) and because workers are sampling job offers from two distributions. In Appendix B we show that it is the solution to:

$$\begin{aligned}\phi_i(b)h_1 - T_i^1(\phi_i(b)h_1) - C_i^1 &= b - T_i^u \\ &+ h_1 \int_{\phi_i(b)}^{\infty} \frac{\left(1 - T_i^{1\prime}(wh_1)\right)\left[(\kappa_{ui}^0 - \kappa_{ei}^0)\overline{F}_0(q_i(w)) + (\kappa_{ui}^1 - \kappa_{ei}^1)\overline{F}_1(w)\right]}{1 + \rho/\delta_i + \kappa_{ei}^0\overline{F}_0(q_i(w)) + \kappa_{ei}^1\overline{F}_1(w)}\,\mathrm{d}w. \quad (1)\end{aligned}$$

The part-time reservation wage for unemployed workers is then given by $q_i(\phi_i(b))$. Henceforth, we will refer to the full-time reservation wage for unemployed workers simply as *the reservation wage*. Before proceeding we note that when job offer arrival rates are independent of employment status, that is $\kappa_{ui}^h = \kappa_{ei}^h$, the integral term in equation 1 is identically zero so that the optimal strategy of workers is independent of the equilibrium wage offer distributions. This is the case analysed in Bontemps, Robin and van den Berg (1999), which we comment on further below.

3.4 Steady State Worker Flows

Reservation wages describe the optimal strategy of individuals and are necessary to characterise labour market flows. The cumulative distribution function of reservation wages amongst all type i workers (both employed and unemployed) is denoted A_i and is related to the distribution of leisure flows according to $A_i(w) = H_i(\phi_i^{-1}(w))$. The respective distributions amongst the stock of unemployed and employed workers are denoted A_{ui} and A_{ei}. Letting u_i denote the unemployment rate, these are related to A_i according to $A_i(w) = u_i A_{ui}(w) + (1-u_i)A_{ei}(w)$. These distributions are derived and characterised in Appendix C.

The presence of reservation wage heterogeneity means that even absent on-the-job search, the cross sectional distribution of wages amongst the employed (earnings) in a given sector will not coincide with the respective wage offer distribution since workers are selective. We denote the cumulative distribution function of sector h earnings for type i individuals as G_{hi} with the corresponding density functions $g_{hi} \equiv G'_{hi}$. Similarly, the fraction of such workers currently employed in an hours h job is denoted m_{hi}. By construction $m_{0i} + m_{1i} = 1 - u_i$. In steady state, the number of type i individuals who leave a full-time job paying wage w (either by their job being destroyed at rate δ_i or by gravitating to a higher value job) must exactly equal the number of individuals who accept such a job (either from the unemployment pool or from a lower value job). Hence,

$$m_{1i} g_{1i}(w) \mathcal{D}_{ei}(w) = f_1(w) \left[\lambda_{ui}^1 u_i A_{ui}(w) + \lambda_{ei}^1 m_{0i} G_{0i}(q_i(w)) + \lambda_{ei}^1 m_{1i} G_{1i}(w) \right], \tag{2}$$

where $\mathcal{D}_{ei}(w) \equiv \left[\delta_i + \lambda_{ei}^0 \overline{F}_0(q_i(w)) + \lambda_{ei}^1 \overline{F}_1(w)\right]$ is the rate at which such a worker will exit their current job. An analogous equation exists for part-time jobs. Equation 2 features a weighted distribution of full-time and part-time earnings amongst the employed, $m_{0i} G_{0i}(q_i(w)) + m_{1i} G_{1i}(w)$, with the hours specific distribution functions in this expression evaluated at wage rates that yield equal value to the worker. And while expressions for G_{0i} and G_{1i} are both individually complicated, this weighted distribution admits a considerably simpler form which we present and derive in Appendix D.

In the appendix we also show that u_i, the unemployment rate of type i workers (which balances the flows from the unemployment pool to employment in either sector, to the job destruction induced flows from employment) is given by:

$$u_i = \frac{1}{1 + \kappa_{ui}^0 + \kappa_{ui}^1} A_i(\underline{\omega}_i) + \int_{\underline{\omega}_i}^{\overline{\omega}_i} \frac{\mathrm{d}A_i(w)}{1 + \mathcal{D}_{ui}(w)/\delta_i} + 1 - A_i(\overline{\omega}_i), \tag{3}$$

where $\underline{\omega}_i \equiv \min\{\underline{w}_1, q_i^{-1}(\underline{w}_0)\}$ and $\overline{\omega}_i \equiv \max\{\overline{w}_1, q_i^{-1}(\overline{w}_0)\}$, and where $\mathcal{D}_{ui}(\phi) \equiv \lambda_{ui}^0 \overline{F}_0(q_i(\phi)) + \lambda_{ui}^1 \overline{F}_1(\phi)$ is the rate at which a type i worker with reservation wage ϕ will exit the unemployment pool into either part-time or full-time employment. This expression decomposes the unemployment rate into the contribution by three (endogenously determined) groups of workers: those who accept all offers; those who accept some and reject others; and those who reject all. Note that u_i is bounded below by $(1 + \kappa_{ui}^0 + \kappa_{ui}^1)^{-1}$, which is the rate that would prevail in the absence of any reservation wage heterogeneity. In contrast to the homogeneous worker model κ_{ei}^h affects u_i through two channels: the direct effect through changes in worker reservation wages and the indirect effect through its potential impact on the equilibrium wage offer distributions (described below).

3.5 Firms

In order to make this an equilibrium model we specify the behaviour of firms. It is the profit maximizing behaviour of firms, taking as given the optimal strategies of workers and other firms, that determines the equilibrium distributions of wage offers and job offer arrival rates. The type of job offer made by firms (full-time or part-time) is an exogenous technological characteristic of the firm and we therefore refer to firms as belonging to a particular hours sector.[15] As in Burdett and Mortensen (1998) we assume that there is wage posting: within each hours sector employers post a single wage w prior to forming matches with potential employees, who can then either accept or reject the offer. Firms also choose a level of recruiting intensity v which raises their visibility in the labour market: the probability that workers draw job offers from a particular firm is proportional to this recruiting intensity. This feature allows firms to change the rate at which they meet potential employees independent of the wage rate, and will also allow us to endogenize the set of job offer arrival rates at the macroeconomic level.

Within each sector, firms differ in their exogenously determined productivity. The cumulative distribution of firm productivity in sector h is denoted Γ_h which is continuous on its support $[\underline{p}_h, \overline{p}_h]$. This productivity corresponds to the hourly flow marginal product of workers, and is independent of both the number and identity of workers.

[15] We do however, allow the contact rate of firms to change differentially following tax reforms by inclusion of a recruiting intensity decision that we describe below. Alternative approaches such as allowing firms to substitute between part-time and full-time workers (Roger and Roux, 2009), or choosing which sector to operate in (Meghir, Narita and Robin, 2015) would complicate the analysis considerably given the richness in worker level heterogeneity that we incorporate here.

The flow cost of recruiting effort also potentially differs across firms. We denote this as $c_h(v;p)$ with this function strictly convex in v and with $c_h(0;p) = 0$ for all p. Henceforth, we parameterise this function as $c_h(v;p) = c_h(p)v^2/2$ with $c_h(p) > 0$ and in Section 3.6 derive an important theoretical result regarding the extent to which assumptions regarding $c_h(p)$ actually matter for our counterfactual simulations.

3.5.1 Firm Size

The number of workers of a given observable type i that a sector h firm employs at wage w and recruiting intensity v is denoted $\ell_{hi}(w,v)$. Since firms may potentially contact workers of all types, total employment at such a firm is given by $L_h(w,v) = \sum_i n_i \ell_{hi}(w,v)$. In what follows, it is convenient to write conditional firm size as $\ell_{hi}(w,v) = \overline{\ell}_{hi}(w) \cdot v/V_h$, where V_h is the aggregate recruiting intensity in sector h:

$$V_h = \int_{\underline{p}}^{\overline{p}} v_h(p)\, \mathrm{d}\Gamma_h(p), \tag{4}$$

and with $v_h(p)$ denoting the *recruiting policy* of a sector h productivity p firm. The steady state employment of type i workers in full-time firms per unit intensity solves:

$$\overline{\ell}_{1i}(w)\mathcal{D}_{ei}(w) = \lambda_{ui}^h u_i A_{ui}(w) + \lambda_{ei}^h m_{0i} G_{0i}(q_i(w)) + \lambda_{ei}^h m_{1i} G_{1i}(w), \tag{5}$$

which balance the number of workers who enter (from non-employment and lower values jobs) and exit employment at a given firm.[16] Note that $\overline{\ell}_{hi}(w)$ is non-decreasing in w. This is because higher wage firms attract more workers from both the unemployment pool (the mechanism in Albrecht and Axell, 1984) and lower value firms (the mechanism in Burdett and Mortensen, 1998). In contrast to models without reservation wage heterogeneity, the absence of on-the-job search ($\lambda_{ei}^h = 0$) does not imply that employment is uniformly distributed across firms when matching is random. This is intuitive because low wage firms are only able to attract low reservation wage workers (it is straightforward to show that $\overline{\ell}_{hi}(w)$ is proportional to $A_{ui}(w)$ in this case). More generally, firm size can be shown to depend upon a weighted distribution of reservation wages amongst employed and unemployed workers, with the weights a function of job offer arrival rates

[16] The assumption that there is a continuous distribution of leisure flows b for each demographic groups $i \leq I$ is important from a technical perspective as it generates a continuous distribution of reservation wages. Absent this assumption, the total labour supply function facing the firms $\overline{L}_h(w)$ would be discontinuous in the wage rate at each $\{\phi_i\}_{i \leq I}$, which greatly complicates the analysis of the model equilibrium.

and the distributions of wage offers.

3.5.2 Firm Profits

Each firm chooses a *wage policy* $w_h(p)$ and *recruiting policy* $v_h(p)$ to maximize its steady state profit flow, taking the arrival rate of job offers, together with the behaviour of other firms (both part-time and full-time) and workers as given.[17] Hence:

$$\{w_h(p), v_h(p)\} = \arg\max_{(w,v)} \overline{\pi}_h(w;p)\frac{v}{V_h} - c_h(v;p), \tag{6}$$

where $\overline{\pi}_h(w;p) = (p-w)h \cdot \overline{L}_h(w)$ is the expected profit flow per unit intensity, with $\overline{L}_h(w)$ such that $L_h(w,v) = \overline{L}_h(w) \cdot v/V_h$. The optimal recruiting policy $v_h(p)$ equates the marginal cost of increasing recruiting effort to the marginal expected profit flow. That is:

$$\left.\frac{\partial c_h(v;p)}{\partial v}\right|_{v=v_h(p)} \equiv c_h(p)v_h(p) = \frac{\overline{\pi}_h(w_h(p);p)}{V_h}. \tag{7}$$

In Appendix E we use standard arguments to show that the optimal wage policy of firms $w_h(p)$ must satisfy the following equation:

$$w_h(p) = p - \left[\pi_h^*(\underline{p}_h) + \int_{\underline{p}_h}^{p} \overline{L}_h(w_h(y))\,\mathrm{d}y\right] \times \frac{1}{\overline{L}_h(w_h(p))}, \tag{8}$$

where $\pi_h^*(\underline{p}_h)$ are the (hourly) profits of the least productive firm in sector h. This is a form that we exploit when we numerically solve for the equilibrium of our model.[18]

3.6 Matching Technology and Equilibrium

In order to close the model we endogenize the arrival rate of job offers by complementing it with aggregate matching functions. The total flow of matches in each hours sector h is

[17] The assumption of steady state profit maximisation is standard in the wage-posting literature. See Mortensen (2000) for a discussion.

[18] While the expression in equation 8 is similar to that derived in e.g. Bontemps, Robin and van den Berg (1999), the solution is somewhat more involved for three main reasons: i) the firm labour supply function depends upon the entire distributions of wage offers and is a much more complicated object; ii) we require an independent update of wage policy of the least productive firm and therefore $\pi_h^*(\underline{p}_h)$; iii) the job offer arrival rates are endogenous (see Section 3.6).

denoted $M_h(V_h, S_h)$; it depends on the total recruiting intensity V_h and the total intensity adjusted search effort of both employed and non-employed workers S_h:

$$S_h = \sum_i n_i \left[s^h_{ui} u_i + s^h_{ei}(1 - u_i) \right], \tag{9}$$

where s^h_{ji} denotes the exogenous search effort of type i workers that is directed to sector h when in employment state $j \in \{u, e\}$. By assumption, the matching function M_h is increasing in both its arguments, concave, and linearly homogeneous. The job offer arrival rates for each worker type are then related to the flows of matches according to:

$$\lambda^h_{ji} = s^h_{ji} \cdot M_h(V_h, S_h)/S_h \tag{10}$$

As is common in the search literature (see, e.g. Petrongolo and Pissarides, 2001), we assume that the matching technology is Cobb-Douglas: $M_h(V_h, S_h) = V_h^{\theta_h} S_h^{1-\theta_h}$. In our application, our main results are calculated under the assumption $\theta_{h_0} = \theta_{h_1} = 1/2$.

4 Estimation and Empirical Implementation

4.1 Data

Before detailing the identification and estimation of our model, we describe the data. Our data comprises a sub-sample of the UK Labour Force Survey (LFS). The LFS is a quarterly survey of around 60,000 households in Great Britain, with these households followed for five successive quarters or "waves". When individuals first enter the survey they are in wave one, so that in any given quarter, there are roughly equal proportions of individuals in each interview wave. This rolling panel structure means that there is approximately an 80% overlap in the samples for successive quarters.

The LFS provides us with very rich information concerning the respondents labour market status. Crucially, we observe employment status and spell durations, together with hours and earnings information (in the first and fifth waves since 1997) for workers.[19] We construct a sample prior to the introduced or announcement of WFTC. In particular, we follow individuals who are observed in the first quarter of 1997 until (at the latest) the first quarter of 1998.

[19]While individuals are interviewed at a quarterly frequency, the start and end date of spells is reported so that we effectively observe continuous time data.

We classify individuals as being employed if they have a job, and non-employed if they do not. Since we do not distinguish between the states of unemployment and non-participation, this definition of non-employment is broader than the standard ILO unemployment definition. Amongst the employed, women who report working less than 30 hours per week are classified as part-time workers, while those working at least 30 hours per week are classified as full-time workers. We set $h_0 = 20$ and $h_1 = 40$, which correspond well to the respective conditional averages. Empirically, very few men work part-time, so we treat all male workers as working full-time and set $C_i^1 = 0$. In both cases, we calculate gross wages using reported hours of work, but then proceed to calculate incomes as if they were working at the relevant discrete hours point.

Individuals who are aged below 21 or above 50 are excluded from our sample, as are individuals in full-time education. We also exclude individuals when any adult family member is either self-employed or long-term sick/disabled, or there is a change in household structure. Motivated by both the tax credit eligibility structure, and the assumption that workers are equally productive at a given firm, we additionally restrict our sample to those individuals with no more than the compulsory level of schooling (that is, GCSE or equivalent), and assume that any higher educated individuals operate in a separate labour market.[20] Together, our sample selection criteria imply that all individuals have a minimum of five years of potential labour market experience. After sample selection we have roughly 24,000 observations. Summary statistics are presented in Appendix L.

4.2 Applying the UK Tax and Transfer System

Our empirical application seeks to accurately represent the main features of the UK tax and transfer system so that we may consider the impact of a series of tax reforms. We do not attempt to describe the full UK system here, but the interested reader may consult Adam and Browne (2009) and Jin, Levell and Phillips (2010) for recent surveys. The underlying tax and transfer schedules are calculated prior to estimation using FORTAX (Shephard, 2009), and reflect the complex interactions between the tax and transfer

[20]Less educated worker are, by far, the largest beneficiaries of tax credits. Other studies have also focused on those with low education (similarly defined), and some *ex-post* evaluations have used single mothers with high education (as an alternative to single women without children) as a control group in a difference-in-differences framework. See, for example, Blundell (2002). A consequence of restricting our sample to individuals with low schooling is that we are not able to capture potential spillover effects on the more highly educated.

system, varying accurately with earnings, hours of work and demographic characteristics.[21] As part of our estimation we calculate net-incomes under the April 1997 system, and assume that individuals always faced this so that the environment is stationary.

To economize on the number of groups that we need to consider (and parameters to estimate), we make a number of further assumptions regarding the set of demographic types. Specifically, we do not allow taxes and transfers to vary by the age of the claimant or by the age of any children. Taxes and transfers are calculated as if the claimant were at least 25 years old, and as if any children are aged 10. Families with more than two children are treated as if there were only two children. Since some benefits have asset tests, we also assume that no families in our sample are affected by them. All families are assigned average band C council tax (a local property based tax).[22]

The model developed in Section 3 assumed the presence of a single economic decision maker. This presents difficulties for our empirical application because transfers and in-work tax credits are assessed on family income in the UK. A complete treatment of couples is beyond the scope of this paper.[23] Rather than providing a detailed characterization of the household decision making process, we take a more limited approach by conditioning upon the current employment status and (discretized) earnings of the individuals' partner so that there are essentially two observations for each two-person household, with the unobserved leisure component for individuals in couples assumed independent conditional on type. We subsume partner earnings in the tax schedule, but allow this tax schedule to accurately vary with the earnings of both individuals. In our empirical application we discretize the empirical distribution of partner earnings (conditional on gender and the presence and number of children) into ten groups, including non-employment (zero earnings); actual partner earnings are then replaced with those observed at either the 10^{th}, $20^{\text{th}}, \ldots,$ or 90^{th} percentile point of the relevant empirical distribution, and these are taken to be policy invariant.

The above categorization requires that we consider $I = 64$ different worker types. Conditional on hours of work, the resultant tax schedules for each of these groups as a

[21] A potentially important benefit that we do not model is housing benefit, a transfer given to low income families to assist with housing rent. The Labour Force Survey data used in our empirical application does not contain data on rents. Since tax credit income results in housing benefit entitlement being withdrawn, families in receipt of housing benefit would gain less from WFTC than otherwise equivalent families. This omission means that we are likely to overstate the initial labour supply response for some types.

[22] Band C is the most common band; the Labour Force Survey data does not report banding information.

[23] See Guler, Guvenen and Violante (2012), for a theoretical characterization of the *reservation wage* strategy of couples with income pooling and Dey and Flinn (2008), for a *partial equilibrium* empirical application.

function of the wage rate will be a piecewise linear function, with possible discontinuities. We first remove these discontinuities by appropriately modifying parameters of the tax and transfer system. The modified marginal tax rate schedule for fixed hours is replaced by a differentiable function using the method proposed by MaCurdy, Green and Paarsch (1990), which smoothes the tax schedule in the neighbourhood of any marginal rate changes. Note that this approach requires a numerical solution to the indifference condition object $q_i(w)$. Details of the smoothing procedure are provided in Appendix J.

4.3 Likelihood Estimation

The derivation of the likelihood function follows standard arguments, and generalises and synthesises that presented in Bontemps, Robin and van den Berg (1999, 2000). Full details are provided in Appendix H. We note some points of significance. First, we use the steady state distributions of earnings and employment/unemployment shares to determine the initial conditions. Second, we do not use any information on the wages received following a job-to-job transition. We comment on the first point further in Section 4.6 in light of our estimation results. The second point represents a common issue with the structural estimation of wage posting models. Namely, that they do not permit job-to-job transitions associated with wage cuts. In the context of the model developed here, wage cuts may be permitted if an individual changes hours sectors, but reductions in the value of jobs are not.[24] This partial information approach is common and has been adopted in a number of other empirical applications of wage posting models (see for example, Bontemps, Robin and van den Berg, 1999, 2000; Kiefer and Neumann, 1993).[25]

[24]The model could potentially be extended to allow for job-to-job transitions associated with lower values by introducing a *reallocation shock* as in Jolivet, Postel-Vinay and Robin (2006). These shocks are draws from the wage offer distributions for which the only alternative to acceptance is to become unemployed. The presence of reservation wage heterogeneity complicates the analysis as some individuals may wish to exercise the unemployment option upon receiving such a shock.

[25]An additional complication here is that the transition between sectors from certain wages may also be a zero probability event in some regions of the parameter space for some individuals. For example, depending upon the parameter values, there may be no part-time job offer that a current high wage full-time worker would accept. While there are a number of ways of potentially addressing this issue, given we do not consider this to be a first order issue for the problem at hand we adopt a simple approach by assuming that there is some probability that the hours sector following a job-to-job transition is observed with error. We estimate this misclassification error probability and assume it is independent of latent hours. Alternatives approaches such as modelling the hours disutility as unobserved heterogeneity, or incorporating the measurement error through wages (as in van den Berg and Ridder, 1998) would complicate the analysis considerably. See Bound et al. (1994) for US evidence on measurement error in wages and hours.

While the tax and transfer schedules may vary with each observable type, we only allow the parameters of the model to depend on a subset of demographic types. For couples we do not allow the parameters to vary with the earnings and labour market status of their partner; for parents we do not allow them to vary with the number of their children. The distribution of work opportunity costs H_i is assumed to be Normally distributed, with mean μ_i and standard deviation σ_i.[26]

4.4 Identification

Before detailing the three-step estimation procedure that we develop, we informally discuss the identification of the wage offer and reservation wage distributions.[27] These ideas are presented more formally in Appendix I. To begin, it is useful to first consider a special case of our model in the absence of hours sectors, a tax system, and demographic heterogeneity, and where the distribution of leisure flows collapses to a degenerate distribution (i.e. workers are homogeneous). This is the model analysed in Bontemps, Robin and van den Berg (2000). Conditional on transitional parameters (job arrival rates and destruction rates), identification of the wage offer distribution follows directly from a steady state relationship between the wage offer and earnings distributions. Moreover, in such a setting all job offers will be accepted by all unemployed workers so that the accepted wage distribution will coincide with the wage offer distribution. This special case of our more general model is therefore over-identified.

Regardless of its source, once we allow for heterogeneity in the reservation wage of unemployed workers the distribution of accepted wages will no longer equal the wage offer distribution. This is because workers are selective in the wages that they are willing to accept, so that the distribution of accepted wages (which will stochastically dominate the wage offer distribution) will depend upon two distributions so that we face a deconvolution problem.[28] Under the maintained assumption of steady state behaviour,

[26] The leisure flow distribution was poorly identified for single women. In the results presented we have restricted the distribution of leisure flows to be the same for married and single women without children.

[27] While these are not primitives of the model, given knowledge of these distributions and the transitional parameters, it is then straightforward to identify the underlying distribution of firm productivities and worker leisure flows by using the equilibrium relationships we derived in Section 3.

[28] An alternative approach (for simplicity, in the context of a single sector model) would be to consider the distribution of wages accepted from individuals currently employed at very low wages $w \approx \underline{w}$. We can apply an identification at infinity type argument for such individuals, as they would essentially accept any other job offer. The distribution of wages that they earn on their next job provides a direct estimate of the wage offer distribution that is valid even in the presence of reservation wage heterogeneity. These arguments extend naturally to multi-sector models. Note that this does not require a steady state assump-

intuitively we are still able to establish non-parametric identification in this case because we observe as many distributions (starting wages and cross-sectional earnings) as distributions that we wish to recover.

4.5 Three Step Estimation Procedure

The likelihood function (derived in Appendix H) depends directly upon the part-time and full-time wage offer distributions, which themselves depend upon the exogenous distributions of firm productivity and the other parameters of the model. Moreover, the conditional earnings distributions, distribution of reservation wages, and the unemployment and employment shares, are all complicated non-linear functions of these distributions and parameters. Rather than attempting to solve the full model at each evaluation of the likelihood function, we instead estimate the model using a three step procedure that is an extension of that proposed in Bontemps, Robin and van den Berg (1999, 2000) to the considerably richer environment that we consider. Specifically:

1. We estimate $\{\underline{w}_0, \overline{w}_0\}$ as the sample minimum and maximum values of observed wages amongst part-time jobs and $\{\underline{w}_1, \overline{w}_1\}$ as the sample minimum and maximum values of observed wages amongst full-time jobs.[29] Consistent with our assumptions regarding market structure, none of these estimates condition upon worker type. We then calculate estimates of the unconditional earnings densities in each sector using a non-parametric estimator. We denote these estimated density functions as $\widehat{g}_0$ and $\widehat{g}_1$.[30]

2. We specify a parametric form for the distribution of unobserved leisure flows H_i with a finite parameter vector $\{\boldsymbol{\theta}_{H_i}\}_{i \leq I}$. Since workers are assumed to sample wages from the same wage offer distributions F_0 and F_1 regardless of their demographic type i, we weight equation 2 by the fraction of each type (n_i) and then sum

tion. While in principal such an estimator can be used as a useful robustness check, we do not pursue this further here because sample sizes are far too low once we condition on both low wages, and observing a job transition with a wage.

[29] This approach is also used in numerous similar studies. While these provide super-consistent estimates, they are potentially vulnerable to wage measurement error.

[30] In our empirical application we use Gaussian kernel estimators with a bandwidth of 0.5. Our results are not sensitive to this particular kernel or bandwidth choice.

to obtain appropriately averaged equations of the form:

$$f_h(w) = \frac{\sum_i n_i m_{hi} g_{hi}(w)}{\sum_i n_i \bar{l}_{hi}(w)}, \tag{11}$$

for $h \in \{0,1\}$. We replace the numerator of equation 11 by $m_h \widehat{g}_h(w)$, where $m_h = \sum_i n_i m_{hi}$.[31] To recover the part-time and full-time offer distributions that induce our estimates of the unconditional empirical earnings distributions, we provide an initial guess of f_0 and f_1 and then repeatedly (and simultaneously) iterate on this equation for both h_0 and h_1. At each iteration step we scale the densities by a normalization factor to ensure that we have proper distribution functions, and then verify that these normalization factors converge to 1. Conditional on the transitional parameters and distributions of leisure flows, we obtain consistent estimates of the offer distributions and their densities, which we respectively denote $\widehat{F}_h$ and $\widehat{f}_h$. These estimates are then substituted into the likelihood function. They are also used to calculate the conditional employment shares and earnings densities: $u_i(\widehat{F}_0, \widehat{F}_1)$, $m_{hi}(\widehat{F}_0, \widehat{F}_1)$, and $g_{hi}(\cdot; \widehat{F}_0, \widehat{F}_1)$.

3. Given a parametric form for the matching functions $M_h(V_h, S_h)$ and the recruiting cost functions $c_h(v; p)$, we obtain the implied distribution of firm productivity and recruiting efforts by rewriting the first order conditions from the firms' maximization problem in each sector h as:

$$p = w_h^{-1}(w) \equiv w + \overline{L}_h(w)/\overline{L}'_h(w), \tag{12}$$

and then using equations 7 and 10, together with the relationship $F_h(w_h(p)) = \int_{\underline{p}_h}^{p} v_h(y)/V_h \, d\Gamma_h(y)$, which follows from the observation that more productive firms offer higher wages. If the discount rate ρ is known, then the distribution of leisure flows H_i can then be recovered using equation 1.

We construct confidence intervals by bootstrapping the three stage estimation procedure. The advantages of this multi-step procedure versus a completely parametric approach (whereby we specify the underlying distribution of firm productivity and then solve for the equilibrium of the model) are essentially threefold. Firstly, it is considerably

[31] Conditional firm size $\bar{l}_{hi}(w)$ is obtained using equation 5 for full-time jobs, and is similarly defined for part-time jobs. These expressions depend on the distribution of reservation wages amongst the non-employed, which is characterised in Appendix C, and the weighted cross-sectional earnings distribution as derived in Appendix D.

easier to perform this numerical inversion than it is to solve the full model at every evaluation of the likelihood function. Second, it permits greater flexibility than simple parametric forms for the productivity distribution. Thirdly, since this semi-nonparametric estimation procedure does not require assumptions regarding the determination of F_h, these estimates and those of the transitional parameters are valid under a range of possible models. Conversely, in addition to the usual efficiency considerations, the main disadvantage of this approach compared to a full model parametric specification, is that it does not guarantee a monotonically increasing relationship between wages and productivity (in which case the empirical distribution of wages can not be an equilibrium outcome from our model), and in general it may not be possible to constrain the parameters to achieve such monotonicity.[32]

4.5.1 Equilibrium and Recruiting Cost Function Parameterisation

Our estimation procedure provides direct estimates of the wage offer distributions and the set of arrival rates (together with all worker preference parameters and distributions). These are endogenous objects. The third step of our multi-step procedure then involves recovering the primitives of the model (firm productivity and search intensities) that induces these estimated objects. Importantly, this third step assumes that both the matching technology, $M_h(V_h, S_h)$ and the recruiting cost function $c_h(p)$ are known.

For the purposes of estimation, both the matching function technology parameter and the cost function are clearly normalisations. What is less clear, however, is the extent to which they may be also considered normalisations for the purposes of both our tax reform and design experiments. In Appendix F we formally prove that the *worker side* equilibrium (that is, the offer distributions and arrival rates that are relevant for the individual decision problem) is in fact *invariant* to our assumptions regarding the recruiting cost, provided that $c_h(p) > 0$. That is, the non-identification *does not matter* for our policy simulations. Thus, without any loss of generality we set $v_h(p) = 1$ in the pre-reform period (also implying that $\Gamma_h(p) = F_h(w_h(p))$) and recover the values of $c_h(p)$ that are consistent with this being an equilibrium outcome.

[32] In principle we could estimate the model using data from both before and after the reforms, treating each as a distinct steady state from the model. Under the assumption that all model parameters were to remain the same, this would permit identification of the matching function parameters θ_h using an approach similar to Flinn (2006) in the context of a labour market search model with matching and bargaining. This would require solving the full model, as the model imposes structure on the relationship between the distributions of wage offers and arrival rates across steady states under different tax systems. It is also complicated by the non-tax changes over this period.

4.6 Estimation Results and Model Fit

Given our parameter estimates (Table 1), the implied wage policy functions $w_0(p)$ and $w_1(p)$ that are obtained from the first order conditions to the firms' profit maximization problem (equation 12) are found to be monotonically increasing in p so that the estimated empirical distribution of wages can be an equilibrium outcome from our model. That is, the theoretical model is not rejected by the data. These wage policy functions are presented in Figure 2a. The first notable feature evident in this figure is that the wage policy functions become flat as productivity increases so that high productivity firms have a high degree of monopsony power. Second, the extent of this monopsony power is typically lower for part-time firms. The underlying distributions of firm productivity are shown in Figure 2b, with both part-time and full-time distributions highly skewed to the right. The associated estimated wage offer distributions are presented in Figure 2c, which shows that there is a relatively higher concentration of low wage offers among part-time firms. Finally, the unconditional distribution of wage earnings that these distributions induce is shown in Figure 2d.

The estimates reveal considerable heterogeneity across groups. The job destruction rate (which is relatively precisely estimated across all groups) is highest for single parents ($\hat{\delta}_i = 0.014$) with this estimate implying that jobs are *exogenously* destroyed on average every 70 months ($= 1/0.014$). The destruction rates are lowest for married men and married women without dependent children, where they are estimated to be around two and a half times as small. The arrival rates of job offers also varies considerably across groups. Job offers arrive most frequently for men: for unemployed married men without children we obtain $\hat{\lambda}^1_{ui} = 0.251$, while for single men and married men without children we obtain lower estimates (0.073 and 0.085 respectively). The estimated total job offer arrival rates $\hat{\lambda}^0_{ui} + \hat{\lambda}^1_{ui}$ for unemployed childless women is broadly similar to the values of $\hat{\lambda}^1_{ui}$ for men. However, for unemployed single parents and married women with children we obtain much lower job offer arrival rates (particularly for full-time jobs).[33]

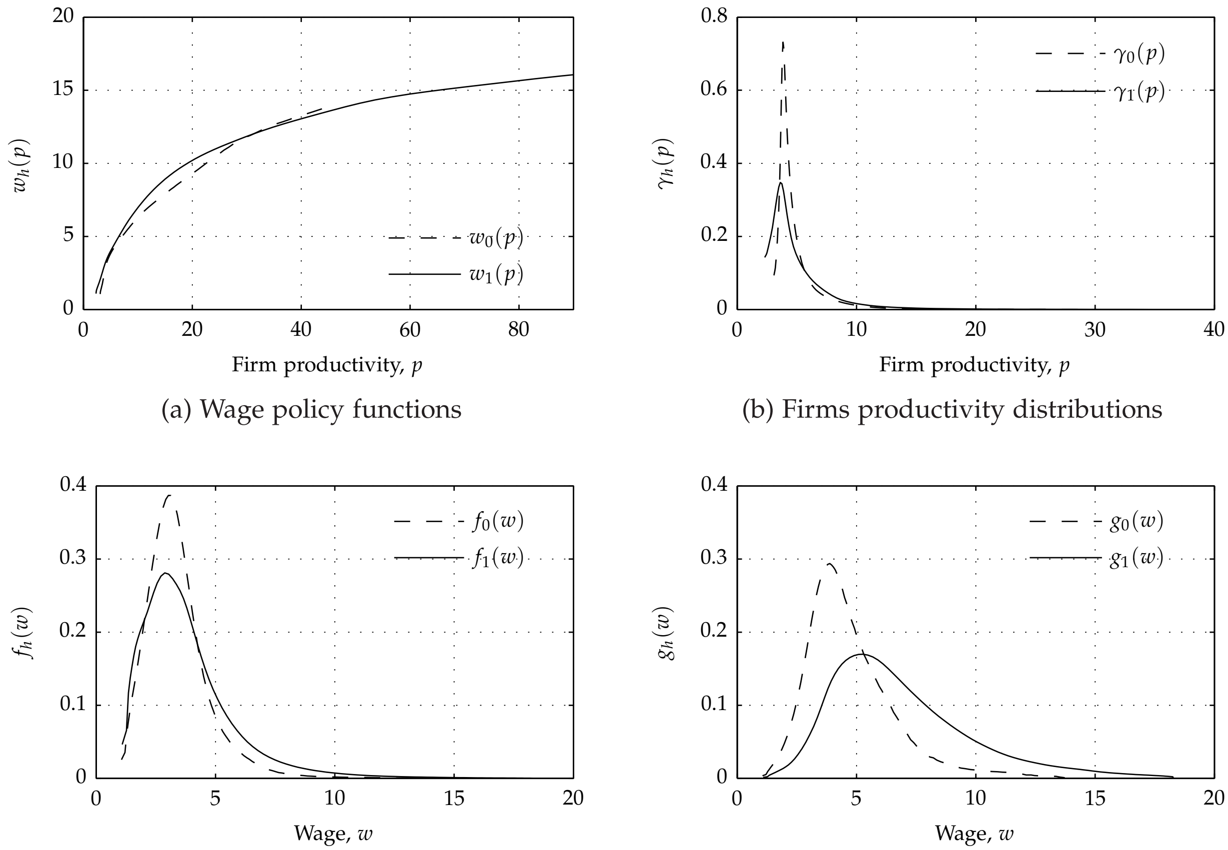
For the majority of groups, the estimated job offer arrival rate when employed is less than that when unemployed, although in some cases the estimated parameters are very similar in value. For single men we obtain the relative arrival rate ratio $\hat{\lambda}^1_{ui}/\hat{\lambda}^1_{ei} =$

[33] While the job offer arrival rates are treated as estimation objects, they are endogenous and are not parameters of the model (see equation 10). However, given a parameterisation of the matching technology and recruiting cost function, we are able to obtain the exogenous search intensity parameters that induce these. Note that the levels of the search intensity parameters are not of direct interest, as they can not be interpreted independently of normalisations in the cost function. See also Appendix F.

Table 1: Maximum Likelihood Parameter Estimates

	$1/\delta_i$	$1/\lambda^0_{ui}$	$1/\lambda^1_{ui}$	$1/\lambda^0_{ei}$	$1/\lambda^1_{ei}$	μ_i	σ_i	C^1_i
single men	90.5	–	13.7	–	21.0	9.9	68.5	–
	[84.6,98.0]		[11.1,17.4]		[17.8,25.5]	[-22.7,29.8]	[42.9,102.6]	
married men, no kids	168.8	–	4.0	–	15.5	-87.4	122.9	–
	[154.3,185.5]		[2.7,5.7]		[13.0,19.2]	[-166.1,-28.5]	[83.4,173.1]	
married men, kids	189.3	–	11.8	–	13.5	9.8	63.0	–
	[176.3,203.0]		[9.7,13.8]		[11.5,16.1]	[-14.3,27.9]	[47.9,82.6]	
single women	126.6	20.7	19.9	81.4	34.1	-73.2	110.0	17.4
	[114.6,137.9]	[15.7,26.9]	[14.3,26.3]	[52.3,158.4]	[28.4,42.6]	[-123.7,-42.8]	[83.3,152.3]	[7.6,29.8]
single parents	70.1	58.4	490.3	72.3	41.5	42.8	32.8	35.3
	[65.1,76.1]	[45.6,97.5]	[308.5,1128.8]	[54.7,99.8]	[32.9,53.6]	[6.2,49.4]	[7.7,105.9]	[32.2,38.8]
married women, no kids	154.6	22.7	17.3	100.3	58.9	-73.2	110.0	50.4
	[142.8,166.6]	[15.9,30.8]	[12.8,23.8]	[75.9,143.1]	[48.8,73.8]	[-123.7,-42.8]	[83.3,152.3]	[42.2,58.4]
married women, kids	102.8	23.6	132.8	33.8	90.2	35.6	49.3	42.8
	[97.5,107.4]	[19.6,28.6]	[90.2,208.7]	[30.0,39.6]	[74.4,110.5]	[29.3,41.0]	[44.1,56.0]	[34.3,51.8]

Notes: All durations are monthly. Incomes are measured in pounds per week in April 1997 prices. The distribution of work opportunity costs H_i is assumed to be Normal, with mean μ_i and variance σ_i^2. The 5^{th} and 95^{th} percentiles of the bootstrap distribution of parameter estimates are presented in brackets, and are calculated using 500 bootstrap replications.



(a) Wage policy functions

(b) Firms productivity distributions

(c) Wage offer distributions

(d) Wage earnings distributions

Figure 2: Pre-reform equilibrium distributions and functions. All figures calculated using the maximum likelihood estimates from Table 1 and calculated under the April 1997 (pre-reform) tax and transfer system. All incomes measured in April 1997 prices. Figure 2a shows how the optimal wage policy of firms varies with hours and firm productivity, and truncated at productivities greater than $w_1^{-1}(\hat{G}_1(0.99))$; Figure 2b shows the underlying distribution of firm productivity as obtained from the first order conditions to the firms' profit maximization problem (with the normalization $v_h(p) = 1$), and truncated at productivities greater than $w_1^{-1}(\hat{G}_1(0.95))$; Figure 2c shows the associated distribution of part-time and full-time wage offers; Figure 2d shows the unconditional distribution of part-time and full-time earnings that these wage offer distributions induce.

1.5, while this ratio is somewhat higher for married men without children (=3.9) and slightly lower for married men with children (=1.1). In this latter case we can not reject the null hypothesis that the arrival rates are equal. These general findings are broadly consistent with the estimates reported in van den Berg and Ridder (1998); they contrast with Bontemps, Robin and van den Berg (2000) which found (using French Labour Force Survey data) that job offers arrive around ten times as frequently for the unemployed compared to the employed. For all groups of women we obtain the relative part-time arrival rate ratio $\hat{\lambda}^0_{ui}/\hat{\lambda}^0_{ei} > 1$ (ranging from around 1.3 for single parents and married women with children to 4 for women without children). Mirroring the pattern observed for men, the relative full-time job offer arrival rate ratio for single women $\hat{\lambda}^1_{ui}/\hat{\lambda}^1_{ei} = 1.7$, while this ratio is again somewhat higher for married women without children (=3.4) and lower for married women with children (=0.7). For single parents we estimate large differences by employment status with $\hat{\lambda}^1_{ui}/\hat{\lambda}_{ei} = 0.1$.[34]

The estimated monetary disutility of full-time work $\hat{C}^1_i$ is lowest for single women (around £20 per week in April 1997 prices), while it is at least twice as high for single parents and married women. We obtain considerable dispersion in the unobserved leisure flows for all groups, and this translates into dispersion in reservation wages. In Appendix L we present results which show the proportion of workers of each type whose reservation wage is below given percentiles of the (full-time) wage offer distribution. In all cases we obtain $\hat{A}_i(\underline{\hat{w}}_1) \ll 1$, so that workers are indeed selective in the wage offers that they are willing to accept. This feature also implies a negative duration dependence in the exit rate out of unemployment. Furthermore, we find that essentially all individuals would be willing to accept the highest full-time wage offer.

In terms of model fit, we first note that there is little mechanical reason for the model to be able to fit certain features of the data conditional on worker type. This is because the wage offer distributions are common to all workers, such that any difference in employment states and the entire distributions of earnings must be explained by the behavioural channels in the model through variation in the transitional parameters, leisure flow distributions, and the tax and transfer system. Despite this, we obtain a good fit to the data which lends support to the empirical content of the model. The difference in the empirical and predicted states for the main demographic groups is small and only

[34] As described in Section 4.3, in order to avoid a potential statistical degeneracy issue, we also estimate a misclassification error probability for job-to-job hours transitions. We obtain an estimate of 10.5%. We also note that conditional on our maximum likelihood estimates (and ignoring wages), no transition across sectors that are observed in our data would actually have zero probability.

rarely does it exceed 1 percentage point (see Table 2). Similarly, we do well in replicating the observed distribution of wage earnings (see Figure 3); for most groups the fit is excellent, although the fit of the full-time earnings distribution for married women with children (Figure 3h) is slightly less satisfactory. Finally, we note that the estimated model also provides a generally good fit to the transitions between the different labour market states. In Appendix L we compare the simulated and empirical one-year transition rates. We replicate the general pattern of transitions across the demographic groups, with a particularly good fit to the one-year job-to-job transition rates. The largest discrepancies occur for the non-employment to employment transition rates for married men and married women women without children: for married men without children we under-predict the transition rate (0.6 compared to 0.8 in the data), and for married women without children we over-predict by a similar absolute amount. Note that these are the groups that are categorically ineligible for tax credits (see Section 2), and for whom the incidence of non-employment is the lowest (again, see Table 2).

5 Simulating Tax Reforms

In this section we simulate the impact of real changes to the UK tax and transfer system between April 1997 (the pre-reform sample period) and April 2002. We also consider the impact of introducing WFTC in isolation. To highlight the relative importance that these reforms have on job acceptance behaviour and the strategy of firms, we present our results in two stages. Firstly, we consider the impact of the reforms holding the distribution of job offers and their arrival rates constant; secondly, we allow firms to respond through their wage policy and recruiting effort. We refer to the first channel as the *direct impact* of the reforms, and the second channel as the *equilibrium impact*.

5.1 Direct Impact

The direct and equilibrium impact of the reforms on employment states is presented in Table 3, and we first discuss the direct effect. The table shows that the (non-WFTC) reforms between April 1997 and April 2002 had a small positive effect on the employment of both singles and couples without children (ranging from 0.2 percentage points for married men without children, to 0.8 percentage points for single men).[35] These

[35]In our analysis demographic types are fixed, so that no transitions are possible between singlehood and marriage, and between parenthood and being childless. If such transitions were possible then the

Table 2: Empirical and Predicted Employment States

	Empirical			Predicted		
	u_i	m_{0i}	m_{1i}	u_i	m_{0i}	m_{1i}
single men	0.251	–	0.749	0.241	–	0.759
	[0.238,0.262]		[0.738,0.762]	[0.230,0.251]		[0.749,0.770]
married men, no kids	0.070	–	0.930	0.063	–	0.937
	[0.061,0.079]		[0.921,0.939]	[0.056,0.071]		[0.929,0.944]
married men, kids	0.123	–	0.877	0.114	–	0.886
	[0.114,0.131]		[0.869,0.886]	[0.108,0.122]		[0.878,0.892]
single women	0.157	0.103	0.741	0.166	0.108	0.726
	[0.144,0.170]	[0.092,0.113]	[0.726,0.757]	[0.156,0.177]	[0.098,0.118]	[0.712,0.740]
single parents	0.601	0.229	0.170	0.595	0.239	0.166
	[0.586,0.615]	[0.216,0.242]	[0.159,0.181]	[0.580,0.610]	[0.227,0.253]	[0.155,0.178]
married women, no kids	0.130	0.224	0.647	0.133	0.228	0.639
	[0.121,0.140]	[0.213,0.237]	[0.631,0.659]	[0.124,0.143]	[0.216,0.241]	[0.624,0.651]
married women, kids	0.342	0.409	0.249	0.339	0.413	0.248
	[0.332,0.351]	[0.400,0.419]	[0.240,0.258]	[0.331,0.348]	[0.404,0.423]	[0.237,0.256]

Notes: Predicted states are calculated using the maximum likelihood estimates from Table 1. Employment states may not sum to one due to rounding. The 5^{th} and 95^{th} percentiles of the bootstrap distribution of employment states are presented in brackets, and are calculated using 500 bootstrap replications.

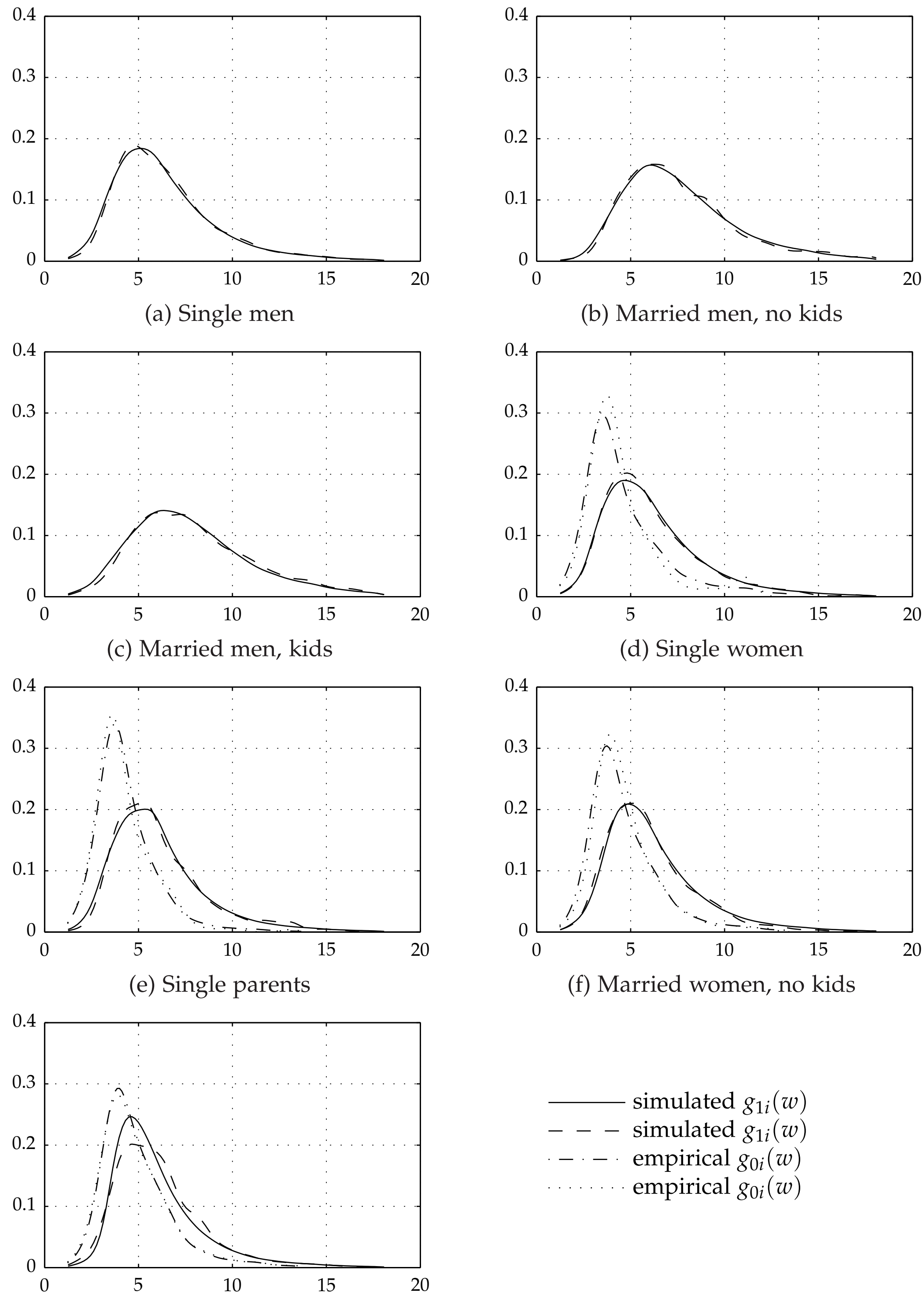


Figure 3: Simulated and empirical wage earnings by group. Horizontal axis refers to hourly wage rate in April 1997 prices; Vertical axis refers to wage density. Empirical distributions are calculated using a Gaussian kernel with a bandwidth of 0.5.

increases are primarily due to small reductions in the real value of out-of-work income, together with small reductions in income-tax (see the discussion in Section 2) which act to raise the value of holding low wage jobs and so lower reservation wages which increases the exit rate from unemployment.

Perhaps unsurprisingly, the largest predicted impact of these reforms is on the employment rate of single parents,[36] where we predict an increase in employment of 5.1 percentage points. Despite both full-time and part-time reservation wages falling for many of these workers,[37] this steady state employment increase is exclusively due to a movement into full-time work. This is largely due to on-the-job search, with the estimated arrival rate of full-time wage offers among the employed far exceeding that of part-time wage offers ($\lambda_{ei}^{1} \gg \lambda_{ei}^{0}$). These differences in arrival rates for employed workers mean that individuals who enter employment as a result of the reform tend to gravitate to the full-time sector in the new steady state. Second, the lower withdrawal rate of WFTC compared to FC as described in Section 2 results in full-time incomes increasing by more than part-time incomes over a large range of wages for this group (Figure 4a shows how the indifference condition $q_i(w)$ changes),[38] therefore making full time work relatively more desirable. This latter feature increases the overall job-to-job transition rate for this group, as does the mechanical compositional effect of workers now accepting lower wage jobs, and then climbing up the job ladder more quickly.

For couples with children the impact of these reforms is more complicated as tax credit entitlement depends upon family income: individuals with a high earning partner are essentially unaffected by the reform; those with a non-working or very low earning partner respond positively, much like single parents; in intermediate cases, movement into work can result in tax credit awards being withdrawn which may induce negative

WFTC reforms will have a direct effect on demographic types that are *currently* categorically ineligible. The size of any direct responses will naturally depend on the transition probabilities, and the extent of labour market frictions.

[36]In-work incomes for a single parent with one child increase by around 18% (13%) as a result of this reform at full-time (part-time) work hours for a worker earning the average wage (amongst single parents). The percentage increases are even large for multi-child families.

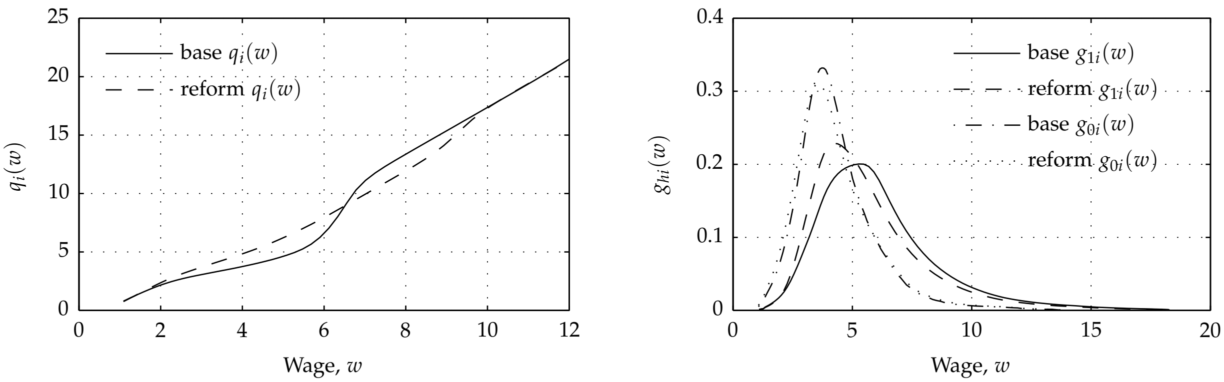
[37]The reservation wages of individuals with very high b will actually increase. These individuals experience an increase in their out-of-work income, but at the high wages that these workers would actually accept they will be ineligible for tax credits so there is little change in their net taxes when employed.

[38]To understand the changes to the indifference condition shown here we note that over a large range of wages the reduction in the taper rate is most important so that full-time work relatively more becomes more desirable. At high wages (where individuals only become eligible for tax credits at full-time hours following the reform), part-time incomes increase by more than full-time incomes. At very high wages individuals are not-affected by the tax credit reform, so there are only small changes in the indifference condition due to the other smaller changes to the tax and transfer system.

Table 3: Employment Impact of Reforms

	Direct Impact			Equilibrium Impact		
	Δu_i	Δm_{0i}	Δm_{1i}	Δu_i	Δm_{0i}	Δm_{1i}
single men	-0.8	–	0.8	-1.1	–	1.1
	[-1.9,0.2]		[-0.2,1.9]	[-2.2,-0.0]		[-0.0,2.2]
married men, no kids	-0.2	–	0.2	-0.3	–	0.3
	[-0.9,0.6]		[-0.6,0.9]	[-1.0,0.5]		[-0.5,1.0]
married men, kids	-1.1	–	1.1	-1.1	–	1.1
	[-1.9,-0.4]		[0.3,1.8]	[-1.9,-0.4]		[0.4,1.9]
single women	-0.5	-0.0	0.5	-0.5	-0.4	0.9
	[-1.4,0.6]	[-1.0,1.1]	[-1.0,1.9]	[-1.5,0.5]	[-1.4,0.7]	[-0.6,2.3]
single parents	-5.1	-1.4	6.5	-4.8	-1.9	6.7
	[-6.9,-1.6]	[-3.6,-0.1]	[4.1,8.5]	[-6.6,-1.5]	[-4.1,-0.5]	[4.3,8.9]
married women, no kids	-0.4	-0.7	1.1	-0.4	-1.1	1.5
	[-1.2,0.6]	[-2.0,0.6]	[-0.4,2.4]	[-1.2,0.6]	[-2.4,0.2]	[0.0,2.9]
married women, kids	0.8	-0.8	0.0	1.0	-1.1	0.1
	[-0.1,1.7]	[-1.9,0.3]	[-1.2,0.9]	[0.1,2.0]	[-2.2,-0.1]	[-1.0,1.0]

Notes: All employment responses are expressed in percentage points. Changes may not sum to zero due to rounding. The direct impact considers all changes to the tax and transfer system between April 1997 and April 2002, holding the wage offer distributions and arrival rates at their pre-reform levels. The equilibrium impact allows the wage offer distribution and arrival rates to change.



(a) Indifference condition

(b) Single parents' wage earnings

Figure 4: Direct impact of tax reforms on single parents. Figure 4a shows the impact of the reforms on the indifference condition for a single parent with two children (truncated at full-time wages greater than £12); Figure 4b shows the direct effect of the reforms on single parents' distribution of wage earnings. All incomes measured in April 1997 prices.

labour supply responses (particularly among the newly eligible families). On balance, these factors lead to a small decrease in the employment of married women with children (a 0.8 percentage point decrease), and increase the employment rate of married men with children by a similar absolute magnitude. Among married women, this decrease in labour supply comes primarily through a reduction in those working part-time. The potential disincentive effects of tax credits programs on family labour supply have long been recognized, with the direction of these responses consistent with those reported in other studies (see for example, Eissa and Hoynes, 2004).

Before we discuss the equilibrium impact of the reforms, we briefly discuss the effect on wages. Note that selection alone implies that wage earnings will change even though the distribution of wage offers is held fixed. This highlights the fact that attempting to estimate the incidence of tax credit programs by comparing changes in observed wages amongst eligible and non-eligible groups is potentially misleading without carefully controlling for these dynamic selection effects. Indeed, selection alone implies some large reductions in full-time average wages. Our simulations imply that single parents experience a 6% reduction in average full-time wage earnings and a 1% reduction in part-time wages (see Figure 4b). The changes for other groups are smaller.

5.2 Equilibrium Impact

In Table 3 we also present the equilibrium impact of the tax reforms, which reflect both the adjustments in wage offers and recruiting intensity decisions. The first immediate thing to note is that the impacts are generally very similar to those obtained from the direct impact. That is, equilibrium considerations do not appear to be very important for this particular set of reforms given our set of parameter estimates. For the group of single parents, the employment increase is reduced from 5.1 to 4.8 percentage points (a 5% decrease). Looking more closely we can see that equilibrium considerations tend to increase employment in full-time jobs, and decrease employment in part-time jobs, although the magnitudes of change are admittedly small.

Given the relatively small magnitude of the changes here, we do not attempt to describe the responses in detail. We note, however, that the direction of the changes to firms' optimal policies can largely be understood by examining the initial direct impact of the reforms on labour supply. As described above, the reduction in reservation wages experienced by many workers raises both part-time and full-time employment at low wages. However, on-the-job search and the changes to the indifference conditions as noted above also induce transitions between the hours sectors. The net effect of these transitions means that part-time employment falls at medium wage levels. Part-time firms which experienced initial increases in their employment generally respond by lowering their wage offers in the new equilibrium and increasing their recruiting intensity; at slightly higher wage rates where employment initially falls we find the opposite effect. Full-time firms have smaller adjustments in their wages (although it is still the case that the firms which experienced the largest initial increase in employment tend to have the greatest reduction in wages). Again, the change in recruiting intensity of these firms closely mirrors the initial labour supply response.[39] In Figure 5 we illustrate these relative changes in firms' strategies, and relate them to the initial labour supply responses as describe here.[40]

[39]Individual search effort is considered exogenous in our empirical framework. Following any change in policy environment, the rate of job offer arrivals will, aside from any compositional effects, only change through adjustment in the recruitment policies of firms (see equation 10). In a more general model with endogenous search intensity, job offers arrivals would change even absent any response from firms. Given the worker side response, this suggests that the incentive that firms have to change their contact rate through recruitment policy may become weaker.

[40]The changes to the wage policy function are quantitatively more important than the adjustments in recruiting intensity in generating the described employment and wage responses. The aggregate effect of changes to firm level recruiting intensity is to raise the arrival rate of full-time job offers by 1.6%, and with a small impact on the arrival rate of part-time job offers. While the changes to recruiting intensity

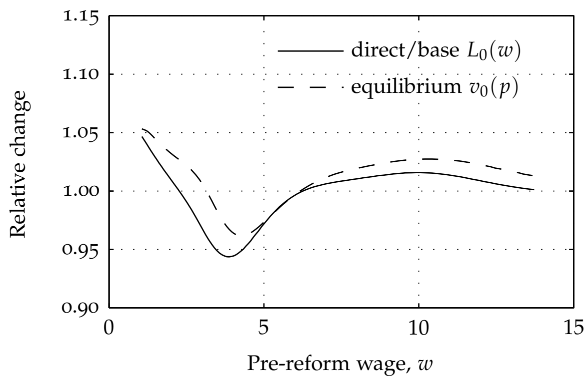
The significance of the finding of slight equilibrium effects should not be understated. Indeed, one important argument made for the introduction of a national minimum wage in the UK at the time, was that it would prevent employers from capturing some of the benefits of the more generous tax credit programme by reducing wages. The analysis here suggests that those fears may have been unfounded. However, as we demonstrate shortly, the *same* reforms had the *potential* to lead to larger equilibrium effects and will depend upon the characteristics of the labour market.

5.3 Other Evaluations

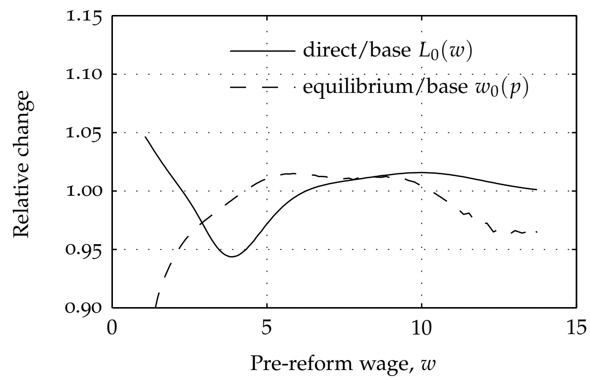
The set of tax reforms considered here have been the subject of a small number of other evaluations, with difference-in-differences being the most common empirical approach. These evaluations have largely focused upon the employment impact of single parents and essentially involve comparing the changing employment outcomes of single mothers to single women without children. While there are sometimes differences in the definition of the sample, and the exact period under investigation, the quantitative impact reported in these studies is remarkably similar to that reported in Table 3. Netting off the impact of these reforms on single women, the relevant comparable employment impact for these difference-in-differences studies is 4.6 (=5.1-0.5) percentage points. This compares to the 3.6 percentage point increase reported in Blundell, Brewer and Shephard (2004), and the 5 percentage point increase in Gregg and Harkness (2003). See Brewer and Browne (2006) for a review of these and other studies. The fact that these different approaches deliver similar quantitative predictions is consistent with the absence of large equilibrium effects (if they were important then the usual stable unit treatment value assumption would be violated).[41] We also note that the employment impact for single parents is also similar to that reported in studies using discrete choice techniques (Blundell and Shephard, 2012). While much less studied, the predicted employment impact for individuals in couples (a small increase for men, and corresponding decrease for women) is very close to that reported in Brewer et al. (2006), but contrast to those in Leigh (2007) where more sizeable (albeit, only marginally significant) employment

produce little further impact on employment rates, they do amplify the compositional shift from part-time to full-time work. Our conclusions here are not very sensitive to our assumptions on the matching function technology parameters θ_h (see Section 3.6).

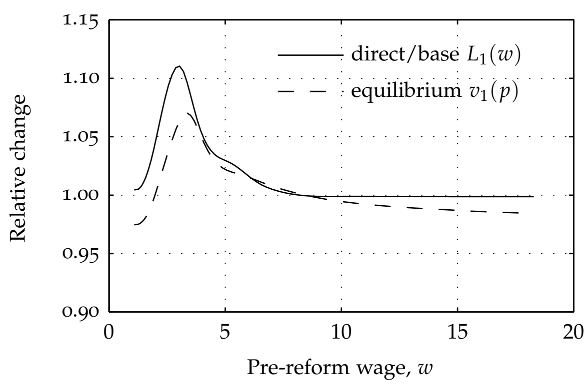
[41] There is no underlying reasons for this similarity to hold. Had search frictions been estimated to be more or less important, for example, then the simulated employment impact could have diverged substantially from that reported in these ex-post evaluations.



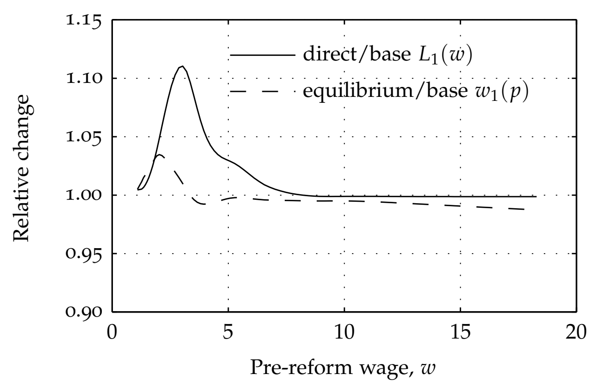
(a) Part-time recruiting intensity



(b) Part-time wage policy



(c) Full-time recruiting intensity



(d) Full-time wage policy

Figure 5: Equilibrium policy responses. Figures 5a and 5c show how the equilibrium recruiting intensity of part-time and full-time firms (as identified by their pre-reform wage policy) changes, and how this compares to the relative direct employment responses. Similarly, Figures 5b and 5d show how the equilibrium wage policy of part-time and full-time firms changes, and again compares this to the relative direct employment responses. All incomes measured in April 1997 prices.

increases for both groups were estimated. Again, see Brewer and Browne (2006) for a comparison of these and a small number of other studies.

5.4 Post-reform Comparison

We now compare our results to the actual changes to employment states between 1997 and 2002. Tabulations are presented in Appendix L. Over this period, all the broad demographic groups experienced an increase in their employment rate. And for all groups except single men and married women with children, we systematically under-predict the growth in employment slightly by between around one and one-and-a-half percentage points. For single men and particularly married women with children, the extent of under-prediction is larger. Overall, this suggests that non-tax changes over this period, including robust productivity growth, changes in the distribution of partner earnings, the introduction of a national minimum wage, and various "New Deal" active labour market policies (particularly relevant for low skilled men) were also important for understanding the changing labour market outcomes. In terms of work hours, for single parent families, the empirical increase in employment is relatively evenly split between movements into both part-time and full-time employment; this contrasts with our simulations which suggested that it was exclusively due to a movement into full-time work.[42]

5.5 Decomposing the Tax and Transfer Changes

The results presented above considered the impact of all reforms to the tax and transfer system between April 1997 and April 2002. However, as described in Section 2, the introduction and expansion of WFTC coincided with a number of other tax reforms. Firstly, there were changes to income tax and National Insurance that affected families

[42] An important caveat to this informal comparison is that we are comparing empirical changes to a theoretical steady state, so that the role of any transitional dynamics is being ignored. Given the differences in the estimated arrival rate parameters, we note that the model implies a short-term increase in both part-time and full-time employment amongst single parents, followed by a shift towards full-time work through the process of on-the-job search (recall that $\lambda^1_{ei} \gg \lambda^0_{ei}$). The model also has implications for wage changes. Given the strong productivity growth over this six year period, discerning the effect of the reform on wages is challenging. However, for the target groups we do see a relatively larger growth in part-time wages compared to full-time wages, that is somewhat consistent with these predictions (over the entire sample period, part-time wages grew over 3% more than did full-time wages for single parents; for categorically ineligible women, both part-time and full-time wages grew at essentially the same rate).

both with and without children. In isolation, these changes had a relatively small impact on budget constraints and on labour market outcomes for all families. The direct effects that we present in Table 3 for families without children reflect the impact of these changes.

Second, in addition to WFTC, families with children were also affected by increases in both Child Benefit and the child additions in Income Support. These changes mean that at the same time that the government increased income in-work through the expansion of tax credits, it also increased out-of-work income through the system of Income Support. Both the WFTC reform and the Income Support expansions are quantitatively large. To understand the relative importance of these changes, we simulate the impact of replacing the tax credit system in April 1997 with that of April 2002, holding all other components of the tax and transfer system fixed. By construction, the direct impact of this hypothetical reform on individuals without children is identically zero. Among families with children, we unsurprisingly find larger effects. For both singles and couples with children, the direct employment impacts now approximately double in size (an employment increase of 11 percentage points for single parents, an increase of 1.8 percentage points for married men with children, and a 1.5 percentage point decrease for married women with children). Again, equilibrium effects are found to be small relative to the initial labour supply response. The difference in these responses relative to our main simulations can therefore be broadly attributed to the changes in Income Support, which appears (particularly for single parent families), to have weakened the impact of WFTC.

5.6 Why Aren't Equilibrium Effects More Important?

Our estimated model suggests that the equilibrium responses to WFTC and contemporaneous reforms are relatively small. There is however, little reason to believe that this would be the case *a priori*, since the size of any equilibrium effects (even for targetted reforms such as WFTC) will be closely linked to the characteristics of the labour market which our earlier estimation exercise uncovered. In Appendix K we demonstrate how the *same* reforms may have quantitatively *large* equilibrium effects under alternative parameterizations of the labour market. Here we discuss the size of any equilibrium effects may depend upon the degree of segmentation of the labour market.

While allowing all workers to compete within the same market was a natural characterization of the labour market, and one which permitted spillover effects, it limits the

the size of potential equilibrium effects following a targeted reform like WFTC if firms are constrained to have a single wage policy.[43] Consider, for illustrative purposes, a labour market comprised of single individuals (both with and without children).[44] Single parents comprise around one-third of this more segmented labour market. Under this alternative assumption we obtain larger within-market equilibrium effects. There are now larger changes in the optimal policies of firms (essentially scaled up versions of the responses shown in Figure 5) which result in a reduced employment response for single parents. The adjustment in wages alone reduce the employment increase from 5.1 to 3.8 percentage points, while allowing for both equilibrium mechanisms results in a 4 percentage point employment increase. The initial direct impact on employment is therefore reduced by over 20% in this case.[45]

6 Tax Credit Design Experiments

In this section we use our estimated model to explore issues related to the design of tax credit programmes such as WFTC. There are two stages to our analysis. First, we consider the impact of extending the generosity of WFTC and show how equilibrium effects become more important. Second, we consider design more broadly by maximising a welfare function subject to a government revenue constraint.

6.1 Extending Tax Credits

We now consider how the labour market impact of WFTC depends upon its generosity. Starting with the April 2002 system, we increase the maximal tax credit amount (i.e. the tax credit entitlement received by eligible households before it start to be withdrawn). Essentially, this form of increased generosity is uniformly shifting the WFTC schedule

[43] In a model with worker and firm bargaining, wages essentially become individualistic so that the potential for equilibrium effects is much larger. Lise, Seitz and Smith (2005) used such a model in their analysis of the Canadian Self-Sufficiency Project, and found substantial equilibrium effects.

[44] This is equivalent to firms being able to discriminate against these demographically identifiable groups, so essentially allowing F_h to become indexed by a set of i. To ensure that the direct impacts remain as in Table 3 we do not re-estimate the model for these illustrations. Instead, we use the same parameter estimates from Table 1 (with the associated non-parametric estimates of F_h), and recover the distribution of firm productivity under alternative market segmentation assumptions. We also attempted this exercise using a market comprised solely of single parents, but encountered large monotonicity violations when using firms' first order conditions to recover the distributions of productivity.

[45] Underlying these changes is a large reduction in part-time and full-time wage offers (on average, 14% and 11% respectively), while the associated job offer arrival rates increase by 2% and 3%.

as presented in Figure 1 upwards. As in our earlier impact analysis, we compare this revised system to the actual April 1997 system with Family Credit.

As an illustration, we consider the impact of increasing the maximal entitlement by 50%. This is a large reform, and implies maximal tax credit awards that are roughly twice as large as what would have been available under Family Credit. The largest employment impact is on single parent families. Using the terminology introduced in Section 5, there is a direct employment impact on single parents of 15.3 percentage points. This is around three times as large as the impact of the actual WFTC. Changes in the equilibrium wage policy of firm reduces this by around a percentage point, while simultaneously allowing the recruiting policy of firms to adjust results in the full equilibrium employment impact (15.9 percentage points) exceeding the direct impact. In terms of other groups, the direct responses for families without children are (by construction) identical to those obtained under the actual 2002 system. For couples with children we again see large direct responses (a 2.3 percentage point increase for married men, and a 3.5 percentage point decrease for married women). As in the case of single parents, the equilibrium wage responses attenuate the direct responses, while the equilibrium recruiting responses result in full effects that are relatively close to the initial direct effect.

Underlying these changes are important changes to the optimal policy of firms. The changes to wages are quantitatively largest in the part-time sector (recall that for women with children we estimate that the part-time job offer arrival rate from non-employment far exceeds those for full-time jobs). Average part-time wage offers fall by an average of 10%. For low productivity firms, the wage reductions are far larger. The changes in the wage policy of firms result in an increase in a 5% increase in the arrival rate of part-time jobs offers, and a 2% increase for full-time offers. This analysis here shows that larger reforms can have quantitatively large equilibrium effects. Moreover, given the different directions in which they operate, it illustrates the importance of having these multiple channels.

6.2 Optimal Design

In this section we consider the design of tax credits by maximising a welfare function subject to a government revenue constraint. We do this by changing *actual parameters* of the UK tax credit system that are related both to its generosity, and how they vary with family income. Since we are interested in both the size and structure of WFTC, we simultaneously allow for changes in the income tax system by allowing marginal income tax rates to vary while preserving the degree of income tax progressivity. As such, the reforms we consider here nest the actual UK tax, transfer and tax credit system and would be directly implementable in practice.

6.2.1 Theoretical Framework

In what follows we use $\boldsymbol{\theta}_T$ to describe the complete tax/transfer/tax credit system parameter vector. We restrict attention to a welfare function that is comprised of a weighted sum of individual values in steady state. In all our illustrations, we set the weights equal to the population shares so that:

$$\mathcal{W}(\boldsymbol{\theta}_T) = \sum_i n_i \int_{\underline{b}_i}^{\overline{b}_i} \left[u_i^b V_{ui}(b) + \sum_h m_{hi}^b \int_{\underline{w}_h}^{\overline{w}_h} V_{ei}^h(w,b)\, \mathrm{d}G_{hi}^b(w) \right] \mathrm{d}H_i(b), \tag{13}$$

where $V_{ui}(b)$ is the value function associated with the non-employment state for a type i worker with leisure flow b, and $V_{ei}^h(w,b)$ is the value function of a worker of the same observed/unobserved type who is employed at wage w and hours h. We also define u_i^b, m_{hi}^b and G_{hi}^b to be the respective non-employment, and hours-specific employment shares and cumulative earnings distribution function in steady state (again, conditional on both the observed and unobserved worker type).[46] All these objects are functions of the parameter vector $\boldsymbol{\theta}_T$.

The design problem concerns the choice of the parameter vector $\boldsymbol{\theta}_T$ from some parameter space (described below) which maximizes our social welfare function (equation 13) subject to the government revenue constraint:

$$\mathcal{R}(\boldsymbol{\theta}_T) = \sum_i \widetilde{n}_i \left[u_i T_u^i + \sum_h m_{hi} \int_{\underline{w}_h}^{\overline{w}_h} T_{ei}^h(w)\, \mathrm{d}G_{hi}(w) \right] \geq \overline{T},$$

where $\overline{T}$ is the exogenous revenue requirement that will be obtained using our estimated model under the actual April 2002 system with equilibrium responses, and $\widetilde{n}_i$ normalises n_i by the number of adults within group i. Note that the definition of the individual value functions embodies that individual behaviour is incentive compatible given $\boldsymbol{\theta}_T$. As in our previous analysis, we will consider the problem when the wage and recruiting

[46] Expressions for the worker value functions are presented in Appendix B, where we derive reservation wage equations. Expressions for the conditional measures and earnings densities are presented in Appendix G.

policy of firms is fixed (at their values from our estimated model), and when they are consistent with the equilibrium given $\boldsymbol{\theta}_T$.

6.2.2 Instrument Set

We now describe our specification of the instrument set. Again, we emphasise that our design experiment is interested in implementable reforms that maintain the same structure and eligibility rules as in the combined UK transfer/tax/tax credit system. There are many parameters that are part of the actual WFTC. First, there is the maximum entitlement which describes the maximum award that a family would receive if their income is sufficiently low. Since this maximum credit award depends on family structure and work hours we denote this $\overline{WFTC}_i^h$. Second, there is an income disregard: the first DIS pounds of family income is *dis*regarded for the purposes of calculating tax credit entitlement. Third, once family income exceeds DIS, tax credit awards are reduced at the constant taper/withdrawal rate $TAPER$. Note that for the purposes of tax credit entitlement, household income is defined *after* income tax and National Insurance deductions.

Letting y denote household income after income tax and National Insurance we note that household WFTC receipts may be written as:

$$WFTC_i^h(y) = \max\{0, \overline{WFTC}_i^h - TAPER \times \max\{y - DIS, 0\}\}.$$

Our design experiments will allow all these parameters of WFTC to vary. Finally, we allow *income tax* rates to change. We maintain the same income tax brackets as operated in practice, but allow all marginal income tax rates to be scaled by some multiplicative factor $k > 0$. Note that while the parameters of WFTC only have a direct impact on the budget sets for families with children, any changes to the income tax rates will directly affect families both with and without children. Moreover, changes in this factor k change the mapping from household earnings to income after income tax and National Insurance for the purposes of calculating tax credit entitlement.[47]

[47] Given a candidate $\boldsymbol{\theta}_T$ we construct the budget set which integrates the modified WFTC with the other parts of the tax and transfer system, applying the same smoothing in the neighbourhood of marginal tax rate changes that we describe in Appendix J. We then solve for the equilibrium wage offer distributions $\langle F_0, F_1 \rangle$ and the vector of job-offer arrival rates using the same algorithm as in our main simulations. The solution to this problem also allows us to evaluate the revenue constraint. In order to evaluate the welfare function, for each $i \leq I$ we construct a quadrature grid for the unobserved leisure component, and then solve for $V_{ui}(b)$ and $V_{ei}^h(\cdot, b)$ using value function iteration for all values on this grid. Conditional on these, we then solve for the conditional flow equations (see Appendix G). The search over $\{\boldsymbol{\theta}_T \backslash k\}$ is performed on a fine grid, with the parameter k used to satisfy the revenue constraint (if a solution exists). To limit

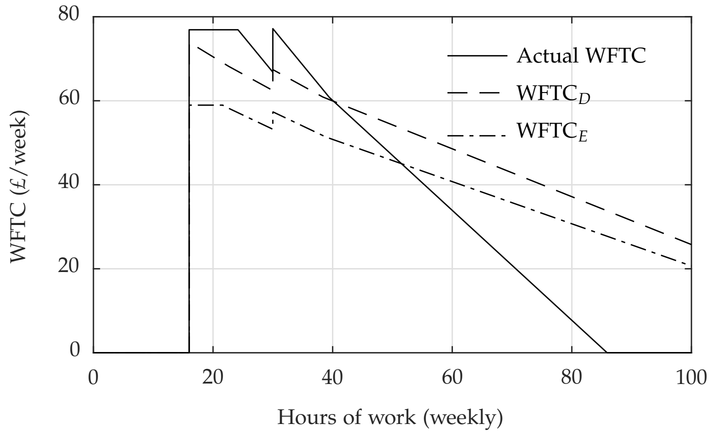


Figure 6: Tax credit awards under WFTC and alternative policies. WFTC refers to Working Families' Tax Credit as of April 2002. WFTC$_D$ corresponds to the design that is optimal under the WFTC instrument set, and only *direct* responses; WFTC$_E$ corresponds to the optimal under the WFTC instrument set, with *equilibrium* responses. Figure assumes a single parent with a single child aged 10, and a constant hourly wage rate of £3.50. All incomes expressed in pounds per week in April 1997

6.2.3 Design Results

We now describe the results of our design experiments which we compare to the actual April 2002 system. As in our earlier analysis of tax reforms, our design exercise is performed by first assuming that there is no adjustment in firm behaviour relative to our estimated model (denoted WFTC$_D$). Second, we repeat our analysis allowing for the equilibrium responses of firms (denoted WFTC$_E$). Recall that all simulations are revenue equivalent to the actual April 2002 system. The parameters from these design experiment illustrations are presented in Table 4, while in Figure 6 we illustrate the associated tax credit schedule for a low wage single parent (recall that this figure will differ by both the gross hourly wage rate, and by family structure).

Relative to the actual system 2002 WFTC system, we obtain larger overall tax credit programs. In order to finance these extended programmes, under WFTC$_D$ marginal income tax rates are increased by 10% (note *percent*, not percentage points), while in the relatively smaller WFTC$_E$ they are increased by only 4%. Compared to the actual system, the most important difference to the structure of the tax credit program is the substantially reduced (more than halved) taper rate, which extends tax credit entitlement further up the income distribution. The taper rate is slightly lower under WFTC$_E$, while

the number of parameters we restrict ourselves to policies which maintain the same relative amount for the maximum award by number of children.

Table 4: Actual and Reformed Tax Credit Parameters

	Actual	Reformed WFTC	
	WFTC, 2002	WFTC_D	WFTC_E
WFTC parameters			
Adult	60.00	62.00	46.00
Per-child element	26.45	27.33	20.27
Full-time premium	11.65	5.59	4.67
Earnings disregard	94.50	37.80	85.05
Taper-rate	0.55	0.25	0.21
Marginal rate scale	1.00	1.10	1.04

Notes: Table presents parameters of actual 2002 WFTC system, as well as the revenue equivalent tax credit systems calculated under no equilibrium effects ($WFTC_D$) and equilibrium effects ($WFTC_E$). All monetary amounts are in April 2002 prices. $WFTC_i^h$ is the sum of the adult parameter, the per-child element (multiplied by the number of children), and the full-time premium (for full-time workers $h = h_1$).

the maximal credit award is approximately 25% lower. Thus, while WFTC_D and WFTC_E are consistent in both suggesting a much reduced tax credit withdrawal rate compared to the actual system, equilibrium considerations do suggest a noticeably smaller programme.[48]

7 Conclusion

This paper has developed an empirical equilibrium job search model with wage posting, and has used it to analyze the impact of a series of UK tax reforms that included the Working Families' Tax Credit reform, and to explore its implications for tax credit design. It presents a synthesis of existing equilibrium job search models, and extends them in a number of important dimensions to incorporate very rich heterogeneity, reflect key

[48]These alternative programmes have some important differences in terms of labour supply. Under WFTC_D the maximal tax credit award is similar to that from the actual system, while the taper rate is lower. This enlarges the budget set in-work for many families with children. Relative to the impact of the actual WFTC system, we find larger absolute employment impacts responses (this is true both for both the direct and equilibrium impact of the policy). In contrast, under WFTC_E the reduction in the maximal award means there is a considerable range of earnings where tax credit entitlement is actually similar to that under Family Credit from the estimated model. Given the contemporaneous changes in the child additions in Income Support described in Section 2, the employment rate for single parents under our optimal system is essentially the same as from our estimated model, although the taper reduction does induce a sizeable compositional shift from part-time to full-time work.

features of the UK labour market, and to allow for the possibility of rich equilibrium effects following tax reforms.

We structurally estimate the model using a semi-nonparametric estimation procedure, and using our estimated model predict that the series of tax reforms had a positive effect on the employment of most groups, with single parents experiencing the largest employment increase. Our simulations show that while equilibrium effects do play a role, the changes in labour market outcomes for these particular reforms are dominated by the direct effect of changing job acceptance behaviour. We also show that the same reforms may have quantitatively large equilibrium effects depending upon the characteristics of the labour market.

Our estimated model is then used to assess the impact of alternative tax credit policies. First, we consider programmes that increase the generosity. Here we show that as maximal tax credit awards are increased, equilibrium effects become much more important. Second, we develop a framework for considering the optimal design of tax credits under a revenue constraint. We focus on practically implementable reforms, that completely nest the actual UK system. Our analysis points towards a reformed tax credit system, with tax credit entitlement extended further up the income distribution. Again, we show the importance of equilibrium considerations.

We believe that this paper represents an important step in using empirical equilibrium job search models to evaluate the impact and design of tax policies. Despite performing our empirical analysis on individuals with low education levels, it is likely that differences in worker ability persist. A natural extension could therefore involve incorporating heterogeneity in worker productivity which necessitates a more detailed modelling of firm production technologies. Furthermore, given that the tax and transfer systems of many countries depend upon family income to some extent, a more detailed characterization of the behaviour of couples would allow us to more rigorously explore the impact of policies on within household labour supply allocations. Finally, given the importance of labour supply in our simulations, incorporating a micro-level search intensity choice would create a further dimension along which individuals can respond. While each of these represent non-trivial extensions, it does suggest a very exciting agenda of future research.

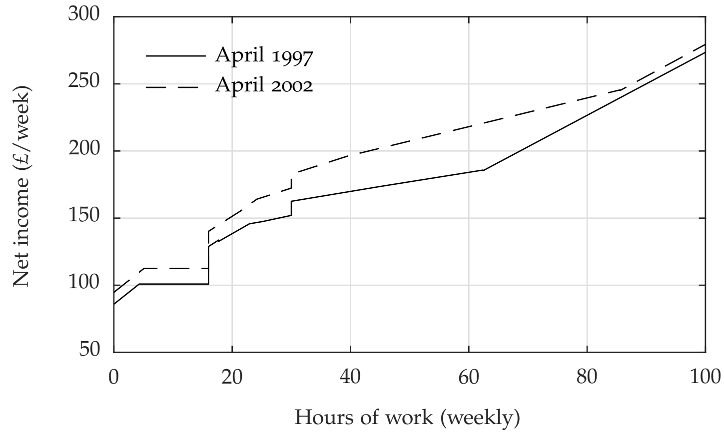


Figure 7: Budget constriant under April 1997 and April 2002 tax and transfer systems. Figure assumes a lone parent with a single child aged 10, and a constant hourly wage rate of £3.50. All incomes expressed in pounds per week in April 1997 prices.

Appendices

A Budget Constraints

In Figure 7 we show the complete budget constraint for a low-wage single parent. This figure reflects both the expansion of tax credits, and the other changes to the tax and transfer system between April 1997 and April 2002 (see Section 2 for a description of these changes). Budget constraints for other families types are presented in Brewer and Browne (2006).

B Reservation Wage Equations

In this appendix we derive the optimal reservation wage strategies of unemployed workers that were presented in Section 3.4. For notational simplicity, we do not explicitly write the value functions or the resultant reservation wages as a function of the unobserved leisure flow b. The value of unemployment V_{ui} must satisfy:

$$\begin{aligned} \rho V_{ui} = b - T_i^u &+ \lambda_{ui}^0 \mathbb{E}_{w\sim F_0} \max\left\{V_{ei}^0(w) - V_{ui}, 0\right\} \\ &+ \lambda_{ui}^1 \mathbb{E}_{w\sim F_1} \max\left\{V_{ei}^1(w) - V_{ui}, 0\right\}, \end{aligned} \tag{B.1}$$

where $V_{ei}^0(w)$ and $V_{ei}^1(w)$ are the values of part-time and full-time employment when receiving wage w, and where $\mathbb{E}_{w\sim F_h}$ indicates that the expectation is taken over the random variable w with cumulative distribution function F_h. For workers who are employed in a part-time job ($h = h_0$) we have:

$$\rho V_{ei}^0(w) = wh_0 - T_i^0(wh_0) + \lambda_{ei}^0 \mathbb{E}_{x\sim F_0} \max\left\{V_{ei}^0(x) - V_{ei}^0(w), 0\right\} \\ + \lambda_{ei}^1 \mathbb{E}_{x\sim F_1} \max\left\{V_{ei}^1(x) - V_{ei}^0(w), 0\right\} + \delta_i(V_{ui} - V_{ei}^0(w)),$$

and for workers employed in a full-time job ($h = h_1$):

$$\rho V_{ei}^1(w) = wh_1 - T_i^1(wh_1) - C_i^1 + \lambda_{ei}^0 \mathbb{E}_{x\sim F_0} \max\left\{V_{ei}^0(x) - V_{ei}^1(w), 0\right\} \\ + \lambda_{ei}^1 \mathbb{E}_{x\sim F_1} \max\left\{V_{ei}^1(x) - V_{ei}^0(w), 0\right\} + \delta_i(V_{ui} - V_{ei}^1(w)).$$

Recalling that $q_i(w)$ is defined such that $V_{ei}^1(w) = V_{ei}^0(q_i(w))$, it follows that the value of a full-time job at wage w may be written as:

$$\rho V_{ei}^1(w) = wh_1 - T_i^1(wh_1) - C_i^1 + \lambda_{ei}^0 \int_{q_i(w)}^{\overline{w}_0} (V_{ei}^0(x) - V_{ei}^1(w))\, \mathrm{d}F_0(x) \\ + \lambda_{ei}^1 \int_{w}^{\overline{w}_1} (V_{ei}^1(x) - V_{ei}^1(w))\, \mathrm{d}F_1(x) + \delta_i(V_{ui} - V_{ei}^1(w)). \tag{B.2}$$

Equating equation B.2 (evaluated at wage w) with the analogous expression for part-time employment (evaluated at wage $q_i(w)$) implies that $q_i(w)$ is the solution to:

$$wh_1 - T_i^1(wh_1) - C_i^1 = q_i(w)h_0 - T_i^0(q_i(w)h_0). \tag{B.3}$$

We obtain this simple expression for the indifference condition because, conditional on being in employment, both the destruction rate and arrival rates for full-time and part-time jobs are assumed independent of work hours so that it is only necessary to compare the instantaneous utility flows. Note also that:

$$q_i'(w) = \frac{h_1}{h_0} \cdot \frac{1 - T_i^{1\prime}(wh_1)}{1 - T_i^{0\prime}(q_i(w)h_0)}.$$

To calculate the reservation wage we proceed by first performing integration by parts on equation B.2 to obtain:

$$\rho V_{ei}^1(w) = wh_1 - T_i^1(wh_1) - C_i^1 + \lambda_{ei}^0 \int_{q_i(w)}^{\overline{w}_0} \overline{F}_0(x) \mathrm{d} V_{ei}^0(x) \\ + \lambda_{ei}^1 \int_{w}^{\overline{w}_1} \overline{F}_1(x) \mathrm{d} V_{ei}^1(x) + \delta_i(V_{ui} - V_{ei}^1(w)) \tag{B.4}$$

which when differentiated with respect to w yields:

$$h_1(1 - T_i^{1\prime}(wh_1)) = (\delta_i + \rho + \lambda_{ei}^0 \overline{F}_0(q_i(w)) + \lambda_{ei}^1 \overline{F}_1(w)) V_{ei}^{1\prime}(w). \tag{B.5}$$

We denote ϕ_i as the lowest acceptable wage offer for *full-time* work. Since $V_{ui} = V_{ei}^1(\phi_i) = V_{ei}^0(q_i(\phi_i))$, the lowest acceptable wage offer for part-time work is then $q_i(\phi_i)$. Using this, we can write equation B.1 as:

$$\rho V_{ui} = b - T_i^u + \lambda_{ui}^0 \int_{q_i(\phi_i)}^{\overline{w}_0} \overline{F}_0(w) \mathrm{d} V_{ei}^0(w) + \lambda_{ui}^1 \int_{\phi_i}^{\overline{w}_1} \overline{F}_1(w) \mathrm{d} V_{ei}^1(w).$$

Substituting the envelope conditions $V_{ei}^{1\prime}(w)$ and $V_{ei}^{0\prime}(w) = V_{ei}^{1\prime}(q^{-1}(w))/q_i'(w)$ in to the above:

$$\rho V_{ui} = b - T_i^u + \lambda_{ui}^0 \int_{q_i(\phi_i)}^{\overline{w}_0} \frac{h_0(1 - T_i^{0\prime}(wh_0))\overline{F}_0(w)}{\delta_i + \rho + \lambda_{ei}^0 \overline{F}_0(w) + \lambda_{ei}^1 \overline{F}_1(q_i^{-1}(w))} \mathrm{d}w \\ + \lambda_{ui}^1 \int_{\phi_i}^{\overline{w}_1} \frac{h_1(1 - T_i^{1\prime}(wh_1))\overline{F}_1(w)}{\delta_i + \rho + \lambda_{ei}^0 \overline{F}_0(q_i(w)) + \lambda_{ei}^1 \overline{F}_1(w)} \mathrm{d}w.$$

By definition of the reservation wage we can set the above equal to $\rho V_{ei}^1(\phi_i)$ (from equation B.2) to obtain the following implicit equation defining ϕ_i:

$$\phi_i h_1 - T_i^1(\phi_i h_1) - C_i^1 = b - T_i^u + (\lambda_{ui}^0 - \lambda_{ei}^0) \int_{q_i(\phi_i)}^{\overline{w}_0} \frac{h_0(1 - T_i^{0\prime}(wh_0))\overline{F}_0(w)}{\delta_i + \rho + \lambda_{ei}^0 \overline{F}_0(w) + \lambda_{ei}^1 \overline{F}_1(q_i^{-1}(w))} \mathrm{d}w \\ + (\lambda_{ui}^1 - \lambda_{ei}^1) \int_{\phi_i}^{\overline{w}_1} \frac{h_1(1 - T_i^{1\prime}(wh_1))\overline{F}_1(w)}{\delta_i + \rho + \lambda_{ei}^0 \overline{F}_0(q_i(w)) + \lambda_{ei}^1 \overline{F}_1(w)} \mathrm{d}w.$$

Dividing both the numerator and denominator of the integral terms by δ_i, and performing a simple change of variable, we then obtain the simplified expression as presented in equation 1.

C Reservation Wage Distributions

Here we characterise the distribution of reservation wages. Recall that the cumulative distribution function of reservation wages amongst all type i workers (both employed and unemployed) is denoted A_i, with A_{ui} and A_{ei} denoting the respective distributions amongst the stock of unemployed and employed workers. These distributions are related according to:

$$A_i(w) = u_i A_{ui}(w) + (1 - u_i) A_{ei}(w) \tag{C.1}$$

The distribution of reservation wages amongst the unemployed A_{ui} allows us to describe the flows from the unemployment pool into employment at a given wage. As we demonstrate shortly, it also allows us to determine the steady state unemployment rate. In steady state the flow of individuals with a reservation wage no greater than ϕ who exit the employment pool following a job destruction shock must exactly equal the flow of such workers who enter employment. Hence,

$$\delta_i(1 - u_i)A_{ei}(\phi) = \lambda_{ui}^0 u_i \int_{-\infty}^{\phi} \overline{F}_0(q_i(w))\,\mathrm{d}A_{ui}(w) + \lambda_{ui}^1 u_i \int_{-\infty}^{\phi} \overline{F}_1(w)\,\mathrm{d}A_{ui}(w). \tag{C.2}$$

By differentiating equation C.2 using Leibniz's rule we obtain a relationship between the densities of employed and unemployed worker reservation wages, which when combined with equation C.1 allows us to establish that the unemployment weighted distribution of reservation wages amongst type i unemployed workers is given by:

$$u_i A_{ui}(\phi) = \int_{-\infty}^{\phi} \frac{\mathrm{d}A_i(w)}{1 + \mathcal{D}_{ui}(w)/\delta_i} \tag{C.3}$$

where we recall that $\mathcal{D}_{ui}(\phi) \equiv \lambda_{ui}^0 \overline{F}_0(q_i(\phi)) + \lambda_{ui}^1 \overline{F}_1(\phi)$ is the rate at which a type i worker with reservation wage ϕ will exit the unemployment pool into either part-time or full-time employment.[49] Note that by letting $\phi \to \infty$ in equation C.3 we obtain the expression for the steady state unemployment rate as presented in equation 3.

[49]The expressions we derive here depend upon the assumption that the job destruction rate δ_i does not vary with full-time/part-time job status. Under this assumption, we are able to characterise the distribution of reservation wages amongst the unemployed A_{ui}, without knowledge of the joint distribution of wages, hours, and reservation wages. In particular, it allows us to express it in terms of the cumulative distribution of leisure flows / reservation wages in the whole population.

D Weighted Earnings Distributions

The characterisation of between job worker flows (equation 2) and firm size (equation 5) depends upon a weighted distribution of full-time and part-time earnings amongst the employed, $m_{0i}G_{0i}(q_i(w)) + m_{1i}G_{1i}(w)$, with the hours specific distribution functions in this expression evaluated at wage rates that yield equal value to the worker. To derive an expression for this object note that the number of individuals who exit either a full-time job paying a wage no-greater than w or a part-time job paying wage no-greater than $q_i(w)$ must exactly equal the number of individuals who exit the unemployment pool to receive such wages. That is:

$$\begin{aligned}&[m_{1i}G_{1i}(w) + m_{0i}G_{0i}(q_i(w))]\,\mathcal{D}_{ei}(w)\\&= \lambda_{ui}^0 u_i \int_{-\infty}^{w} (F_0(q_i(w)) - F_0(q_i(x))\,\mathrm{d}A_{ui}(x) + \lambda_{ui}^1 u_i \int_{-\infty}^{w} (F_1(w) - F_1(x))\,\mathrm{d}A_{ui}(x).\end{aligned} \tag{D.1}$$

The RHS of equation D.1 may be written as:

$$\begin{aligned}&\lambda_{ui}^0 u_i \int_{-\infty}^{w} \overline{F}_0(q_i(x))\,\mathrm{d}A_{ui}(x) + \lambda_{ui}^1 u_i \int_{-\infty}^{w} \overline{F}_1(x)\,\mathrm{d}A_{ui}(x)\\&\qquad\qquad - \left[\lambda_{ui}^0 \overline{F}_0(q_i(w)) + \lambda_{ui}^1 \overline{F}_1(w)\right] u_i A_{ui}(w),\end{aligned}$$

or equivalently by using equations C.1 and C.2 as,

$$\delta_i A_i(w) - u_i A_{ui}(w)\,[\delta_i + \mathcal{D}_{ui}(w)]\,. \tag{D.2}$$

Setting equation D.2 equal to the LHS of equation D.1 and rearranging terms, we obtain the following form for the weighted earnings distributions:

$$m_{0i}G_{0i}(q_i(w)) + m_{1i}G_{1i}(w) = \frac{A_i(w) - u_i A_{ui}(w)[1 + \mathcal{D}_{ui}(w)/\delta_i]}{\mathcal{D}_{ei}(w)/\delta_i}. \tag{D.3}$$

Using this equation, we are then able to obtain expressions for the earnings densities and firm sizes in terms of the transitional parameters, wage offer distributions, and distribution of reservation wages. These may then be integrated to obtain the respective individual cumulative distribution functions and employment shares.

E Wage Policy

Maximized expected profit flow per unit intensity is given by $\overline{\pi}_h(p) = \overline{\pi}_h(w_h(p); p) = (p - w_h(p))h \cdot \overline{L}_h(w_h(p))$ so that $\overline{\pi}'_h(p) = h \cdot \overline{L}_h(w_h(p))$ by the Envelope Theorem. Since $\overline{L}_h(w)$ is increasing in w, and $w_h(p)$ is increasing in p, it follows that the maximized expected profit flow per unit intensity is a convex function of p. Rather than working directly with the first order conditions for the optimal wage policy of firms, we write firms' expected profit flow per unit intensity as:

$$\overline{\pi}_h(p) = h\overline{\pi}^*_h(\underline{p}_h) + h \int_{\underline{p}_h}^{p} \overline{L}_h(w_h(y))\, \mathrm{d}y \tag{E.1}$$

where $\overline{\pi}^*_h(\underline{p}_h) = \max_w(\underline{p}_h - w)h\overline{L}_h(w)$ are the maximized profits *per-hour* for the least productive sector h firm. Setting equation E.1 equal to $(p - w_h(p))h\overline{L}_h(p)$ and rearranging we obtain the following implicit equation for the wage policy function:

$$w_h(p) = p - \left[\pi^*_h(\underline{p}_h) + \int_{\underline{p}_h}^{p} \overline{L}_h(w_h(y))\, \mathrm{d}y \right] \times \frac{1}{\overline{L}_h(w_h(p))}$$

which is equation 8 from the main text.

F Equilibrium Invariance to Recruiting Cost Function

In Section 3.6 we argued that the recruiting cost function $c_h(p)$ is not identified from worker side data, and that this non-identification does not matter as any counterfactual simulation is invariant to our parameterisation of $c_h(p)$ (provided that $c_h(p) > 0$ for all h and p). To demonstrate this invariance result we consider the pair of recruiting cost functions $c_h(p)$ and $\widetilde{c}_h(p)$ for $h \in \{0, 1\}$. We proceed by first showing what relationships must hold in the estimated baseline model for $c_h(p)$ and $\widetilde{c}_h(p)$ to induce the same equilibrium. We then consider *any* equilibrium of the model (following a tax reform, for example) and show that any equilibrium obtained under $c_h(p)$ is also an equilibrium under $\widetilde{c}_h(p)$ *given the relationship that must hold between the primatives of the model under the alternative cost functions.*

Since more productive firms pay higher wages in equilibrium, the wage offer distribution is equal to a recruiting intensity weighted firm productivity distribution. Thus, for these different cost functions to induce the same (estimated) distribution of wage offers we must have $v_{h\star}(p)\gamma_h(p)/V_{h\star} = \widetilde{v}_{h\star}(p)\widetilde{\gamma}_h(p)/\widetilde{V}_{h\star}$ under the estimated equilibrium, where we use the convention that a tilde is used to denote variables under the alternative cost function $\widetilde{c}_h(p)$ and $\star$ is used to denote endogenous objects under the estimated base system. Using the first order conditions for the optimal choice of recruiting intensity (equation 7) this implies:

$$\widetilde{\gamma}_h(p) = \frac{\gamma_h(p)\widetilde{c}_h(p)\widetilde{V}_{h\star}^2}{c_h(p)V_{h\star}^2}, \tag{F.1}$$

which relates the implied estimates of the productivity distribution under the different cost functions. We now demonstrate that the worker side equilibrium of the model for any *counterfactual* under $c_h(p)$ is also an equilibrium under the alternative $\widetilde{c}_h(p)$. That is, none of our equilibrium reform simulations will depend upon the assumption on $c_h(p)$.

We now demonstrate that we obtain the same distribution of wage offers following the tax reform under $\widetilde{c}_h(p)$ with the alternative recruiting policy function $\widetilde{v}_h(p)$ as given by:

$$\widetilde{v}_h(p) = \frac{c_h(p)v_h(p)V_h}{\widetilde{c}_h(p)\widetilde{V}_h}. \tag{F.2}$$

which obtained by the necessary condition that the expected profit flow per unit intensity under the alternative cost functions is the same (see equation 7 from the main text). This choice of recruiting policy also induces the same wage offer distributions. Using equation F.1 and equation F.2:

$$\begin{aligned}
\widetilde{F}(\widetilde{w}_h(p)) &= \int_{\underline{p}_h}^{p} \frac{\widetilde{v}_h(p)\,\mathrm{d}\widetilde{\Gamma}_h(p)}{\widetilde{V}_h} \\
&= \int_{\underline{p}_h}^{p} \frac{c_h(p)v_h(p)V_h\,\mathrm{d}\widetilde{\Gamma}_h(p)}{\widetilde{c}_h(p)\widetilde{V}_h^2} \\
&= \left(\frac{V_h/V_{h\star}}{\widetilde{V}_h/\widetilde{V}_{h\star}}\right)^2 \int_{\underline{p}_h}^{p} \frac{v_h(p)\,\mathrm{d}\Gamma_h(p)}{V_h} \\
&= F(w_h(p)),
\end{aligned} \tag{F.3}$$

with the final equality following from the observation that:

$$\widetilde{V}_h = \int_{\underline{p}_h}^{\overline{p}_h} \widetilde{v}_h(p)\,\mathrm{d}\widetilde{\Gamma}(p) = \int_{\underline{p}_h}^{\overline{p}_h} \frac{c_h(p)v_h(p)V_h\,\mathrm{d}\widetilde{\Gamma}_h(p)}{\widetilde{c}_h(p)\widetilde{V}_h} = \left(\frac{V_h}{\widetilde{V}_h}\cdot\frac{\widetilde{V}_{h\star}^2}{V_{h\star}^2}\right)\int_{\underline{p}_h}^{\overline{p}_h} v_h(p)\,\mathrm{d}\Gamma_h(p),$$

which also means that the aggregate recruiting intensity *ratio* in the reform and base systems is the same irrespective of the cost function parametrization. That is,

$$\frac{V_h}{V_{h\star}} = \frac{\widetilde{V}_h}{\widetilde{V}_{h\star}}. \tag{F.4}$$

We verify that the set of job offer arrival rates are the same by showing that the set of search intensities that would induce these arrival rates do not change between the base and reform systems. Note that the arrival rates must satisfy:

$$\lambda_{ji}^h = s_{ji}^h \left[\frac{V_h}{M_h}\right]^{\frac{\theta_h}{1-\theta_h}}$$

and that if the set of arrival rates are the same then so is the flow of matches. Thus, we obtain the same set of arrival rates with the alternative cost functions if:

$$\frac{s_{ji}^h}{\widetilde{s}_{ji}^h} = \left[\frac{V_h}{\widetilde{V}_h}\right]^{\frac{\theta_h}{1-\theta_h}}.$$

From equation F.4 we know that $V_h/\widetilde{V}_h = V_{h\star}/\widetilde{V}_{h\star}$ so that there is no change in this ratio between the base and reform systems. Since the arrival rates are the same, then so too is the labour supply function facing the firm and therefore we must also have $w_h(p) = \widetilde{w}_h(p)$.

G Conditional Flow Equations

In this Appendix we derive and present flow equations conditional on the observed type i and unobserved leisure flow b. These are used when evaluating our welfare function in Section 6 from the main text. Let ϕ_{ib} denote the reservation wage of such an $\langle i, b\rangle$ worker worker (see Appendix B for an expression). It is straightforward to show that the steady state unemployment rate for such a worker is given by:

$$u_i^b = \frac{1}{1 + \mathcal{D}_{ui}(\phi_i^b)/\delta_i},$$

where $\mathcal{D}_{ui}(\phi_i^b)$ is the exit rate from unemployment (see Section 3.4). We may similarly characterise the between-job flow equation for full-time work. For wages $w > \phi_i^b$ we require that the outflows (due to job destruction, or exits to a higher value job) balances the inflows from unemployment and lower value jobs. We therefore have:

$$m_{1i}^b g_{1i}^b(w)\mathcal{D}_{ei}(w) = f_1(w)\left[\lambda_{ui}^1 u_i^b + \lambda_{ei}^1 m_{0i}^b G_{0i}^b(q_i(w)) + \lambda_{ei}^1 m_{1i}^b G_{1i}^b(w)\right],$$

where $\mathcal{D}_{ei}(w)$ is the exit rate from a full-time job paying wage w (again, see Section 3.4). Between-job flow equations for part-time jobs can be similarly derived. Both of these flow equations involve the (conditional) weighted cumulative distribution functions of full-time and part-time earnings amongst the employed. Using the definition of the conditional non-employment rate above, it is straightforward to show that this may be written as:

$$\begin{aligned} m_{0i}^b G_{0i}^b(q_i(w)) &+ m_{1i}^b G_{1i}^b(w) \\ &= \frac{\lambda_{ui}^0 \max\{F_0(q_i(w)) - F_0(q_i(\phi_i^b)), 0\} + \lambda_{ui}^1 \max\{F_1(w) - F_1(\phi_i^b), 0\}}{(1 + \mathcal{D}_{ui}(\phi_i^b)/\delta_i) \cdot \mathcal{D}_{ei}(w)}. \end{aligned}$$

H Likelihood Function

In this appendix we derive the likelihood contribution for individuals in different initial labour market positions, and with different observed transitions. Note that we do not use any information beyond the first observed transition, and that the steady state distributions of earnings and employment/unemployment shares have been used to determine the initial conditions.[50] See Section 4 in the main text for futher discussion. The presentation closely follows that of Bontemps, Robin and van den Berg (1999), and in what follows the durations beyond the selection date (the residual duration) and the

[50]While we may observe long elapsed spell durations, we nonetheless impose left censoring for durations greater than 24 months as it is difficult to justify the assumption that they were generated from the same steady state.

duration at the selection date (the elapsed duration) are given by:

$$\begin{aligned}
t_{ub} &= \text{elapsed unemployment duration} \\
t_{uf} &= \text{residual unemployment duration} \\
d_{ub} &= \text{1 if unemployment duration left-censored, otherwise 0} \\
d_{uf} &= \text{1 if unemployment duration right-censored, otherwise 0} \\
t_{eb} &= \text{elapsed employment duration} \\
t_{ef} &= \text{residual employment duration} \\
d_{eb} &= \text{1 if employment duration left-censored, otherwise 0} \\
d_{ef} &= \text{1 if employment duration right-censored, otherwise 0,}
\end{aligned}$$

while earned and accepted wages are denoted as follows:

$$\begin{aligned}
w_u &= \text{full-time wage accepted by unemployed individuals} \\
q_i(w_u) &= \text{part-time wage accepted by unemployed individuals} \\
d_u &= \text{1 if wage accepted by unemployed is unobserved, otherwise 0} \\
w_e &= \text{full-time wage of employees at date of first interview} \\
q_i(w_e) &= \text{part-time wage of employees at date of first interview} \\
d_e &= \text{1 if wage of employees is unobserved, otherwise 0.}
\end{aligned}$$

Current employment is indexed by:

$$\begin{aligned}
h_e^0 &= \text{1 if employed work in the part-time sector, otherwise 0} \\
h_e^1 &= \text{1 if employed work in the full-time sector, otherwise 0,}
\end{aligned}$$

and initial transitions are indexed by:

$$\begin{aligned}
v_u^0 &= \text{1 if unemployed accept a part-time job, otherwise 0} \\
v_u^1 &= \text{1 if unemployed accept a full-time job, otherwise 0} \\
v_e^0 &= \text{1 if employed accept a part-time job, otherwise 0} \\
v_e^1 &= \text{1 if employed accept a full-time job, otherwise 0.}
\end{aligned}$$

H.1 Unemployed Workers

The exact form that the likelihood contribution for unemployed workers of type i will take will depend upon whether unemployment durations are subject to any censoring and the type of wage offer accepted, if observed. If unemployed workers are observed to exit unemployment to a full-time job paying w_u or a part-time job paying $q_i(w_u)$, then we must have both $d_u = 0$ and $d_{uf} = 0$. The likelihood contribution is given by:

$$\int_{-\infty}^{w_u} \mathcal{D}_{ui}(\phi)^{2-d_{ub}} \exp\left[-\mathcal{D}_{ui}(\phi)(t_{ub}+t_{uf})\right] \times \frac{(\lambda_{ui}^0 f_0(q_i(w_u)))^{v_u^0}(\lambda_{ui}^1 f_1(w_u))^{v_u^1}}{\mathcal{D}_{ui}(\phi)} \frac{\mathrm{d}A_i(\phi)}{1+\mathcal{D}_{ui}(\phi)/\delta_i},$$

where we have integrated over the distribution of possible reservations wages given the observed accepted wage rate using equation C.3.

If we do not observe a wage accepted by the unemployed ($d_u = 1$), but we nonetheless have $d_{ub} + d_{uf} < 2$, then it still must be the case that the full-time reservation wage of such an individual is no greater than $\overline{\omega}_i$. The likelihood contribution is therefore:

$$\int_{-\infty}^{\overline{\omega}_i} \mathcal{D}_{ui}(\phi)^{2-d_{ub}-d_{uf}} \exp\left[-\mathcal{D}_{ui}(\phi)(t_{ub}+t_{uf})\right] \times \left[\frac{(\lambda_{ui}^0 \overline{F}_0(q_i(\phi)))^{v_u^0}(\lambda_{ui}^1 \overline{F}_1(\phi))^{v_u^1}}{\mathcal{D}_{ui}(\phi)}\right]^{1-d_{uf}} \frac{\mathrm{d}A_i(\phi)}{1+\mathcal{D}_{ui}(\phi)/\delta_i}.$$

Finally, if we have both $d_u = 1$ and $d_{ub} + d_{uf} = 2$, then the individual is never observed in the employment state so we must also consider the probability that such an individual has a reservation wage that is greater than $\overline{\omega}_i$. The likelihood contribution then becomes:

$$\int_{-\infty}^{\overline{\omega}_i} \exp\left[-\mathcal{D}_{ui}(\phi)(t_{ub}+t_{uf})\right] \frac{\mathrm{d}A_i(\phi)}{1+\mathcal{D}_{ui}(\phi)/\delta_i} + [1 - A_i(\overline{\omega}_i)].$$

H.2 Employed Workers

The likelihood contribution of a type i individual working full-time (part-time) at wage w_e ($q_i(w_e)$) is given by:

$$\{m_{0i}g_{0i}(q_i(w_e))\}^{h_e^0}\{m_{1i}g_{1i}(w_e)\}^{h_e^1}\mathcal{D}_{ei}(w_e)^{2-d_{eb}-d_{ef}}\exp\left[-\mathcal{D}_{ei}(w_e)(t_{eb}+t_{ef})\right]$$
$$\times\left[\frac{\delta_i^{1-v_e^0-v_e^1}(\lambda_{ei}^0\overline{F}_0(q_i(w_e)))^{v_e^0}(\lambda_{ei}^1\overline{F}_1(w_e))^{v_e^1}}{\mathcal{D}_{ei}(w_e)}\right]^{1-d_{ef}}.$$

The likelihood function takes the same form for an employed worker whose wage is unobserved ($d_e = 1$), except that we now integrate the above likelihood contribution over the support of wages.

I Identification

In Section 4.4 we discussed the identification of our model, and we now illustrate these ideas more formally. Here we set out to show that conditional on the set of transitional parameters, the observed distributions of part-time and full-time wages, together with the distributions of wages accepted by the unemployed are sufficient to separately identify the wage offer and reservation wage distributions if the labour market is in steady state.[51] Once these are known, the structure of the model then permits identification of the opportunity cost and productivity distributions. In what follows, we let G_{1i}^U and G_{0i}^U denote the respective cumulative distribution functions of wages first accepted by type i unemployed workers in full-time and part-time jobs. Since individuals will accept any wage offer that is at least as high as their reservation wage, G_{1i}^U will be given by:

$$G_{1i}^U(w)=\int_{-\infty}^{w}\Pr(W_1<w|W_1>x)\,\mathrm{d}A_{ui}(x)=\int_{-\infty}^{w}\frac{F_1(w)-F_1(x)}{\overline{F}_1(x)}\,\mathrm{d}A_{ui}(x)$$
$$=A_{ui}(w)-\overline{F}_1(w)\left[\int_{\underline{w}}^{w}\frac{\mathrm{d}A_{ui}(x)}{\overline{F}_1(x)}+A_{ui}(\underline{w})\right].$$

[51]The argument that follows is subject to the usual caveat that the distribution of reservation wages is only non-parametrically identified on the support of observed wages. In our empirical application (see Section 4 in the main text) we assume a parametric distribution of leisure flows, and therefore require that this distribution is recoverable in the sense of Flinn and Heckman (1982).

Similarly the fraction of part-time jobs accepted that pay no more than $q_i(w)$ can be shown to be given by:

$$G_{0i}^U(q_i(w)) = A_{ui}(w) - \overline{F}_0(q_i(w)) \left[\int_{\underline{w}}^{w} \frac{\mathrm{d}A_{ui}(x)}{\overline{F}_0(q_i(x))} + A_{ui}(\underline{w}) \right].$$

If we combine the above two expressions with the respective density functions of accepted wages $g_{hi}^U \equiv G_{hi}^{U\prime}$ we can write:

$$A_{ui}(w; F_0) = G_{0i}^U(q_i(w)) + \frac{\overline{F}_0(q_i(w)) g_{0i}^U(q_i(w))}{f_0(q_i(w))} \tag{I.1}$$

and:

$$A_{ui}(w; F_1) = G_{1i}^U(w) + \frac{\overline{F}_1(w) g_{1i}^U(w)}{f_1(w)}, \tag{I.2}$$

which therefore demonstrates that the distribution of reservation wages amongst the unemployed on support $[\underline{\omega}_i, \overline{\omega}_i]$ is identified given knowledge of the wage offer functions F_0 and F_1.[52] The monetary disutility of full-time work C_i^1 is identified by observing how the job-to-job transitions across hours sectors varies with the current wage rate.

Substituting equations I.1 and I.2 into equation 2 from the main text, we can eliminate the unobserved reservation wage distribution to obtain the following differential equations governing the evolution of the two wage offer distributions:

$$\begin{aligned} F_1'(w) &= m_{1i} g_{1i}(w) R_i^1(w; F_0, F_1) && \text{(I.3)} \\ F_0'(q_i(w)) &= m_{0i} g_{0i}(q_i(w)) R_i^0(w; F_0, F_1) && \text{(I.4)} \end{aligned}$$

where:

$$R_i^1(w; F_0, F_1) \equiv \frac{\left(1 + \kappa_{ei}^0 \overline{F}_0(q_i(w)) + \kappa_{ei}^1 \overline{F}_1(w)\right) - u_i g_{1i}^U(w) \kappa_{ui}^1 \overline{F}_1(w)}{\kappa_{ui}^1 u_i G_{1i}^U(w) + \kappa_{ei}^1 \left(m_{0i} G_{0i}(q_i(w)) + m_{1i} G_{1i}(w)\right)}$$

and:

$$R_i^0(w; F_0, F_1) \equiv \frac{\left(1 + \kappa_{ei}^0 \overline{F}_0(q_i(w)) + \kappa_{ei}^1 \overline{F}_1(w)\right) - u_i g_{0i}^U(q_i(w)) \kappa_{ui}^0 \overline{F}_0(q_i(w))}{\kappa_{ui}^0 u_i G_{0i}^U(q_i(w)) + \kappa_{ei}^0 \left(m_{0i} G_{0i}(q_i(w)) + m_{1i} G_{1i}(w)\right)}.$$

Equations I.3 and I.4 define a system of differential equations, which together with the initial conditions $F_1(\underline{\omega}_i) = 0$ and $F_0(q_i(\underline{\omega}_i)) = 0$, establishes non-parametric identifi-

[52]See the discussion in footnote 29 from the main text for an alternative approach to identifying the wage offer distributions by using information of the wages that low earners accept in their next job.

cation of both wage offer functions conditional on the set of transitional parameters. Identification of the underlying opportunity cost distribution and the productivity distributions then follows as described in Section 4.5.

J Tax Schedule Smoothing

Conditional on hours of work h, we remove small discontinuities in the budget constraint by setting the minimum transfer amount to zero for all benefits. We also remove the National Insurance (payroll tax) entry fee that existed prior to April 1999. With K tax brackets, the marginal tax rate approximation at hours h and earnings wh for an individual of demographic type i is given by:

$$MTR_i^h(wh) = \sum_{k=1}^{K} [\Phi_{i,k}^h(wh) - \Phi_{i,k+1}^h(wh)]\tau_{i,k}^h(wh),$$

where $\tau_{i,k}^h$ is the marginal tax rate at the k^{th} bracket and $\Phi_{i,k}^h$ is the normal cumulative distribution function with a mean equal to the value of the k^{th} tax bracket and with standard deviation $\sigma_{i,k}^h$. The value of $\sigma_{i,k}^h$ determines how quickly the smoothed marginal tax rates MTR_i^h change in the neighbourhood of the break points, with a small value fitting the underlying step function more closely. We set $\sigma_{i,k}^h = 20$ (measured in pounds per week in April 1997 prices), although our results are not sensitive to this particular choice.

K Alternative parameterisations

In this appendix we describe how the direct and equilibrium impact of WFTC and contemporaneous reforms may differ depending upon the characteristics of the labour market. For illustrative purposes, suppose that we were to first increase the worker level search intensity when employed by 50% for all $i \leq I$ and $h \in \{0, 1\}$ under the pre-reform policy environment. This results in a new pre-reform equilibrium, which we now perturb by introducing the same set of tax reforms that we considered earlier. Given both the structure of the model, and the nature of the reforms, it not immediate how the size of any initial labour supply responses and any corresponding equilibrium adjustments will change. In this case, we find the equilibrium channels imply a proportionally larger reduction in employment and wages. For single parents, where we again see the largest direct impact of the reform, in the new equilibrium we find that equilibrium adjustments reduce the employment response by 21%.[53] In fact, it is straightforward to construct a range of alternative parameterizations of the labour market where the relative size of equilibrium effects are either smaller or larger. For example, an increase in the dispersion of leisure flows is found to also increase the size of any equilibrium labour market adjustments.[54]

L Additional Parameter and Results Table

In Table 5 we present some data summary statistics; in Table 6 we present results which show the proportion of workers of each type whose reservation wage is below given percentiles of the (full-time) wage offer distribution, as described in Section 4.6 from the main text; in Table 7 we compare empirical and simulated one-year transitions, as described in Section 4.6 from the main text; in Table 8 we compare the predicted changes from the model to the actual changes based on our sample selection criteria, and as discussed in Section 5.4 from the main text.

[53] The direct impact (which necessarily differs relative to our baseline in this reparameterised economy) is simulated to be 5.6 percentage points. The adjustment in wages reduces the employment increase from 5.6 to 4.2 percentage points. The full equilibrium impact of the reform partially offsets some of the effects on wages, with employment increasing by 4.4 percentage points overall.

[54] We considered an alternative parameterization where we increase σ_i by 50% (relative to our estimated model) for all $i \leq I$. This increases the dispersion of wage offers in the pre-reform economy, and reduces the lowest equilibrium wage offers $\underline{w}_h$. In the post-reform economy, the equilibrium adjustments act to reduce employment. Amongst single parents, equilibrium effects reduce the direct employment effect by almost 20%.

Table 5: Descriptive Statistics

	Unemployed				Employed						
	$\#N_u$	$u \to h_0$	$u \to h_1$	$\#w_u$	$\#N_e^0$	$\#N_e^1$	$e \to h_0$	$e \to h_1$	$e \to u$	$\#w_e^0$	$\#w_e^1$
single men	796	–	149	57	–	2372	–	96	98	–	1332
married men, no kids	132	–	36	16	–	1763	–	74	29	–	1210
married men, kids	504	–	99	57	–	3602	–	134	97	–	2451
single women	357	26	33	37	234	1684	13	63	52	135	1053
single parents	1661	100	12	89	630	467	28	18	65	421	323
married women, no kids	417	25	22	28	719	2077	23	74	87	538	1480
married women, kids	2176	204	42	153	2594	1583	91	55	180	1943	1165

Notes: $\#N_u$ refers to the number of unemployed observations in a given category; $\#N_e^0$ and $\#N_e^1$ respectively refer to the number of part-time and full-time employment observations. $\#w_u$ refers to the number of observed accepted wages from unemployment; $\#w_e^0$ and $\#w_e^1$ refer to the number of cross-sectional wage observations in part-time and full-time employment. $i \to j$ refers to the numbers of observed transitions from state i to state j, with states u, e, h_0 and h_1, denoting unemployment, overall employment, part-time employment, and full-time employment respectively.

Table 5: (continued)

	Part-time wages							Full-time wages						
	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	mean	SD	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	mean	SD
single men	–	–	–	–	–	–	–	3.59	4.41	5.79	7.58	9.93	6.33	2.67
married men, no kids	–	–	–	–	–	–	–	4.32	5.46	7.03	9.16	11.78	7.61	3.00
married men, kids	–	–	–	–	–	–	–	4.22	5.54	7.41	9.86	12.46	7.90	3.22
single women	2.82	3.37	3.97	5.16	6.86	4.54	2.01	3.46	4.25	5.46	7.28	9.46	6.07	2.55
single parents	2.75	3.29	3.80	5.01	6.37	4.24	1.54	3.66	4.37	5.57	7.16	9.29	6.10	2.42
married women, no kids	3.07	3.66	4.27	5.38	6.90	4.73	1.75	3.57	4.41	5.56	7.09	9.22	6.03	2.36
married women, kids	3.00	3.61	4.40	5.72	7.09	4.86	1.88	3.66	4.40	5.64	7.11	8.97	6.06	2.32

Notes: All wages are hourly and are expressed in April 1997 prices. P_{10}, P_{25}, P_{50}, P_{75}, and P_{90} respectively refer to the 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentiles of the cross-sectional hourly wage distribution; SD refers to the standard deviation.

Table 6: Reservation Wage Distribution

	Percentile of full-time wage offer distribution					
	5	20	40	60	80	95
single men	0.300	0.446	0.589	0.726	0.878	0.989
	[0.184,0.482]	[0.327,0.599]	[0.495,0.704]	[0.660,0.810]	[0.836,0.936]	[0.965,0.999]
married men, no kids	0.138	0.311	0.509	0.688	0.868	0.983
	[0.064,0.278]	[0.191,0.471]	[0.378,0.642]	[0.577,0.784]	[0.808,0.919]	[0.965,0.994]
married men, kids	0.610	0.702	0.767	0.819	0.883	0.978
	[0.515,0.691]	[0.633,0.760]	[0.714,0.809]	[0.780,0.850]	[0.860,0.903]	[0.968,0.986]
single women	0.547	0.670	0.760	0.831	0.906	0.978
	[0.415,0.670]	[0.560,0.752]	[0.683,0.815]	[0.776,0.869]	[0.871,0.933]	[0.961,0.991]
single parents	0.437	0.565	0.636	0.691	0.774	0.986
	[0.188,0.628]	[0.475,0.763]	[0.569,0.908]	[0.620,0.968]	[0.678,0.998]	[0.837,1.000]
married women, no kids	0.288	0.499	0.679	0.805	0.907	0.981
	[0.161,0.518]	[0.358,0.675]	[0.582,0.784]	[0.747,0.862]	[0.880,0.935]	[0.968,0.991]
married women, kids	0.283	0.471	0.636	0.760	0.875	0.973
	[0.216,0.390]	[0.388,0.576]	[0.558,0.722]	[0.691,0.823]	[0.832,0.908]	[0.960,0.984]

Notes: Table shows the fraction of individuals whose full-time reservation wage is below various percentiles p of the full-time wage offer distribution, $A_i(\hat{F}_1^{-1}(p))$, and is calculated using the maximum likelihood estimates from Table 1. The 5^{th} and 95^{th} percentiles of the bootstrap distribution are presented in brackets, and are calculated using 500 replications.

Table 7: Empirical and Predicted One-Year Transitions

	Empirical			Predicted		
	$u \to e$	$e \to e$	$e \to u$	$u \to e$	$e \to e$	$e \to u$
single men	0.320	0.093	0.053	0.312	0.087	0.097
	[0.219,0.411]	[0.066,0.124]	[0.032,0.076]	[0.283,0.322]	[0.085,0.100]	[0.086,0.099]
married men, no kids	0.800	0.098	0.020	0.587	0.085	0.033
	[0.519,1.000]	[0.071,0.124]	[0.009,0.035]	[0.493,0.594]	[0.073,0.087]	[0.029,0.038]
married men, kids	0.490	0.079	0.025	0.372	0.086	0.041
	[0.377,0.609]	[0.060,0.100]	[0.015,0.036]	[0.345,0.389]	[0.082,0.092]	[0.039,0.045]
single women	0.367	0.078	0.035	0.293	0.098	0.059
	[0.239,0.521]	[0.052,0.109]	[0.017,0.055]	[0.279,0.327]	[0.081,0.097]	[0.055,0.066]
single parents	0.170	0.110	0.110	0.101	0.105	0.145
	[0.125,0.218]	[0.065,0.160]	[0.064,0.159]	[0.092,0.107]	[0.088,0.108]	[0.133,0.155]
married women, no kids	0.149	0.092	0.039	0.358	0.068	0.050
	[0.068,0.240]	[0.069,0.114]	[0.024,0.055]	[0.314,0.364]	[0.058,0.069]	[0.046,0.054]
married women, kids	0.229	0.069	0.054	0.195	0.085	0.087
	[0.191,0.270]	[0.053,0.085]	[0.040,0.069]	[0.184,0.202]	[0.082,0.092]	[0.085,0.094]

Notes: Predicted transitions are simulated using the maximum likelihood estimates from Table 1. All transitions measure differences in employment states over a period of one-year (irrespective of any within year transitions). Empirical transitions are calculated using individuals observed in both Q1 1997 and Q1 1998. The 5^{th} and 95^{th} percentiles of the bootstrap distribution of annual transition rates are presented in brackets, and are calculated using 500 replications.

Table 8: Post-reform Comparison

	Empirical			Predicted		
	Δu_i	Δm_{0i}	Δm_{1i}	Δu_i	Δm_{0i}	Δm_{1i}
single men	-5.0	–	5.0	-1.1	–	1.1
married men, no kids	-1.9	–	1.9	-0.3	–	0.3
married men, kids	-3.1	–	3.1	-1.1	–	1.1
single women	-1.8	0.5	1.3	-0.5	-0.4	0.9
single parents	-6.5	3.1	3.4	-4.8	-1.9	6.7
married women, no kids	-2.3	-1.2	3.5	-0.4	-1.1	1.5
married women, kids	-3.4	0.7	2.7	1.0	-1.1	0.1

Notes: All employment responses are expressed in percentage points. Changes may not sum to zero due to rounding.

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