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The incidence of income tax on wages and labour supply

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Abstract

In the simple framework of a static model for equilibrium wages and labour supplies, we show that the incidence of income tax on equilibrium wages can be measured independently from the individual labour supply elasticity. This extends recent work by [Journal of Labour Economics, 15(3) (1997) S72–S101] and [Journal of Public Economics, 65 (1997) 119–145], who estimate tax incidence on earnings, and [Econometrica, 66(4) (1998) 827–861] and [NBER Working Paper 5023 (1995)], who estimate labour supply elasticities. Our measurements are based on a large multi-level longitudinal data set of Danish private sector establishments and workers. We show that, allowing for labour supply response, there is strong evidence for partial shifting of the burden of income tax from worker to employer. Higher marginal tax rates are associated with increases in gross wages and earnings.

JEL classification: H22; J22; J31; C33

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1. Introduction

Tax reforms have several simultaneous effects. In principle both market prices and individual behaviour are affected. However, most empirical research focuses

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exclusively on the determinants of individual responses and ignores price effects. The maintained hypothesis is that taxes are fully incident on those who are formally liable to pay them and that market prices are left unchanged by tax reforms. This is an important and understated caveat to the measurements provided by recent empirical studies which use tax reforms as a source of quasi-experimental variation in order to identify and estimate 'structural' parameters.

In this paper we propose a simple model of the determination of equilibrium wages and labour supply in the presence of income tax. The parameters of the model are measured using a Danish matched establishment-worker panel of individual workers. We show that it is possible to identify the incidence of income taxes on gross wages and the elasticity of labour supply with respect to the net wage rate. Hence, we are able to extend recent studies of work incentives to allow taxes on employees (or employers) to be incident on employers (or employees), as well as allowing workers to respond to changes in the relevant equilibrium wage. Thus we do not impose an important maintained hypothesis of much other empirical work.

There is little consensus on the responsiveness of gross wages and employment to changes in labour taxation.[1] The magnitude of these elasticities depends upon three related factors: first the nature of the tax wedge driven between the real consumption wage and the real product wage, i.e., how taxes are raised;[2] second, the degree of labour market competition (reflected in the institutional structure of wage setting) and the degree of product market competition; and third, the perceived links between labour taxes and future benefits, for example through pensions, sickness and unemployment transfers.

The theoretical labour tax incidence literature has produced a variety of results according to different wage setting assumptions.[3] For example, Pissarides (1998) compares four equilibrium models of unemployment and wage determination: competitive, union-firm bargaining over wages, search with employee-firm bargaining over wages, and shirking-efficiency wages. Simulations of the theoretical models show that increased progressivity moderates wage demands and reduces unemployment in both bargaining frameworks, whereas progressivity is irrelevant in competitive and shirking-efficiency wage models.

Some papers, although primarily theoretical, turn to data in order to illustrate their arguments. Holmlund and Kolm (1995) provide Swedish evidence suggesting

[1] For a recent survey see Liebfritz et al. (1997).

[2] Nickell and Layard (1998) suggest two cases in which the type of taxation may matter for incidence. Firstly, moving from tax on income (earned and unearned) to payroll taxes on earnings only reduces the tax rate on non-labour income, which may reduce labour supply. Secondly, in the presence of minimum wages, a switch from income to payroll tax reduces the demand for minimum wage earner services because the wage cannot adjust downwards.

[3] See for example Malcomson and Sartor (1987); Jackman and Layard (1990); Lockwood and Manning (1993); Mortensen and Pissarides (1994); and Holmlund and Kolm (1995).

tax progressivity contributes to wage moderation. A number of studies have used Danish data to examine the link between tax progressivity and wage setting. Lockwood et al. (1995) and Hansen et al. (1995) obtain mixed results from a time series study on aggregate data, respectively, at the level of (5) income groups and (2) occupation groups. Pedersen et al. (1998) find similarly mixed results from longitudinal individual data grouped according to union affiliation. Effects are positive, negative or insignificant according to the way in which the data is cut or grouped. Furthermore, in their survey of a large number of aggregate time series studies of tax shifting into wages, Liebfritz et al. (1997) find that empirical evidence on tax shifting varies between countries and studies. No clear pattern emerges on the effect of different types of taxes on wages.

Our work extends and clarifies that of Gruber (1997), who uses Chilean firm-level micro data to analyse a large one-off reduction in payroll tax. Gruber is able to identify incidence on gross earnings as well as on employment by exploiting variation in payroll tax changes between firms. The benefit of the payroll tax cut is found to have been fully shifted to workers through higher earnings, with no significant employment effects. With similar objectives, Anderson and Meyer (1997, 1998) use US firm-level micro data to measure the effects of changes in an experience rated Unemployment Insurance system. Payment variation between firms, due to the number of workers laid off subsequently claiming UI benefits, allows identification of the incidence of the tax on earnings. At the four-digit industry level, Anderson and Meyer find full shifting of the burden of higher payroll tax from employers to workers in the form of lower earnings. They report insignificant employment effects.

We find strong evidence of partial shifting of the burden of income tax from worker to employer. Although income tax is incident on equilibrium wages, the tax burden is not fully shifted. Furthermore, the labour supply elasticity with respect to the wage is small if it is compared with conventional estimates, but it is precisely measured.[4] Measurements of the labour supply response to wages which implicitly assume no shifting of the burden of taxation, comparable to those presented by Eissa (1995), are found to overestimate the incentive effects of income taxation by a factor of two. Moreover, we show that ignoring the potential labour supply response to a tax change, following the methodology of Gruber (1997) or Anderson and Meyer (1998), as well as ignoring the endogeneity of the marginal tax rate, may lead to the erroneous conclusion that the tax is fully incident on equilibrium earnings.

The remainder of the paper is organised as follows. The next section sets up a simple economic model of labour tax incidence. Section 3 describes the data and institutional background of wage setting and the labour taxes in Denmark. Section 4 presents the empirical counterpart to the economic model and details the

[4]See the recent findings in Blundell et al. (1998), Eissa (1995) and Graversen (1996).

identification strategy which enables measurement of incidence. Section 5 presents and discusses the results and Section 6 summarises and concludes.

2. Economic model

For small tax changes which have no effect on individual work participation, the effect of a change in payroll tax or direct tax on individual equilibrium earnings can be decomposed as follows:

$$\varepsilon_{wh|1-\tau} = \varepsilon_{w|1-\tau}(1 + \varepsilon_{h|w}) + \varepsilon_{h|w}, \tag{1}$$

where $\varepsilon_{x|y}$ denotes the elasticity of x with respect to y, for example $\varepsilon_{h|w}$ is the elasticity of labour supply with respect to the gross wage rate. In principle, both $\varepsilon_{w|1-\tau}$, the incidence of taxation on equilibrium gross wages, and $\varepsilon_{h|w}$, the elasticity of labour supply with respect to wages, are of interest to policy makers. For example, in order to calculate the effect on public finances of an increase in the marginal income tax rate. The literature to date has provided many measures of the elasticity of labour supply, $\varepsilon_{h|w}$,[5]; however, little is known about $\varepsilon_{w|1-\tau}$. The purpose of this section is to present a simple model which allows the separate measurement of $\varepsilon_{w|1-\tau}$ and $\varepsilon_{h|w}$.

Our model considers establishments[6] that employ individuals who are endowed with identical characteristics but are taxed differently at the margin. Within establishment differences in the tax treatment of identical individuals is not uncommon. For example, in France, otherwise identical workers may face different tax treatments because of differences in their household compositions. In our particular context, within the same establishments, workers living in different municipalities face different tax rates. Moreover we assume that individuals can only vary their marginal tax rate through a variation of their labour supply. In other words, there exist differences in individual tax treatment such that two identical individuals may exhibit different marginal tax rates uniformly over the hours range and independently of the wage rate. Furthermore, in what follows the maintained hypothesis is that the establishment is unable to discriminate between otherwise identical employees on the basis of their marginal tax rates.

Consider the following per period specification for equilibrium gross earnings within an establishment

$$w_{ipt}.h_{ipt} \equiv w_{ipt}[1 - \tau_{pt}].h_{ipt}[(1 - \tau_{pt}).(1 - \theta_{ipt}).w_{ipt}[1 - \tau_{pt}],z_{ipt}], \tag{2}$$

where i identifies individuals in establishment p at time t. w_{ipt} denotes establish-

[5]See Blundell and MaCurdy (1999) for a recent survey.

[6]In developing the economic model we use the generic term establishment to refer to a business unit.

ment p's values per period equilibrium gross wage, whereas h_{ipt} denotes per period individual labour supply. $w_{ipt}[1-\tau_{pt}]$ summarizes the dependence of establishment p's equilibrium wage at time t on some aggregate measure(s) of the level of taxation at the establishment level, say $1-\tau_{pt}$, (average payroll tax or average of individual marginal income tax rates). For convenience, we assume that $1-\tau_{pt}$ is the within establishment-period geometric mean of $1-\tau_{ipt}$. $h_{ipt}[(1-\tau_{pt})(1-\theta_{ipt})w_{ipt}[1-\tau_{pt}],z_{ipt}]$ describes the dependence of individual equilibrium labour supply on the relevant establishment's equilibrium gross wage, on the marginal individual income tax rate $(1-\tau_{pt})(1-\theta_{ipt})$ and some characteristics, z_{ipt}. $1-\theta_{ipt}$, is defined as the ratio of the individual marginal tax rate to the establishment's geometric average $1-\tau_{pt}$.[7]

A change in the average tax rate faced by the firm, i.e., a change in $1-\tau_{pt}$, affects individual equilibrium earnings exactly according to Eq. (1) above. Given this quantity only, the incidence on gross wages of the tax change and the labour supply response to a variation of the net wage can not be distinguished. However, given the wage rate, the inability to discriminate between otherwise identical workers on the basis of individual net wages implies that, within establishment, labour demand is perfectly elastic. Any within-establishment variation in earnings must arise from a variation in labour supplied. Hence, the within establishment variation in labour supply or gross earnings at any moment in time arises from labour supply responses to within establishment variation in the net wage,[8] i.e., differences between individuals in $1-\theta_{ipt}$. This allows the identification of the labour supply elasticity. Clearly it can be combined with the measure of the total effect of a tax change on individual equilibrium earnings to give $\varepsilon_{w|1-\tau}$.

3. Data description, wages and labour taxes

The dataset we use is drawn from the Statistics Denmark Integrated Labour Market Database (IDA), which comprises the Danish population of individual and establishment administrative tax records together with background characteristics.[9] A random 5% sample of private sector establishments in the size class 5–500

[7]The geometric mean imposes that $\frac{1}{N_{pt}}\Sigma_{i\epsilon pt}\ln(1-\theta_{ipt})=0$, where individual i is employed in establishment p at time t.

[8]This leaves open the question of whether the establishment could propose side payments to its employees in order to equalise their net wage. Nevertheless, provided that the establishment is only interested in total labour input, for small within establishment variations in labour supply and such that the fixed costs per employee are covered, it seems that the establishment should not be concerned about within establishment variation in individual labour supply.

[9]See Leth-Sørensen (1998) for a detailed description of IDA, and works cited therein using different samples drawn from IDA. An establishment is defined as a unique physical address, and it is the effort made by Søren Leth-Sørensen in checking continuity of these establishment identifiers which allows us to exploit the matched longitudinal structure.

primary employees is sampled in 1980.[10] These units are followed until 1991. Any unit disappearing from the sample at time t is replaced by a unit which is born into the size class at t, making the sample representative of small-to-medium sized establishments in any cross-section, while retaining the longitudinal dimension. We are able to identify workers and establishments overtime, and all workers are followed as long as they are employed at a sampled establishment. Labour supply analysis in the next section is all conditional upon working. The sample comprises 76 143 workers in 1388 establishments, each observed in at least 1 year. In total there are 11 402 establishment-year observations, and 244 074 worker-year observations. The average duration in the sample for a worker is 3.2 years, and for an establishment is 8.2 years. The average establishment has 24.4 primary workers. More importantly for the measurement of interest, 30.2% of workers live in a different municipality to the one in which they work.[11] Furthermore, 83.0% of enterprises employ workers from more than one municipality.

The Danish administrative registers, which we have access to, record individual annual earnings and enough information to accurately compute income tax liability, together with some demographic characteristics (age, gender, number of children, occupation, home municipality). Also, the registers contain imperfect information on total annual hours worked for each employee. However, dealing with measurement errors in hours and consequently wages from this source is beyond the scope of this paper.[12] The analysis is based upon annual taxable earnings as individually filed and recorded in the administrative tax register.

3.1. Wage setting

It is important to describe and contrast the wage setting institutions and tax-benefit linkage in any single country study in order to motivate the relevance of evidence from its experience in other contexts. The proportion of the Danish

[10] Attachment of a worker to an establishment is defined as of the last week of November each year. A primary employee is a worker whose main source of labour earnings on that day is due to an attachment with a sampled establishment.

[11] Average travel to work distances are 2 and 9 km conditional on living and working in different municipalities. Income tax registers record commuting distance, which can be approximately priced by the rate of public sector travel allowance. Reducing gross earnings to account for fixed commuting costs in this way has negligible impact on model estimates.

[12] The relevant information for computing hours comprises mandatory pension contributions which are made weekly at three levels according to hours worked in the ranges 10–19, 20–29, 30+. Contributions are recorded in weekly, monthly or quarterly sums depending on the accounting convention of the employer. Hours measurements from this source would be biased down for those with low (below 10) and high (above 40) weekly hours. Hourly wage rates computed from annual earnings divided by mis-measured hours would also be biased as a consequence.

private sector covered by union agreements is below the OECD average.[13] Central negotiations are conducted between industries organised within the Employers Confederation (DA) and affiliates of the Trade Union Congress (LO). These negotiations are staggered over time, cover 2–3-year periods, and increasingly focus on non-wage compensation.[14]

Wages which are covered by these union agreements are set according to two systems. The 'normal wage' system covers 10% of workers and has centrally negotiated wage changes with locally negotiated additions. The remaining 60% are under the 'minimal wage' system, whereby central bargaining sets a wage floor, above which wages are fully determined at the firm or establishment level.[15] Alongside these systems a national minimum wage is agreed below which no wage must fall. However, this constraint has become much less binding over time as the afore-mentioned two systems agree wages increasingly above this floor.[16]

3.2. Labour tax changes

Denmark has an absence of mandated employer provided benefits and no earmarked labour taxation. This is in contrast to most OECD countries which have compulsory social insurance, whereby benefits are financed by payroll taxes. Financing of the Danish system of public pensions, sickness and health transfers is largely through general taxation. However, benefits exclusive to workers that are effectively[17] financed through income tax include unemployment insurance and a publicly funded early retirement programme. These transfers are a proportion of previous earnings, but they are subject to a low ceiling which is binding for 85%

[13]Union density in Denmark (76%) is average for the Nordic countries, but well above that for the OECD as a whole (38%). Coverage (69%) is closer to the OECD average (68%). See Flanagan (1999) for more details. Coverage is 100% in the Danish public sector and 52% in the private sector which we study here.

[14]All non-wage compensation (with the exception of pension contributions) is taxable, but not observed separately from other taxable income in our data. However, we would expect most variation in non-wage compensation to be between establishments, which would in any case be controlled for in our estimation strategy.

[15]Haar et al. (1997) provides a good description, in English, of the key institutional features of, and recent developments in, the Danish labour market.

[16]Anticipating on the description of our data, we calculate only about 3% of our sample falls within 5% of the agreed minimum wage floor at any time. See Albæk and Madsen (1995) for more institutional detail and a macroeconomic analysis of the employment and wage effects of Danish minimum wage changes.

[17]Membership of, and contributions, to an unemployment insurance fund gives entitlement to unemployment and pension transfers. However 75% of benefits are financed through general taxation.

of workers, making them largely flat rate benefits. The lack of benefits in proportion to individual contributions weakens the tax-benefit linkage.[18]

Taxes on labour in Denmark are characterised by the absence of payroll tax and high marginal rates of income tax (1980–91 private sector average 56.0%). Income tax is assessed on an individual basis and is levied by (275) Municipalities, (15) Counties, Central Government and the Church.[19,20] Local (County, Municipality and Church) taxes are proportional to labour income with respective average rates over the 1980–91 sample period of 8.6, 18.2 and 1.0% (1.5, 2.6 and 0.3% standard deviation). Church tax varies at the Municipality level. Central Government taxes are progressive with three bands averaging an additional 17.5, 11.0 and 11.3% (3.9, 4.4, 0.6 standard deviation).[21] Local and national taxes are added together to give the total marginal rate. The marginal tax rate is subject to a ceiling of 68.8%. This is binding for 10.5% of our private sector sample.

The analysis presented in the next section relies on variations in income tax which are exogenous to the individual. For these exogenous variations provided by the tax system to be informative we require them to be correlated with both individual marginal tax rates and individual annual earnings. In this sub-section it is shown that these correlations survive the removal of firm-year and individual-specific effects.

The main changes in income taxes during the 1980s, and the most important for our purposes, are year-to-year changes in local rates. These are the main changes in that they explain more of the variance in individual marginal tax rates than do changes at the national level in income tax rates, personal tax allowances and tax band thresholds.[22] Overall, the marginal basic, intermediate and top tax rates increased (on average) from 41.8, 56.2 and 66.7% to 50.8, 56.8 and 68.8%,

[18]See Summers et al. (1993) on the linkage between labour taxes and worker benefits.

[19]Church membership is declared on individual annual tax returns. 95.0% of our sample are members, and we assume membership to be exogenous for the purposes of the present analysis.

[20]Variation in income tax rates between Municipalities suggests variation in provision of local public goods, which relates to our earlier discussion about the importance of the tax-benefit linkage. The correlation between local annual per capita revenue and expenditure is 0.71, which is below unity mainly due to the complex system of re-distribution of revenues between Municipalities according to population composition and movements. We are unable to measure directly the correlation between local income tax revenues and local good provision. If the relation between local income tax rates and local good provision changed over time between Municipalities, then individuals may choose to locate according to this variation and the validity of local tax rates as instruments would be called into question.

[21]The relative importance of local versus state income taxes in Denmark can be put in an international perspective by contrasting with Norway, Sweden and Switzerland where local taxes are more important, and the US and Japan where they are less so (Messere, 1998).

[22]Tax changes at the national level are composed of several small year-on-year changes and two minor reforms: in 1983 local tax rates increased by 3.0% on average, and the automatic indexation of tax allowances and band thresholds was abolished; in 1987 personal allowances and tax deductions were reduced. See Graversen (1996) for a detailed description and Statistics Denmark (1980–91) for the raw numbers.

respectively. However, year-to-year changes over time in local tax rates show both 15% decreases and 28% increases. Hence we observe upward as well as downward tax variations. This contrasts with the analysis of Gruber (1997) where only a one-off reduction in payroll tax is observed, and Eissa (1995) where different income tax reductions are compared.

In Denmark workers pay income tax according to where they live rather than where they work. For workers who are employed at the same establishment, our empirical methodology exploits these differential variations in taxes between home municipalities and over time. The simplest example is of two groups of workers employed at one establishment, where one group is affected by a tax change and another is not. This variation is similar to the Eissa (1995) and Feldstein (1995) setting of a single tax reform affecting two aggregate groups differentially. In their case what is essentially a two by two table: before/after, treated/non treated, is enough to present the evidence. In our context a comparable exhaustive presentation is difficult. However, the same evidence can be presented using F-tests of joint significance for the exogenous sources of variation, while controlling for any other relevant effects. In a before/after, treated/non-treated setting, this would be equivalent to testing for the significance of a treatment dummy, while controlling for common changes.

The issue is whether exogenous changes in local income tax rates, as they interact with the national tax system, explain the variation between individual income tax rates within establishments, and, furthermore, whether they explain variations in the individual annual earnings. It is straightforward to assess whether local income tax rates explain the variation between individual income tax rates within establishments by a simple regression. Although the regional income tax rate is just one number for each municipality in each year, characterisation of this together with the national tax system is more involved because of the interaction with the national tax rates and changing tax band thresholds. To circumvent this difficulty, we construct a budget constraint for each of the (275) municipalities in each of the (12) years our data covers. The marginal tax rate is calculated at (20) fixed and equidistant levels of earnings along these constraints, and can be matched to workers by home municipality and year. These budget constraints characterise the tax *system* faced by individuals over time in a useful way.

Table 1 presents an inspection of the raw data. The relationship of primary interest (recall Eq. (2)) is that between individual gross earnings and marginal tax rates. It is the purpose of Table 1 to show that variation in local income tax rates explains a significant amount of the variation in gross earnings and marginal tax rates between individuals. Each test statistic and associated p-value are from a separate regression. They test the explanatory power of the tax system in a regression where all other observables are controlled for. Column 4 shows that for untransformed worker-year observations, local income tax rates and budget constraints are important determinants of individual earnings and marginal tax rates. The characterisation of the whole income tax system by way of discretised

Table 1
Individual earnings and marginal income tax rates OLS regressions: explanatory power of local taxes and budget constraints[a]

Dependent variable	Explanatory variables	Test statistic	Transformations				
			None	Within-pt	Within-pt within-w	bet'n-pt	bet'n-pt within-pt
1	2	3	4	5	6	7	8
$\ln(w_{ipt}h_{ipt})$	Local tax rate	*t*-test	28	21	3	31	30
		p-value	0.000	0.000	0.000	0.000	0.000
$\ln(w_{ipt}h_{ipt})$	Budget constraint	*F*-test	404	90	4	134	96
		p-value	0.000	0.000	0.002	0.000	0.000
$\ln(1-\tau_{ipt})$	Local tax rate	*t*-test	174	76	66	49	47
		p-value	0.000	0.000	0.000	0.000	0.000
$\ln(1-\tau_{ipt})$	Budget constraint	*F*-test	1857	314	188	239	107
		p-value	0.000	0.000	0.000	0.000	0.000

[a] τ_{ipt} denotes individual marginal income tax rate and $w_{ipt}h_{ipt}$ denotes individual gross earnings. The dependent variables vary between worker-year and the explanatory variables of interest vary between municipality-year. Each test statistic and associated *p*-value are for a separate OLS regression. Additional explanatory variables included but not shown and not included in the test statistics are gender, age, number of children, occupation dummies and year dummies where appropriate. *pt* denotes establishment-year and *w* denotes worker.

budget constraints provides additional explanatory power compared with using local income tax rates on their own. This is an important precursor to the empirical identification arguments to be presented in Section 4.

Importantly for our modelling strategy, much explanatory power is preserved when we consider variation between workers in the same establishment. The statistical significance of the tests calculated on within establishment-year data shows this clearly. Nevertheless, between-municipality and within-year income tax rate variations may be the cause of this significance. For example, the presence of unobserved municipality and worker heterogeneity correlated with the explanatory variables may create a spurious significance. Longitudinal data can address these issues, since it allows a further transformation within-worker. The explanatory power of local taxes and of the discretised budget constraints remains, as is shown in column 6.

Variation between establishments in a year is considered in column 7. Local taxes and budget constrains are found to be significant determinants in this dimension as well. Workers' home municipalities are not so disperse as to even out differences in taxes between establishments. The characterisation of the tax system in terms of the discretised budget constraints is a stronger determinant of earnings and marginal tax rates, than is the local tax rate on its own. This explanatory power is preserved when further transforming the data within-establishment and therefore accounting for establishment-specific effects, as shown in column 8.

The empirical correlations illustrated in Table 1 are necessary to identify the

model presented in Section 2. It remains for the subsequent analysis to show whether variations in marginal income tax rates can *explain* earnings once the potential endogeneity has been accounted for. The next section develops an empirical counterpart to the economic model following a twice transformed (difference-in-differences) instrumental variables approach alluded to in our inspection of the raw data.

4. Identification and empirical strategy

The discussion which follows expands on the theoretical model presented in the second section in order to propose a formulation which facilitates empirical work. In particular we want to be able to allow for a more heterogeneous population within establishment. That is we want to allow for variations in observables (occupation, age, etc.) and unobservables (either time-, establishment-, individual-specific effects or idiosyncratic components). To that end, suppose that it is possible to decompose any establishment's per period equilibrium gross wage into two components in the following way:

$$w_{ipt}[1-\tau_{pt}] = \tilde{w}_{pt}[1-\tau_{pt}],\hat{w}_{it}. \tag{3}$$

where $\tilde{w}_{pt}[.]$ is the component of the individual equilibrium gross wage which depends only on the establishment, whereas $\hat{w}_{it}$, is the component of individual remuneration which depends on individual characteristics only. In other words, the ratio of the wage rates for two employees within the same establishment depends only on their characteristics excluding their income tax treatment, whereas the ratio of the wage rates for two identical employees belonging to different establishments depends on establishment characteristics only. Moreover the establishment-wide marginal tax rate, $1-\tau_{pt}$, is identically incident on every individual equilibrium wage rate within the establishment. Putting aside the latter, these properties are assumed throughout the literature on wage structure, where the logarithm of the wage rate depends on a linear combination of individual and establishment-wide observable and unobservable characteristics.[23]

A possible parameterisation of the assumption that the ratio of wage rates for any two employees in the establishment depends only on characteristics of the employees is such that:

$$\ln(\tilde{w}_{pt}[1-\tau_{pt}]) = \tilde{x}_{pt}\xi + \pi_1 \ln(1-\tau_{pt}), \tag{4}$$

where $\tilde{x}_{pt}$ is a vector of observed and unobserved establishment characteristics. ξ is a vector of parameters, and π_1 is a scalar and can be interpreted as the elasticity

[23] See Abowd et al. (1999) and references therein.

of the equilibrium wage rate with respect to $1-\tau_{pt}$. Moreover, the individual part of the wage rate is assumed to have the following structure

$$\ln(\hat{w}_{it}) = \hat{x}_{it}\delta, \tag{5}$$

where $\hat{x}_{it}$ is a vector of observable and unobservable individual characteristics and δ is a vector of parameters.

Suppose that the individual labour supply for the N_{pt}, workers belonging to establishment p at time t is a log linear function of w and can be described as follows

$$\ln(h_{ipt}[w]) = \alpha \ln(w) + \gamma_{ipt}, \tag{6}$$

where α is the individual labour supply elasticity with respect to the wage rate and γ_{ipt} describes the quality of the match between the individual and the establishment, at time t, which may depend on establishment or individual characteristics, observable or not. In particular, γ_{ipt} varies across individuals, time and establishments, in so far as individual preferences depend on variables specific to individuals, time or establishments.

Allowing for the effect of taxation on gross wages, the individual equilibrium labour supply becomes:

$$\ln(h_{ipt}[(1-\tau_{ipt})w_{ipt}]) = \alpha \ln(\tilde{w}_{pt}) + \alpha\hat{x}_{it}\delta + \alpha \ln(1-\tau_{ipt}) + \gamma_{ipt}. \tag{7}$$

This leads to the equation defining individual equilibrium earnings which is the basis for our empirical measurements:

$$\begin{aligned}\ln(w_{ipt}h_{ipt}[(1-\tau_{ipt})w_{ipt}]) = {} & (1+\alpha)\tilde{x}_{pt}\xi + \ln(1-\tau_{pt})(1+\alpha)\pi_1 \\ & + \alpha \ln(1-\tau_{ipt})(1+\alpha)\hat{x}_{it}\delta + \gamma_{ipt}.\end{aligned} \tag{8}$$

Consider now the average equilibrium log earnings in establishment p at time t:

$$\begin{aligned}&\frac{1}{N_{pt}}\sum_{i\in p \text{ at } t}\ln(w_{ipt}h_{ipt}[(1-\tau_{ipt})w_{ipt}]) = \\ &(1+\alpha)\tilde{x}_{pt}\xi + \ln(1-\tau_{pt})\{(1+\alpha)\pi_1 + \alpha\} + \\ &(1+\alpha)\frac{1}{N_{pt}}\sum_{i\in p \text{ at } t}\hat{x}_{it}\delta + \frac{1}{N_{pt}}\sum_{i\in p \text{ at } t}\gamma_{ipt},\end{aligned} \tag{9}$$

where $\{(1+\alpha)\pi_1 + \alpha\}$ can be understood as the elasticity of equilibrium individual earnings with respect to establishment average marginal tax rate, and corresponds exactly to the right hand side of Eq. (1). This quantity is effectively what is estimated in Gruber (1997). If we turn to the expression of the difference in earnings from the within establishment-period mean we obtain:

$$\ln(w_{ipt}h_{ipt}[(1-\tau_{ipt}w_{ipt})]) - \frac{1}{N_{pt}}\sum_{j\in p \text{ at } t}\ln(w_{jpt}h_{jpt}[(1-\tau_{jpt})w_{jpt}]) =$$
$$\alpha\left\{\ln(1-\theta_{ipt}) - \frac{1}{N_{pt}}\sum_{j\in p \text{ at } t}\ln(1-\theta_{jpt})\right\} + \tag{10}$$
$$(1+\alpha)\left\{\hat{x}_{it}\delta - \frac{1}{N_{pt}}\sum_{j\in p \text{ at } t}\hat{x}_{jt}\delta\right\} + \gamma_{ipt} - \frac{1}{N_{pt}}\sum_{j\in p \text{ at } t}\gamma_{jpt},$$

which does not depend directly on $\tilde{w}_{pt}$. This transformation effectively removes all establishment-time-specific effects. The effect of this transformation is to make α, the elasticity of labour supply with respect to wages, the parameter of interest. However, in general a further differencing within-individual is required in order to remove individual-specific effects. The following transformation achieves this for the dependent variable:

$$\ln(w_{ipt}h_{ipt}[(1-\tau_{ipt})w_{ipt}]) - \frac{1}{N_{pt}}\sum_{j\in p \text{ at } t}\ln(w_{jpt}h_{jpt}[(1-\tau_{jpt})w_{jpt}])$$
$$-\frac{1}{N_{ipt' \text{ s.t. } i\in p}}\sum\left\{\ln(w_{ipt}.h_{ipt}.[(1-\tau_{ipt}.[(1-\tau_{ipt}.)w_{ipt}.])\right.$$
$$\left.-\frac{1}{N_{pt'}}\sum_{j\in p \text{ at } t'}\ln(w_{jpt'}h_{jpt}[(1-\tau_{jpt'})w_{ipt'}])\right\} \tag{11}$$

where N_{ip} stands for the number of time periods individual i is observed in establishment p.

The order in which we perform the differencing transformations is important.[24] The effect of the first transformation is to remove establishment-year-specific effects and to set the labour supply elasticity as the parameter of interest (as opposed to the elasticity of equilibrium individual earnings with respect to $1-\tau_{pt}$). This is sensible since it is defined only within establishment-year (as discussed in Section 2). The second differencing transformation applies to the individual worker's history with respect to the establishment-year mean (i.e., within-worker) and removes the worker-specific effects, but does not change the nature of the parameter of interest.

Identification of the labour supply parameter, i.e., the capacity one has to measure a parameter without bias, relies on our ability to observe, within the same establishment at a given time, identical enough (i.e., after controlling for observable differences) workers who are paid the same gross amount but who supply different amounts of labour. Furthermore, we require that the marginal tax rate for the same workers differ and explain the labour supply differences. If for

[24] Abowd et al. (1999), using a similar matched establishment-worker panel data structure for different purposes, discuss the importance of order dependent or independent sequences of transformations. In their context, order independence is desirable.

some reason we do not observe differences between individuals in the amount of labour supplied or in observed marginal tax rates, the labour supply elasticity with respect to the wage will fail to be identified.

Hence the empirical strategy we follow here is comparable to the difference in differences methodology proposed elsewhere, for example in Blundell et al. (1998), Gruber (1997), Eissa (1995) and Feldstein (1995). This approach, or any variation of it, relies on the successive removal of observation unit-specific effects (and to some degree their interactions) that may be correlated with the explanatory variables. Although, in some instances it is sufficient,[25] in the present context it is unlikely to allow consistent estimation on its own. Indeed, $1-\tau_{ipt}$ (and therefore $1-\theta_{ipt}$) depends, by definition, on individual earnings and is therefore correlated with any unobserved components of earnings, transformed or not.

Instrumental variables are required to deal with the potential endogeneity of marginal tax rates. Assuming the exogeneity of individual dwelling location for labour supply decisions, we argue that local income tax rates characterised by budget constraints provide potentially valid instruments. Indeed these rates vary between individuals within a given establishment and, as illustrated in Section 3, they are correlated with individual marginal income tax rates and individual annual earnings.

The exogeneity assumption is reasonable to the extent that the transaction cost of moving is greater than the income tax difference between municipality. Borjas (1999) finds that choice of initial residence location by immigrants to the US can be explained by welfare generosity rather than tax. He argues that conditional upon the decision to migrate, the cost of moving to a generous state is small With our longitudinal data, taking a within-person transform addresses the potential endogeneity of individual location of home municipality according to local tax rate. However, it may still be the case that individuals re-locate according to differential tax changes. The high transaction costs of buying and selling a house in Denmark mitigates against this. Only 1.0% of workers in our sample move home municipality.[26] The data selection criteria requires that workers remain attached to a sampled establishment. Omitting movers from our study does not change the model estimates.[27]

When unobservable individual-specific effects are uncorrelated with our instruments (local taxes), a single cross-section of workers and establishments allows a consistent estimation of the parameters of interest. Alternatively, if unobservable

[25]Gruber (1997) may be such a case. See Blundell and MaCurdy (1999) for a discussion of the maintained hypotheses that lead to consistent estimators.

[26]For this group of movers, the difference between the local tax changes in their origin and destination municipalities, was not significantly different from zero.

[27]Papke (1991) finds evidence of local business tax differentials explaining new establishment start-ups for a number of US manufacturing industries. Since taxes vary according to where employees live, rather than work; this is less of an issue in the Danish context.

individual-specific effects are correlated with the local tax rate (say because of the decision to locate), then instrumental variables estimates based on a single cross-section will be biased. In the latter case, longitudinal data allows us to difference out individual-specific effects from the deviations from establishment-year mean earnings. An instrumental variables methodology applied to this (twice) differenced model will lead to consistent estimates. Moreover, longitudinal data enable us to use additional instruments: the time series of variations of the national and local income tax system, as captured by budget constraints.

To conclude this section, it may be useful to compare and contrast the features of our empirical income tax incidence model with the more conventional labour supply models that have been estimated recently. The latter use the quasi-experimental nature of income tax reforms to estimate labour supply elasticities with respect to the wage, but ignore the potential incidence on equilibrium wages of the reform itself. In our context this amounts to regressing $\ln(h_{ipt}[(1-\tau_{ipt})w_{ipt}])$ $\ln(1-\tau_{ip})$ and observable characteristics in $\gamma_{ipt'}$, with the help of an instrumental variables scheme suggested by the nature of the tax system. In the absence of any incidence of taxation on equilibrium wages these procedures can lead to consistent estimates of the labour supply elasticities. Otherwise, incidence $\ln(1-\tau_{pt})$ is an omitted variable and biases estimates of the elasticity of labour supply with respect to the wage.

5. Results and discussion

Table 2 presents estimates of the parameters of interest α and $(\alpha+1)\pi_1+\alpha$, as well as specification tests for instrument validity.[28] Each column of Table 2 corresponds to a different kind of observation unit. For example, the third column refers to worker-year (wt) observations from which the worker (w) mean is removed, i.e., within worker differences. The fourth column uses worker-year observations from which the establishment-year (pt) mean and worker mean is further removed. Establishment-year units have establishment means removed and are the basis for the results reported in columns 5 and 6. Out of the total sample size of 244 074 worker-year observations, the third column reports estimates and tests computed over 167 931 informative observations which are worker-year deviations from worker means. By informative we mean observations or transformations of observations which are non-trivial, i.e., deviations from a mean require at least two untransformed observations and lead to the loss of one effective observation. The fourth column reports the results for an effective sample of 159 411 observations, removing establishment-year units leads to a further loss of 8520. The fifth column presents results obtained from the sample of establis-

[28] We also control for age, age^2, gender, five occupation groups, number of children in three age groups as well as year of observations when relevant. See Appendix Table A2 for details.

Table 2
OLS and IV selected model estimates and test statistics[a]

	Dep. variable observation unit 1st transform 2nd transform	Earnings wt within-w	Earnings wt within-pt within-w Eq. (11) α	Earnings pt between-pt within-p Eq. (9) $(\alpha+1)\pi_1+\alpha$	Employment pt within-p
1	2	3	4	5	6
OLS	Parameter	−0.6450	−0.7177	−1.2747	−0.1779
	Standard error	(0.0037)	(0.0038)	(0.0201)	(0.0467)
IV	Parameter	0.2683	0.1416	−0.3570	−0.4719
	Standard error	(0.0204)	(0.0414)	(0.0592)	(0.1792)
F-test	Test statistic	1701.8	553.2	329.8	329.8
Hausman	Test statistic	211.7	104.2	35.44	1.368
Overident.	Test statistic	764.1	9.130	58.87	16.21
	p	23	15	34	34
	q	11	11	22	22
#Informative obs.		167931	159411	10014	10014
#Actual obs.		244074	244074	11402	11402

[a] Test statistics are distributed: t with 1 degree of freedom for Hausman, $\chi^2(p-q)$ for overidentification, and $F(p$, no. of actual observations-p-1) for the F-test of the explanatory power of the instruments. All standard errors are heteroscedastic-consistent (White, 1980).

hment-year deviations from within establishment unit means, 10 014 effective observations.

Column 3 OLS estimates are comparable those of Graversen (1996) and Eissa (1995), which are traditional labour supply estimates in the sense that they impose the implicit assumption of no shifting of the burden of taxation. Our uncompensated conditional elasticity of hours with respect to the net wage rate (for men and women together) is −0.64, Graversen finds −0.26 for Danish women, Eissa obtains unconditional hours elasticities of 0.8 to 1.0 for US women. As expected, instrumentation leads to a change of sign as well as a loss of precision, without precluding significance. Column 5 estimates are akin to Gruber (1997).[29] The OLS value of −1.275 (0.02) is close to Gruber's −1.120 (0.10), but instrumenting has a large effect changing our estimates to −0.357 (0.05). Gruber applies a similar instrumental variable procedure, where his instruments are industry specific, therefore less variable than ours, and reports an elasticity of −1.412(0.25). Gruber's findings lead him to conclude that the tax changes were

[29] Gruber uses a specification which is semi-log in the ratio of marginal tax rate over average tax rate, but for the range of taxes he considers the parameter for this ratio approximates to an elasticity comparable to ours.

fully incident on workers (full shifting of a payroll tax levied on employers corresponds to zero shifting of an income tax levied on workers).

Our preferred estimate for the labour supply elasticity is obtained in column 4, where both the establishment-year-specific effects and worker-specific effects have been removed as we describe in Section 4 (Eq. (11)). As far as the elasticity of individual equilibrium earnings with respect to the marginal tax rate is concerned, the fifth column presents our preferred estimates for the total incidence of income taxes on equilibrium earnings $+0.357$, where the establishment-specific effect has been differenced out of the establishment-year averages. Note that successive transformations have important costs in terms of degrees of freedom but do not remove significance.[30]

Consider the consequences of a marginal tax increase implied by our preferred estimates. From Table 2 we can recover the elasticity of the gross wage with respect to $1-\tau_{pt}$, i.e., π_1. We find: $\hat{\pi}_1 = -0.437$ with a standard error of $\hat{\sigma}_{\hat{\pi}_1} = 0.051$. Hence our estimates conclusively indicate that there is partial shifting of the income tax burden from worker to employer. An increase in the tax rate at the margin does not lead to a one for one increase in the gross wage. Moreover, gross earnings increase by a smaller proportion because of the small, but significant, labour supply elasticity with respect to the wage rate.

Several tests are informative on the quality of the measures we propose. First, we claim that our choice of instrumental variables is a priori sensible since we obtain large test statistics (F-tests) of joint significance of the parameters in the linear regression of the endogenous explanatory variable on the instrument set. Then, we present Hausman test statistics[31] which show that the IV estimates are significantly different from the OLS estimates. Finally we present test statistics for overidentification,[32] which are more problematic since our calculated statistics are consistently above the 1% critical level. This suggests that some instruments are inappropriately excluded from the equation of interest. A possible explanation is that the elasticity varies by income group, and we are rejecting the assumption of constant labour supply elasticity and constant incidence on the equilibrium wage

[30]Table A2 in the Appendix presents the full set of IV estimates including controls which are not presented in Table 2 of the main text. We have further extended the analysis to distinguish between male and female equilibrium wage and labour supply. The results exhibit the expected difference between gender: female labour supply is more responsive to wage change, whereas changes in the marginal tax rates are less incident on female gross wages than they are on male gross wages. Estimates presented in the text are roughly a weighted average of the gender-specific ones. These results are available upon request from the authors.

[31]This is the value of the t-statistic for the significance of the residual from the regression of the endogenous explanatory variable on the instruments, when these residuals are included as an explanatory in the regression of interest.

[32]The overidentification test is calculated as the uncentred R^2 of the regression of the residual of the structural regression on the instruments.

rates which our simple linear-specification imposes. In this case, our measures are to be understood as average elasticities over the different income groups.[33]

A concern may be that our estimated conditional labour supply elasticities ignore potentially more important participation effects. Participation is ruled out of the labour supply model, and only conditional elasticities are estimated because of data limitations: we only observe a worker during employment at a sampled establishment.[34] Column 6 of Table 2 shows the elasticity of employment with respect to income tax is $+0.47$, which is of opposite sign to the labour supply response. A negative employment response, together with a negative labour supply response would give support to concerns about the validity of our labour supply elasticity. In this regard we interpret the result as the model passing an informal specification check. Gruber (1997) performs a similar-specification check using an employment equation. In his context, no employment response supported the finding of full shifting of the payroll tax burden into earnings.

We find that employers are substituting more heads for fewer (more expensive) hours in response to an increase in the marginal tax rate. While this is intuitively plausible, it is at odds with the findings of Holmlund and Kolm (1995) in support of their theoretical model using a different specification on Swedish data. However, we are in line with the simulation results of Pissarides (1998) which show that for a range of different labour market models higher income tax leads to an increase in employment.

6. Summary and conclusions

We have extended recent applied studies of work incentives to allow for taxes on employees (or employers) to be incident on employers (employees). A simple economic model is proposed which allows the separate measurement of the effect of income tax on gross wages and the labour supply wage elasticity. In order to separately identify these two parameters, the nature of the Danish tax system is exploited together with administrative tax records matching workers and establishments over time. In Denmark, income tax varies regionally, and workers pay tax according to where they live rather than where they work. This provides variation in tax rates within establishments beyond that which is due to gross earnings differences alone.

Our simple economic model, together with institutional specifics, suggest caution should be exercised when generalising the estimates for Denmark to elsewhere. Notwithstanding these caveats the results are in sharp contrast to the conventional tax incidence and traditional labour supply literatures. Previous

[33] We are grateful to an anonymous referee for pointing this out to us.

[34] See Heckman (1993) for a review of the evidence on the relative empirical importance of hours and participation effects in labour supply modelling.

empirical work on incidence of labour taxes has focused on the total effects of taxes on gross earnings and employment. For example, Gruber (1997) reports that employees face the burden of Chilean payroll tax because of full shifting of the burden from employers into workers earnings. In general, however, the incidence of taxation on gross earnings is a mix of direct gross wage and labour supply responses. Furthermore, the finding that worker earnings bear the full burden of a tax may be consistent with off-setting gross wage and hours responses. The evidence we present here shows that, in Denmark, gross earnings bear less than the full the burden of labour taxes, and that gross wages bear proportionally more of that burden because of a partially offsetting labour supply response.

With respect to the marginal rate of income tax, the elasticity of gross earnings is $+0.36$ (partial burden shifting), the elasticity of gross wages is $+0.44$ (partial burden shifting again). The conditional elasticity of labour supply with respect to wages is $+0.14$. All of these elasticities are precisely measured. A traditional labour supply model, which allows for individual heterogeneity and is conventionally instrumented, but implicitly assumes no shifting of the burden of taxation is found to overestimate the incentive effects of income taxation by a factor of about two. More importantly, we show that ignoring the potential labour supply response to a tax change, as well as ignoring the endogeneity of the marginal tax rate, may lead to the erroneous conclusion that the tax is fully incident on equilibrium earnings.

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Appendix

Table A.1. Descriptive statistics

1st Transform	None	None	Within-w	Within-pt	Within-pt	bet'n-pt	bet'n-pt
2nd transform					within-w		within-p
Variable	Mean	S.D.	S.D	S.D.	S.D.	S.D.	S.D.
Log(employ.)	3.9539	1.2613	0.2289	0.0000	0.0000	0.9591	0.3994
Log(earnings)	12.0335	0.6839	0.2292	0.5717	0.2279	0.4682	0.2277
Log(1-marg tax)	−0.8490	0.2350	0.1195	0.2007	0.1075	0.1483	0.0951
Age	36.7430	12.1461	2.0876	11.1352	2.2601	6.7113	3.3916
$Age^2/100$	14.9758	9.5630	1.7273	8.8233	1.8634	5.1132	2.6255

Table A.1. Descriptive statistics

1st Transform	None	None	Within-w	Within-pt	Within-pt	bet'n-pt	bet'n-pt
2nd transform					within-w		within-p
Variable	Mean	S.D.	S.D	S.D.	S.D.	S.D.	S.D.
#Kids 0–2	0.1101	0.3325	0.2128	0.3226	0.2084	0.1307	0.1069
#Kids 3–6	0.1442	0.3902	0.2397	0.3778	0.2345	0.1522	0.1195
#Kids 7–17	0.4897	0.7830	0.3647	0.7510	0.3558	0.3329	0.2390
Log(l-local tax)	−0.3364	0.0374	0.0187	0.0176	0.0082	0.0347	0.0241
White collar	0.4358	0.4958	0.1298	0.3983	0.1350	0.2953	0.8593
Skilled	0.1847	0.3881	0.0990	0.3110	0.1039	0.2321	0.0626
Unskilled	0.2388	0.4263	0.1115	0.3525	0.1172	0.2397	0.0729
Missing skill	0.1405	0.3475	0.1236	0.3005	0.1254	0.1744	0.078 1
Male	0.6145	0.4866	0.0000	0.3911	0.0581	0.2895	0.7217

Table A.2. IV (2SLS) Model estimates (standard errors)

Dep. variable	Earnings	Earnings	Earnings	Employment
Observation unit	(p)wt	(p)wt	(p)wt	pt
1st transform	within-w	within-pt	between-pt	within-p
2nd transform		within-w	within-p	
		α	$(\alpha+1)\pi_1+\alpha$	
Intercept	0.0000	0.0000	0.0552	0.0933
	(0.0004)	(0.0004)	(0.0086)	(0.0192)
Male	–	0.3742	0.3211	−0.1967
	–	(0.0141)	(0.0359)	(0.0739)
Log(1−τ)	0.2683	0.1416	−0.3570	−0.4719
	(0.0204)	(0.0414)	(0.0592)	(0.1792)
Age	0.1297	0.1183	0.1004	−0.0289
	(0.0016)	(0.0016)	(0.0055)	(0.0125)
Age^2	−0.0012	−0.0013	−0.0011	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0001)
White collar[a]	−0.0332	−0.0722	−0.4162	0.3978
	(0.0053)	(0.0055)	(0.0524)	(0.1298)
Skilled	−0.0741	−0.1355	−0.4217	0.8132
	(0.0090)	(0.0086)	(0.0512)	(0.1488)
Unskilled	−0.0695	−0.1668	−0.5751	0.9576
	(0.0089)	(0.0082)	(0.0470)	(0.1392)
Missing skill	−0.2429	−0.3511	−0.9586	0.8019
	(0.0100)	(0.0100)	(0.0590)	(0.1362)
#Kids 0–2	−0.0699	−0.0625	−0.0197	−0.1070
	(0.0029)	(0.0029)	(0.0225)	(0.0628)
#Kids 3–6	−0.0452	−0.0416	0.0570	0.0151
	(0.0024)	(0.0024)	(0.0199)	(0.0475)
#Kids 7–17	−0.0480	−0.0465	−0.0361	0.1028
	(0.0017)	(0.0016)	(0.0135)	(0.0277)
R^2	0.0068	0.0615	0.3910	0.3823
#Actual obs.	244 074	244 074	11 402	11 402
#Informative obs.	167 931	159 411	10 014	10 014

[a] Year dummies were also included to control for common shocks.

[b] The reference occupation group consists of managers and professionals.

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