I Z A Institute of Labor Economics

Initiated by Deutsche Post Foundation

DISCUSSION PAPER SERIES

IZA DP No. 13107

Income Taxation and Dual Job Labour Supply

Chung Choe
Ronald L. Oaxaca
Francesco Renna

MARCH 2020

I Z A Institute
of Labor Economics
Initiated by Deutsche Post Foundation

DISCUSSION PAPER SERIES

IZA DP No. 13107

Income Taxation and Dual Job Labour Supply

Chung Choe
Konkuk University

Ronald L. Oaxaca
University of Arizona, GLO, LISER, PRESAGE and IZA

Francesco Renna
University of Akron

MARCH 2020

ISSN: 2365-9793

IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

Income Taxation and Dual Job Labour Supply

This paper examines the effects of increasing marginal tax rates on labour supply in a setting in which workers may hold two jobs and may be constrained in their weekly hours on their main jobs. A panel data, multi-equation labour supply model is estimated with correction for tax system endogeneity and multi-sample selection in a correlated random effects framework. Data come from the British Household Panel Survey. The effects of counterfactual increases in marginal tax rates are obtained from Gauss-Seidel simulations of labour supply embedded in a tax system with allowances, tax credits, and child benefits. Labour supply to the main job is reduced by increased marginal tax rates while labour supply to the second job is increased. On net total labour supply is reduced. These effects diminish with increased marginal tax rates. In addition there are labour force withdrawal effects as well as transitions from dual job holding to unitary job holding in response to increased marginal tax rates.

JEL Classification: J01, J22, H24

Keywords: dual job, labour supply, taxation, simulation

Corresponding author:
Francesco Renna
Department of Economics
University of Akron
Akron, OH 44325-1908
USA
E-mail: frenna@uakron.edu

The effect of income taxation on labour supply has always been controversial, mostly because it is not clear whether an increase in taxation would lead to a reduction or to an increase in work effort. Assuming that leisure is a normal good, an increase in the income tax rate could lead to an increase or a decrease in work effort depending on the relative magnitudes of the income and substitution effects generated by the decrease in the after-tax wage rate. The theoretical and empirical bases for determining the effects of income taxation on labour supply are further complicated by factors such as marginal tax rate endogeneity, kinked budget constraints arising from a graduated income tax system, dual job holding, binding constraints on desired hours of work, and sample selection.

In this paper we seek to view the impacts of income taxation on dual job labour supply in the UK through the lens of a Stone-Geary utility function that accommodates six mutually exclusive labour supply regimes defined by unitary/dual job holding status and the direction of binding constraints on desired hours of work on one's main job, i.e. underemployed/overemployed. Our approach takes account of the endogeneity of marginal tax rates, sample selection, correlated random effects, and the lack of a closed-form solution to the combined labour supply and income taxation system.

The rest of the paper is organised as follows: Section 1 is the literature review, Section 2 is an overview of the income tax system in U.K., Section 3 illustrates the theoretical framework used to derive our labour supply equations, Section 4 describes the data, Section 5 discusses the methodology implemented to estimate labour supply, Section 6 explains the estimation strategy for the counterfactual income tax policy, Section 7 presents the empirical findings, and Section 9 concludes with some final remarks.

1 Literature Review

Due to the convexity of the budget constraint, the progressive nature of typical income tax regimes adds an additional element of theoretical uncertainty about the labour supply effects of income taxes (Moffitt, 1990). Overall the previous literature has consistently found very small (and negative) wage elasticities of labour supply suggesting that a change in the marginal tax rate should not have a major impact on annual hours of work, at least for men (Meghir and Phillips, 2008). However, recent work on dual job holding seems to point to more elastic labour supply on the second job (Choe et al., 2018). As such, the level of taxation could potentially have significant effects on the labour supply of dual job holders.

Only a handful of studies have examined the effect of taxation on the labour supply of dual job holders. O'Connell (1979) finds that the elasticity of moonlighting hours with respect to the tax rate is between -0.43 and -0.56. The negative tax elasticity suggests an upward sloping supply curve for dual job holders. On the contrary, Hunt et al. (1985) conclude that labour supply for dual job holders is backward bending: a one percentage point increase in the marginal tax rate is expected to elicit about 3 additional hours of work per year in the second-job. Considering that on average dual job holders work approximately only 390 hours annually on their second job, one can conclude that changes in the tax regimes are expected to have substantial effects on the second job. Using a unique policy change in Germany which exempted earnings from the second job to any form of income taxation, Tazhitdinova (2017) is able to identify the impact of a large tax reform on dual job holding. Using a difference-in-difference procedure she found that the rate of dual job holding more than doubled and that the participation elasticity on the second job was much higher than the participation elasticity on the primary job. Frederiksen et al (2008) estimate labour supply functions for Danish workers subject to a non-linear budget constraint with kinks arising from overtime wage premiums and second job wage rates. They use sample distributions of the estimated substitution and income elasticities to simulate four potential income tax reforms and their effect on the public-sector revenue. They conclude that reducing the marginal tax rate for the median income earner is the reform which is the closest to self-financing. Reducing the marginal tax rates for high-income earners is relatively expensive.

While our emphasis is dual job holding, our paper can be placed in the line of prolific research initiated by Hausman (1985) and his work on labour supply and taxation in the presence of a kinked budget constraint. In response to the common critique to Hausman's assumption that individuals cannot freely choose the location on the segment of the budget line which maximises their income (MaCurdy et al., 1990), we control for whether the individual is bounded on the hours he can work on the main job. Contrary to Ham (1982), which only controls for conditions of underemployment, we are able to identify in our data if the respondent is underemployed or overemployed.

Following Rosen (1976) we treat the marginal tax rate as endogenous, and we estimate instrumented and selectivity-corrected labour supply functions. Unfortunately, the marginal tax rate is endogenous in a fairly complicated nonlinear way because of features of graduated income tax systems such as earnings-based tax credits, tax allowances, and child tax benefits. For example, a change in income tax rates affects labour supply which impacts labour earnings which in turn impacts tax bands. Thus, it is clear that there are no simple analytic derivative expressions for obtaining the labour supply effects of exogenous changes in statutory marginal tax rates. In the absence of closed-form solutions for the set of nonlinear equations comprising labour supply and a graduated income tax system, we use the Gauss-Seidel algorithm methodology to obtain numerical solutions to counterfactual changes in statutory marginal tax rates.

Conceptually, our theoretical approach bears some resemblance to the literature on the effect of taxation on joint husband-wife labour supply (Hausman and Ruud, 1984). The difference is that in our set-up the decision maker is the individual rather than the household, and the individual allocates his working time over two jobs. Analogous to this literature that found larger responses in the work intensity of wives than husbands (Aaberge et al., 1999; Bourguignon and Magnac, 1990), we find that a change in the taxation rate does not have substantial effects on the hours supplied to the main job, but its impacts on the hours supplied to the second job are not trivial.

2 Overview of the UK Income Tax System

Like many western economies, the British income tax system can be described as one of progressive tax rates with allowances and tax credits including child benefits. The rates on labour earnings are set on three income bands: *starting rate*, *basic rate*, and *higher rate*. During the period from 1992 to 2008, both the *starting rate* and the *basic rate* have been revised. The *starting rate* was lowered from 20% to 10% in 1990 while the *basic rate* dropped gradually over time from 25% to 22% between 1995-6 and 2000-1. The *higher rate* remained unchanged at 40% during this time period. Together with the decrease of the *starting rate* in 1990, there was a decrease in the annual maximum taxable income from £4500 to £1500 that would make an individual eligible for the *starting rate*. Thus, while some individuals may have seen a decrease in the amount of income taxes to be paid, many moved to the *basic rate* and paid higher income taxes because of the reform. Different tax rates have been applied to dividend and savings income. The basic rate on savings income has remained constant at 20%. The *basic rate* of tax on dividends was 20% from 1993-4 to 1998-9 and 10% since 1999-00, when the *higher rate* of tax on dividends became 32.5%. However, an offsetting dividend tax credit meant that the effective tax rates on dividends have been constant at zero *basic rate* and 25% *higher rate* since 1993-4.

Taxable income is defined as the income after deduction of personal allowances. An additional allowance of £1720 was permitted for married individuals or single parents with at least 1 child. This additional allowance operated as a tax credit from the 1993-4 tax year to 1999-00. While personal deductions are typically not means tested, tax credits are based on the income of the tax payer and/or the number of children. When family income reaches some pre-set thresholds, the amount of benefits are reduced. The first U.K. tax credit program in support of low paid workers with dependent children was the Family Income Supplement. In 1988 the Family Income Supplement was renamed the Family Credit. Initially, families with children where there was at least one person working more than 24 hours a week were eligible for the tax credit. In the first half of the 1990s, the hour requirement was lowered to 16.

In 1999 both the single parent allowance and Family Credit programs were terminated and replaced with the Working Family Tax Credit. While these programs all shared the same design, the level of generosity of the benefits increased over time. After the 2003 reform, the working and family status conditions no longer had to be jointly satisfied. The Working Tax Credit (WTC) program guaranteed that any working family, whether a childless couple or a working family with dependents, would be eligible for a tax credit if their income was below a first threshold level. The amount of the credit is reduced by 0.41 (withdraws rate) for each pound above £6,420 until the credit is completely exhausted. In addition, individuals may be entitled to a Child Tax Credit (CTC) if they are responsible for any child, independently from whether they receive WTC. There is no pre-set income threshold above which the CTC benefits begins to taper off (it depends on family circumstances). However for the majority of claimants the threshold is £50,000.

3 Conceptual Framework

Consider a graduated three-band income tax system. Annual taxable income (Y_{tax}) is gross income net of tax exempt allowances. The marginal labour and nonlabour income tax rates for each band are respectively given by $0 < \tau_{w1} < \tau_{w2} < \tau_{w3} < 1$, and $0 < \tau_{I1} < \tau_{I2} < \tau_{I3} < 1$. Indicator variables for one's tax status are defined as

$$D_1 = 1(0 < Y_{tax} \leq Y_{U1})$$

$$D_2 = 1(Y_{U1} < Y_{tax} \leq Y_{U2})$$

$$D_3 = 1(Y_{U2} < Y_{tax}),$$

where Y_{U1} and Y_{U2} are tax band boundary values such that $0 < Y_{U1} < Y_{U2}$. One's annualised <u>net</u> income tax is calculated as

$$
\begin{aligned}
Tax = {} & D_1 \left[\tau_{w1} \left(Y_{tax} - 52I\right) + 52\tau_I I\right] + D_2 \left[\tau_{w1} Y_{U1} + \tau_{w2} \left(Y_{tax} - 52I - Y_{U1}\right) + 52\tau_{I2} I\right] \\
& + D_3 \left[\tau_{w1} Y_{U1} + \tau_{w2} Y_{U2} + \tau_{w3} \left(Y_{tax} - 52I - Y_{U2}\right) + 52\tau_{I3} I\right] - TC,
\end{aligned}
$$

where I is weekly nonlabour income and TC is the annual sum of tax credits. The marginal tax rates on labour earnings and nonlabour income are given by

$$
\begin{aligned}
\tau_w = {} & \tau_{w_1} D_1 + \tau_{w_2} D_2 + \tau_{w_3} D_3 \\
\tau_I = {} & \tau_{I_1} D_1 + \tau_{I_2} D_2 + \tau_{I_3} D_3.
\end{aligned}
$$

A nice example of modelling constrained labour supply in an explicit utility function framework can be found in O'Leary (1991). This work examined labour supply of overemployed and underemployed workers in the context of Cobb-Douglas, Stone-Geary, and Constant Elasticity of Substitution utility functions. However, neither dual job holding nor income taxation were considered. We generalise the theoretical dual job labour supply functions obtained from utility maximisation for a Stone-Geary Utility function (Choe et al., 2018) to incorporate a graduated income tax system with tax allowances (deductions) and tax credits. The weekly labour supply regimes for unconstrained and constrained dual and unitary job holders are presented below in terms of after-tax weekly earnings on each job.

Unconstrained dual job holder

Consider utility maximisation for a multiple (dual) job holder who is not constrained in their choice of working hours:

$$
U = \left(\gamma_1 - h_1^*\right)^{\alpha_1} \left(\gamma_2 - h_2^*\right)^{\alpha_2} \left(y^* - \gamma_3\right)^{1-\alpha_1-\alpha_2} \tag{1}
$$

where $\alpha_1, \alpha_2, \gamma_1, \gamma_2, \gamma_3 > 0$, h_m^* represents the time allocated to job m, and y^* is net (after tax) income. The parameters γ_1 and γ_2 represent the upper bounds on the hours that can be expended on jobs 1 and 2, and still have the utility function defined. They satisfy the restriction

$$\sum_{m=1}^{2} \gamma_m = T,$$

where T is the total time available for work and leisure. The parameter γ_3 represents the lower bound on the amount of income necessary for the utility function to be defined. The terms $(\gamma_m - h_m^*)$, $m = 1, 2$ represent the times freed up by each job for leisure consumption. Total consumption of leisure time ℓ is residually obtained as

$$\begin{aligned} \ell &= T - h_1^* - h_2^* \\ &= \gamma_1 + \gamma_2 - h_1^* - h_2^* \\ &= (\gamma_1 - h_1^*) + (\gamma_2 - h_2^*) \, . \end{aligned}$$

The economic problem facing the dual job holder can be stated as

$$\begin{aligned} \max_{h_1, h_2, y} U &= (\gamma_1 - h_1^*)^{\alpha_1} \, (\gamma_2 - h_2^*)^{\alpha_2} \, (y^* - \gamma_3)^{1-\alpha_1-\alpha_2} \\ \text{s.t. } y^* &= \sum_{m=1}^{2} W_m h_m^* + I - D_1 \left[\tau_{w1} \left(\sum_{m=1}^{2} W_m h_m^* - A \right) + \tau_{I1} I \right] \\ &\quad - D_2 \left[\tau_{w1} y_{u1} + \tau_{w2} \left(\sum_{m=1}^{2} W_m h_m^* - A - y_{u1} \right) + \tau_{I2} I \right] \\ &\quad - D_3 \left[\tau_{w1} y_{u1} + \tau_{w2} y_{u2} + \tau_{w3} \left(\sum_{m=1}^{2} W_m h_m^* - A - y_{u2} \right) + \tau_{I3} I \right] + T_c, \\ &\quad 0 < h_m^* < \gamma_m, \; m = 1, 2 \text{ and} \\ \sum_{m=1}^{2} h_m^* &\le T, \end{aligned}$$

where W_m is the gross wage or pecuniary rewards to the mth job, I is exogenous (before tax) non-labour income, A is the allowance for the amount of income exempt from taxes (applied first to individual earnings), and T_c is any applicable tax credit. The utility maximising dual labour supply after-tax weekly earnings functions are given by

$$\begin{aligned}(1-\tau_w)W_1h_1^* =&\alpha_1\Bigg\{\gamma_3 - \left[D_2\left(\tau_{w2}-\tau_{w1}\right) - D_3\tau_{w3}\right]y_{u1} - D_3(\tau_{w3}-\tau_{w2})y_{u2} \\ &- (1-\tau_I)I - \tau_w A - (1-\tau_w)(\gamma_1 W_1 + \gamma_2 W_2) - T_c\Bigg\} + \gamma_1(1-\tau_w)W_1 \end{aligned} \tag{2}$$

$$\begin{aligned}(1-\tau_w)W_2h_2^* =&\alpha_2\Bigg\{\gamma_3 - \left[D_2\left(\tau_{w2}-\tau_{w1}\right) - D_3\tau_{w3}\right]y_{u1} - D_3(\tau_{w3}-\tau_{w2})y_{u2} \\ &- (1-\tau_I)I - \tau_w A - (1-\tau_w)(\gamma_1 W_1 + \gamma_2 W_2) - T_c\Bigg\} + \gamma_2(1-\tau_w)W_2. \end{aligned} \tag{3}$$

Unconstrained unitary job holders

For individuals who hold only one job, we then condition on $h_2^* = 0$:

$$\begin{aligned}\max_{h_1,y} U \; &= (\gamma_1 - h_1^*)^{\alpha_1} \; (\gamma_2 \;)^{\alpha_2} \left(y^* - \gamma_3\right)^{1-\alpha_1-\alpha_2} \\ \text{s.t. } y^* &= W_1h_1^* + I - D_1\left[\tau_{w1}\left(W_1h_1^* - A\right) + \tau_{I1}I\right] \\ &- D_2\left[\tau_{w1}y_{u1} + \tau_{w2}\left(W_1h_1^* - A - y_{u1}\right) + \tau_{I2}I\right] \\ &- D_3\left[\tau_{w1}y_{u1} + \tau_{w2}y_{u2} + \tau_{w3}\left(W_1h_1^* - A - y_{u2}\right) + \tau_{I3}I\right] + T_c, \\ 0 < h_1^* \; &< \gamma_1, \\ h_1^* &\le T.\end{aligned}$$

The utility maximising unitary after-tax weekly earnings function is given by

$$(1-\tau_w)W_1h_1^* = \left(\frac{\alpha_1}{1-\alpha_2}\right)\Bigg\{\gamma_3 - \left[D_2\left(\tau_{w2}-\tau_{w1}\right) - D_3\tau_{w3}\right]y_{u1} - D_3(\tau_{w3}-\tau_{w2})y_{u2}$$
$$- (1-\tau_I)I - \tau_w A - \gamma_1(1-\tau_w)W_1 - T_c\Bigg\} + \gamma_1(1-\tau_w)W_1. \tag{4}$$

Constrained dual job holder

Due to data restrictions we can only consider constrained labour supply on job 1, i.e. workers are constrained either because they desire more hours on job 1 (underemployed) or they desire fewer hours on job 1 (overemployed). Consequently, constrained dual job holders are assumed to be working their desired hours on job 2 conditional on their constrained hours in job 1. For an individual who is constrained at $h_1 = \dot{h}_1$, the utility maximisation problem becomes

$$\max_{h_2,y} U = \left(\gamma_1 - \dot{h}_1\right)^{\alpha_1} \left(\gamma_2 - h_2^*\right)^{\alpha_2} \left(y^* - \gamma_3\right)^{1-\alpha_1-\alpha_2}$$
$$\text{s.t. } y^* = W_1\dot{h}_1 + W_2h_2^* + I - D_1\left[\tau_{w1}\left(W_1\dot{h}_1 + W_2h_2^* - A\right) + \tau_{I1}I\right]$$
$$- D_2\left[\tau_{w1}y_{u1} + \tau_{w2}\left(W_1\dot{h}_1 + W_2h_2^* - A - y_{u1}\right) + \tau_{I2}I\right]$$
$$- D_3\left[\tau_{w1}y_{u1} + \tau_{w2}y_{u2} + \tau_{w3}\left(W_1\dot{h}_1 + W_2h_2^* - A - y_{u2}\right) + \tau_{I3}I\right] + T_c,$$
$$0 \leq h_2^* < \gamma_2, \quad 0 \leq \dot{h}_1 < \gamma_1, \text{ and}$$
$$\dot{h}_1 + h_2^* \leq T,$$

While labour supply to job 1 is fixed at $\dot{h}_1$, the utility maximising labour supply after tax earnings function for job 2 is given by

$$(1-\tau_w)W_2h_2^* = \frac{\alpha_2}{1-\alpha_1}\Bigg\{\gamma_3 - \left[D_2\left(\tau_{w2}-\tau_{w1}\right) - D_3\tau_{w3}\right]y_{u1} - D_3(\tau_{w3}-\tau_{w2})y_{u2}$$
$$- (1-\tau_I)I - \tau_w A - (1-\tau_w)\left(W_1\dot{h}_1 + \gamma_2 W_2\right) - TC\Bigg\} + \gamma_2(1-\tau_w)W_2 \qquad (5)$$

Constrained unitary job holder

For a constrained unitary job holder, hours worked ($\dot{h}_1$) are treated as exogenous so there is no labour supply equation to estimate.

4 Data

Our data are from the British Household Panel Survey (BHPS) and span the years 1991 to 2008. Details of the construction of our estimation sample are reported in Choe et al. (2018). The present paper focuses on how labour supply decisions are impacted by marginal tax rate considerations in a dual job holding setting.

From an individual's annualised taxable income $Y_{tax_{it}}$, we determine their marginal income tax rates according to 3-band marginal tax rate schedules.[1] Indicators for one's tax status and corresponding marginal tax rates are defined by

$$D_{1it} = 1(0 < Y_{tax_{it}} \leq Y_{U1_{it}})$$

$$D_{2it} = 1(Y_{U1_{it}} < Y_{tax_{it}} \leq Y_{U2_{it}})$$

$$D_{3it} = 1(Y_{U2_{it}} < Y_{tax_{it}})$$

$$\tau_{wit} = \tau_{w_{1it}}D_{1it} + \tau_{w_{2it}}D_{2it} + \tau_{w_{3it}}D_{3it}$$

$$\tau_{Iit} = \tau_{I_{1it}}D_{1it} + \tau_{I_2}D_{2it} + \tau_{I_{3it}}D_{3it}.$$[2]

[1] A 2-band marginal tax rate schedule was in effect only for the first year and last year of our data. For these two years the tax status indicator D_{1it} is unchanged; however, $D_{3it} = 0$ and $D_{2it} = 1(Y_{U1_{it}} < Y_{tax_{it}})$.

Taxable income is calculated for each hours-constrained regime according to

$$
\begin{aligned}
Y_{tax_{it}} &= 52 * \left(\sum_{m=1}^{2} W_{mit} h_{mit} + I_{it} - A_{it} \right) \text{(unconstrained dual job holders)} \\
&= 52 * \left(W_{1it} h_{1it} + I_{it} - A_{it} \right) \text{(unconstrained unitary job holders)} \\
&= 52 * \left(W_{1it} \dot{h}_{1it} + W_{2it} h_{2it} + I_{it} - A_{it} \right) \text{(constrained dual job holders).}
\end{aligned}
$$

Over the period 1991-92 to 1999-00, single parents were entitled to an additional tax allowance. Also over the same period, married individuals were eligible for a tax credit. A married couple was free to divide the tax credit between them in any way they wished. Because we do not know how a couple might have divided the tax credit, and because it would make sense to allocate most or all of the credit to the highest earner, we assign the full amount of the tax credit to the husband. This was also the default by the UK tax authorities for any married couple who did not elect to make an explicit division of the tax credit. Changes in British tax law after 1993 treat dividend and savings income differently from other forms of non-labour income. Since we are unable to identify the separate components of non-labour income, we apply the savings marginal tax rates to the entire amount of non-labour income.

For purposes of tax and tax credit computations, we use the nominal values of wages and income based on the applicable nominally valued tax tables. For purposes of model estimation we adjust the wage and income variables for inflation using the Consumer Price Index (base year = 2008). We denote the inflation corrected variables with superscript r.

Table 1 reports the descriptive statistics of the variables included in our analysis disaggregated by hour constraint and dual job status. We focus on male, working for pay only individuals since self-employed individuals can generally set their hours to match their desired hours. Our sample consists of 46,928 observations over 8,405 individuals. Therefore, on average each individual appears 5.6 times in our data. About 6 percent of the unitary job observations refer to an episode of underemployment. More prevalent is the instance of being overemployed with about 35 percent of the unitary job sample reporting that they

[2] Lacking complete information on the "ownership" of non-labour income within a married/civil union household, we assign all of the non-labour income to the sample individual.

desired to work fewer hours on job 1. Among the total dual job observations, 9 percent pertains to instances of underemployment and 31 percent to instances of overemployment.

The data confirm the reasonable expectation that overemployed individuals work more hours on job 1 than both unconstrained and underemployed workers. On the other hand underemployed workers work shorter workweeks. The difference in the hours worked on the second job is not statistically significant across the three hour-constraint regimes. Overemployed workers consistently earn more on a weekly basis than the remaining two categories of workers. This result is a combination of the fact that overworked individuals work more hours and they earn a higher hourly wage.

In terms of demographics, individuals differ substantially across the labour regimes. Dual job holders are younger than their unitary counterparts. Within each job holding category, underemployed workers are the youngest and overemployed are the oldest. We do not observe significant differences in the distribution of the individuals by educational attainment among unconstrained, underemployed, and overemployed unitary job holders. Overall, about half of our unitary job observations holds either a Level A or a Level O diplomas. Among dual job holders, underemployed individuals tend to be more likely to hold Level A or Level O diplomas, while overemployed tend to be more likely to hold advanced degrees such as higher degrees and 1st degree. Underemployed unitary job holders are less likely to be married but have the highest number of children. Underemployed dual job holders are also less likely to be married but have the lowest number of children. Because of these differences in family composition, there is little variation in the amount of tax credits across the 6 categories of job holders.

5 Empirical Model

Our sample is partitioned according to six mutually exclusive outcomes: (1) unconstrained dual job holders, (2) unconstrained unitary job holders, (3) constrained dual job holders desiring fewer hours on job 1 (overemployed), (4) constrained dual job holders desiring more hours on job 1 (underemployed), (5) constrained unitary job holders desiring fewer hours (overemployed), and (6) constrained unitary job holders desiring more hours (underemployed). Because constrained hours on job 1 are treated as exogenous, we are left with five labour supply functions to estimate that span four selection regimes: h_1 and h_2 for case (1), h_1 for case (2), h_2 for case (3), and h_2 for case (4). Hours are measured as hours per week, wages are measured as hourly wage rates, and non-labour and total income are measured on a weekly basis. All monetary variables are expressed in terms of 2008 prices. Estimation of the labour supply model to be used for evaluating labour supply effects of exogenous changes in the income tax structure requires that we address two econometric issues: 1) sample selection with correlated random effects, and 2) endogeneity of the marginal tax rate and tax credits.

The first stage of our panel data treatment of the dual labour supply model is estimation of separate multinomial logit models for each data period. From these estimates we are able to construct Inverse Mills Ratios (IMR's) that will be added to the labour supply equations for sample selection correction. Our analysis based on Choe and Oaxaca (2016) extends the sample selection approaches of Lee (1983), Wooldridge(1995; 2010), and Dustmann and Rochina-Barrachina (2007) to multivariate selection in a panel data setting. The second stage is estimation of the fitted values of the endogenous variables involving the marginal tax rate. The third stage is joint estimation of the instrumented selectivity-corrected labour supply functions with cross-equation restrictions.

The multinomial logit model exogenous variables include the current values and the time-averaged values common to all six hours-constrained regimes:

$$x_{it} = (W^r_{1it}, I^r_{it}, \mathrm{Age}_{it}, \mathrm{Educ}_{it}, \mathrm{MS}_{it}, \mathrm{DP}_{it})$$

$$\overline{\omega}_i = \left(1, \overline{W}^r_{1i}, \overline{I}^r_i, \overline{\mathrm{Age}}_i, \overline{\mathrm{Educ}}_i, \overline{\mathrm{MS}}_i, \overline{\mathrm{DP}}_i\right).$$

where Age is the individual's age, Educ is a vector of educational attainment dummy variables, MS is marital status (= 1 if married), DP is the number of dependent children, and the elements of $\overline{\omega}_i$ are the sample means of the variables for each individual plus a constant term.[3]

The probabilities associated with the six labour supply regimes are obtained from the multinomial logit models separately estimated each period:

$$\begin{aligned} P_{jit} &= P\left(s_{it} = j \mid x_{it}, \bar{\omega}_i\right), j = 1, ..., 5, t = 1, ...T_i \\ &= \Lambda\left(x_{it}, \bar{\omega}_i, \beta_{jt}\right) \\ P_{0it} &= 1 - \sum_{j=1}^{5} P_{ijt}, \end{aligned}$$

where s_{it} is an index of labour supply regime, and β_{jt} is the multinomial logit parameter vector for labour supply regime j in period t. Let $z_{jit} = \Phi^{-1}\left(P_{jit}\right)$, where Φ^{-1} is the inverse standard normal CDF. Thus, $\Phi\left(z_{jit}\right) = P_{jit} = \Lambda\left(x_{it}, \overline{\omega}_i, \beta_{jt}\right)$. Accordingly, the appropriate IMR variables are derived as $\lambda_{jit} = \dfrac{\phi\left(z_{jit}\right)}{\Phi\left(z_{jit}\right)}$. In practice the Inverse Mills Ratios (IMR's) are replaced by the values obtained from the multinomial logit models estimated separately for each period.

Following Choe et al. (2018), our empirical estimation is conducted for the earnings version of the Stone-Geary labour supply model. We estimate the Stone-Geary model's boundary parameters γ_1, γ_2, and γ_3 directly from our panel data sample. Let $\tilde{\gamma}_1$ be the highest integer value that satisfies $h_1^{\max} < \tilde{\gamma}_1 \leq 1 + h_1^{\max}$ for the combined samples for all workers who work job 1 over all periods; let $\tilde{\gamma}_2$ be the highest integer value that satisfies $h_2^{\max} < \tilde{\gamma}_2 \leq 1 + h_2^{\max}$ for the combined samples for all workers who work job 2 over all periods; and let $\tilde{\gamma}_3$ be the lowest integer value that satisfies $y^{r-\min} - 1 \leq \tilde{\gamma}_3 < y^{r-\min}$ for the combined samples for all workers over all periods, where $h_m^{\max}$ is the maximum observed hours of work for job m and $y^{r-\min} = \min\{y_{it}^r\}$ is the lowest observed inflation corrected

[3]Because the marginal tax rates on earnings and nonlabour income are endogenous, we include only the before-tax nonlabour income and real hourly earnings on the main job.

after-tax weekly income. The value of real, net after-tax income y^r_{it} is obtained as

(unconstrained dual job holders)

$$y^r_{it} = \sum_{m=1}^{2} W^r_{mit} h_{mit} + I^r_{it} - D_{1it}\left[\tau_{w1it}\left(\sum_{m=1}^{2} W^r_{mit} h_{mit} - A^r_{it}\right) + \tau_{I1it} I^r_{it}\right]$$

$$- D_{2it}\left[\tau_{w1it} y^r_{u1_{it}} + \tau_{w2it}\left(\sum_{m=1}^{2} W^r_{mit} h_{mit} - A^r_{it} - y^r_{u1_{it}}\right) + \tau_{I2it} I^r_{it}\right]$$

$$- D_{3it}\left[\tau_{w1it} y^r_{u1_{it}} + \tau_{w2it} y^r_{u2_{it}} + \tau_{w3it}\left(\sum_{m=1}^{2} W^r_{mit} h_{mit} - A^r_{it} - y^r_{u2_{it}}\right) + \tau_{I3it} I^r_{it}\right] + T^r_{cit}$$

(unconstrained unitary job holders)

$$= W^r_{1it} h_{1it} + I^r_{it} - D_{1it}\left[\tau_{w1it}\left(W^r_{1it} h_{1it} - A^r_{it}\right) + \tau_{I1it} I^r_{it}\right]$$

$$- D_{2it}\left[\tau_{w1it} y^r_{u1_{it}} + \tau_{w2it}\left(W^r_{1it} h_{1it} - A^r_{it} - y^r_{u1_{it}}\right) + \tau_{I2it} I^r_{it}\right]$$

$$- D_{3it}\left[\tau_{w1it} y^r_{u1_{it}} + \tau_{w2it} y^r_{u2_{it}} + \tau_{w3it}\left(W^r_{1it} h_{1it} - A^r_{it} - y^r_{u2_{it}}\right) + \tau_{I3it} I^r_{it}\right] + T^r_{cit}$$

(constrained dual job holders)

$$= W^r_{1it} \dot{h}_{1it} + W^r_{2it} h_{2it} + I^r_{it} - D_{1it}\left[\tau_{w1it}\left(W^r_{1it} \dot{h}_{1it} + W^r_{2it} h_{2it} - A^r_{it}\right) + \tau_{I1it} I^r_{it}\right]$$

$$- D_{2it}\left[\tau_{w1it} y^r_{u1_{it}} + \tau_{w2it}\left(W^r_{1it} \dot{h}_{1it} + W^r_{2it} h_{2it} - A^r_{it} - y^r_{u1_{it}}\right) + \tau_{I2it} I^r_{it}\right]$$

$$- D_{3it}\left[\tau_{w1it} y^r_{u1_{it}} + \tau_{w2it} y^r_{u2_{it}} + \tau_{w3it}\left(W^r_{1it} \dot{h}_{1it} + W^r_{2it} h_{2it} - A^r_{it} - y^r_{u2_{it}}\right) + \tau_{I3it} I^r_{it}\right] + T^r_{cit}.$$

The empirical weekly earnings labour supply functions are specified below.[4] Each labour supply function contains a single endogenous variable Q_{kit} that is a function of the endogenous tax bands and is defined below for each labour supply regime. We adopt the estimation strategy given in Semykina and Wooldridge (2010) to obtaining the fitted values $\tilde{Q}_{kit}$ from pooled first-stage estimates for each labour supply regime subsample. The empirical labour supply equations described below are jointly estimated by pooled, non-linear Seemingly Unrelated Regressions with cross-equation restrictions on the parameters α_1 and α_2.

[4]For the sample mean values used to correct for unobserved heterogeneity in the labour supply equations, we average only over the time-series for which the individual was in the particular labour supply regime.

Unconstrained dual job holders

$$(1-\tau_{wit})W^r_{1it}\,(h_{1it}-\tilde{\gamma}_1)=\alpha_1\tilde{Q}_{1it}+\theta_{11}\hat{\lambda}_{1it}+\bar{Z}_{1i}\pi_{11}+\ u^*_{11it} \tag{6}$$

$$(1-\tau_{wit})W^r_{2it}\,(h_{2it}-\tilde{\gamma}_2)=\alpha_2\tilde{Q}_{1it}+\theta_{21}\hat{\lambda}_{1it}+\bar{Z}_{1i}\pi_{21}+\ u^*_{21it}, \tag{7}$$

where $Q_{1it}=\Bigg\{\gamma_3-\Bigg[D_{2it}\,(\tau_{w2it}-\tau_{w1it})-D_{3it}\tau_{w3it}\Bigg]y^r_{u1_{it}}-D_{3it}(\tau_{w3it}-\tau_{w2it})y^r_{u2_{it}}$
$-\,(1-\tau_{Iit})I^r_{it}-\tau_{wit}A^r_{it}-(1-\tau_{wit})(\gamma_1W^r_{1it}+\gamma_2W^r_{2it})-T^r_{cit}\Bigg\}$,
$\bar{Z}_{1i}=\Big(1,\overline{W}^r_{1i},\overline{W}^r_{2i},\overline{I}^r_i,\overline{\mathrm{Age}}_i,\overline{\mathrm{Educ}}_i,\overline{\mathrm{MS}}_i,\overline{\mathrm{DP}}_i\Big)$, π_{11},π_{21} are the corresponding parameter vectors, and u_{11it},u_{21it} are error terms. The instruments used to generate the fitted values $\tilde{Q}_{1it}$ are $W^r_{1it},W^r_{2it},I^r_{it},\mathrm{Educ}_{it},\mathrm{MS}_{it},\mathrm{DP}_{it}$, $\hat{\lambda}_{1it}$, and $\bar{Z}_{1i}$.

Unconstrained unitary job holders

$$(1-\tau_{wit})W^r_{1it}\,(h_{1it}-\tilde{\gamma}_1)=\left(\frac{\alpha_1}{1-\alpha_2}\right)\tilde{Q}_{2it}+\theta_{12}\hat{\lambda}_{2it}+\bar{Z}_{12i}\pi_{12}+\ u^*_{12it} \tag{8}$$

where $Q_{2it}=\Bigg\{\gamma_3-\Bigg[D_{2it}\,(\tau_{w2it}-\tau_{w1it})-D_{3it}\tau_{w3it}\Bigg]y^r_{u1_{it}}-D_{3it}(\tau_{w3it}-\tau_{w2it})y^r_{u2_{it}}$
$-(1-\tau_{Iit})I^r_{it}-\tau_{wit}A^r_{it}-\gamma_1(1-\tau_{wit})W^r_{1it}-T^r_{cit}\Bigg\}$, $\bar{Z}_{12i}=\overline{\omega}_i=\Big(1,\overline{W}^r_{1i},\overline{I}^r_i,\overline{\mathrm{Age}}_i,\overline{\mathrm{Educ}}_i,\overline{\mathrm{MS}}_i,\overline{\mathrm{DP}}_i\Big)$,
π_{12} is the corresponding parameter vector, and u_{12it} is the error term. The instruments used to generate the fitted values of $\tilde{Q}_{2it}$ are $W^r_{1it},I^r_{it},\mathrm{Educ}_{it},\mathrm{MS}_{it},\mathrm{DP}_{it}$, $\hat{\lambda}_{2it}$, and $\bar{Z}_{12i}$.

Constrained dual job holders

Constrained dual job holders desiring either fewer or more hours:

$$(1-\tau_{wit})W^r_{2it}\,(h_{2it}-\tilde{\gamma}_2)=\left(\frac{\alpha_2}{1-\alpha_1}\right)\tilde{Q}_{23it}+\theta_{23}\hat{\lambda}_{23it}+\bar{Z}_{3i}\pi_{23}+u^*_{23it}\ \text{(overemployed)} \tag{9}$$

$$(1-\tau_{wit})W^r_{2it}\,(h_{2it}-\tilde{\gamma}_2)=\left(\frac{\alpha_2}{1-\alpha_1}\right)\tilde{Q}_{24it}+\theta_{24}\hat{\lambda}_{24it}+\bar{Z}_{3i}\pi_{24}+u^*_{24it}\ \text{(underemployed)}, \tag{10}$$

where $Q_{23it}, Q_{24it} = \Bigg\{ \gamma_3 - \Bigg[D_{2it} \left(\tau_{w2it} - \tau_{w1it}\right) - D_{3it}\tau_{w3it} \Bigg] y^r_{u1_{it}} - D_{3it}(\tau_{w3it} - \tau_{w2it}) y^r_{u2_{it}}$ $- (1 - \tau_{Iit}) I^r_{it} - \tau_{wit} A^r_{it} - (1 - \tau_{wit}) \left(W_{1it}\dot{h}_{1it} + \gamma_2 W_{2it} \right) - T^r_{cit} \Bigg\}$, $\dot{h}_{1it}$ is the constrained hours on job 1, $\bar{Z}_{3i} = \left(1, \overline{W}^r_{2i}, \overline{W}^r_{1i}\dot{h}_{1i}, \overline{I}^r_i, \overline{\text{Age}}_i, \overline{\text{Educ}}_i, \overline{\text{MS}}_i, \overline{\text{DP}}_i\right)$, π_{23}, π_{24} are the corresponding parameter vectors, and u_{23it}, u_{24it} are error terms. The instruments used to generate the fitted values of $\tilde{Q}_{23it}$ for the overemployed are $W^r_{1it}, W^r_{2it}, I^r_{it}, \text{Educ}_{it}, \text{MS}_{it}, \text{DP}_{it}$, $\hat{\lambda}_{23it}$, and $\bar{Z}_{3i}$. For the underemployed the instruments used to generate the fitted values of $\tilde{Q}_{24it}$ are $W^r_{1it}, W^r_{2it}, I^r_{it}, \text{Educ}_{it}, \text{MS}_{it}, \text{DP}_{it}$, $\hat{\lambda}_{24it}$, and $\bar{Z}_{3i}$.

6 Counterfactual Income Tax Policy

In order to fully estimate the effects of counterfactual increases in the marginal tax rates on labour earnings in the context of dual job holding with and without hours constraints on the main job (job 1), it essential that one take account of a myriad of feedback effects. These include the policy labour supply effects on earnings which in turn impact taxable income. Taxable income affects one's tax band as well as tax credits and child tax credits/benefits, etc. Unfortunately, these relationships are highly nonlinear so consequently there are no simple closed (reduced) form solutions for the outcome variables.

We capture the feedback loop effects of counterfactual changes in the income tax structure on labour supply by using simulation methodology based on the Gauss-Seidel algorithm for numerically solving a large set of nonlinear equations. This approach is applied to each of the labour supply regimes and can be used to simulate over any year or historical period. The equation residuals ($\hat{u}$) are added to the equations with the tax policy change so that the final tax effects can be calculated as the difference between the policy (counterfactual) solution values of the labour supply variables and the control solution (actual historical) values of these variables. As in the case of conventional two-stage least squares, these residuals are calculated using the original values of the endogenous variables Q_{kit} rather than the fitted values $\tilde{Q}_{kit}$ used in the estimation.

We impose a menu of exogenous changes in the marginal tax rate schedule for labour income:

$$\begin{aligned}(1+\delta)\tau_{wit} =&(1+\delta)\left(\tau_{w_{1it}}D_{1it}+\tau_{w_{2it}}D_{2it}+\tau_{w_{3it}}D_{3it}\right)\\ =&\tau^p_{w_{1it}}D^p_{1it}+\tau^p_{w_{2it}}D^p_{2it}+\tau^p_{w_{3it}}D^p_{3it}\\ =&1(0<Y^p_{tax_{it}}\leq Y_{U1})\tau^p_{w_{1it}}+1(Y_{U1}<Y^p_{tax_{it}}\leq Y_{U2})\tau^p_{w_{2it}}+1(Y_{U2}<Y^p_{tax_{it}})\tau^p_{w_{3it}},\end{aligned}$$

where $\delta = 0.10, 0.15, 0.20$, $\tau^p_{w_{jit}} = (1+\delta)\tau_{w_{jit}}$ for $j = 1, 2, 3$, and $Y^p_{tax_{it}}$ is marginal tax policy induced taxable income.

The simulation convergence criteria are given by $\left|\dfrac{\Delta X^{(n)}_{it}}{X^{(n-1)}_{it}}\right| < 0.0005$, where X_{it} is an endogenous variable of interest, $\Delta X^{(n)}_{it} = X^{(n)}_{it} - X^{(n-1)}_{it}$, and $X^{(n)}_{it}$ is the value of X_{it} at the nth iteration. At convergence $X^p = X^{(n)} \approx X^{(n-1)}$ is the value of X_{it} under the new tax regime.

Tax effects are calculated for the endogenous variables within each labour supply regime:

(unconstrained dual job holders) $h_{1it}, h_{2it}, Y_{tax_{it}}, \tau_{wit}$, and y^r_{it};

(unconstrained unitary job holders) $h_{1it}, Y_{tax_{it}}, \tau_{wit}$, and y^r_{it}; and

(constrained dual job holders) $h_{2it}, Y_{tax_{it}}, \tau_{wit}$, and y^r_{it}.

Our simulation methodology identifies cases in which an individual moves into a different income tax band in response to exogenous changes in the marginal tax rate parameters.[5]

7 Empirical Results

The estimated parameter values for the basic labour supply model and the selection IMR's are reported in Table 2. The boundary parameters are obtained from the closest integer values associated with the sample highest (lowest) observed values of weekly hours worked

[5]Details on the tax simulations are documented in a technical appendix available upon request of the authors.

on each job (real, after-tax weekly income). The highest weekly hours beyond which utility is not defined are 81 hours for job 1 and 26 hours for job 2, a maximum of 107 hours per week. The lowest real, after-tax weekly income below which utility is not defined is £50. The estimated α parameters from the utility function have the theoretically expected positive signs and are statistically significant.

All of the estimated selection term parameters were positive and statistically significant. The parameters were relatively large in magnitude for unconstrained unitary job holders (171.878) and overemployed dual job holders (250.088). This pattern would suggest that unobserved factors among unconstrained unitary job holders and overemployed dual job holders are associated with higher expected labour supply as measured by weekly earnings. When looking at the descriptive statistics in Table 1, part of this pattern might be explained by 1) higher average wage rates on job 1 for unconstrained unitary job holders (£11.58) compared with the average wage rates on job 1 among unconstrained dual job holders (£10.36), and 2) higher average wage rates on job 2 for overemployed dual job holders (£18.15) compared with the average wage rates on job 2 among unconstrained dual job holders (£14.54). However, the differences in comparable wage rates are proportionally far less than the proportionate differences in the corresponding estimated selection parameters. This suggests that the unobservables are associated with stronger preferences for labour supply.

Table 3 reports the simulation results from counterfactual increases in the marginal tax rates on earnings. The first panel provides the baseline historical means of the outcome variables. On average the marginal tax rates were 26% for unconstrained workers (unitary and dual job holders), 24% for underemployed dual job holders, and 28% for overemployed dual job holders. These realised marginal tax rates are consistent with the corresponding average annual taxable incomes.

The remaining panels in Table 3 report the simulated values of the outcome variables arising from counterfactual percent increases (10%, 15%, 20%) in the marginal tax rates. The realised marginal tax rates would also rise with the counterfactual increases in the statutory marginal tax rates. Increases in the marginal tax rates would reduce the weekly hours on job 1 for unconstrained workers and increase weekly hours on job 2 for dual job holders. In the case of unconstrained dual job holders, total weekly hours are reduced by increases in the marginal tax rates because the increases in weekly hours on job 2 are less than the reductions in weekly hours on job 1.

For dual job holders, changes in annual taxable income and weekly net income induced by increased marginal tax rates are not always monotonic with respect to the baseline historical values. Among unconstrained dual job holders, a 10% increase in the marginal tax rates would increase annual taxable income but a 15% or 20% increase in the marginal tax rates would reduce annual taxable income relative to the historical values. Weekly net income on the other hand would monotonically decline with increases in the marginal tax rates. Among underemployed dual job holders, annual taxable income would be higher than the historical baseline for every counterfactual increase in the marginal tax rates. On the other hand, weekly net income would exceed the historical value for 10% and 15% increases in the marginal tax rates but would be less than the historical value for a 20% increase. In the case of overemployed workers, annual taxable income would be higher than the historical value for all 3 counterfactual increases in the marginal tax rates. However, weekly net income is higher than the historical value only in the case of a 10% increase in the marginal tax rates. For marginal tax rate increases of 15% and 20%, weekly net income is about the same and significantly lower, respectively.

The non-monotonicities we observe stem from changes in the composition of the sample within constrained labour supply regimes. Changes in the marginal tax rates can lead to changes in labour force participation and to changes in labour supply regimes. When simulated values of weekly hours are less than 1 hour, we infer that the worker would drop out of the labour force. It is only possible to make this inference for unconstrained workers since hours supplied to job 1 are exogenous in the model for constrained job holders. While some of these workers could drop out of the labour force, we can only observe if their simulated weekly hours on job 2 are less than 1 hour. In this case we assume that they transition to unitary job holding at their previous constrained hours.

The simulation results show that increasing the marginal tax rates would lead to labour force withdrawals and transitions from dual job holding to unitary job holding for every tax rate increase we consider. For example a 10% increase in marginal tax rates would yield 1,859 (7.1%) labour force withdrawals among unconstrained unitary job holders and 170 (9.8%) withdrawals among unconstrained dual job holders. In addition there would be 559 (32.2%) unconstrained dual job holders transitioning to unitary job holding, 114 (42.5%) instances of underemployed individuals transitioning to unitary job holding, and 435 (48.1%) instances of overemployed individuals transitioning to unitary job holding. These figures represent the totals and percentages observed across all individuals over all time periods. Thus, in principle it is possible that some individuals could leave and return to the labour force multiple times as well as transitioning back and forth between dual job holding and unitary job holding. With larger counterfactual increases in the marginal tax rates, the number and percentages of labour force withdrawals increase among hours unconstrained workers. A 20% increase in marginal tax rates would yield a labour force drop out rate (across workers and years) of 11.8% and 14.1% for unconstrained unitary and dual job holders, respectively. Transition rates to unitary job holding among dual job holders are fairly high and increasing in the marginal tax rates. These effects are the largest for overemployed dual job holders, reaching 50.1% with a 20% increase in marginal tax rates.

Although our primary focus is on the tax policy simulated values of weekly hours relative to the historical baseline, it is also interesting to examine how the simulated changes in labour supply compare across the 3 counterfactual marginal tax rates we consider. In the case of unconstrained job holders, the reduction in weekly labour supply to job 1 steadily diminishes with increased marginal tax rates. For dual job holders, the increase in labour supply to job 2 steadily diminishes with increases in the marginal tax rates. Thus, the overall labour supply effects of increased marginal tax rates are diminishing with successively higher marginal tax rates.

A further advantage of the simulation methodology is that it permits calculation of elasticities of labour supply with respect to exogenous changes in marginal tax rates (τ), i.e.

$$\eta^p_{h_j\tau} = \left(\frac{\bar{h}^p_j - \quad \bar{h}_j}{\bar{h}_j} \right) \left(\frac{1}{\delta} \right), j = 1, 2.$$

These elasticities calculated from the simulation results in Table 3 are reported in Table 4. The labour supply elasticities on job 1 for unconstrained unitary and dual job holders are negative, relatively inelastic, and decreasing in magnitude with larger percentage increases in marginal tax rates. On the other hand, the labour supply elasticities on job 2 for dual job holders are positive, relatively elastic, and decreasing with larger percentage increases in marginal tax rates. The job 2 labour supply elasticities are the largest for overemployed workers. While the hours constraint on job 1 is treated as exogenous, the only change in job 1 hours possible for constrained dual job holders is to quit job 1 entirely which makes job 2 become the unitary job. This could account for some of the tax rate induced increases in job 2 labour supply among dual job holders. Among unconstrained dual job holders, total labour supply elasticity is relatively inelastic and is largely invariant with respect to the magnitudes of the percentage increases in marginal tax rates. This is a reflection of the partial substitution of job 2 hours for job 1 hours seen in Table 3.

8 Summary and Conclusions

While the textbook model of labour supply assumes that individuals hold only one job, the empirical evidence clearly shows that individuals occasionally hold multiple jobs simultaneously. Within the framework of a unitary job worker, the impact of income taxation on labour supply is well understood. Still, two open questions have not being completely addressed by the previous literature: (1) if labour supply is limited only to the hours worked on the main job, what is the tax responsiveness on the second job? (2) How does the presence of hour constraints affect the estimation of such responsiveness? To address both issues, we build upon existing models of multiple job holding which account for hour constraints to estimate a model based on the UK tax system (Choe et al., 2018).

Because of a piecewise budget constraint generated by a tiered tax system, workers whose hours-wage combinations in the neighborhood of a kink can move to their optimal income tax bracket by adjusting their intensity to work. Under this scenario, the tax rate itself becomes endogenous. Also, the possibility of moving to a different labour supply regime following a change in the tax schedule implies that the impact of a discrete change in the income tax rate cannot be approximated by a simple coefficient from labour supply function estimates. Hence we use the Gauss-Siedel algorithm to simulate the impact of a change in the taxation regime on the labour efforts of male workers in the UK.

We find that a more aggressive tax system would reduce the individual's work attachment, with some dual job holders dropping the second job and some unitary and dual job holders dropping out of the labour market altogether. However, while we observe a reduction in weekly labour supply following an increase in the tax rate, weekly labour supply to the second job actually increases for the same change in the tax rate. Since, on average, the sum of the simulated hours worked on all jobs decreases from the baseline historical value, we conclude that raising income tax rates in the UK would reduce overall work effort (both at the intensive and extensive margins) and lead dual job holders to shift some working time from job 1 to job 2.

References

Aaberge, R., Colombino, U., and Strom, S. (1999). Labour Supply in Italy: An Empirical Analysis of Joint Household Decisions, with Taxes and Quantity Constraints. *Journal of Applied Econometrics*, 14(4):403–422.

Bourguignon, F. and Magnac, T. (1990). Labor Supply and Taxation in France. *Journal of Human Resources*, 25(3):358–389.

Choe, C. and Oaxaca, R. L. (2016). Wage Decompositions using Panel Data Sample Selection Correction. *Korean Economic Review*, 32(2):201–218.

Choe, C., Oaxaca, R. L., and Renna, F. (2018). Constrained vs unconstrained labor supply: the economics of dual job holding. *Journal of Population Economics*, 31(4):1279–1319.

Dustmann, C. and Rochina-Barrachina, M. (2007). Selection correction in panel data models: An application to the estimation of females' wage equations. *The Econometrics Journal*, 10(2):263–293.

Ham, J. C. (1982). Estimation of a Labour Supply Model with Censoring Due to Unemployment and Underemployment. *Review of Economic Studies*, 49(3):335–354.

Hausman, J. and Ruud, P. (1984). Family Labor Supply with Taxes. *American Economic Review*, 74(2):242–248.

Hausman, J. A. (1985). Taxes and labor supply. In Auerbach, A. J. and Feldstein, M., editors, *Handbook of Public Economics*, volume 1 of *Handbook of Public Economics*, pages 213–263. Elsevier.

Hunt, J. C., Hill, C. R., and Kiker, B. F. (1985). The effect of taxation on labor supply - the case of moonlighting. *Applied Economics*, 17(5):897–905.

Lee, L.-F. (1983). Generalized econometric models with selectivity. *Econometrica*, 51(2):507–12.

MaCurdy, T., Green, D., and Paarsch, H. (1990). Assessing Empirical Approaches for Analyzing Taxes and Labor Supply. *Journal of Human Resources*, 25(3):415–490.

Meghir, C. and Phillips, D. (2008). Labour Supply and Taxes. IZA Discussion Papers 3405, Institute of Labor Economics (IZA).

Moffitt, R. (1990). The Econometrics of Kinked Budget Constraints. *Journal of Economic Perspectives*, 4(2):119–139.

O'Connell, J. F. (1979). Multiple job holding and marginal tax rates. *National Tax Journal*, 32(1):73–76.

O'Leary, C. J. (1991). Estimating labour supply functions under the rationing constraints of over-and under-employment. *Applied Economics*, 23(4):675–684.

Rosen, S. (1976). A Theory of Life Earnings. *Journal of Political Economy*, 84(4):45–67.

Semykina, A. and Wooldridge, J. M. (2010). Estimating panel data models in the presence of endogeneity and selection. *Journal of Econometrics*, 157(2):375–380.

Tazhitdinova, A. (2017). Increasing Hours Worked: Moonlighting Responses to a Large Tax Reform. SSRN Discussion Papers 3405, SSRN.

Wooldridge, J. (1995). Selection corrections for panel data models under conditional mean independence assumptions. *Journal of Econometrics*, 68(1):115–132.

Wooldridge, J. (2010). *Econometric Analysis of Cross Section and Panel Data*. The MIT Press.

Table 1: Summary Statistics: Mean (SD)

Variable	Unitary job holders: Unconstrained		Unitary job holders: Underemployed		Unitary job holders: Overemployed		Dual job holders: Unconstrained		Dual job holders: Underemployed		Dual job holders: Overemployed	
Weekly hours worked on job 1	43.05	(8.20)	40.41	(9.56)	47.30	(9.23)	41.95	(8.88)	38.87	(10.53)	45.30	(8.88)
Weekly hours worked on job 2	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)	7.04	(6.01)	6.95	(5.71)	6.74	(5.65)
Weekly non-labour income	68.21	(111.63)	69.81	(103.41)	67.08	(126.96)	71.64	(108.22)	69.32	(90.82)	64.59	(103.38)
Weekly earnings on job 1	494.53	(278.40)	379.35	(223.28)	575.73	(341.04)	430.85	(243.17)	318.91	(167.51)	510.14	(347.36)
Wage rate on job 1	11.58	(6.27)	9.38	(5.23)	12.32	(6.89)	10.36	(5.61)	8.16	(3.74)	11.38	(6.68)
Weekly earnings on job 2	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)	75.82	(87.96)	68.21	(89.50)	91.35	(112.91)
Wage rate on job 2	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)	14.54	(15.12)	12.06	(13.20)	18.15	(18.10)
Age	37.90	(11.92)	33.11	(11.33)	40.75	(10.90)	36.34	(11.47)	31.57	(10.66)	38.44	(10.30)
Educational attainment												
Higher degree (omitted)	0.04	(0.19)	0.02	(0.14)	0.04	(0.19)	0.04	(0.21)	0.01	(0.11)	0.06	(0.23)
1st degree	0.13	(0.34)	0.10	(0.30)	0.15	(0.35)	0.12	(0.33)	0.10	(0.30)	0.16	(0.36)
HND, HNC, teaching	0.09	(0.28)	0.07	(0.26)	0.10	(0.30)	0.08	(0.27)	0.05	(0.22)	0.09	(0.28)
A level	0.24	(0.43)	0.26	(0.44)	0.23	(0.42)	0.23	(0.42)	0.35	(0.48)	0.23	(0.42)
O level	0.26	(0.44)	0.28	(0.45)	0.25	(0.43)	0.30	(0.46)	0.32	(0.47)	0.27	(0.44)
CSE	0.07	(0.25)	0.08	(0.28)	0.06	(0.23)	0.08	(0.27)	0.06	(0.24)	0.06	(0.24)
None of these	0.17	(0.38)	0.18	(0.39)	0.19	(0.39)	0.14	(0.35)	0.10	(0.31)	0.14	(0.35)
Married (=1)	0.71	(0.45)	0.60	(0.49)	0.80	(0.40)	0.68	(0.47)	0.56	(0.50)	0.77	(0.42)
Number of children	0.67	(0.98)	0.72	(1.04)	0.70	(0.99)	0.74	(1.02)	0.66	(0.92)	0.84	(1.06)
Tax allowance	102.70	(12.03)	102.01	(12.95)	102.59	(12.27)	101.00	(11.50)	100.31	(12.74)	101.87	(12.43)
Tax credit	25.85	(20.13)	28.71	(24.46)	25.40	(18.09)	26.17	(18.28)	27.15	(20.19)	26.60	(16.90)
Number of individuals	4683		726		2353		381		89		173	
Number of observations	25784		2677		15558		1736		268		905	

Notes: Based on British Household Panel Survey (1991-2008). All income variables are gross figures with prices in 2008.

Table 2: Weekly Labor Supply Model Estimates

	Boundary Parameters	
$\widehat{\gamma}_1$	81	
$\widehat{\gamma}_2$	26	
$\widehat{\gamma}_3$	50	
	Weekly Earnings Labor Supply Parameters	
$\widehat{\alpha}_1$	0.073$*$	
	(0.000)	
$\widehat{\alpha}_2$	0.128$*$	
	(0.001)	
$\widehat{\theta}_{11}$	53.563$*$	
	(2.585)	
$\widehat{\theta}_{21}$	56.020$*$	
	(3.759)	
$\widehat{\theta}_{12}$	171.878$*$	
	(4.794)	
$\widehat{\theta}_{23}$	250.088$*$	
	(3.321)	
$\widehat{\theta}_{24}$	2.390†	
	(1.293)	
Log likelihood	-1.1e+06	
N	46928	

Notes: Pooled data from BHPS 1991-2008; All income variables are expressed in 2008 prices; Estimated standard errors in parentheses are bootstrap estimates from 200 replications that account for all estimation steps, including the estimation of multinomial logit regression and boundary parameters.; $*$ and † indicate significance at 1, and 5 percent levels respectively; Time averaged explanatory variables are included - complete results available from authors.

Table 3: Tax Simulation Results

	Unitary job holders	Dual job holders		
	Unconstrained	**Unconstrained**	**Underemployed**	**Overemployed**
Baseline Historical Values				
Weekly hours worked on job 1	43.05	41.95		
Weekly hours worked on job 2		7.04	6.95	6.74
Annual taxable income	24213.76	25094.86	18834.34	29657.05
Marginal tax rate	0.26	0.26	0.24	0.28
Weekly net income	448.95	459.69	371.52	518.45
$\delta = 10\%$				
Weekly hours worked on job 1	40.70	38.19		
Weekly hours worked on job 2		9.84	9.10	9.91
Annual taxable income	23101.20	25318.03	19996.47	31409.96
Marginal tax rate	0.28	0.28	0.27	0.31
Weekly net income	416.51	458.78	379.37	526.74
Transitioning to OLF	1859 (7.1%)	170 (9.8%)		
Transitioning to unitary job		559 (32.2%)	114 (42.5%)	435 (48.1%)
$\delta = 15\%$				
Weekly hours worked on job 1	40.07	37.64		
Weekly hours worked on job 2		9.81	8.91	9.77
Annual taxable income	22719.89	25009.13	19872.18	31241.85
Marginal tax rate	0.29	0.29	0.28	0.33
Weekly net income	405.96	447.93	373.85	517.72
Transitioning to OLF	2327 (9.0%)	202 (11.6%)		
Transitioning to unitary job		552 (31.8%)	117 (43.7%)	443 (49.0%)
$\delta = 20\%$				
Weekly hours worked on job 1	39.43	37.14		
Weekly hours worked on job 2		9.77	8.74	9.61
Annual taxable income	22324.81	24659.46	19773.40	31063.89
Marginal tax rate	0.30	0.30	0.29	0.34
Weekly net income	395.21	438.04	368.79	508.55
Transitioning to OLF	3036 (11.8%)	259 (14.1%)		
Transitioning to unitary job		518 (29.8%)	119 (44.4%)	453 (50.1%)
N of observations	25784	1736	268	905

Notes: Based on British Household Panel Survey (1991-2008). All income variables are gross figures with prices in 2008.

Table 4: Labor Supply Tax Elasticities

	Unitary job holders	**Dual job holders**		
	Unconstrained	**Unconstrained**	**Underemployed**	**Overemployed**
		$100 \times \delta = 10\%$		
Job 1	-0.55	-0.90		
Job 2		3.98	3.09	4.70
Job 1 + Job 2		-0.20		
		$100 \times \delta = 15\%$		
Job 1	-0.46	-0.68		
Job 2		2.62	1.88	3.00
Job 1 + Job 2		-0.21		
		$100 \times \delta = 20\%$		
Job 1	-0.42	-0.57		
Job 2		1.94	1.29	2.13
Job 1 + Job 2		-0.21		
N of observations	25784	1736	268	905

Notes: Based on British Household Panel Survey (1991-2008). All income variables are gross figures with prices in 2008.