Incentives, productivity and the excess burden of taxation: Evidence from a field experiment

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Abstract

This study conducts a field experiment to analyze the disincentive effects of labor taxation on productivity (effort) and its associated social costs. Our experiment was conducted in a tree-planting firm in British Columbia where workers are hired to plant trees on given blocks and are paid on a piece rate basis. It involved two basic treatments, applying tax rates of 4 cents and 6 cents per tree with different levels of base wage. This corresponds to marginal tax rates ranging from 15% to 33% depending on the standard piece rate in place on the blocks. We applied both non-structural and structural econometric techniques on this experimental data to measure the effect of taxation on worker's effort and productivity. We show that for an average daily production of 2000 trees per worker and an initial tax rate of 15%, an increase of 10% of the tax rate will induce a decline of daily production of 28 trees per worker. This increases to 39 and 52 trees for initial tax rates of 20% and 25% respectively. Daily average excess burden on experimental observations represents 0.12 of the collected tax revenue with substantial heterogeneity across workers. We generalize our results to tax rates beyond those observed in our experiment and observe that the ratio of the excess burden to tax revenue rises disproportionately with the tax rate attaining more than 0.65 at the tax rate of 0.56 that maximizes tax revenue. Our analysis advocate for a broad-based and low tax rate system.

1 Introduction

Labor income tax is one of the largest sources of government revenues in most economies. Tax revenues enable the government to finance social programs, public goods and transfer payments to reduce inequalities. However, labor income taxes reduce incentives to work (substitution effect) and as a result, reduce economic wealth. These disincentive effects generate an excess burden or social cost of taxation[1] as tax revenues are smaller than the reduction in workers' earnings (see Killingsworth; 1983; Chetty; 2009; Finkelstein and Hendren; 2020; Creedy and Mok; 2022). Measuring the social cost of taxation is essential for the design of efficient tax policies. An optimal tax policy aims to minimize this social cost for a given level of tax revenue.

Several studies[2] have examined the impact of taxes on labor supply. Two main dimensions have been addressed: the extensive margin (labor market participation) and the intensive margin (hours worked or wages) (Heckman; 1993; Alpert and Powell; 2020; Keane; 2021; Hansen; 2021). Regarding the extensive margin, the literature has established significant labor supply elasticities with respect to taxes (Eissa and Liebman; 1996; Meyer and Rosenbaum; 2001; Keane and Rogerson; 2012, 2015; Alpert and Powell; 2020). In contrast, there is little consensus over the magnitude of the labor supply elasticities with respect to taxes when considering the intensive margin (Meghir and Phillips; 2010; Keane; 2011; Alpert and Powell; 2020; Blomquist et al.; 2021). Zubrickas (2022) evokes the vast variation, both quantitative and qualitative, in the estimates of labor supply elasticities. The majority of empirical studies on wage taxation and labor supply rely on econometric techniques exploiting non-experimental data. However, these data often lack detailed and accurate information on key variables such as effective hours worked, level of effort, wages and tax rate. Dickinson (1999) and Keser et al. (2020) point out that non-experimental data may contain correlated causal chains that can be misleading. Such correlated causal relation among variables can, however, be reduced in an experiment. Banerjee et al. (2017) have emphasized the potential of experimentation as a method of investigation for both theorists and practitioners.

Experiments provide the researcher the possibility to create exogenous variations in key variables such as the level of the taxation and measure causal effects (List and Reiley; 2008). Experiments have been suggested as research tools to analyze the impact of taxes and transfers in the labor market at least since Orcutt and Orcutt (1968). One well-known example is the large-scale Negative Income Tax Experiments (NIT) in the United States as described in Robins (1985). Due to their extremely high costs (approximately $338 million evaluated in 1996), Dickinson (1999) suggests alternatively much cheaper laboratory experiments. However settings in laboratory experiments may not reproduce the

[1]Referring to Dupuit (1844), "... if we triple the tax, lost utility becomes nine times greater ... The higher the taxes, the less they produce relatively ...".

[2]See Blundell et al. (1988); MaCurdy et al. (1990); Blundell (1992); Blundell et al. (1992, 1998); Meghir and Phillips (2010); Keane (2011); Saez et al. (2012, 2019); Alpert and Powell (2020); Keane (2021); Iskhakov and Keane (2021)

realism of the labor market and consequently affect results (Harrison and List; 2004).

One of the contributions of this study is to develop a field experiment that is both affordable in the sense of Dickinson (1999) and realistic in the sense of Harrison and List (2004) to analyze the impact of taxes on work incentives and productivity. We use the resulting experimental data to measure the excess burden induced by different levels of taxation. Another contribution of this research relates to the variable of interest : productivity or work intensities. Traditional measures of the response of labor supply to taxation focus on hours worked. Studies such as Keane and Rogerson (2012, 2015); Azmat (2019); Martinez et al. (2021) and Sumiya and Bagger (2022) have investigated the impact of taxes on hours worked and/or wages. Other studies such as Dickinson (1999); Goerg et al. (2019); DellaVigna et al. (2020) and Ku (2022) have proposed to focus on other labor supply measures in particular productivity (work intensities or effort). We follow these latter studies and focus on the intensive margin of labor supply measured by work intensities. We examine the disincentive effects of taxes on labor supply and worker intensities (productivity) in the real economy using experimental data.

We address issues related to wage taxation and labor supply using experimental data in a real-world context. We measure directly the change in worker productivity induced by taxes which may be imperceptible in hours worked and calculate the associated social cost. Our data comes from an experiment conducted in a British Columbia tree-planting firm. Workers in this firm are hired to plant trees on given blocks during the planting season[3]. The recruited workers are paid on a piece rate contract. The piece rate is fixed by the firm and closely tied to the planting conditions of the block. Production is accurately measured by the number of the trees planted. The payroll data of the firm provides information on the contract (the piece rate paid to workers) and the daily productivity of the workers (the number of trees planted).

Our analysis builds on the framework developed by Prendergast (2015) who demonstrates how the effect of a piece rate reduction on productivity can be mapped to the effect of taxation on productivity.[4] Prendergast (2015) shows how a piece rate reduction is equivalent to taxation when the incentive pay is the sole reason to exert effort. Indeed both taxation and a piece rate reduction reduce the marginal value of effort. We focus on the case when taxes are completely levied on the workers [5] and developed an experiment that enables us to introduce exogenous variation in the workers' contracts. These contracts simulated taxes and transfers without altering the workers' environment. Indeed, we

[3]Planting is mainly done in the spring and summer from April to June. This study relates to the 2019 planting season.

[4]In his paper, Prendergast (2015) argues how responses to tax reforms would be informative about response to incentives due to the correspondence between taxation and reduction of performance pay.

[5]Studies using micro-data and payroll tax reforms have found evidence of employer payroll taxes shifted to employees (see Gruber (1997) for Chile, Cruces et al. (2010) for Argentina, Anderson and Meyer (1997, 2000) for US unemployment insurance payroll taxes and Deslauriers et al. (2021) for Canada). In contrast, Kugler and Kugler (2009) and Bozio et al. (2017) found out in their study that payroll taxes are not always completely passed on employees.

introduced a proportional wage tax by reducing the firm's piece rate offered to workers. In order to induce workers to accept the reduced piece rate contract (the taxation contract), we provided a base wage. The experiment involved two basic treatments, applying tax rates of 4 cents and 6 cents per tree. This corresponds to marginal tax rates ranging from 15% to 33% depending on the standard piece rate in place on the blocks.

We applied both non-structural and structural econometric techniques on this experimental data to measure the effect of taxation on worker's effort and productivity. The non-structural and structural econometric techniques employed in the paper exhibit very close estimates of labor supply (effort) elasticity with respect to tax rates. In the absence of seasonal effect (our Model 1), we show that for an average daily production of 2000 trees per worker and an initial tax rate of 15%, an increase of 10% of the tax rate will induce a decline of daily production of 5 trees per worker. This daily decline will be of 7 and 10 trees for initial tax rates of 20% and 25% respectively. As we control for seasonal effects (our Model 2), we show that for an average daily production of 2000 trees per worker and an initial tax rate of 15%, an increase of 10% of the tax rate will induce a decline of daily production of 6 trees per worker. This daily decline will be of 9 and 12 trees for initial tax rates of 20% and 25% respectively. These estimates increase about 4.5 times when we account for base wage effects. We observe a daily productivity decline of 28, 39 and 52 trees respectively for initial tax rates of 15%, 20% and 25%.

Our experimental setting enables us to calculate the hicksian measure of the excess burden based on the compensating variation. The evaluation of the excess burden on experimental tax rates show that average excess burden amounts to 0.12 of collected tax revenue. Risk preference affects modestly the value of the excess burden. We use our structural estimates to evaluate worker's compensating variation, government tax revenue per worker and the excess burden beyond levels of taxation observed in our experiment. Results show that the ratio of the excess burden to tax revenue increases very rapidly with the tax rate, attaining more than 0.65 at the tax rate of 0.56 that maximizes tax revenue.

The next sections of the article expose the institutional aspects and experimental design of the study, present the data, the structural model and econometric analysis. We also consider extensions to our modeling by incorporating base wage effects and risk preference. We assess the performance of our structural model before generalizing our results. We finally present concluding remarks.

2 Institutional aspects

Our field experiment took place in a tree-planting firm in British Columbia. This firm recruits workers to plant trees on given blocks and pays them piece rates. British Columbia is one of the largest producers of timber in North America. About 25% of North American softwood lumber supply is produced in the region. And to maintain a steady supply of lumber, reforestation is indispensable. The mechanics of reforestation in the region is organized by the Ministry of Forests and the major timber-harvesting firms. Tracts of land that have recently been logged are allocated to tree-planting firms for reforestation through a process of competitive bidding initiated by either a timber-harvesting firm or the Ministry of Forests. These auctions usually take place in the autumn of the year preceding the planting season, which generally runs from early spring to late summer. The lowest-bidding firm wins the contract and is in charge of reforesting the given site the following year.

An average site is around 250 hectares and would necessitate about 500 person-days. Tree-planting firms in the region usually employ fewer than 100 workers. These workers represent a very broad group of individuals including returning seasonal workers and students working on their summer holidays, male, female, youths, adults. They are free to leave the firm at any time if they are not satisfied with the work conditions.[6] In this setting, participation/employment of the worker is closely approximated by a daily decision. If recruited, workers are responsible for planting seedlings on the site. The firm divides the site into homogeneous blocks depending on planting conditions (rockiness, steepness of the land) and randomly assigns workers to planting sites. The workers move around allotted blocks on foot, carrying seedlings to be planted in a sack that fits around their hips. To plant a tree, they dig a hole in the terrain with a special shovel, place the seedling in the hole, and tamp down the earth around the seedling. There is no evidence of team production. A worker's productivity depends on his/her effort and the conditions of the terrain being planted. Blocks that are steep or contain compact or rocky soil are more difficult to plant, compared to flat and cleared blocks. Hence planting conditions can vary a great deal from block to block.

These workers are predominantly paid on a piece rate contract. For each block to be planted, the firm decides on a piece rate to be paid to the workers. The piece rate accounts for the planting conditions on that block. Blocks that are more difficult to plant (due to their steepness for example) require higher piece rates to attract workers. The piece rate applies to all planting done on a block. Thus all workers on the same block receive the same piece rate. The daily earnings of a worker is determined by the product of the piece rate and the number of trees he/she planted. Given the firm can't know completely the land conditions for the whole block and given the contract (piece rate) is constant within each block, some workers will invariably end up working in more difficult conditions under the same contract. Also note, there is no systematic matching of workers to planting conditions within the firm. Indeed, workers typically meet at a central location each morning and are transported to the planting sites in trucks. They are then assigned to plots of land as they arrive. Workers are placed under the direction of a supervisor who is responsible for monitoring their output. The firm holds a payroll data which contains information on the piece rate received by each planter, as well as the planter's daily productivity and earnings. The experiments we conduct will add to this rich

[6]There are no unions and rigid employment contract.

payroll data exogenous taxes.

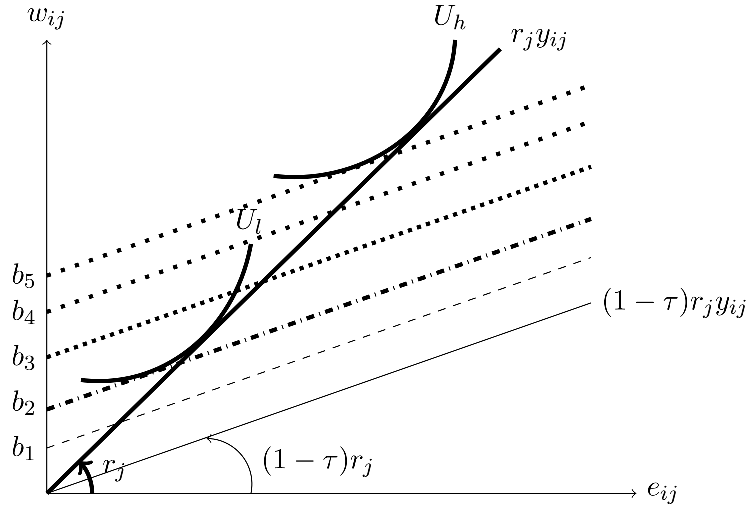
3 Experimental design

Our experiment was conducted on workers of a tree-planting firm in British Columbia and lasted 8 days. Its main goal was to introduce exogenous variation in contracts which simulate taxes without altering the workers' environment. To do so, we introduced a proportional wage tax by reducing the piece rate. In order to induce workers to accept the reduced piece rate contract, we provided a base wage.

During the experiment, each worker was offered a menu of choices between their regular piece rate contract without base wage (which we refer to as the piece rate contract) and a taxed piece rate contract coupled with a base wage (which we refer to as the taxation contract or base wage contract). An example of the decision sheet is given in the Appendix A. Each worker was asked to indicate his/her preference between the piece rate contract and the taxed piece rate contract for each level of the base wage on the decision sheet. For example, suppose a worker's regular piece rate contract was 16 cents per tree and the experimental tax rate is 4 cents per tree (τ=25%). The worker would make 14 decisions. Each decision is between the piece rate contract (paying a piece rate of 16 cents per tree) and the taxed piece rate contract (paying a piece rate of 12 cents per tree plus an offered base wage). The base wage for the first decision is C$20. The base wage increases by C$20 dollars at each decision. As the base wage increases, the taxation contract becomes more attractive relative to the piece rate contract. Before making their choices, workers were told that one of their decisions would be drawn at random and the worker would be paid according to his/her choice for that decision. By indicating his preference for the complete sequence, the worker reveals the base wage which renders him indifferent between the standard piece rate contract and the taxed contract. Below that revealed value, worker prefers his standard piece rate contract and above that value he prefers the taxed contract with a base wage. As the randomly selected contract (which can be the taxed contract with a base wage or the standard contract) is administered, we observe the worker's level of productivity under that contract.

Moreover the base wage (or lump-sum payment) that renders the worker indifferent between the taxation contract and the standard piece rate contract enables us to estimate the excess burden of taxation. The economic intuition and mechanic behind the contract choice experiment are well depicted by the graph below.

Figure 1: Contract Choice



The standard piece rate (r_j) is represented by the solid thick line while the thin line gives the slope of the contract payment in presence of a proportional taxation i.e. $(1-\tau)r_j$. The level of effort of the worker i on block j, his productivity and total earnings are designated by e_{ij}, y_{ij} and w_{ij} respectively. The taxation contract is accompanied by a lump-sum payment (base wage), b, which shifts the intercept. For each level of b, the worker indicates his/her preference between the regular piece rate contract and the taxation contract. For strictly convex preferences, there is a unique lump-sum payment (or base wage) which renders the worker indifferent to standard piece rate contract. This equivalent base wage contract is worker specific and depends on his/her preferences. It reveals the worker's minimum compensation (reservation base wage) for a given level of taxation. For example, given the marginal tax rate τ, the minimum compensation (reservation base wage) of the worker with utility U_l is given by b_2. For the worker with utility U_h, it is given by b_5.

The contract choice experiment involved two basic treatments, applying tax rates of 4 cents and 6 cents per tree respectively. This corresponds to marginal tax rates ranging from 15% to 33% depending on the standard piece rate in place on the blocks. The offered base wages (compensation) varied from C$20 to C$280 for the tax rate of 4 cents per tree and from C$20 to C$320 for the taxation of 6 cents per tree. These ranges were sufficiently broad to identify the equivalent base wage contract for each worker under each tax rate. These treatments are split into 2 sub-treatments. First, the worker's preferred contract was randomly selected over the entire range of proposed base wages. This sub-treatment will be labeled unrestricted base wage draw. A second sub-treatment used the same decision sheet as in the first sub-treatment, but the worker's preferred contract was randomly selected above the worker's reservation base wage. Workers were then given the choice of accepting or rejecting the selected contract.[7] This will be labeled restricted base wage draw. The goal of this sub-treatment

[7]Some workers had changed planting blocks (and hence regular piece rates) from the day on which they had filled

is to increase our chances of observing each worker under the taxation contract and to reduce selection bias in the experiment.

- **Treatment 1** : Taxation of 4 cents per output and unrestricted base wage draw **(T1)**.
- **Treatment 2** : Taxation of 6 cents per output and unrestricted base wage draw **(T2)**.
- **Treatment 3** : Taxation of 4 cents per output and restricted base wage draw **(T3)**.
- **Treatment 4** : Taxation of 6 cents per output and restricted base wage draw **(T4)**.

On each experimental day, one half of the workers were randomly offered the contract choice treatments (exposed group) while the other half of the workers planted under their regular piece rate contract. We call this group the non-exposed group. The following day, the exposed group and the non-exposed group are switched. This process of switching between exposed and non-exposed group is repeated throughout the whole experiment.

The treated group is composed of workers who are observed under the taxation contract. This includes workers who drew a base wage, $b_{i\tau}$, that was greater than their reservation base wage $b^*_{i\tau}$[8]. The control group is composed of workers who are observed under the regular piece rate contract. Based on the experimental design, we distinguish two control sub-groups : first, those who were randomly allocated to the non-exposed group and second, those who were in the exposed group and drew a base wage below their reservation base wage $b^*_{i\tau}$.

Workers were given paper instructions, a decision sheet, a clipboard, and an ink pen on each experimental day in the morning before planting. The decision sheet presents to each participant a series of Decisions between two options : Option A indicating the worker's regular piece rate contract and Option B indicating a base wage contract with taxation. For each Decision, workers must choose either Option A or Option B but not both. They are informed that only one of their Decisions between Option A and Option B will be randomly chosen to determine their contract and thus their earnings. Each Decision is represented by a poker chip numbered accordingly. We have an equal number of Decisions and poker chips. The experiment proceeds as follows. The chips are placed in a bag. After the workers made all Decisions, they are asked to draw one chip out of the bag. The selected chip indicates which Decision will be used to determine the worker's contract. For example, if the worker draws the chip with the number 3, then his choice between Option A and option B for Decision 3 will determine his contract. If he draws the chip with the number 8, then his choice for Decision 8 between Option A and option B will determine his contract. Each Decision has an equal chance of being selected based on the chip drew out of the bag. The decision sheet and detailed instructions of the experiment are presented in Appendix **??**.

in the decision sheet, necessitating that we allow them to reject the base-wage contract chosen in favor of their new standard piece rate contract.

[8]The index i is to indicate worker i and τ is the marginal tax rate.

4 Analysis of the experimental data

The contract choice experiment provided the data to analyze the impact of taxes on the worker's labor supply in terms of productivity (work intensities or effort). This data will also serve to estimate the social cost of taxation. Table 1 below depicts relevant information regarding the planting season of 2019 in the absence of our experimental treatments. The planting season of 2019 is the period in which we conducted our experiments. Workers plant on average about 2000 trees per day and earn about C$480.

Table 1: Summary statistics : Planting season of 2019

By Individual-Day : 2568 Observations				
Variable	Average	sd	Minimum	Maximum
Number of trees	2281.82	758.59	100.00	5270.00
Regular piece rate	0.22	0.03	0.15	0.36
Daily earnings (in C$)	487.01	139.94	20.00	1104.10

The main data of this study comes from the contract choice experiment. The treated group is composed of workers observed under the base wage contract with taxation while the control group is composed of workers observed under the regular piece rate contract without taxation. Summary statistics of the contract choice experiment is presented in table 2 and 3.

Table 2: Summary statistics: Contract choice experiment

Variables	Average	sd	Minimum	Maximum
Taxation at 4 cents per tree				
Control sample (No Taxation) : 86 Observations				
Number of trees	2369.54	794.90	750.00	4100.00
Regular piece rate	0.22	0.03	0.18	0.32
Discounted earnings	501.01	138.09	150.00	820.00
Treatment sample (Taxation) : 49 Observations				
Number of trees	2215.51	786.96	650.00	3855.00
Regular piece rate	0.22	0.04	0.18	0.32
Discounted earnings	483.15	138.94	117.00	909.60
Tax rate	0.18	0.03	0.13	0.22
Base wage	195.92	50.82	100.00	280.00
Taxation at 6 cents per tree				
Control sample (No Taxation) : 98 Observations				
Number of trees	2608.78	874.49	510.00	4470.00
Regular piece rate	0.21	0.04	0.18	0.33
Discounted earnings	539.66	155.98	102.00	883.00
Treatment sample (Taxation) : 45 Observations				
Number of trees	2407.22	900.88	840.00	4200.00
Regular piece rate	0.21	0.04	0.18	0.31
Discounted earnings	502.86	170.69	168.00	996.00
Tax rate	0.29	0.04	0.19	0.33
Base wage	234.67	43.36	160.00	340.00

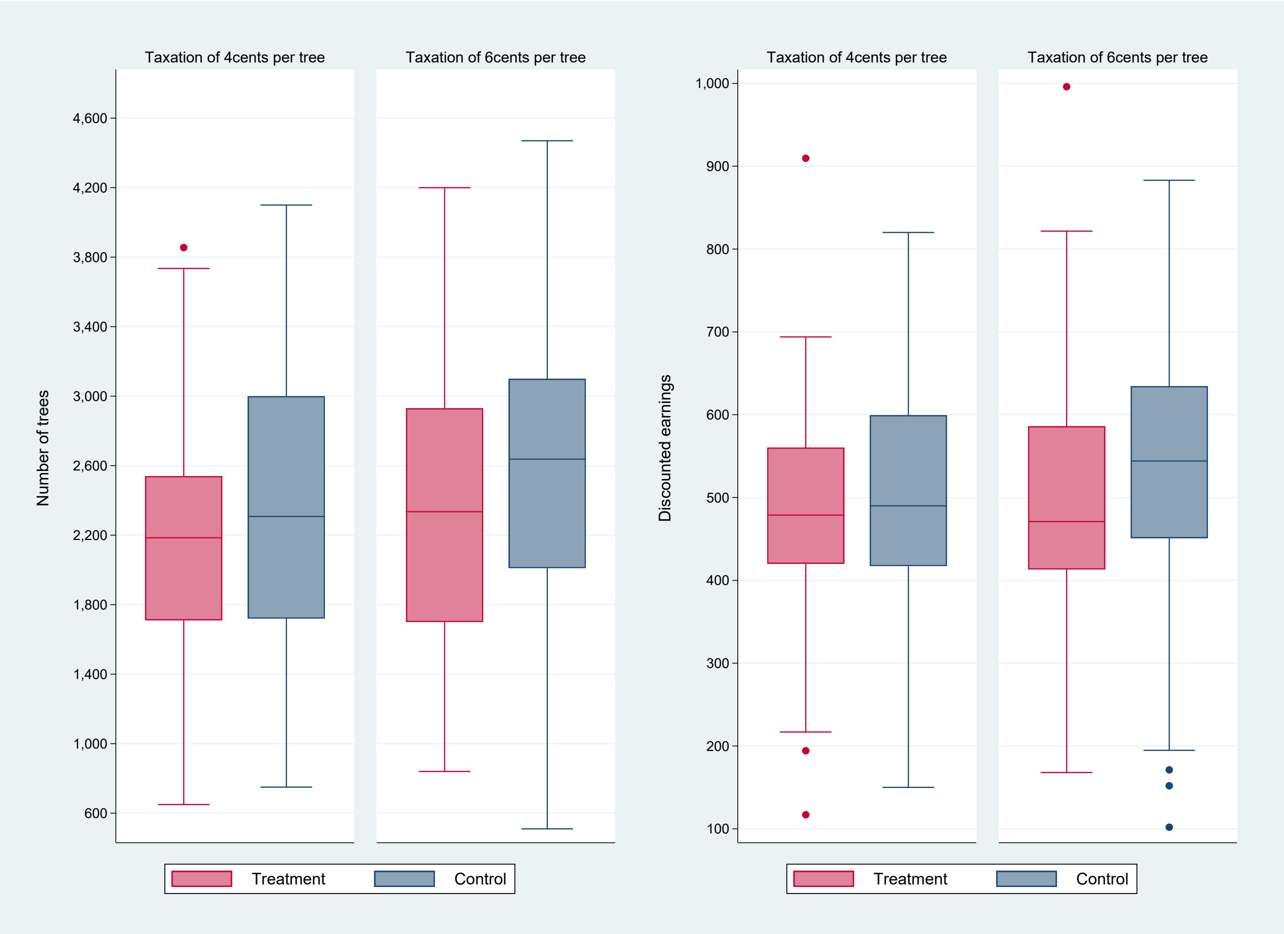
Table 3: Summary statistics on reported compensation ($b^*_{i\tau}$)

	Average	sd	Minimum	Maximum	Observations
Taxation of 4 cents per tree	132.24	40.30	80.00	240.00	67
Taxation of 6 cents per tree	182.25	44.02	60.00	280.00	71
All treatments	157.97	49.01	60.00	280.00	138

Table 2 shows that the average daily productivity of the control group of the 4 cents per tree taxation treatment is 2369 trees compared to 2215 for the treated group. This represents a significant differential in average productivity between the two groups of about 154 trees detrimental to the treated group. Thus the 4 cents per tree taxation treatment induces a decline of average productivity of 6.5%. This decline of productivity increases to 7.7% with the 6 cents per tree taxation. These differentials in average productivity detrimental to the treated group are also observed in daily earnings. The 4 cents per tree taxation treatment induces a decline of daily discounted earnings of 3.56% in average . This deterioration of daily discounted earnings becomes greater as the taxation increases to 6 cents per tree. We note a decline of 6.82% in average.

Regarding the reported worker's compensation $b^*_{i\tau}$ (reservation base wage) to accept a given level of taxation, Table 3 shows that average compensation required by workers to accept the taxation treatment of 4 cents per tree is C$132.24. This average compensation rises to C$182.25 for the taxation treatment of 6 cents per tree.

Figure 2: Daily productivity and discounted earnings by treatment



5 Model and econometric analysis

We develop an economic model to characterize the effects of taxation on worker productivity. The model is based on an effort-incentive framework in which the worker responds to tax changes by adjusting his level of effort. This distinguishes our analysis from most labor supply and taxes studies that model labor supply in terms of hours worked via a labor-leisure model. In our approach, the level of effort and output are the relevant measures of the worker's labor supply. Hours worked is fixed.[9] This allows us to measure the effect of taxes on productivity (work intensities or effort), which may be imperceptible in hours worked. Our model is based on Shearer (2004).

We model productivity of worker i on a block j and on day t as the product of his/her effort e_{ijt} and productivity shocks s_{ij} and d_t inherent respectively to the block and the day :

$$y_{ijt} = e_{ijt} s_{ij} d_t \tag{1}$$

The productivity shock s_{ij} represents planting conditions on block j beyond the worker's control (such as the hardness of the ground). We assume that s_{ij} follows a log-normal distribution of parameters μ_j and σ_j^2 ($\log s_{ij} \sim N(\mu_j, \sigma_j^2)$). Thus, on a given block j, each worker i receives an independent shock s_{ij} which is a realization of a log-normal distribution of mean μ_j and variance σ_j^2. The productivity shock d_t captures day-specific effects which includes weather conditions or any other day-specific effects that affect productivity.

The level of productivity of the worker generates daily earnings $r_j y_{ij}$, where r_j denotes the regular piece rate paid on block j. During the experiment, taxes are collected on daily earnings at a constant marginal tax rate τ. The worker also receives a base wage (lump-sum payment) of $b_{i\tau}$. The net earnings of the worker can then be written :

$$w_{ijt} = b_{i\tau} + (1-\tau) r_j y_{ijt} \qquad \text{with} \qquad 0 \leq \tau < 1 \qquad \text{and} \qquad b_{i\tau} \geq 0.$$

This can be seen as a general linear base wage contract where the worker receives a base wage of $b_{i\tau}$ and is paid proportionally at a piece rate of $r'_j = (1-\tau) r_j$.

Worker's utility is function defined over net daily earnings and effort as :

$$U_i(w_{ij}, e_{ij}) = w_{ij} - C_i(e_{ij}) \tag{2}$$

$C_i(e_{ijt})$ represents worker i's monetary cost of effort and is given by:

$$C_i(e_{ijt}) = \frac{k_i e_{ijt}^{\eta}}{\eta} \qquad \text{with} \qquad k_i = \exp(\lambda_i) \quad \text{and} \quad \eta > 1 \tag{3}$$

Where η determines the curvature of the cost function. The coefficient λ_i captures worker heterogeneity in planting ability.

The timing of the model is as follows. For each plot to be planted :

1. Nature chooses (μ_j, σ_j^2) ;

[9] This is consistent with the firm in which the experiment was completed. A standard work day in this firm entails 8 hours of planting and transport to and from the planting site (which can take up to two hours).

2. the firm observes (μ_j, σ_j^2) and proposes two contracts :

$$\Omega = \begin{cases} r_j y_{ijt} & \text{Standard piece rate contract without taxes and base wage} \\ (1-\tau) r_j y_{ijt} + b_{i\tau} & \text{Taxation contract with base wage} \end{cases}$$

3. the worker observes (μ_j, σ_j^2) and either choses one contract or rejects both contracts ;
4. conditional on accepting a contract, the worker observes a particular value s_{ij} and chooses an effort level e_{ij}, producing y_{ij};
5. the firm observes y_{ij} and pays w_{ij} according to the contract chosen by the worker.

Conditional on a realization s_{ij}, the optimal effort of the worker that maximizes his/her utility is given by :

$$e^*_{ijt} = \left[\frac{(1-\tau) r_j s_{ij} d_t}{\exp(\lambda_i)}\right]^\gamma \qquad \text{with} \qquad \gamma = \frac{1}{\eta - 1}$$

Notice that the second-order sufficient conditions for optimal effort are satisfied. The second derivative of the worker's utility with respect to effort, evaluated at the optimal effort is negative if $\eta > 1$.

The elasticity of the worker's effort with respect to the marginal tax rate τ is :

$$\xi = -\frac{\tau}{1-\tau}\gamma \tag{4}$$

This is also the elasticity of output with respect to the tax rate. The effect of taxation on the worker's effort is negative and it increases with the tax rate.
Substituting optimal effort into equation (1) gives optimal output :

$$y^*_{ijt} = \left[\frac{(1-\tau) r_j}{\exp(\lambda_i)}\right]^\gamma d_t^{\gamma+1} s_{ij}^{\gamma+1} \tag{5}$$

Taking the logarithm of this equation gives

$$\log y^*_{ij} = \gamma \log r_j + \gamma \log(1-\tau) - \gamma\lambda_i + (\gamma+1)\log d_t + (\gamma+1)\log s_{ij} \tag{6}$$

The derived net daily earnings of the worker is given by :

$$w^*_{ijt} = b_{i\tau} + \left[\frac{1}{\exp(\lambda_i)}\right]^\gamma (1-\tau)^{\gamma+1} r_j^{\gamma+1} d_t^{\gamma+1} s_{ij}^{\gamma+1} \tag{7}$$

Piece rates are determined endogenously by the firm in response to expected production on a block, independently of weather conditions. They are derived under regular circumstances where tax rate and base wage are zero. Following Paarsch and Shearer (1999), we assume that the firm chooses the piece rate that satisfies the expected utility constraint of the marginal worker. The marginal worker,

h is defined as that worker who is indifferent between accepting the firm's contract and refusing the contract. Let $\bar{u}$ denote his alternative utility of refusing the contract. Thus r_j solves h's expected utility constraint relative to the regular piece rate contract without taxes and lump-sum payment.

$$E_{pc}[U_h(\overset{*}{w}_{ij}, \overset{*}{e}_{ij})] = \bar{w} \tag{8}$$

Where $\bar{w}$ represents the net market alternative. Given the optimal values of w_{ij} and e_{ij} and properties of the log-normal distribution, we can express the piece rate chosen by the firm as :

$$r_j^{\gamma+1} = \bar{w}(\gamma+1)\exp^{-[(\gamma+1)\mu_j+\frac{1}{2}(\gamma+1)^2\sigma_j^2]+\gamma\lambda_h} \tag{9}$$

By combining equations (6) and (9) we have

$$\begin{aligned}\log r_j \overset{*}{y}_{ijt} = &\log(\bar{w}) + \log(\gamma+1) + \gamma\log(1-\tau) + \gamma(\lambda_h - \lambda_i) - \frac{1}{2}(\gamma+1)^2\sigma_j^2 + (\gamma+1)\log d_t \\ &+ \underbrace{(\gamma+1)\log s_{ij} - (\gamma+1)\mu_j}_{\epsilon_{ij}} \quad \text{with} \quad \epsilon_{ij} \sim N(0, (\gamma+1)^2\sigma_j^2)\end{aligned} \tag{10}$$

This is the monetized productivity equation derived from our economic model. It shows that worker's productivity and gross daily earnings depend on his ability λ_i, block-specific effects μ_j and σ_j^2 capturing planting conditions, day-specific effects d_t which includes essentially weather conditions or any other day-specific effect that can affect productivity, worker's net market alternative $\bar{w}$ and the tax rate τ.

5.1 Contract choice

We derive the reservation base wage (compensation) $b_{i\tau}^*$ that renders the worker indifferent between the taxation contract and regular piece rate contract without taxation. This value $b_{i\tau}^*$ is given by solving

$$E_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})] = E_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})] \tag{11}$$

The maximum expected utility of the worker under the standard piece rate contract without taxes and base wage is given by :

$$E_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})] = \bar{w} d_t^{\gamma+1} \exp^{\gamma(\lambda_h - \lambda_i)}$$

Under the taxation contract with base wage, it is given by :

$$E_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})] = b_{i\tau} + (1-\tau)^{\gamma+1}\bar{w} d_t^{\gamma+1} \exp^{\gamma(\lambda_h - \lambda_i)}$$

The reservation base wage (compensation) $b_{i\tau}^*$ that renders the worker indifferent between the taxation contract and regular piece rate contract with no taxation is given as :

$$b_{i\tau}^{*}=[1-(1-\tau)^{\gamma+1}]\bar{w}d_t^{\gamma+1}\exp^{\gamma(\lambda_h-\lambda_i)} \tag{12}$$

Below $b_{i\tau}^{*}$, the worker prefers the regular piece rate contract with no taxation and base wage, and above $b_{i\tau}^{*}$, he prefers the taxation contract with base wage. We also note the following implications :

Result 1. *The reservation base wage $b_{i\tau}^{*}$ is an increasing function of the marginal tax rate and depends on the worker's level of ability. The elasticity of the reservation base wage $b_{i\tau}^{*}$ with respect to marginal tax rate is greater than one. The required compensation increases more than proportionally to the increase of the tax rate.*

Result 2. *For a given level of taxation, τ, high ability workers will require , ceteris paribus, a greater base wage as compensation compared to low ability workers. High ability workers are more penalized from taxation and consequently will require higher compensation.*

Result 3. *For a given level of taxation, τ, increases in the net market alternative $\bar{w}$ imply a larger base wage as compensation. Indeed, as the worker's net market alternative is high, the impact of the taxation on the worker is greater. This will consequently necessitate a higher compensation.*

5.2 Econometric strategy

The estimated elasticity of the worker's effort and output respective to the marginal tax rate τ is given by :

$$\hat{\xi}=-\frac{\tau}{1-\tau}\hat{\gamma} \tag{13}$$

The evaluation of $\hat{\xi}$ requires beforehand the estimation of key parameter $\hat{\gamma}$. For this purpose, we consider the estimation of structural equation (10) which is re-written as a regression model :

$$\log r_j y_{ijt}^{*}=\beta_0+\beta_1\log(1-\tau)+\sum_{i=1}^{N_w-1}\beta_{2i}DI_i+\sum_{j=1}^{N_b}\beta_{3j}DB_j+\sum_{t=1}^{N_d-1}\beta_{4t}DD_t+\epsilon_{ij}$$
$$\text{with}\quad \epsilon_{ij}\sim N(0,\theta_j^2)\ ,\ \beta_{3j}=-\frac{\theta_j^2}{2} \tag{14}$$

Where DI_i is a worker-specific dummy variable, N_w is the number of workers, DB_j is a block-specific dummy variable and N_b is the number of blocks, DD_t is a day-specific dummy variable and N_d the total number of days.

Also note that , there is a restriction between the variances of error terms and the block-specific coefficients in equation (14).

Under standard personnel policy (control group observations), the regression model of the worker's monetized productivity given in equation (14) becomes :

$$
\log r_j \overset{*}{y}_{ijt} = \beta_0 + \sum_{i=1}^{N_w-1} \beta_{2i} DI_i + \sum_{j=1}^{N_b} \beta_{3j} DB_j + \sum_{t=1}^{N_d-1} \beta_{4t} DD_t + \epsilon_{ij}
$$
$$
\text{with} \quad \epsilon_{ij} \sim N(0, \theta_j^2)\ ,\ \beta_{3j} = -\frac{\theta_j^2}{2} \tag{15}
$$

Let D_{it} denotes a dummy variable equal to 1 if the worker is observed under the taxation contract on day t and 0 if observed under regular piece rate contract with no taxation. By combining equations (14) and (15) , we have

$$
\log r_j \overset{*}{y}_{ijt} = \begin{cases} \beta_0 + \beta_1 \log(1-\tau) \quad + \sum_{i=1}^{N_w-1} \beta_{2i} DI_i + \sum_{j=1}^{N_b} \beta_{3j} DB_j + \sum_{t=1}^{N_d-1} \beta_{4t} DD_t + \epsilon_{ij} & \text{if } D_{it} = 1 \\ \\ \beta_0 \quad + \sum_{i=1}^{N_w-1} \beta_{2i} DI_i + \sum_{j=1}^{N_b} \beta_{3j} DB_j + \sum_{t=1}^{N_d-1} \beta_{4t} DD_t + \epsilon_{ij} & \text{if } D_{it} = 0 \end{cases} \tag{16}
$$

with

$$
D_{it} = 1_{\{b_{i\tau}^d \geq b_{i\tau}^*\}}
$$

Where $\epsilon_{ij} \sim N(0, \theta_j^2)$, $\beta_{3j} = -\frac{\theta_j^2}{2}$; $b_{i\tau}^d$ is the base wage (lump-sum payment) drew by the worker when randomly assigned to the contract choice experiment and $b_{i\tau}^*$ is the worker's reservation base wage (the minimum base wage required to induce the worker to accept the taxation contract).

We use I and T to denote respectively the reference worker and the reference day omitted for estimation purposes. The correspondence between the structural and regression parameters is established as follows :

$$
\begin{aligned}
&\beta_0 = \log(\bar{w}) + \log(\gamma+1) + \gamma(\lambda_h - \lambda_I) + (\gamma+1)\log d_T \\
&\beta_1 = \gamma \\
&\beta_{2i} = \gamma(\lambda_I - \lambda_i) \\
&\beta_{3j} = -\frac{1}{2}(\gamma+1)^2 \sigma_j^2 \\
&\theta_j = (\gamma+1)\sigma_j \\
&\beta_{4t} = (\gamma+1)(\log d_t - \log d_T)
\end{aligned} \tag{17}
$$

If marginal worker is in the experimental sample and known, then maximum likelihood estimation of equation (16) on the experimental data enables to establish the following points:

1. the exogenous variation in tax rates directly identifies γ
2. Given γ, the block-specific term (β_{3j}) or the variance of $\log r_j \overset{*}{y}_{ij}$ identifies σ_j^2
3. Given γ, the worker-specific term (β_{2i}) identifies $(\lambda_h - \lambda_i)$

One can no longer identify $(\lambda_h - \lambda_i)$ if marginal worker is not in the experimental sample or known, however, we can still identify γ and σ_j^2.

We consider for comparison sake the unrestricted form of our structural equation (16) (no restriction between the variance of the error terms and block-specific coefficients). Interestingly, the unrestricted form of equation (16) without any modeling forms an ANOVA model. In this context, one block-specific dummy variable must be omitted since there is no restriction equating its coefficient to the variance of the error term. Consequently the correspondence between structural and regression parameters identified in equation (17) becomes :

$$\begin{aligned}
\beta_0 &= \log(\bar{w}) + \log(\gamma+1) + \gamma(\lambda_h - \lambda_I) + (\gamma+1)\log d_T - \frac{1}{2}(\gamma+1)^2\sigma_J^2 \\
\beta_1 &= \gamma \\
\beta_{2i} &= \gamma(\lambda_I - \lambda_i) \\
\beta_{3j} &= -\frac{1}{2}(\gamma+1)^2(\sigma_J^2 - \sigma_j^2) \\
\beta_{4t} &= (\gamma+1)(\log d_t - \log d_T)
\end{aligned} \tag{18}$$

Where J is the index of the omitted block-specific dummy variable. The advantage of the unrestricted model (non-structural model) is that estimation is straightforward with OLS. Moreover the tax-induced effect can be identified without strong functional form or other identifying restrictions. Structural modeling, however, enables us to generalize results beyond the scope of our experiment.

Comparing the productivity of workers under the taxation contract ($D_{it} = 1$) with those under the piece rate contract without taxation ($D_{it} = 0$) forms the basis to estimate the effects of taxation on worker productivity. Recall that workers can be allocated to the control group for two reasons. First, they can be exogenously assigned to the piece rate contract without taxation. Second, they can be exogenously assigned to the taxation contract, but drew a value of $b_{i\tau}$ lesser than $b^*_{i\tau}$. By selecting a value of $b^*_{i\tau}$ that is very high (or very low), workers can exert some control over which contract (regular contract without taxation or taxation contract with compensation) is finally administered. This is particularly true for Treatments 1 and 2 presented in Section 3 where the likelihood of observing exposed workers[10] under the taxation contract varies with their revealed $b^*_{i\tau}$

As workers may exert some indirect control on the administered contract during the experiment, observing workers' productivity under the taxation contract may be subject to selection bias. This arises when the treated group is not completely random and is composed of a specific sub-group of the population or sample. We will test explicitly for selection bias in Section 5.4 below.

5.3 Estimation of parameters

The results from estimating equation (16) are presented in Table 4. We present two versions of the model depending on whether we include or not day-specific effects to estimate our structural parameters. Model 1 does not include day-specific effects whereas Model 2 considers day-specific

[10] Exposed workers are workers that are randomly offered the contract choice treatment on a given day.

effects. For each of these models, we consider their non-structural and structural version. We report robust OLS standard errors based on block clusters to take into account heteroscedasticity and non-interdependence of the error terms in the unrestricted models.

The key parameter capturing the effect of taxation on productivity is γ. Its estimated value is positive in all models, and statistically significant. The positive value of γ implies a negative tax-induced effect on productivity as shown in equation (4). The structural and non-structural estimates of γ are quite close for Model 1 and Model 2. Including day-specific[11] effects in Model 2 improves estimation results compared to Model 1. Model 2 exhibits a higher Adjusted R^2 and a lower Bayesian Information Criterion (BIC). The day-specific effects are significant and accounting for them amplifies the value of γ from 0.1433 to 0.1733.

From the estimation of $\hat{\gamma}$, we can derive an estimate of the worker's output and effort elasticity with respect to tax rate using equation (13). Given the structural estimate of γ of 0.1433 based on Model 1, estimated output and effort elasticity with respect to the tax rate equal to -0.025, -0.036 and -0.048 for tax rates of 15%, 20% and 25% respectively. Hence for an average daily production of 2000 trees per worker and an initial tax rate of 15%, an increase of 10% of the tax rate will induce a decline of daily production of 5 trees per worker.[12] This daily decline will be of 7 and 10 trees for initial tax rates of 20% and 25% respectively. Given the structural estimate of γ of 0.1734 based on Model 2, estimated output and effort elasticity respective to tax rate equal to -0.031, -0.043 and -0.058 for tax rates of 15%, 20% and 25% respectively. Hence for an average daily production of 2000 trees per worker and an initial tax rate of 15%, an increase of 10% of the tax rate will rather induce a decline of daily production of 6 trees per worker. This daily decline will be of 9 and 12 trees for initial tax rates of 20% and 25% respectively.

[11] In an alternative version of Model 2, we considered climate variables instead of day-specific variables. The results showed a net preference for the day-specific variables in regard to the Adjusted R^2 and the Bayesian Information Criterion (BIC).

[12] A 1% increase in the tax rate would reduce production by (0.025*2000)/100=0.5 trees. A 10% reduction would reduce production by 10*0.5 = 5 trees per day.

Table 4: Estimation of Model 1 and 2 : Non-Structural vs Structural Model

	Non-Structural Estimates		Structural Estimates	
	Model 1	Model 2	Model 1	Model 2
γ	0.1594**	0.1989**	0.1433*	0.1734***
	(0.0577)	(0.0630)	(0.0817)	(0.0585)
β_0	5.6536***	5.5522***	5.8878***	5.6471***
	(0.1142)	(0.0994)	(0.0707)	(0.0750)
$\lambda_I - \lambda_{Min}$			5.6374*	5.2554***
			(3.2736)	(1.8281)
$\lambda_I - \lambda_{Max}$			-5.2906*	-2.6313***
			(3.1452)	(0.9997)
σ^2_{Max}			0.0789***	0.0508***
			(0.0221)	(0.0134)
σ^2_{Min}			0.0109**	0.0001**
			(0.0048)	(0.0001)
d_T/d_{Min}				1.2763***
				(0.0309)
d_T/d_{Max}				0.9958***
				(0.0395)
Individual effect	yes	yes	yes	yes
Day-specific effect	no	yes	no	yes
Observations	258	258	258	258
Adjusted R^2	0.731	0.748		
BIC			102.26	9.347

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5.4 Testing for selection

In previous estimations, the inclusion of dummy individual-fixed effects served as a strategy to deal with endogeneity due to selection. This strategy is valid under the assumption that the source of selection is due exclusively to individual time-invariant characteristics. Selection and endogeneity issues may, however, persist if there are unobservables, not completely captured by the individual-specific dummy variables, influencing both contract choices and productivity. One possibility would be if the cost of effort varies over time due to fatigue for instance. Here fatigue is a random and independent shock - a poor night sleep for example.

To illustrate these aspects, we enrich our model to take into account of these unobservables in the cost function by posing :

$$\lambda_{it} = \bar{\lambda}_i + \vartheta_{it} \quad \text{where} \quad \vartheta_{it} \sim N(0, \sigma^2_\vartheta).$$

We assume that ϑ_{it} captures unobservables that are independent across time, workers and blocks. We also assume that the worker observes ϑ_{it} each morning before the contract decisions. The unobservables ϑ_{it} influence the worker's reservation base wage $b^*_{i\tau}$ to accept a taxation contract with tax rate τ. The reservation base wage (minimum compensation), $b^*_{i\tau}$ in this context is then expressed as :

$$b^*_{i\tau} = \frac{b_{0i}}{\exp^{\gamma\vartheta_{it}}}[1 - (1-\tau)^{\gamma+1}] \quad \text{with} \quad b_{0i} = \bar{w}\exp^{\gamma(\lambda_h - \bar{\lambda}_i)}$$

The worker's minimum compensation for a given taxation contract with tax rate τ is a decreasing function of ϑ_{it} . High values of ϑ_{it} (which imply a high cost of effort on that day) lead workers to set a lower value of $b^*_{i\tau}$ and are more likely to be assigned to a taxation contract. Workers with a high value of ϑ_{it} are likely to have low productivity and compensation anyway, and are more likely to select the taxation contract with compensation. If so, a selection bias will arise, driven by fatigue where highly fatigued workers with lower productivity are more likely to be observed under the taxation contract. Thus the taxation contracts may select more fatigued workers.

The monetized productivity equation in the presence of unobservables ϑ_{it} is given as :

$$\begin{aligned} \log r_j y^*_{ijt} =& \log(\bar{w}) + \log(\gamma+1) + \gamma\log(1-\tau) + \gamma(\lambda_h - \bar{\lambda}_i) - \frac{1}{2}(\gamma+1)^2\delta_h\sigma_j^2 + (\gamma+1)\log d_t \\ & - \gamma\vartheta_{it} + \epsilon_{ij} \quad \text{with } \vartheta_{it} \sim N(0,\sigma^2_\vartheta)\,;\ \epsilon_{ij} \sim N(0,(\gamma+1)^2\sigma_j^2)\,;\ E(\vartheta_{it}\epsilon_{ij}) = 0 \end{aligned} \tag{19}$$

It shows explicitly that ϑ_{it} influences also productivity. High levels of ϑ_{it} (high fatigue) reduce worker's daily productivity and consequently daily earnings. Endogeneity issue in previous estimations based on equation (16) would then be characterized by the fact that fatigued workers exhibiting high values of ϑ_{it} with lower productivity (and earnings) are the most likely to end up with the taxation contract with compensation (base wage contract). The equivalent empirical model of equation (19) is derived as follows :

$$\log r_j y^*_{ijt} = \beta_0 + \beta_1\log(1-\tau) + \sum_{i=1}^{N_w-1}\beta_{2i}DI_i + \sum_{j=1}^{N_b}\beta_{3j}DB_j + \sum_{t=1}^{N_d-1}\beta_{4t}DD_t + \underbrace{\epsilon_{ij} - \beta_1\vartheta_{it}}_{\epsilon_{ijt}} \tag{20}$$

where the error structure is given by

$$
\begin{aligned}
E(\epsilon_{ijt}) &= 0 \\
E(\epsilon_{ijt}.\epsilon_{ijt}) &= (\gamma+1)^2\sigma_j^2 + \gamma\sigma_\vartheta^2 \\
E(\epsilon_{ijt}.\epsilon_{i'j't'}) &= 0 \\
E(\epsilon_{ijt}.\epsilon_{i'j't}) &= 0 \\
E(\epsilon_{ijt}.\epsilon_{i'jt'}) &= 0 \\
E(\epsilon_{ijt}.\epsilon_{ij't'}) &= 0 \\
E(\epsilon_{ijt}.\epsilon_{i'jt}) &= 0 \\
E(\epsilon_{ijt}.\epsilon_{ijt'}) &= (\gamma+1)^2\sigma_j^2 \\
E(\epsilon_{ijt}.\epsilon_{ij't}) &= \gamma^2\sigma_\vartheta^2
\end{aligned}
\tag{21}
$$

The correspondence between structural and regression parameters is straightforward as seen in precedent sections. Under our control group observations, the monetized productivity equation is specified as

$$\log r_j y_{ijt}^* = \beta_0 + \sum_{i=1}^{N_w-1} \beta_{2i} DI_i + \sum_{j=1}^{N_b} \beta_{3j} DB_j + \sum_{t=1}^{N_d-1} \beta_{4t} DD_t + \epsilon_{ijt} \tag{22}$$

With the error structure given in equation (21).

This equation offers a framework to test for selection bias and endogeneity in our data. Given our control group observations is formed of two sub-groups as seen in section 3 on the experimental design: the non-exposed group, which was randomly assigned to the piece rate contract without taxation, and the exposed control group which consists of workers who ended up with the regular piece rate contract without taxation because they drew a compensation below their reservation value $b_{i\tau}^*$. For the non-exposed control sub-group, random assignment eliminates selection bias. Moreover each worker has been randomly assigned to this sub group at least once during the whole experiment.[13] If there is a selection bias, then it must be in the exposed control group. We therefore test for the presence of selection bias by comparing productivity and earnings of workers between the exposed and non-exposed control group.

In the presence of selection bias, expected earnings of the two sub-groups would differ by the expectation of the error term. On the contrary if there is no selection bias, the expected earnings of the two sub-groups would be identical. This test can be performed by including a dummy variable in equation (22) to indicate whether or not the observation is in the exposed control sub-group or the non-exposed control sub-group. If the dummy variable is significant, this will suggest selection bias (and endogeneity), otherwise there is no statistical evidence for selection bias (and endogeneity). Let

[13] Recall that on each experimental day, half of the workers are randomly offered the contract choice treatments (exposed group) while the other half of the workers are not exposed to the contract choice treatments. The following day, the exposed group and the non-exposed group are switched.

CD_{it} denotes a dummy variable equal to 1 if the worker belongs to the exposed control sub-group on day t and 0 if he belongs to the non-exposed control sub-group. We have the following regression

$$\log r_j y^*_{ijt} = \beta_0 + \sum_{i=1}^{N_w-1} \beta_{2i} DI_i + \sum_{j=1}^{N_b-1} \beta_{3j} DB_j + \sum_{t=1}^{N_d-1} \beta_{4t} DD_t + \varphi CD_{it} + \epsilon_{ijt} \tag{23}$$

We relax the error structure given by equation (21) for flexibility and rather consider robust OLS standard errors based on block clusters to take into account heteroscedasticity and non-interdependence of the error terms to perform our test. The results of our estimation are presented in Table 5. There is no statistical evidence that selection is a problem in our data. The coefficient φ has a p-value of 0.389 and is not statistically significant.

Table 5: Test for selection bias and endogeneity

	Value	Std. Error	P-Value
φ	-0.0372	0.0405	0.3886
β_0	5.0249***	0.1356	0.0000
Obs	172		
Adjusted R^2	0.705		

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

6 Tax revenues and excess burden

In this section, we analyze tax revenues and excess burden generated by the experiment. The results are derived in the context of a proportional taxation.

6.1 Taxation and tax revenues

We evaluate the effect of different tax rates on tax revenues. For a given tax rate τ, the expected tax revenue collected on worker i on block j on day t during the experiment is given by :

$$\mathbb{E}[TX_{ijt}] = \tau(1-\tau)^{\gamma}(\gamma+1)\bar{w}d_t^{\gamma+1}\exp^{\gamma(\lambda_h-\lambda_i)} \tag{24}$$

Result 4. *In our framework, the expected tax revenue has an inverted "U" shape in conformity with economic intuition behind the Dupuit-Laffer taxation curve* [14]*. The tax rate that maximizes tax*

[14]The Dupuit-Laffer curve is typically represented as a graph that starts at 0% tax with zero revenue, rises to a maximum rate of revenue at an intermediate rate of taxation, and then falls again to zero revenue at a critical 100% tax rate. Dupuit showed the relationship between tax revenue and the tax rate, more than a hundred years before Laffer popularized the concept in the 1970s.

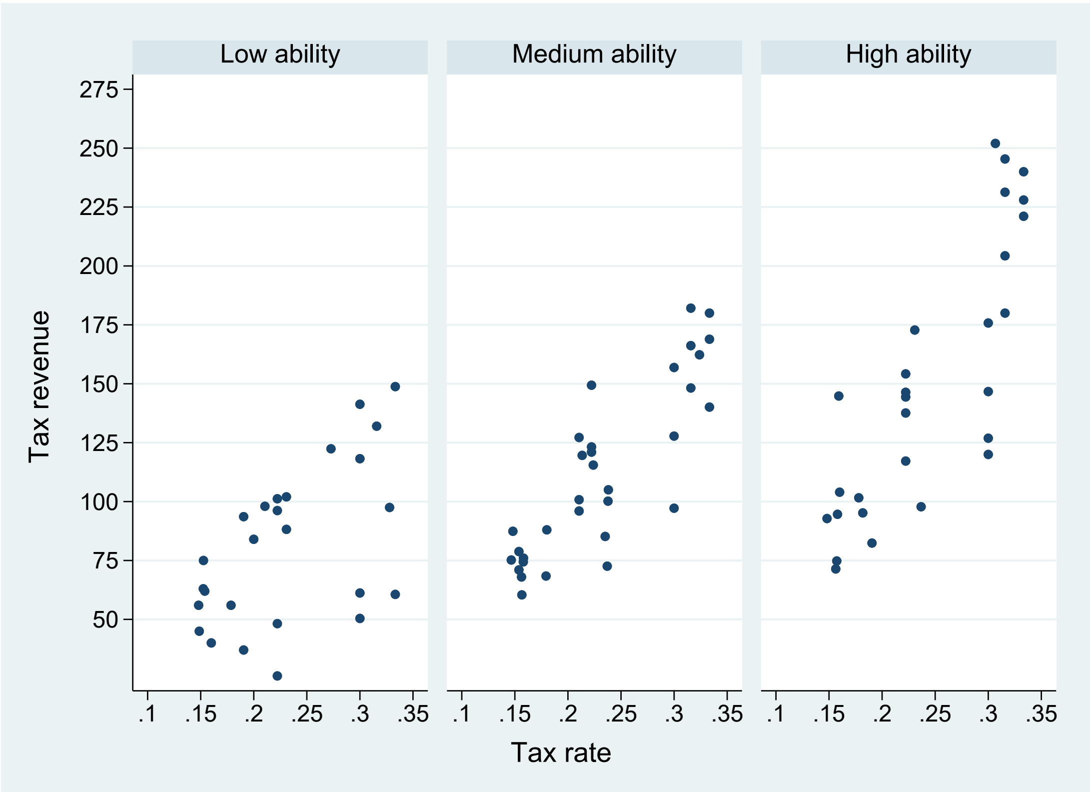
revenues is given by $\tau^* = \frac{1}{1+\gamma} < 1$ *with* $\gamma > 0$*. The higher* γ *is, the lower is the tax rate* τ^* *that maximizes tax revenue. Indeed a high value of* γ *indicates an important disincentive effect.*

Result 5. *Expected tax revenue is an increasing function of the worker's level of ability. A higher worker's ability (a lower* λ_i*) induces a greater (a lower) tax revenue.*

Result 6. *A higher net market alternative* $\bar{w}$ *would imply a higher incentive to relax worker's participation constraint. This is expressed by higher piece rates inducing higher income for the worker and consequently higher tax revenues.*

Figure 3 shows the relationship between tax revenue and ability in our sample. It shows that individual tax revenue increases with the level of ability in our sample. Indeed, we use worker's average productivity as a proxy of his level of ability (low ability, medium ability and high ability). The upper bound of our simulated tax rates is quite low (33%) rendering impossible to identify an inverted "U" pattern in tax revenues as tax rate increases in our experimental data.

Figure 3: Individual tax revenue by worker's level of ability



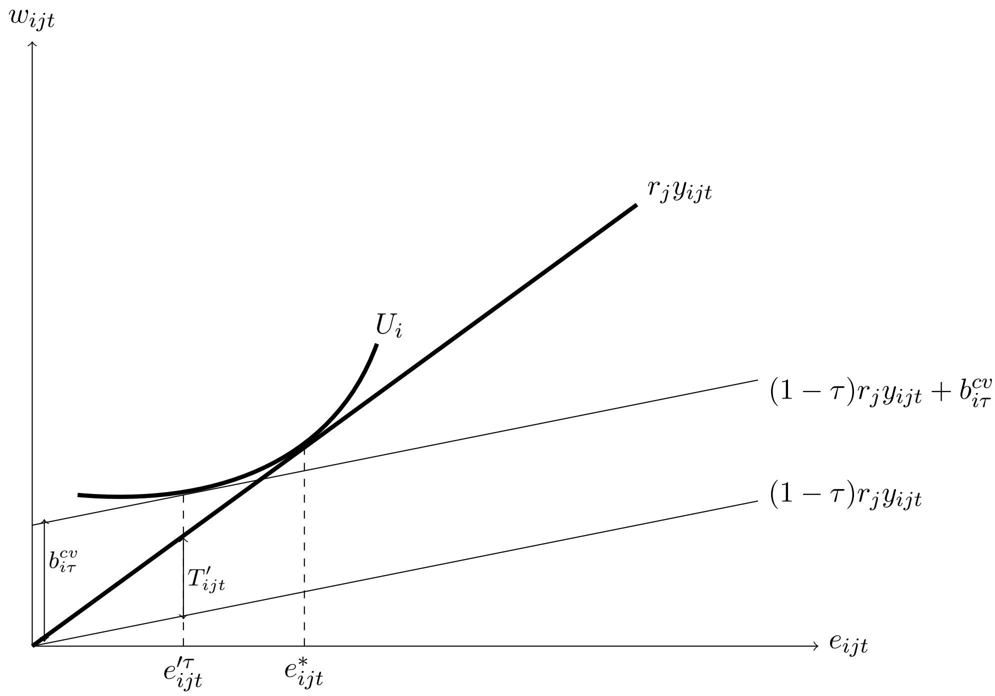
6.2 Measurement of the Excess burden

We can derive an excess burden of taxation relative to the worker's initial utility in the absence of taxation. This is done using the individual's compensating variation (see Killingsworth; 1983). The compensating variation is defined as the amount of money the worker requires in compensation to reach his initial utility level in the absence of taxation. For worker i on block j on day t and a given tax rate τ, the excess burden of taxation based on the compensating variation measure is the difference between the compensating variation[15] and the tax revenue collected :

$$\begin{aligned} EBCV_{ijt} =& b^{cv}_{i\tau}(\tau) - T_{ijt} \\ =& b^{cv}_{i\tau}(\tau) - r_j y^{\tau}_{ijt}\tau \end{aligned} \tag{25}$$

On Figure 4 below, e^{τ}_{ijt} is the effort level observed under taxation level τ. y^{τ}_{ijt} is the corresponding productivity level. In the absence of taxation, effort level is given by e^*_{ijt} which is greater than e^{τ}_{ijt} as taxation introduces disincentives to work. Taxes collected following taxation is given by T_{ijt}. The individual, however, requires a compensating variation of $b^{cv}_{i\tau}$ to reach his initial level of utility. This compensation is greater than the tax revenue collected. The difference between $b^{cv}_{i\tau}$ and T_{ijt} is the excess burden of taxation.

Figure 4: Tax-induced effects and Excess burden of taxation



Evaluating equation (25) requires a measure of the worker's compensating variation $b^{cv}_{i\tau}$. In our framework, the compensating variation is exactly the amount of lump-sum payment or base wage ($b^*_{i\tau}$) that renders the worker indifferent between the standard piece rate contract without taxation and the base wage contract with taxation. In section 8, we show how $b^*_{i\tau}$ no longer represents the compensating variation ($b^{cv}_{i\tau}$) in the presence of base wage effects.

Equation (25) can be calculated in two ways: i) It can be calculated using the worker's reported reservation base wage $b^*_{i\tau}$ during the experiment. This will be referred to our non-structural estimate

[15] Alternatively to the compensating variation, we could use the equivalent variation which is the amount of money the worker is ready to pay to avoid taxes.

of the excess burden, ii) By considering equation (5), (9) and (12), we can also evaluate expected excess burden in function of our structural parameters as :

$$\begin{aligned} \mathbb{E}[EBCV_{ij}] &= b^*_{i\tau} - r_j y^{\tau}_{ij}\tau \\ &= [1-(1-\tau)^{\gamma+1} - \tau(1-\tau)^{\gamma}(\gamma+1)]\bar{w}d_t^{\gamma+1}\exp^{\gamma(\lambda_h-\lambda_i)} \end{aligned} \quad (26)$$

This is our structural estimate of the excess burden. It shows that the compensating variation is a function of the tax rate, worker's ability, participation parameters and day-specific parameters. The analytical form of equation (26) enables to study properties of the expected burden in regards of certain key parameters such as the marginal tax rate τ, the worker's ability parameter λ_i and the worker's net market alternative $\bar{w}$. Econometric estimates of relevant parameters can help predict expected the excess burden using this analytical form for levels of taxation beyond the scope of our experiment.

Result 7. *Expected excess burden increases as the level of taxation increases. A one percent increase of the marginal tax rate induces an increase of more than one percent of the expected excess burden. Indeed the elasticity of expected excess burden with respect to the marginal tax rate is* $\frac{\gamma(\gamma+1)\tau^2(1-\tau)^{\gamma-1}}{1-(1-\tau)^{\gamma}(1+\tau\gamma)}$ *which is greater than one.*

Result 8. *Given the level of taxation τ, expected excess burden increases with the level of ability. Workers with high ability will suffer from a higher excess burden compared to low ability workers.*

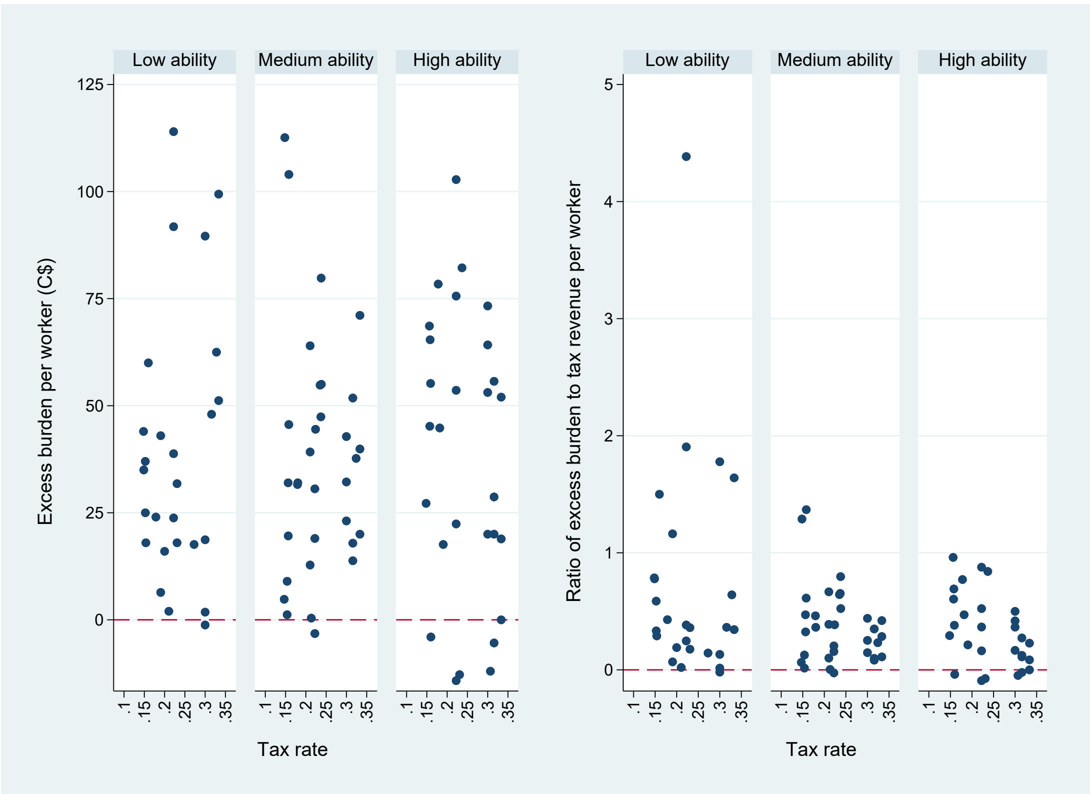
Result 9. *Given the level of taxation τ, a higher net market alternative $\bar{w}$ generates ceteris paribus, a greater excess burden for workers. Indeed, as the worker's net market alternative is high, the impact of the taxation on the worker is greater.*

6.2.1 Non-Structural estimates of the Excess burden

We compute the excess burden expressed in equation (25) based on the worker's reported reservation base wage during the contract choice experiment. Our experiment in general confirms the existence of a social cost to taxation as depicted in Figure 5 and 6. The 45-degree lines of Figure 5 represent a zero excess burden when tax revenue equates the worker's reported base wage. Points below the 45-degree line characterizes positive excess burden while points above characterizes negative excess burden. A negative excess burden is inconsistent with traditional economic theory. We, however, have few cases in our experimental sample. These inconsistencies relate to 7 observations (essentially high ability workers) who may have understated their reservation base wage. In Figure 6, we compute and plot the value of each Individual-Day excess burden.

Figure 5: Reported reservation base wage and tax revenue by worker's level of ability

Figure 6: Excess burden based on reported reservation base wage by worker's level of ability



Focusing solely on consistent values of the excess burden (positive values), the taxation treatment of 4 cents per tree generated a daily average excess burden of C$41.72. The average daily ratio of excess burden to tax revenue at this taxation treatment is evaluated at 0.60. Thus for one dollar of tax revenue collected at this taxation treatment, there is a social loss of more than 50 cents. The excess burden is however unevenly borne among workers. The ratio of the excess burden to taxes revenues reaches the 100% for some workers while for others it is less than 1%. Some workers bear a daily excess burden of more than a C$100 while others bear less than a dollar. This differential is partly explained by differential in worker's ability (and consequently productivity) as suggested by our theoretical predictions. Similar results are seen at the taxation treatment of 6 cents per tree. The induced average excess burden is estimated at C$42.74 per worker when we consider consistent values of the excess burden. The average daily ratio of excess burden to tax revenue at this taxation treatment is evaluated at 0.39.

Table 6: Daily excess burden per worker by treatment based on worker's reported reservation base wage

		Excess burden		Ratio of excess burden to tax revenue	
	Statistics	All	Consistent	All	Consistent
Taxation of 4 cents per tree	Average	38.53	41.72	56.18%	60.46%
	sd	32.10	30.70	72.23%	72.81%
	Minimum	-14.20	0.40	-9.21%	0.33%
	Maximum	114.00	114.00	438.46%	438.46%
	Observations	46	43	46	43
Taxation of 6 cents per tree	Average	37.68	42.74	34.91%	39.24%
	sd	28.12	24.80	39.02%	38.77%
	Minimum	-12.80	0.00	-7.41%	0.00%
	Maximum	99.40	99.40	177.78%	177.78%
	Observations	40	36	40	36
All treatments	Average	38.14	42.18	46.29%	50.79%
	sd	30.14	28.00	59.79%	60.35%
	Minimum	-14.20	0.00	-9.21%	0.00%
	Maximum	114.00	114.00	438.46%	438.46%
	Observations	86	79	86	79

Table 7: Total excess burden generated by the experiment based on worker's reported reservation base wage

	Taxation of 4cent per tree		Taxation of 6cent per tree		All treatement	
	All	Consistent	All	Consistent	All	Consistent
Total tax revenue (EB_T)	1772.60	1794.00	1507.10	1538.50	3279.70	3332.50
Total excess burden (TX_T)	4127.40	3746.00	5772.90	5041.50	9900.30	8787.50
Ratio (EB_T/TX_T)	42.95%	47.89%	26.11%	30.52%	33.13%	37.92%
Obs	46	43	40	36	86	79

6.2.2 Structural Estimates of the excess burden

We evaluate the excess burden expressed in equation (26) using our estimated structural parameters. As indicated in equation (26), it is always positive. In Table 8, we present summary statistics of the structural estimates of the excess burden and that of the ratio of the excess burden to tax revenue on experimental observations.

The average daily excess burden predicted by Model 1 and Model 2 at the taxation treatment of 4 cents per tree is C$1.46 and C$1.67 respectively. At this taxation treatment, average daily ratio of excess burden to tax revenue predicted by Model 1 and Model 2 is respectively 1.53% and 1.86%. These values are small in comparison to those found in Table 6 for the unrestricted estimate: C$41.72 for the excess burden and 60.48% for the ratio of excess burden to tax revenue.

At the taxation treatment of 6 cents per tree, Model 1 and Model 2 predict an average daily excess burden of C$4.09 and C$5.05 respectively. Average daily ratio of excess burden to tax revenue predicted by Model 1 and Model 2 is respectively 2.72% and 3.30%. These values are much smaller than their non-structural counterparts found in Table 6: C$42.74 for the excess burden and 39.24% for the ratio of excess burden to tax revenue. In section 7 below, we compare more formally the structural and non-structural estimates of the excess burden.

Table 8: Daily excess burden per worker by treatment based on structural estimates

		Excess burden		Ratio of excess burden to tax revenue	
Treatment	Statistics	Model 1	Model 2	Model 1	Model 2
Taxation of 4 cents per tree	Average	1.46	1.67	1.53%	1.86%
	sd	0.59	0.75	0.29%	0.35%
	Minimum	0.49	0.64	1.17%	1.42%
	Maximum	2.77	3.16	1.90%	2.30%
	Observations	46	46	46	46
Taxation of 6 cents per tree	Average	4.09	5.05	2.72%	3.30%
	sd	1.54	2.18	0.42%	0.51%
	Minimum	1.33	1.69	1.92%	2.32%
	Maximum	6.88	9.31	3.16%	3.85%
	Observations	40	40	40	40
All treatments	Average	2.68	3.24	2.08%	2.53%
	sd	1.74	2.31	0.69%	0.84%
	Minimum	0.49	0.64	1.17%	1.42%
	Maximum	6.88	9.31	3.16%	3.85%
	Observations	86	86	86	86

7 In sample prediction of Model 1 and Model 2

Using estimated structural parameters and equations 12 and 24, we compute predicted government tax revenue per worker and worker's minimum base wage (reservation base wage) at observed tax rates during the experiment[16]. These values are then compared to actual tax revenue paid by the worker and reported reservation base wage during the experiment. We also compare the excess burden based on worker's reported reservation base wage (non-structural estimate of the excess burden) to predicted values from Model 1 and Model 2 (structural estimate of the excess burden).

Figure 7 shows comparison between actual tax revenue per worker and predicted tax revenue at

[16]The taxation treatment of 4 cents and 6 cents per tree correspond to tax rates ranging from 15% to 33% depending on the standard piece rate in place during the experiment

observed tax rates during the experiment. Both Model 1 and Model 2 fit the data quite well. The predictions of Model 2 fit the actual tax revenue much better than those of Model 1.

Figure 8 shows comparison between predicted worker's reservation base wage and actual reservation base wages, as reported during the experiment. Here, we see that the models do not fit the reported data very well. Predicted base wages are consistently below their actual values, as reported during the experiment.

Figure 7: Actual tax revenue vs Predicted tax revenue

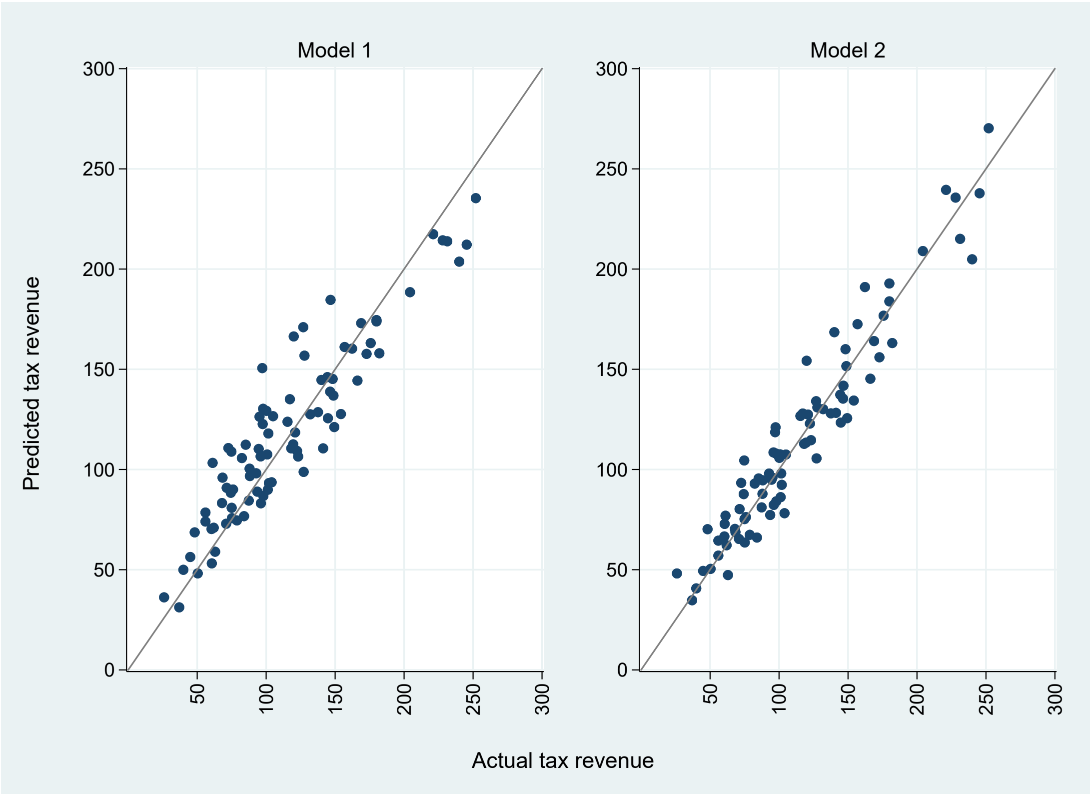


Figure 8: Reported reservation base wage vs Predicted reservation base wage

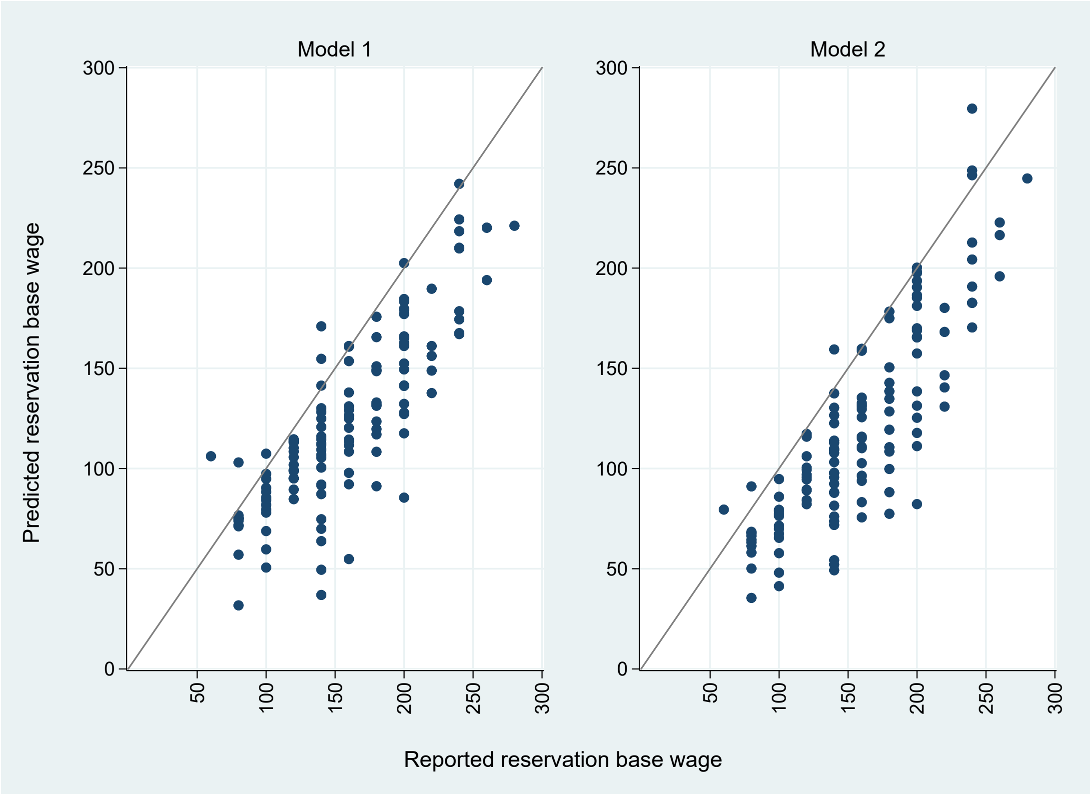


Figure 9 shows comparison between the non-structural and structural estimates of the excess burden. Figure 10 shows comparison between the non-structural and structural estimates of the ratio of the excess burden to tax revenue. In general, structural estimates are much smaller than their non-structural counterparts. Both Model 1 an Model 2 have difficulties in matching the non-structural estimates. This holds on the inability of both models (Model 1 and Model 2) to predict reported reservation base wage $b^*_{i\tau}$ as shown in figure 8.

Figure 9: Non-structural and Structural estimates of excess burden

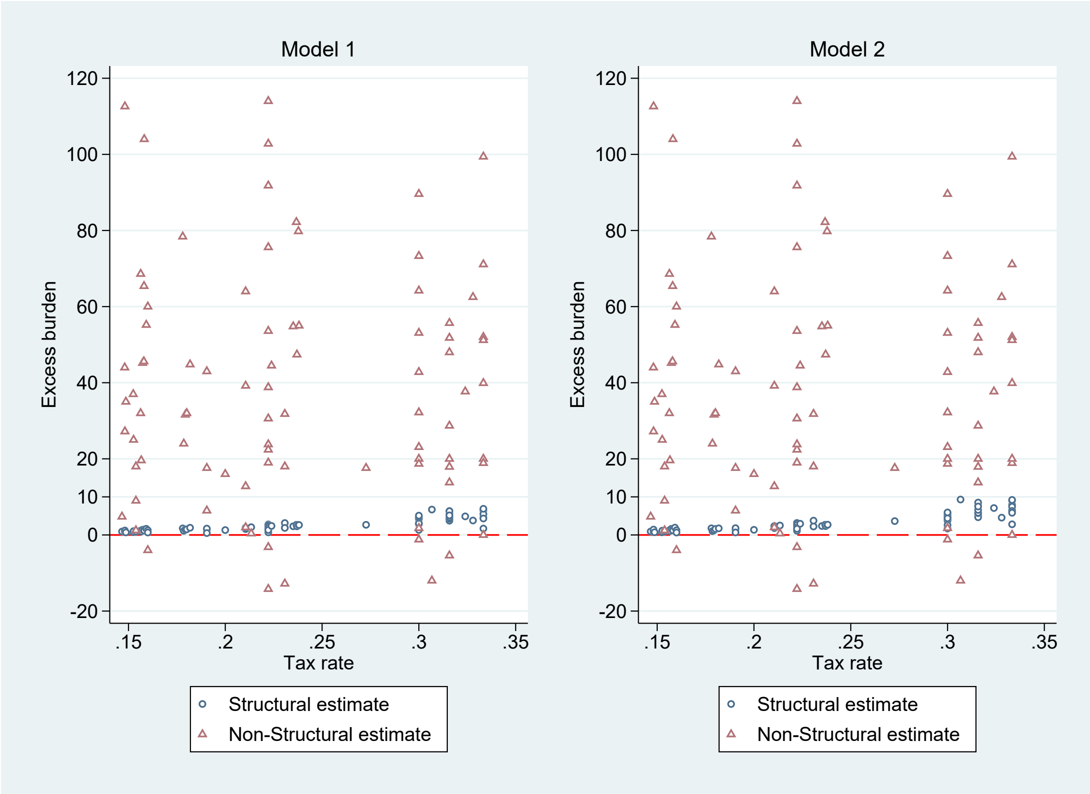
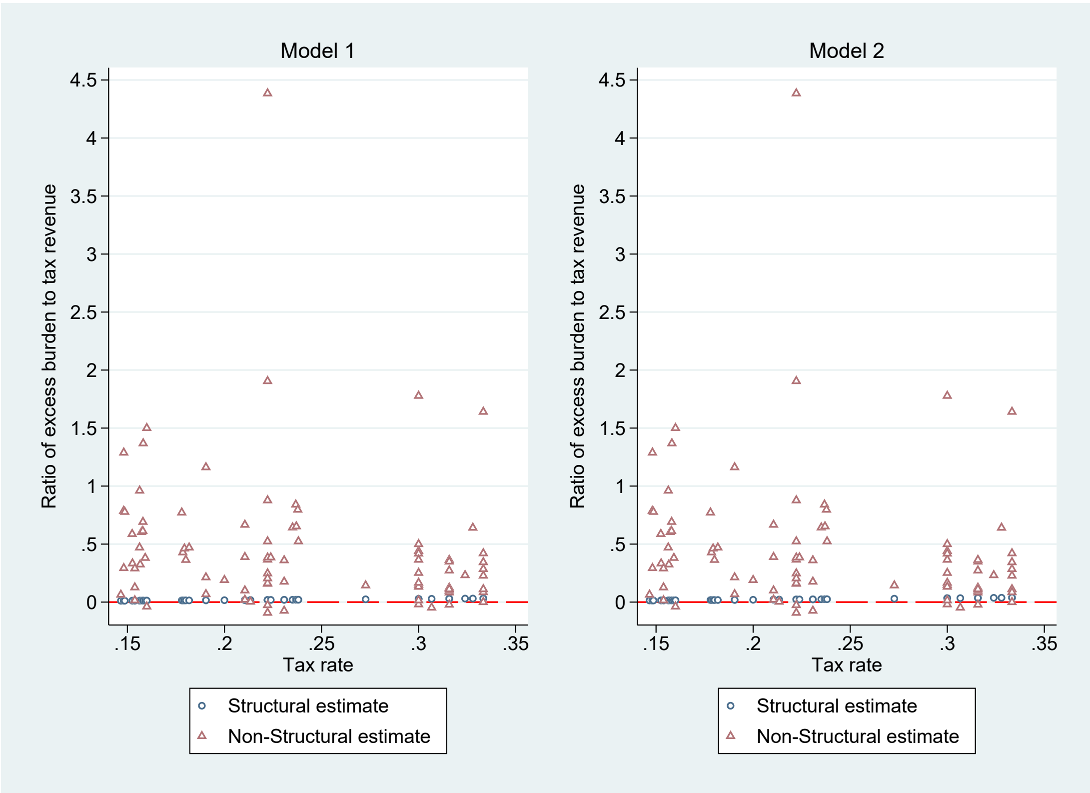


Figure 10: Non-structural and Structural estimates of the ratio excess burden to tax revenue



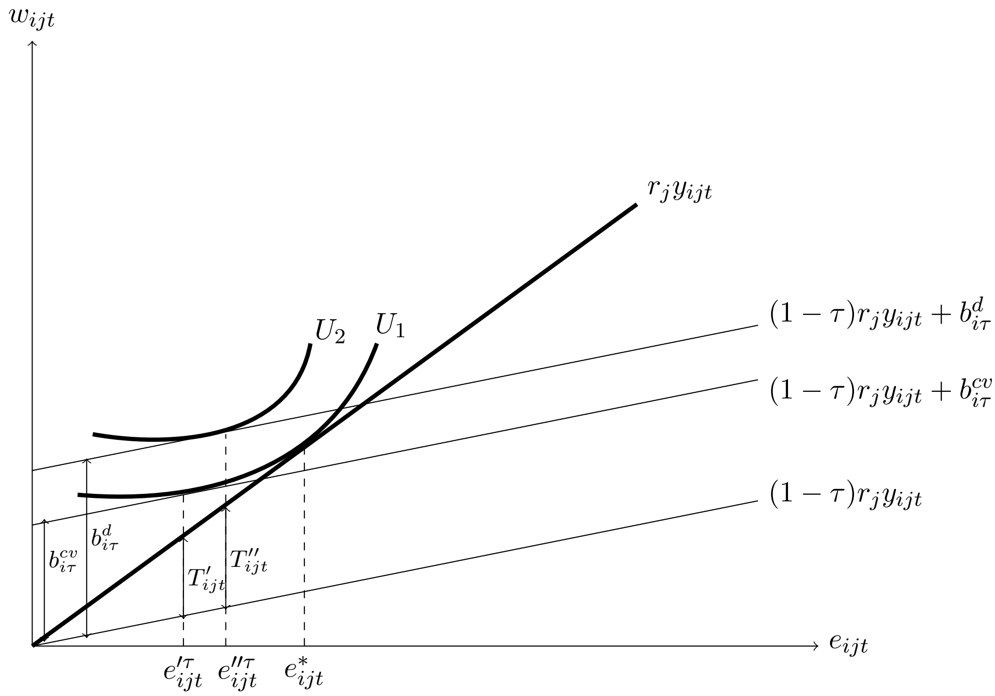
The structural estimates of the excess burden are determined by the value of the structural parameters. Equation (26) shows that a higher γ results in a higher excess burden. We estimated a value of γ of 0.17 for Model 2 (0.14 for Model 1) which are quite small and may play a role in explaining the low values of the predicted structural excess burden compared to their non-structural counterparts. Estimation of γ is determined by the change in the output following the taxation. To date, our modeling has ruled out base-wage (or income) effects. This is potentially important because the worker randomly drew a base wage during the experiment to determine his/her contract. If the drawn base wage is greater than his/her reservation base wage, the worker would earn rents. In the presence of base-wage effects, these rents can affect productivity. The observed change in productivity would then be the sum of two effects : the base-wage effect and the tax-induced effect. These two effects are subsumed in γ unless they are disentangled. The excess burden focuses solely on tax-induced effects and any base wage effect must consequently be purged out.

Figure 11 illustrates how in our setting worker's change in productivity is affected by both the taxation and the amount of the base wage. At taxation level τ and base wage level corresponding to the compensating variation $b_{i\tau}^{cv}$, worker's effort decreases from e_{ijt}^{*} to $e_{ijt}^{\prime\tau}$. The collected tax revenue is given by $T_{ijt}^{\prime}$. The difference between $b_{i\tau}^{cv}$ and $T_{ijt}^{\prime}$ gives the excess burden of taxation. When the base wage rises above the compensating variation $b_{i\tau}^{cv}$ to $b_{i\tau}^{d}$ which is observed in the experiment, the worker can attain a higher utility $U_2 > U_1$.

In the presence of base-wage effects, this increase in utility can affect effort. As drawn, this effect is positive. Consequently, the worker's effort increases to $e_{ijt}^{\prime\prime\tau}$ which is greater than $e_{ijt}^{\prime\tau}$. In such a case, the base-wage effect counteracts the effect of taxation. Tax revenue collected at $b_{i\tau}^{d}$ is given by $T_{ijt}^{\prime\prime}$ and is higher than $T_{ijt}^{\prime}$ when the base wage corresponds to the compensating variation $b_{i\tau}^{cv}$. This results in a lower excess burden (difference between the compensating variation and tax revenue) when structural parameters are identified from observed change in productivity without accounting for base wage effects.

The presence of base wage effects biases our evaluation of the excess burden (both the structural and non-structural estimates) in previous sections in two ways. Firstly, observed change in productivity and consequently tax revenues contained both tax-induced effects and base wage effects. The latter need to be purged out when computing the excess burden. Secondly, $b_{i\tau}^{*}$ that equates maximum expected utility under the taxation contract and the no taxation contract (and so reported workers' $b_{i\tau}^{*}$) no longer represents the worker's compensating variation $b_{i\tau}^{cv}$. Indeed, in the presence of base wage effects, $b_{i\tau}^{*}$ is the worker's compensation that subsumes both base wage effects and tax-induced effects whereas $b_{i\tau}^{cv}$ (compensating variation) focuses solely on tax-induced effects. In section 8, we discuss these issues and evaluate the excess burden in the presence of base wage effects.

Figure 11: Base wage effects and Excess burden of taxation



8 Accounting for base-wage effects

To account for base-wage effects, we redefine the worker's cost function in equation (3) to account for base wage effects. The new cost function is expressed as :

$$C_i(e_{ijt}) = \frac{k_i e_{ijt}^{\eta}}{\eta} \qquad \text{with} \qquad k_i = \exp\left(\lambda_i + \alpha_i b_{i\tau}\right) \quad \text{and} \quad \eta > 1 \tag{27}$$

This new cost function differs from the initial one expressed in equation (3) by a multiplicative factor of $\exp\left(\alpha_i b_{i\tau}\right)$. The coefficient α_i - which can be positive or negative - captures the base wage effect. When α_i is zero, there is no base wage effect and the two cost functions (and effort choices) are identical.Apart the adjustment in the worker's cost function, we adopt the same behavioral modeling (utility function, timing, participation constraint) as developed in section 5.

The optimal effort that maximizes worker's utility in this new setting is given by :

$$e^{*}_{ijt} = \Big[\frac{(1-\tau)r_j s_{ij} d_t}{\exp\left(\lambda_i + \alpha_i b\right)}\Big]^{\gamma} \qquad \text{with} \qquad \gamma = \frac{1}{\eta - 1} \tag{28}$$

Worker's optimal effort is now affected by both the tax rate τ and base wage $b_{i\tau}$. The elasticity of the worker's effort with respect to the marginal tax rate τ remains the same as in previous sections:

$$\xi = -\frac{\tau}{1-\tau}\gamma$$

The elasticity of worker's effort with respect to the base wage is given by :

$$\zeta = -\alpha_i \gamma b_{i\tau} \tag{29}$$

This elasticity characterizes effort as an "inferior good" ($\alpha_i \geq 0$) or a "normal good" ($\alpha_i < 0$). The base wage has a disincentive effect on the productivity when effort is an "inferior good" and an incentive effect when effort is a "normal good". Numerous studies have documented the possibility of a positive relationship between wages and effort. The positive reciprocity literature show how workers reciprocate to wage increases by increasing their effort (Akerlof and Yellen; 1988, 1990; Gneezy and List; 2006; Cohn et al.; 2015; Sliwka and Werner; 2017; Cobo-Reyes et al.; 2017; Charness et al.; 2020).[17]

Due to the high number of parameters to estimate, we impose $\alpha_i = \alpha \; \forall i$ making our modeling more parsimonious in parameters. The derived monetized productivity which now accounts for base wage effects is given :

$$\begin{aligned}\log r_j y^*_{ijt} =& \log(\bar{w}) + \log(\gamma+1) + \gamma \log(1-\tau) + \gamma(\lambda_h - \lambda_i) - \frac{1}{2}(\gamma+1)^2\sigma_j^2 + (\gamma+1)\log d_t \boldsymbol{-\gamma\alpha b_{i\tau}} \\ &+ \underbrace{(\gamma+1)\log s_{ij} - (\gamma+1)\mu_j}_{\epsilon_{ij}} \quad \text{with} \quad \epsilon_{ij} \sim N(0, (\gamma+1)^2\sigma_j^2)\end{aligned} \tag{30}$$

Compared to the structural equation (10), there is an additional term $-\gamma\alpha b_{i\tau}$ which accounts for the base wage effects. The corresponding regression model in this setting that we note as Model 3 is

$$\log r_j y^*_{ijt} = \begin{cases} \beta_0 + \beta_1 \log(1-\tau) + \sum_{i=1}^{N_w-1} \beta_{2i} DI_i + \sum_{j=1}^{N_b} \beta_{3j} DB_j + \sum_{t=1}^{N_d-1} \beta_{4t} DD_t + \beta_5 b_{i\tau} + \epsilon_{ij} & \text{if } D_{it} = 1 \\ \\ \beta_0 + \sum_{i=1}^{N_w-1} \beta_{2i} DI_i + \sum_{j=1}^{N_b} \beta_{3j} DB_j + \sum_{t=1}^{N_d-1} \beta_{4t} DD_t + \epsilon_{ij} & \text{if } D_{it} = 0 \end{cases} \tag{31}$$

with

$$D_{it} = 1_{\{b^d_{i\tau} \geq b^*_{i\tau}\}}$$

Where $\epsilon_{ij} \sim N(0, \theta_j^2)$, $\beta_{3j} = -\frac{\theta_j^2 \delta_h}{2}$, $\beta_5 = -\gamma\alpha$, $D_{it} = 1_{\{b^d_{i\tau} \geq b^*_{i\tau}\}}$; $b^d_{i\tau}$ is the base wage drawn by the worker when randomly assigned to the taxation contract and $b^*_{i\tau}$ is the reservation base wage indicated by the worker to accept the taxation contract.

Similarly to identification strategy in section 5.2, maximum likelihood of equation 31 identifies γ, σ_j^2, $(\lambda_h - \lambda_i)$ and the base wage effect parameter α. If the marginal worker is in the experimental data and known, then we can also identify $\bar{w}$.

Estimation of equation (31) is given in Table 9. As we account for base wage effect in Model 3, the value of γ increases considerably. It rises from 0.14 in Model 1 (0.17 in Model 2, see Table 4)[18]

[17] Riley and Bondibene (2017); Zhao and Sun (2021); Ku (2022) and Coviello et al. (2022) have also showed how increases in minimum wage can raise productivity.

[18] We focus on structural estimates

to 0.78. This shows that both base wage and taxed induced effects were subsumed in parameter γ in previous estimates - explaining its low value. The base wage effect was counteracting the tax induced effects (see Figure 11). Indeed the base wage parameter α in Model 3 is estimated at -0.0008. It is statistical significant and negative implying that effort is a "normal good" as seen in equation (9). Thus the base wage has an incentive effect which induces workers to produce more, counterbalancing the effect of taxes in previous estimates. In term of performance, Model 3 which accounts for base wage effects also displays a better Bayesian Information Criterion (BIC).

Given the structural estimate of γ of 0.7853 based on Model 3, estimated output and effort elasticity with respect to the tax rate equal to -0.139, -0.196 and -0.262 for tax rates of 15%, 20% and 25% respectively. Hence for an average daily production of 2000 trees per worker and an initial tax rate of 15%, an increase of 10% of the tax rate will induce a decline of daily production of 28[19] trees per worker. This daily decline will be of 39 and 52 trees for initial tax rates of 20% and 25% respectively. These estimates are about 4.5 times larger than those found in Model 1 and Model 2 which did not account for the base-wage effects.

[19] A 1% increase in the tax rate would reduce production by 0.1389*2000=2.78 trees. A 10% reduction would reduce production by 10*2.78 = 27.8 trees per day.

Table 9: Structural estimation of Model 3

	Structural Model
γ	0.7853***
	(0.1637)
α	-0.0008***
	(0.0001)
β_0	5.6099***
	(0.0769)
$\lambda_I - \lambda_{Min}$	1.1878***
	(0.2638)
$\lambda_I - \lambda_{Max}$	-0.5282***
	(0.1583)
σ^2_{Max}	0.0229***
	(0.0068)
σ^2_{Min}	0.0000**
	(0.0000)
$\frac{d_T}{d_{Min}}$	1.2099***
	(0.021)
$\frac{d_T}{d_{Max}}$	1.0090***
	(0.026)
Individual effect	yes
Day-specific effect	yes
Observations	258
BIC	-0.521

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The calculation of the excess burden based on the reported base wages ($b^*_{i\tau}$) in Tables 6 and 7 relied on the assumption that there are no base wage effects in productivity. In the presence of base wage effects, excess burden is assessed through structural estimates which enables us to net out the base-wage effect and focus solely on the distortion generated by taxes. Using estimates from Model 3, we recompute the excess burden of taxation as

$$\begin{aligned} \mathbb{E}[EBCV_{ijt}] =& b^{cv}_{i\tau} - T_{ijt} \\ =& b^{cv}_{i\tau} - r_j \times y_{ijt}|_{(b^{cv}_{i\tau}=0,\tau)} \times \tau \end{aligned} \tag{32}$$

$b^{cv}_{i\tau}$ is the compensating variation -the additional income independent from production required by the worker to accept taxation level τ. It solves for

$$\underbrace{\bar{w}d_t^{\gamma+1}\exp^{\gamma(\lambda_h-\lambda_i)}}_{E_{pc}[U_i(w_{ijt},e_{ijt}|_{(b^{cv}_{i\tau}=0,\tau=0)})]} = \underbrace{b^{cv}_{i\tau} + (1-\tau)^{\gamma+1}\bar{w}d_t^{\gamma+1}\exp^{\gamma(\lambda_h-\lambda_i)}}_{E_{bc}[U_i(w_{ijt}(b^{cv}_{i\tau}),e_{ijt}|_{(b^{cv}_{i\tau}=0,\tau)})]} \tag{33}$$

Where E_{pc} is the expected utility under the standard piece rate contract without taxation and E_{bc} is the expected utility under the base wage contract with taxation. Substituting equation (28) in the worker's expected utility under the base wage contract with taxation introduces a base wage effect that affects productivity. We eliminate this base wage effect by setting it to zero in order to focus solely on the tax-induced effect. The compensating variation enters equation (33) only as an additional income to enable the worker attain his initial pretax utility. By eliminating the wage effect in equations (32) and (33), we also ensure that taxes and excess burden are evaluated at the same effort $(e_{ijt}|_{(b^{cv}_{i\tau}=0,\tau)})$ and consequently the same productivity level. Solving equation (33) and taking the expected value of equation (32) yield equation (34).

$$\begin{aligned}\mathbb{E}[EBCV_{ij}] &= b^{cv}_{i\tau} - r_j \times y_{ijt}|_{(b^{cv}_{i\tau}=0,\tau)} \times \tau \\ &= [1-(1-\tau)^{\gamma+1} - \tau(1-\tau)^{\gamma}(\gamma+1)]\bar{w}d_t^{\gamma+1}\exp^{\gamma(\lambda_h-\lambda_i)}\end{aligned} \tag{34}$$

In the presence of base wage effects, the compensation $b^*_{i\tau}$ that equates maximum expected utility under the taxation contract and the no taxation contract differs from the compensating variation $b^{cv}_{i\tau}$. The latter ($b^{cv}_{i\tau}$) is evaluated at $E_{bc}[U_i(w_{ijt}(b^{cv}_{i\tau}), e_{ijt}|_{(b^{cv}_{i\tau}=0,\tau)})]$ whereas the former ($b^*_{i\tau}$) is evaluated at $E_{bc}[U_i(w_{ijt}(b^*_{i\tau}), e_{ijt}|_{(b^*_{i\tau},\tau)})]$. Indeed, in the presence of base wage effects, $b^*_{i\tau}$ is the worker's compensation that subsumes both base wage effects and tax-induced effects whereas $b^{cv}_{i\tau}$ (compensating variation) focuses solely on tax-induced effects. When there is no base wage effects $b^*_{i\tau}$ and $b^{cv}_{i\tau}$ are equal. Structural and non-structural estimates of the excess burden in previous sections assumed there is no base wage effects which biased our results.

Table 10 presents summary statistics of the excess burden using structural estimates of Model 3 that accounts for base wage effects. In Figure 12, we graph the excess burden derived from Model 3 for different values of our experimental tax rates and compare them with estimates from Model 1 and Model 2. The left panel of Figure 12 shows the worker's excess burden whereas the right panel presents the ratio of the excess burden to the tax revenue. Model 1 and Model 2 don't account for base wage effects whereas Model 3 account for base wage effects.

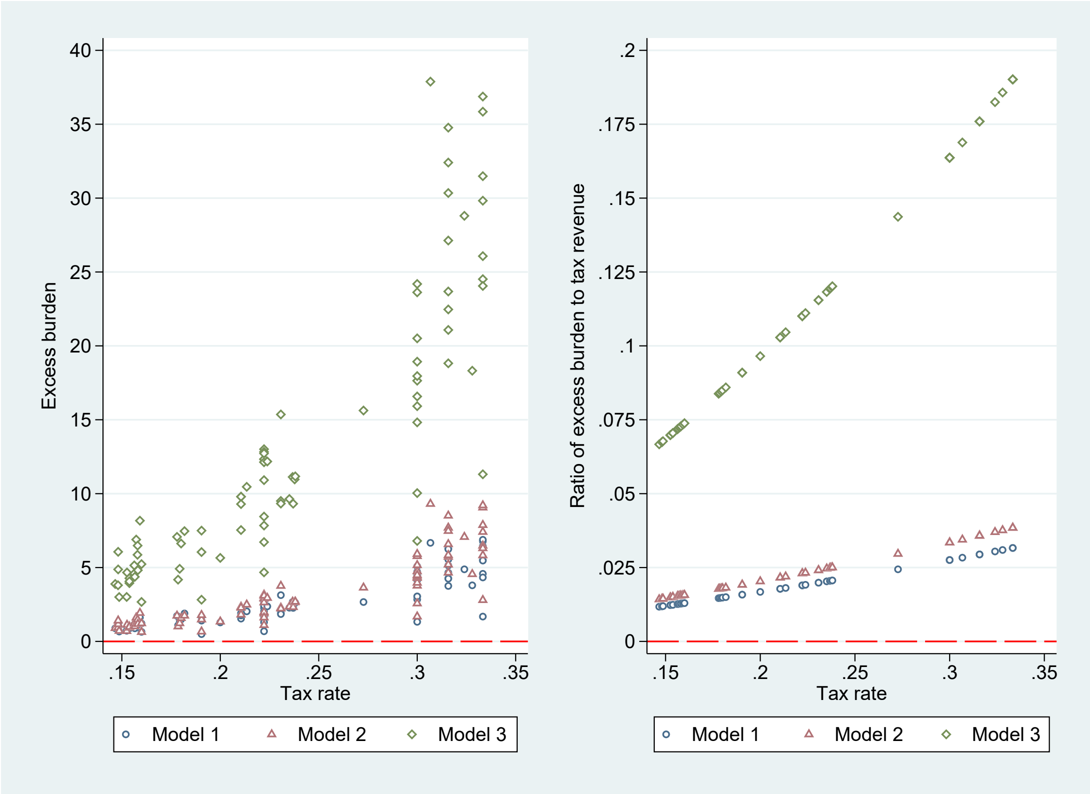
As we account for base wage effects in Model 3, the value of the excess burden increases significantly for all tax rates as seen in Figure 12. Daily average excess burden increased more than fourfold to C$13.23 in Model 3. They were evaluated at C$2.68 and C$3.24 respectively in Model 1 and Model 2 (see Table 8). The ratio of excess burden to tax revenue also rise significantly from 2.08% in Model

1 (2.53% in Model 2) to 12.22% in Model 3. These increases in the excess burden and the improved model fit show the importance of accounting for base wage effects.

Table 10: Daily excess burden per worker by treatment based on structural estimates of Model 3

Treatment	Statistics	Excess burden	Ratio of excess burden to tax revenue
Taxation of 4 cents per tree	Average	6.98	8.79%
	sd	3.11	1.71%
	Minimum	2.67	6.67%
	Max	13.01	11.01%
	Obs	46	46
Taxation of 6 cents per tree	Average	20.42	16.16%
	sd	8.79	2.65%
	Minimum	6.80	11.11%
	Max	37.88	19.02%
	Obs	40	40
All treatments	Average	13.23	12.22%
	sd	9.28	4.30%
	Minimum	2.67	6.67%
	Max	37.88	19.02%
	Obs	86	86

Figure 12: Structural estimation of Excess burden from Model 1, Model 2 and Model 3



9 Accounting for risk preference

Since the taxation contract introduces a base wage and hence some insurance to daily earnings, worker decisions may be affected by their risk preferences. To consider the role of risk preferences, we now consider a CRRA utility function defined over worker's net daily earnings and effort [20] :

$$U_i(w_{ij}, e_{ij}) = \begin{cases} \frac{1}{\delta_i}(w_{ij} - C_i(e_{ij}))^{\delta_i} & \text{if} \quad w_{ij} > C_i(e_{ij}) \\ -\infty & \text{otherwise} \end{cases} \tag{35}$$

Where δ_i is the worker's risk preference parameter. This utility function nests the previous one in equation (2) where all workers were assumed risk neutral ($\delta_i = 1$). We maintain the same timing and participation constraint as developed in 5 and adopt the cost function in equation (27) that incorporates base wage effects.

Optimal effort that maximizes utility remains unchanged as in equation (28). It is independent of risk as there is no uncertainty given workers observe the productivity shock s_{ij} before selecting their effort level. The participation constraint defined for the marginal worker in equation (8) to determine the firm's piece rate r_j becomes

$$E_{pc}[U_h(\overset{*}{w}_{ij}, \overset{*}{e}_{ij})] = \bar{u} = \frac{1}{\delta_h}\bar{w}^{\delta_h}$$

[20]These are the same preferences used in Bellemare and Shearer (2013) to analyze the importance of risk and matching.

Equation (36) introduces the marginal worker's risk preference δ_h as an extra parameter multiplying the block variances σ_j^2 in the worker's monetized productivity equation. The monetized productivity equation is now given as

$$\begin{aligned}\log r_j y_{ijt}^* =& \log(\bar{w}) + \log(\gamma+1) + \gamma \log(1-\tau) + \gamma(\lambda_h - \lambda_i) - \frac{1}{2}(\gamma+1)^2 \delta_h \sigma_j^2 + (\gamma+1)\log d_t - \gamma\alpha b_{i\tau} \\ &+ \underbrace{(\gamma+1)\log s_{ij} - (\gamma+1)\mu_j}_{\epsilon_{ij}} \quad \text{with} \quad \epsilon_{ij} \sim N(0, (\gamma+1)^2\sigma_j^2)\end{aligned} \tag{36}$$

As the marginal worker is unknown, we assume for simplicity $\delta_h = 1$. Equation (36) then replicates equation (30) above. Assuming $\delta_h = 1$ does not affect previous estimates in section 8 apart from the identification of the block variances σ_j^2 which is of secondary importance in this paper. In fact, the introduction of risk preferences does not affect the estimation of structural parameters. It does, however, affects the worker's compensating variation and thus the evaluation of the excess burden. The worker's compensating variation $b_{i\tau}^{cv}$ is given as the solution of

$$E_{pc}[U_i(w_{ijt}, e_{ijt}|_{(b_{i\tau}^{cv}=0,\tau=0)})] = E_{bc}[U_i(w_{ijt}(b_{i\tau}^{cv}), e_{ijt}|_{(b_{i\tau}^{cv}=0,\tau)})]$$

Expanding on this equation in the case of risk preference yields

$$\underbrace{\frac{1}{\delta_i}\bar{w}^{\delta_i} d_t^{\delta_i(\gamma+1)} \exp^{\delta_i\gamma(\lambda_h-\lambda_i)+\frac{1}{2}\delta_i(\gamma+1)^2(\delta_i-\delta_h)\sigma_j^2}}_{E_{pc}[U_i(w_{ijt}, e_{ijt}|_{(b_{i\tau}^{cv}=0,\tau=0)})]} = \underbrace{\frac{1}{\delta_i} E\left[\left(b_{i\tau}^{cv} + (1-\tau)^{\gamma+1}\bar{w} d_t^{\gamma+1} s_{ij}^{\gamma+1} \exp^{\gamma(\lambda_h-\lambda_i)-[(\gamma+1)\mu_j+\frac{1}{2}(\gamma+1)^2\delta_h\sigma_j^2]}\right)^{\delta_i}\right]}_{E_{bc}[U_i(w_{ijt}(b_{i\tau}^{cv}), e_{ijt}|_{(b_{i\tau}^{cv}=0,\tau)})]} \tag{37}$$

The compensating variation $b_{i\tau}^{cv}$ is now not only function of the tax rate, the worker's ability but also function of the worker's risk preference and consequently so is the excess burden. We face a couple of complexities in evaluating the worker's compensating variation and the excess burden in the presence of risk preference. Firstly, we no longer have, a closed-form solution for $b_{i\tau}^{cv}$ as in equation (34). Secondly, we need estimates of each worker's risk preference parameter δ_i.

We use a Holt and Laury (2002) lottery experiment to measure each participant's risk preferences. This experiment consists of a series of choices between two lotteries (one riskier than the other for different levels of odds). During the experiment, workers are asked to make 10 decisions. For each decision there is a safe lottery (lottery A) and risky lottery (Lottery B). The realization of the high or low payoffs is determined by chance. The actual decision sheet and lottery instructions are presented in Appendix B.

For the first decision, the probability of the high payoff for both lotteries is 10%, so only an extreme risk-lover would choose lottery B. The probability of winning the high payoff increases gradually for the subsequent decisions, increasing the relative payoff of the risky lottery B. It is of 20% for the second decision, 30% for the third decision etc and 100% for the tenth decision which is the last decision of the Decision sheet. Consequently, an individual should eventually cross over and start choosing lottery B (the risky lottery) over lottery A (the safe lottery) as the probability of winning the high payoff of the lotteries increases. In fact, for the last decision, the high payoff of each lottery is realized with certainty (probability of 100%). The number of safe choices refers to the total number of choice of the safe lottery (Lottery A) over the risky lottery (Lottery B). A consistent lottery decision pattern is established when there is a unique cross point between the safe lottery and the risky lottery. Indeed, once the worker switches from the safe lottery to the risky lottery at a given point, economic rationality keeps him from switching back to the safe lottery at higher points.

The pattern of lottery decisions chosen by the individual in the Holt and Laury experiment can be related to the constant relative risk aversion utility function (CRRA) defined in equation (35). This pattern gives an interval estimate of the individual's risk preference parameter (δ_i) depending on the point at which a worker switches from the safe to the risky lottery. Following Bellemare and Shearer (2013), we use the mid-point of the relevant interval as our estimate of each worker's value of delta.

Table 11 presents the distribution of risk preference among workers involved in our contract choice experiment. It shows that 56% of the workers are risk neutral or slightly risk-averse. While 28% of the workers are considered risk-averse, evidence of strong risk aversion can be established for only 14% of the workers. A weaker proportion of less than 3% appears to be risk-lovers.

Table 11: Distribution of lottery choice

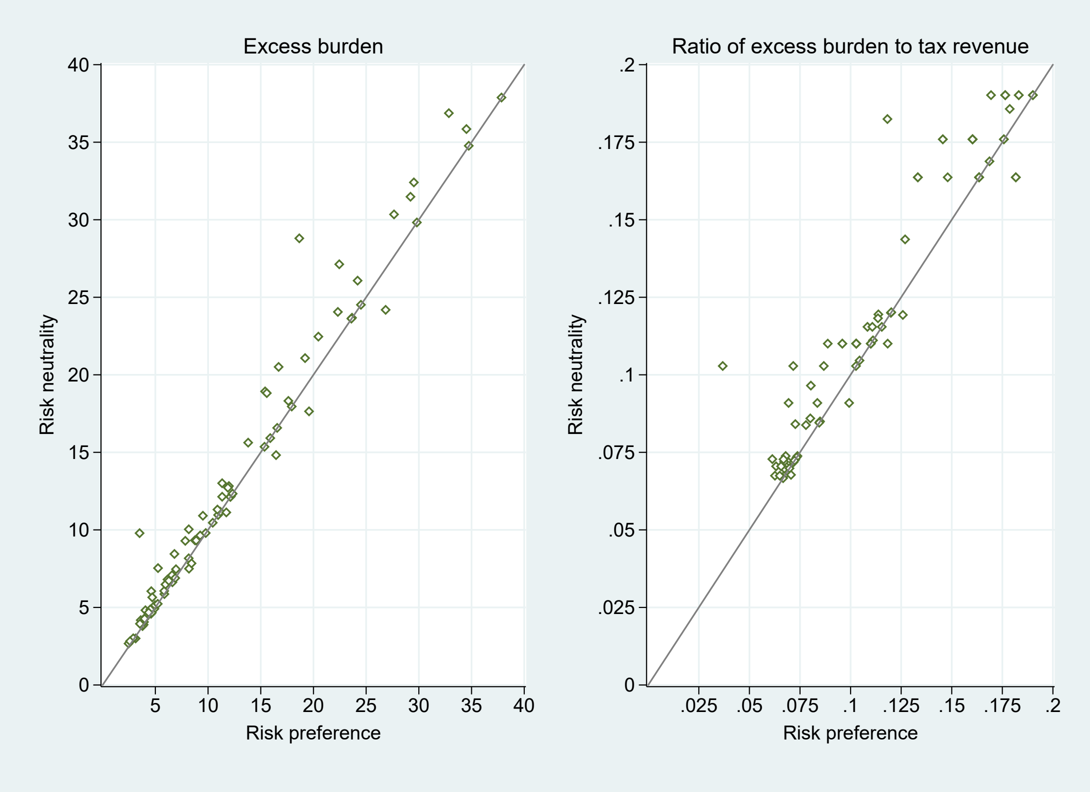
Number of safe choices	$U = \frac{1}{\delta}x^{\delta}$	Risk type	Cumulative distribution	
			All	Consistent [21]
0-1	$\delta > 1.95$	Extreme risk loving	0.000	0.000
2	$1.49 < \delta \leq 1.95$	High risk loving	0.000	0.000
3	$1.14 < \delta \leq 1.49$	Risk loving	0.054	0.028
4	$0.85 < \delta \leq 1.14$	Risk neutral	0.324	0.306
5	$0.59 < \delta \leq 0.85$	Weak risk averse	0.595	0.583
6	$0.32 < \delta \leq 0.59$	Risk averse	0.865	0.861
7	$0.03 < \delta \leq 0.32$	High risk averse	0.973	0.972
8	$-0.37 < \delta \leq 0.03$	Very high risk averse	1.000	1.000
9-10	$\delta \leq -0.37$	Extreme risk averse	1.000	1.000
Sample			37	36

We used structural estimates of Model 3 and our estimates of δ_i from the lottery experiment to

[21] Only one worker showed an inconsistent decision pattern. An inconsistent decision patterns happens when the worker has more than two cross points. This situation which expresses a non-orthodox behavior, may occur if the worker misunderstood the lottery instructions or is motivated by principles other than economic rationality.

derive worker's compensating variation in equation (37) and consequently evaluate the excess burden. Figure 13 compares excess burden in the presence of risk preference to previous estimates when we implicitly assume all workers are risk neutral. The left panel of the graph shows the worker's excess burden whereas the right panel presents the ratio of the excess burden to the tax revenue. The horizontal axes accounts for risk preference and the vertical axes assume risk neutrality. Figure 13 shows that the excess burden is, in general, slightly smaller when we account for risk preference.

Figure 13: Excess burden under risk preference using structural estimates of Model 3



10 Prediction of contract choice in the presence of base wage effects and risk preference

The introduction of base wage effects and risk preference in our modeling does not only affect the evaluation of the compensating variation and the excess burden. But it also affects predictions derived in section 5.1 regarding workers' choices in the contract choice experiment. In the presence of base wage effects and risk preference, the value of the lump-sum payment (compensation) $b^*_{i\tau}$ that renders the worker indifferent between the taxation contract with base wage and the regular piece rate contract with no taxation is obtained by solving

$$\underbrace{\frac{1}{\delta_i}\bar{w}^{\delta_i} d_t^{\delta_i(\gamma+1)} \exp^{\delta_i\gamma(\lambda_h-\lambda_i)+\frac{1}{2}\delta_i(\gamma+1)^2(\delta_i-\delta_h)\sigma_j^2}}_{E_{pc}[U_i(w_{ijt},e_{ijt}|_{(b^*_{i\tau}=0,\tau=0)})]} = \underbrace{\frac{1}{\delta_i}E\Big[\Big(b^*_{i\tau}+(1-\tau)^{\gamma+1}\bar{w}d_t^{\gamma+1}s_{ij}^{\gamma+1}\exp^{\gamma(\lambda_h-\lambda_i)-[(\gamma+1)\mu_j+\frac{1}{2}(\gamma+1)^2\delta_h\sigma_j^2]-\gamma\alpha_i b^*_{i\tau}}\Big)^{\delta_i}\Big]}_{E_{bc}[U_i(w_{ijt}(b^*_{i\tau}),e_{ijt}|_{(b^*_{i\tau},\tau)})]} \tag{38}$$

The compensation $b^*_{i\tau}$ that equates maximum expected utility under the taxation contract and the no taxation contract differs from the compensating variation $b^{cv}_{i\tau}$ in the sense that the latter is evaluated at $E_{bc}[U_i(w_{ijt}(b^{cv}_{i\tau}), e_{ijt}|_{(b^{cv}_{i\tau}=0,\tau)})]$ whereas the former is evaluated at $E_{bc}[U_i(w_{ijt}(b^*_{i\tau}), e_{ijt}|_{(b^*_{i\tau},\tau)})]$. There is an additional term $\exp^{-\gamma\alpha_i b^*_{i\tau}}$ affecting productivity which appears when evaluating $b^*_{i\tau}$. In the absence of base wage effects, $b^*_{i\tau}$ equals to $b^{cv}_{i\tau}$. Otherwise $b^*_{i\tau}$ is less than $b^{cv}_{i\tau}$ if the base wage has incentive effects on productivity ($\alpha_i < 0$). Though there is no closed form for $b^*_{i\tau}$ except in the absence of base wage effects and risk neutrality, we can still have useful insight on worker's contract choice.

Result 10. *If $\alpha_i\gamma b_{i\tau} < (\gamma+1)\log(1-\tau)$ or equivalently effort is considered as a "highly superior good" with respect to the base wage, the risk-neutral worker's utility under the base wage contract with taxes is always greater than his utility under the regular piece contract without taxes. There is a net preference for the base wage contract over the piece rate contract.*

Result 11. *When effort is not considered as a "highly superior good" with respect to the base wage ($\alpha_i\gamma b_{i\tau} \geq (\gamma+1)\log(1-\tau)$)[22], there is a unique strictly positive value $b^*_{i\tau}$ that renders the risk-neutral worker indifferent between the regular piece rate contract and the base wage contract. Below this value, the risk-neutral worker prefers the regular piece rate contract. Beyond this value $b^*_{i\tau}$, the worker prefers the base wage contract. This value is given by*

$$(\gamma+1)\log(1-\tau) = \gamma\alpha_i b^*_{i\tau} + \log\left[1 - \frac{b^*_{i\tau}}{\bar{w}A\exp^{\frac{1}{2}(\gamma+1)^2(1-\delta_h)\sigma_j^2}}\right]$$

$$\textit{with} \quad A = d_t^{\gamma+1}\exp^{\gamma(\lambda_h-\lambda_i)} \quad \textit{and} \quad \alpha_i\gamma b_{i\tau} \geq (\gamma+1)\log(1-\tau)$$

Result 12. *If $\alpha_i\gamma b_{i\tau} + \frac{1}{2}(\gamma+1)^2(\delta_i-1)\sigma_j^2 < (\gamma+1)\log(1-\tau)$, the risk lover prefers the base wage contract over the standard piece rate contract. This condition is similar to the one identified under risk neutrality $\alpha_i\gamma b_{i\tau} < (\gamma+1)\log(1-\tau)$, except an additional term $\frac{1}{2}(\gamma+1)^2(\delta_i-1)\sigma_j^2$ which captures the risk preference effect of the worker in his contract choice.*

Result 13. *Assuming $\alpha_i\gamma b_{i\tau} + \frac{1}{2}(\gamma+1)^2(\delta_i-1)\sigma_j^2 \geq (\gamma+1)\log(1-\tau)$, the risk-lover worker will require a minimum compensation (lump-sum payment) $b^l_{i\tau}$ of at most $\hat{b}_{i\tau}$ to accept the base wage contract with taxation . The value of $\hat{b}_{i\tau}$ is given by :*

$$(\gamma+1)\log(1-\tau) = \gamma\alpha_i\hat{b}_{i\tau} + \frac{1}{2}(\gamma+1)^2(\delta_i-1)\sigma_j^2 + \log\left[1 - \frac{\hat{b}_{i\tau}}{\bar{w}A\exp^{\frac{1}{2}(\gamma+1)^2(\delta_i-\delta_h)\sigma_j^2}}\right]$$

$$\textit{with} \quad A = d_t^{\gamma+1}\exp^{\gamma(\lambda_h-\lambda_i)}$$

[22] Effort is viewed in this context as "moderate/inferior good" with respect to the base wage.

Result 14. *Assuming* $\frac{1}{2}(\gamma+1)^2(\delta_i-1)\sigma_j^2 > (\gamma+1)\log(1-\tau)$*, the risk-averse worker will ask a compensation* $b^a_{i\tau}$ *of at least* $\hat{b}_{i\tau}$ *to accept the base wage contract with taxation. The value of* $\hat{b}_{i\tau}$ *is given by*

$$(\gamma+1)\log(1-\tau) = \gamma\alpha_i\hat{b}_{i\tau} + \frac{1}{2}(\gamma+1)^2(\delta_i-1)\sigma_j^2 + \log\left[1 - \frac{\hat{b}_{i\tau}}{\bar{w}A\exp^{\frac{1}{2}(\gamma+1)^2(\delta_i-\delta_h)\sigma_j^2}}\right]$$

$$\textit{with} \quad A = d_t^{\gamma+1}\exp^{\gamma(\lambda_h-\lambda_i)}$$

The proofs of the above implications regarding contract choice are provided in Appendix C.

11 Model Fit

Expected tax revenue collected on worker i on block j on day t at tax rate τ in the presence of base wage effects and risk preference is given by :

$$\mathbb{E}[TX_{ijt}] = \tau(1-\tau)^{\gamma}(\gamma+1)\bar{w}d_t^{\gamma+1}\exp^{\gamma(\lambda_h-\lambda_i)+\frac{1}{2}(\gamma+1)^2(1-\delta_h)\sigma_j^2-\gamma\alpha b_{i\tau}} \tag{39}$$

Using estimated structural parameters of Model 3 and equations (38) and (39) , we compute worker's reservation base wage and expected tax revenue per worker.[23] These values are then compared to actual tax revenue paid by the worker and reported reservation base wage during the experiment to assess the performance of Model 3.

Figure 14 compares predicted tax revenues from Model 3 to actual tax revenues.[24] The 45-degree line of Figure 14 represents perfect prediction. As with models 1 and 2, we fit quite well tax revenues and hence production. In contrast, Figure 15 shows that Model 3 performs poorly in predicting the worker's reported reservation base wage that dictates his contract choice between the taxation and the no-taxation contract in section 3. As in Model 1 and Model 2 in Figure 8, Model 3 is under-predicting the worker's reported reservation base wage.

[23] We also account for risk preference and pose for simplicity $\delta_h = 1$ as in section 9. The marginal worker h is assumed to be risk neutral.

[24] The taxation treatment of 4 cents and 6 cents per tree correspond to tax rates ranging from 15% to 33% depending on the standard piece rate in place during the experiment.

Figure 14: Actual tax revenue vs Predicted tax revenue : Model 3

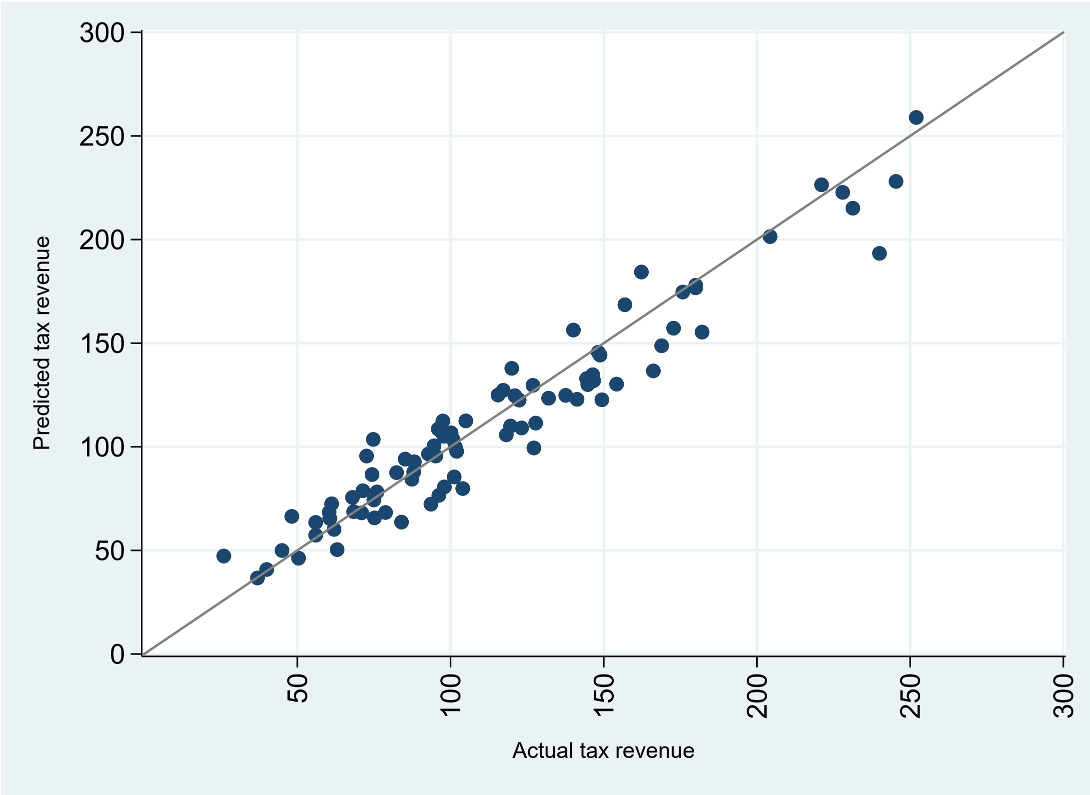
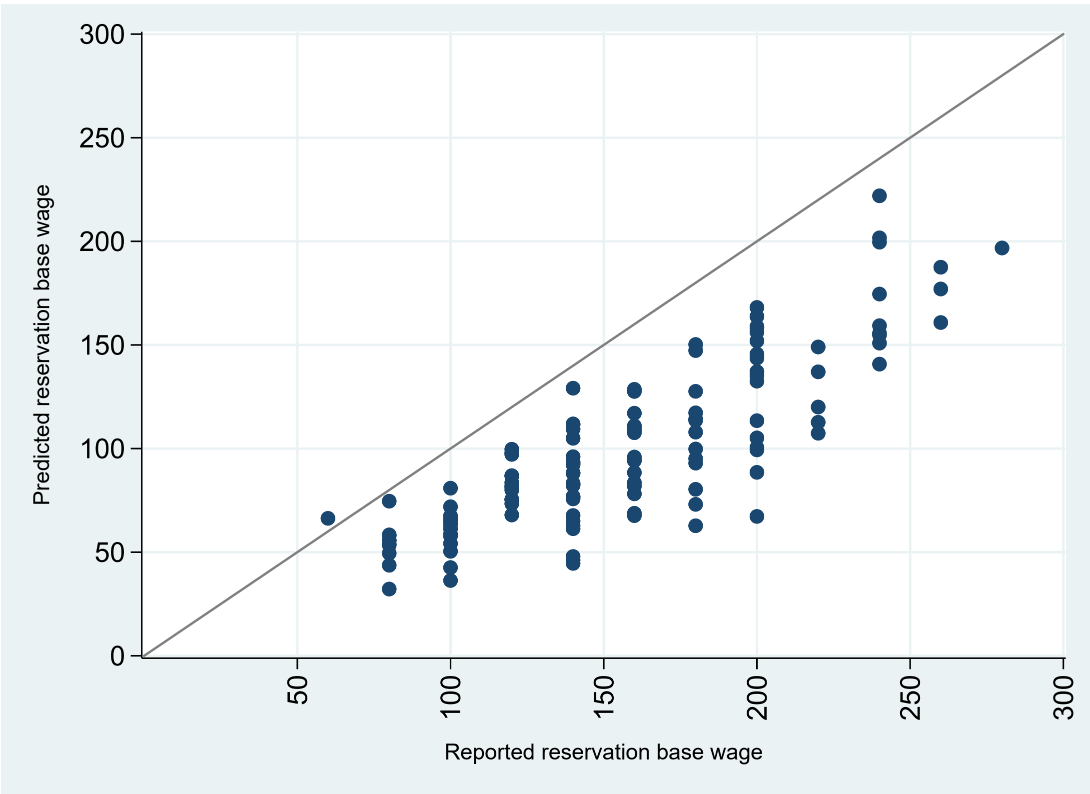


Figure 15: Actual reservation base wage vs Predicted reservation base wage based on expected utility : Model 3



12 A heuristic decision rule based on expected earnings for the contract choice

One possible explanation of our poor performance in predicting the worker's reservation base wage is that the values reported by workers during the experiment may relate to expected earnings instead of expected utility.Workers may thus resort to simple heuristic decision rules based on expected earnings instead of expecting utility. Doing so would imply that workers ignore the cost of effort in their contractual choice decisions.

To investigate this, we now use our structural parameters to compute the worker's reservation base wage $b^w_{i\tau}$ that equates expected earnings between the taxation and the no-taxation contract using equation (40). We concentrate on Model 3 as that is our preferred model to date.

The worker's reservation base wage ($b^w_{i\tau}$) that equates expected earnings between the taxation and no-taxation contract solves for

$$\underbrace{(\gamma+1)\bar{w}d_t^{\gamma+1}\exp^{\gamma(\lambda_h-\lambda_i)+\frac{1}{2}(\gamma+1)^2(1-\delta_h)\sigma_j^2}}_{E_{pc}[w_{ijt}]} = \underbrace{b^w_{i\tau}+(\gamma+1)(1-\tau)^{\gamma+1}\bar{w}d_t^{\gamma+1}\exp^{\gamma(\lambda_h-\lambda_i)+\frac{1}{2}(\gamma+1)^2(1-\delta_h)\sigma_j^2-\gamma\alpha_i b^w_{i\tau}}}_{E_{bc}[w_{ijt}]} \tag{40}$$

In the absence of base-wage effects (Model 1 and Model 2), $b^w_{i\tau}$ has an analytical form and is given by equation (41). We pose for simplicity $\delta_h = 1$ as in section 9.

$$b^w_{i\tau} = (\gamma+1)[1-(1-\tau)^{\gamma+1}](\gamma+1)\bar{w}d_t^{\gamma+1}\exp^{\gamma(\lambda_h-\lambda_i)} \tag{41}$$

Combining equations (41) and (12) establishes a relationship between $b^w_{i\tau}$and $b^*_{i\tau}$ in the absence of base wage effects. This relationship is given by

$$b^w_{i\tau} = (\gamma+1)b^*_{i\tau} \tag{42}$$

Equation (42) still holds when we relax the assumption of $\delta_h = 1$ posed for simplicity. It shows that $b^w_{i\tau}$ is proportional to $b^*_{i\tau}$ by a factor of $\gamma+1$ which is positive (since $\gamma > 0$). Hence Result 1, Result 2 and Result 3 derived in section 5.1 still hold. Since $\gamma > 0$, equation (42) also clearly shows how in general $b^w_{i\tau}$ is higher than $b^*_{i\tau}$ when the worker ignore the cost of effort and focus solely on expected earnings to make contract choices. In this case, below $b^w_{i\tau}$, the worker prefers the regular piece rate contract with no taxation, and above $b^w_{i\tau}$, he prefers the taxation contract with base wage.

In the presence of base wage effects, $b^w_{i\tau}$ no longer has an analytical solution. Expanding on equation 40, we show that if $\alpha_i\gamma b_{i\tau} < (\gamma+1)\log(1-\tau)$ then expected earnings under the taxation with base wage contract is always greater than expected earnings under the regular piece rate contract with no taxation and base wage. Thus workers who ignore the cost of effort and focus solely on expected earnings to make contract choice will have a net preference for the base wage contract with taxation.

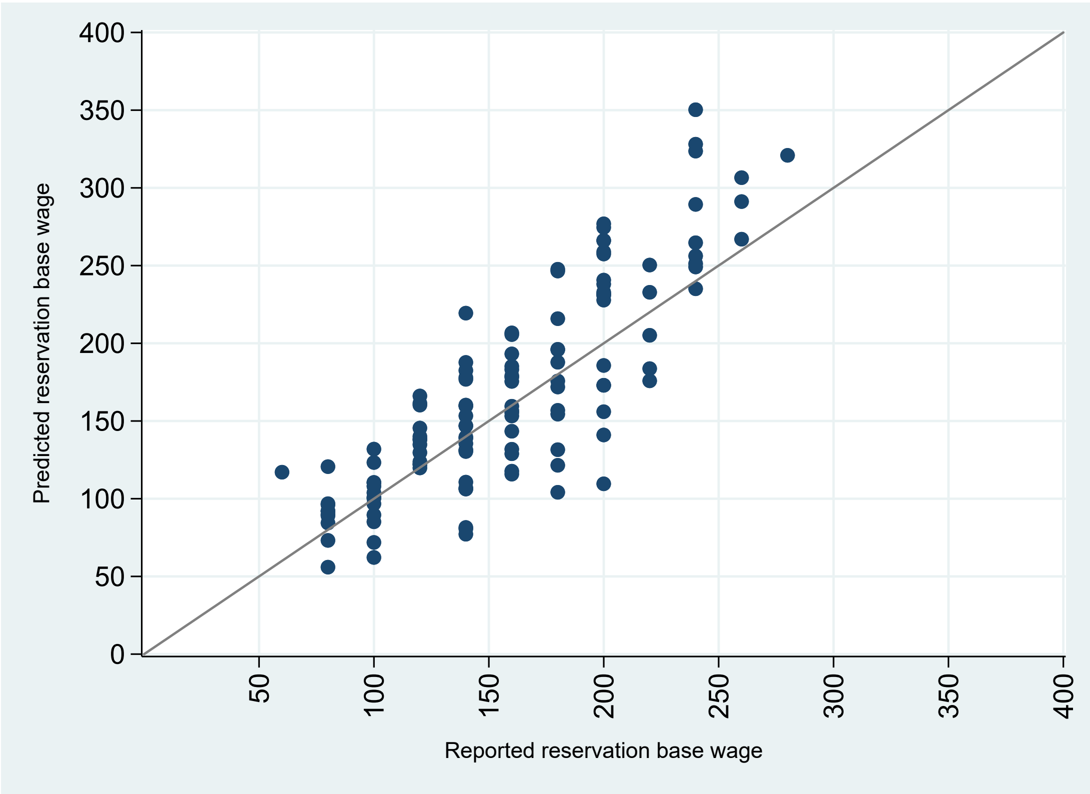
Inversely if $\alpha_i\gamma b_{i\tau} \geq (\gamma+1)\log(1-\tau)$, then there is a unique strictly positive value $b^w_{i\tau}$ that equates the worker's expected earnings between the base wage contract with taxation and the regular piece rate contract with no taxation and base wage. Below $b^w_{i\tau}$, the worker prefers the regular piece rate contract with no taxation and base wage, and above $b^w_{i\tau}$, he prefers the base wage contract with taxation. This value of $b^w_{i\tau}$ solves

$$(\gamma+1)\log(1-\tau) = \gamma\alpha_i b^w_{i\tau} + \log\left[1 - \frac{b^w_{i\tau}}{(\gamma+1)\bar{w}A\exp^{\frac{1}{2}(\gamma+1)^2(1-\delta_h)\sigma_j^2}}\right]$$

$$\text{with} \quad A = d_t^{\gamma+1}\exp^{\gamma(\lambda_h-\lambda_i)} \quad \text{and} \quad \alpha_i\gamma b_{i\tau} \geq (\gamma+1)\log(1-\tau)$$

Figure 16 compares predicted $b^w_{i\tau}$ that equates expected earnings between the taxation and the no-taxation contract from equation (40) to the reported values of workers. Interestingly, we now see that the predicted $b^w_{i\tau}$ now matches the reported reservation base wage of the workers much better. This suggests that the reported reservation base wage by the workers are indeed relative to expected earnings and not expected utility.

Figure 16: Actual reservation base wage vs predicted reservation base wage based on expected earnings : Model 3



The fact that workers make their contract choice on the basis of expected earnings -ignoring the cost of effort- instead of utility as a whole is,perhaps, not surprising. Many studies have shown how individuals resort to simplified decision rules (Tversky and Kahneman; 1974; Kahneman et al.; 1991; Hafenbrädl et al.; 2016; Xiao; 2022) and thus ignore key aspects when making decisions.

By ignoring the cost of effort and focusing only on expected earnings, the reported reservation base wage of the workers don't relate to utility. And as such, they are distorted measures of the worker's compensating variation. It follows that our non-structural estimates of the excess burden based on the worker's reported reservation base wage in Tables 6 and 7 and Figures 9 and 10 are also distorted values of the excess burden. In contrast, our structural estimates remain valid as they are based on the utility function parameters, estimated from worker production decisions.

13 Generalization of results

Structural estimation allows us to generalize results beyond tax rates observed in the experiment. This is useful for policy analysis. We generalize our results by defining a representative average worker. This is the worker with the average ability in the experimental sample. We also consider average working conditions relative to the day-specific and block-specific effects observed in the experiment. Using estimated structural parameters of Model 3 and equations (32), (37), (38) and (39) , we predict the reservation base wage ($b^*_{i\tau}$), the compensating variation ($b^{cv}_{i\tau}$), the expected tax revenue and the excess burden relative to this representative average worker for different levels of taxation including those beyond the scope of the experiment.

Figure 17 shows the trajectory of the reservation base wage ($b^*_{i\tau}$) and compensating variation of the representative average worker ($b^{cv}_{i\tau}$) as a function of the tax rate. Both $b^*_{i\tau}$ and $b^{cv}_{i\tau}$ are increasing functions of the tax rate. $b^*_{i\tau}$ is slightly inferior to $b^{cv}_{i\tau}$ due to the incentive effect of the base wage on productivity. When calculating $b^{cv}_{i\tau}$, this incentive effect is set to zero as we focus solely on the distortion caused by taxes -causing $b^{cv}_{i\tau}$ to be greater than $b^*_{i\tau}$. Risk-averse workers, ceteris paribus, will require a lower compensation to accept taxation as the compensation ($b^*_{i\tau}$ or $b^{cv}_{i\tau}$) introduces a fixed wage and reduces their income variance. They are willing to pay a premium to reduce their income variance. This reduces the compensation required to accept taxation. Comparison with the risk neutrality case, holding everything else constant, gives a sense of the magnitude of the premium due to risk aversion. Inversely, risk lovers will require a higher compensation as they are less inclined to pay a premium to reduce their income variance.

Figure 17: Predicted reservation base wage ($b^{*}_{i\tau}$) and compensating variation ($b^{cv}_{i\tau}$) of average worker : Model 3

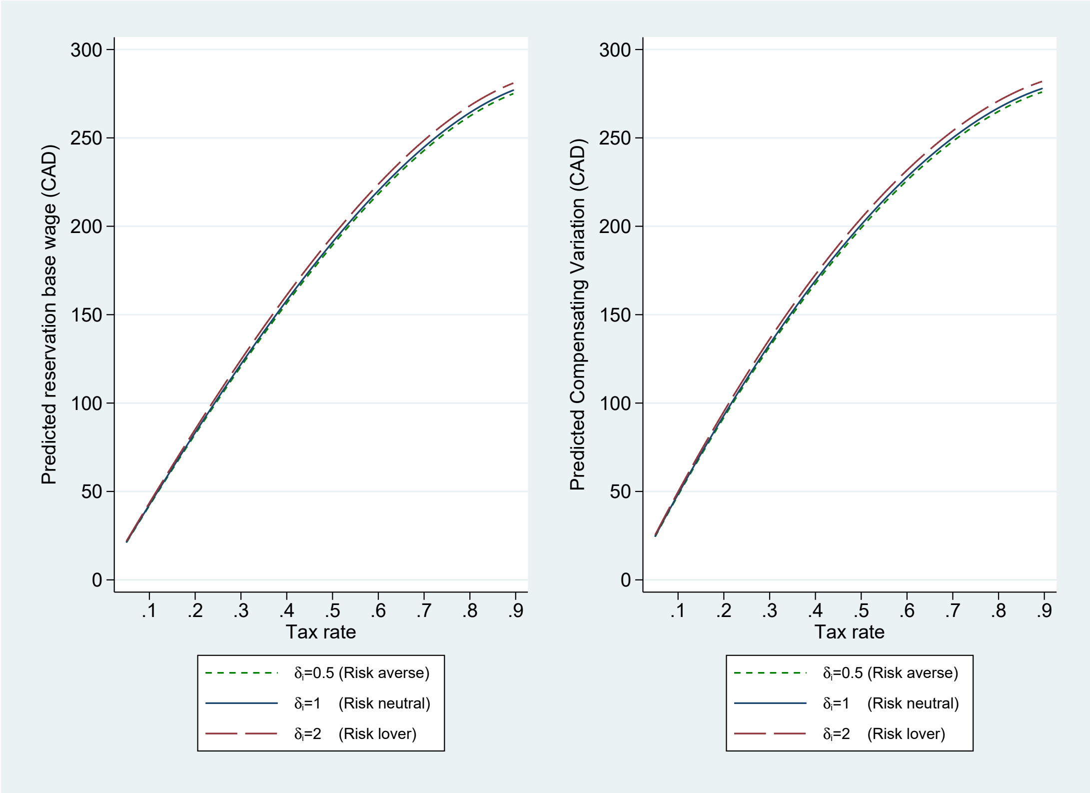


Figure 18 shows the trajectory of predicted tax revenue for the representative worker as a function of the tax rate. Worker's risk preference does not affect tax revenue as productivity is independent of risk once the worker observes productivity shock and selects his effort level. Productivity and tax revenue in this setting is affected only by the marginal worker risk preference through the participation constraint used by the firm to set the piece rate (see Discussion in section 9). Tax revenue increases independently of worker's risk preference with tax rates till a maximum and then declines -depicting the inverted U shape commonly referred as the Dupuit-Laffer taxation curve. This is shown in Figure 18. The tax rate that maximizes tax revenue on average worker in our setting is 0.56 for an average daily earnings of C$487. Interestingly this value is just two percent point below the one found by Holter et al. (2019) regarding the U.S Dupuit-Laffer curve.[25] At the tax rate of 0.56, tax revenues are maximized regardless of the social cost generated. An optimal tax rate should, however, also take into account generated social cost.

[25] Holter et al. (2019) developed a large scale overlapping generations model with single and married households facing idiosyncratic income risk, extensive and intensive margins of labor supply, as well as endogenous accumulation of human capital through labor market experience to analyze the U.S Dupuit-Laffer curve. They found that the peak of the U.S. Laffer curve is attained at an average labor income tax rate of 58%.

Figure 18: Predicted daily income tax paid by average worker : Model 3

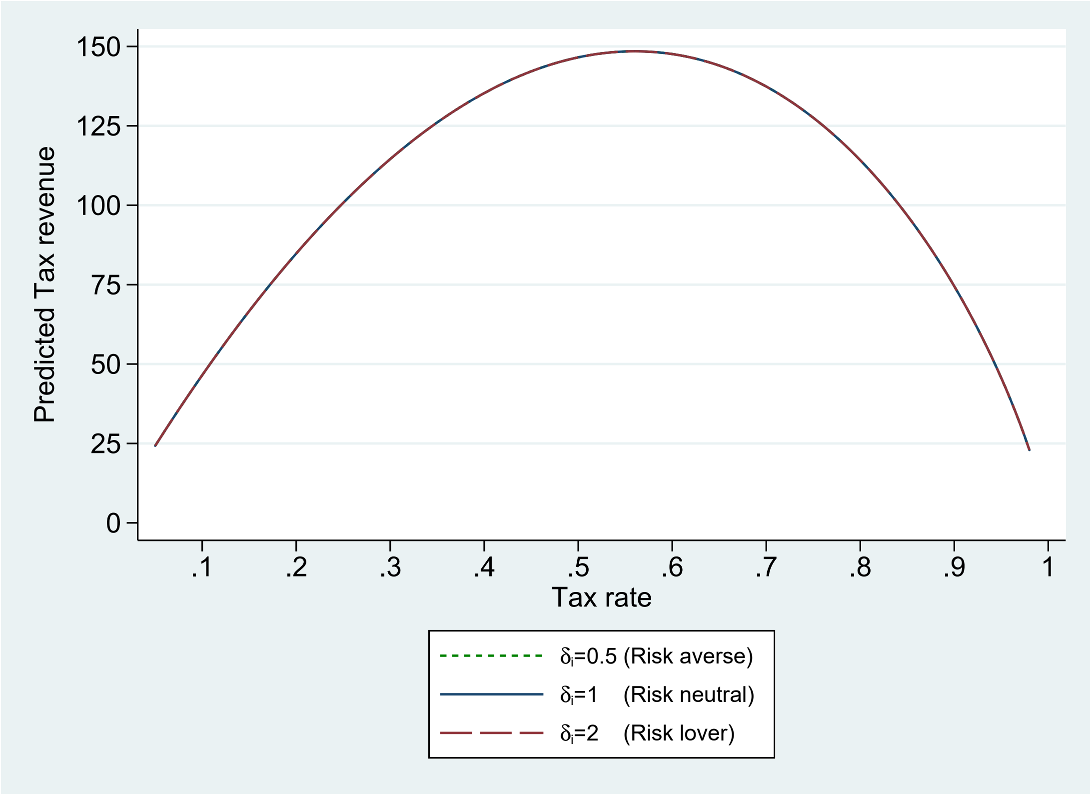
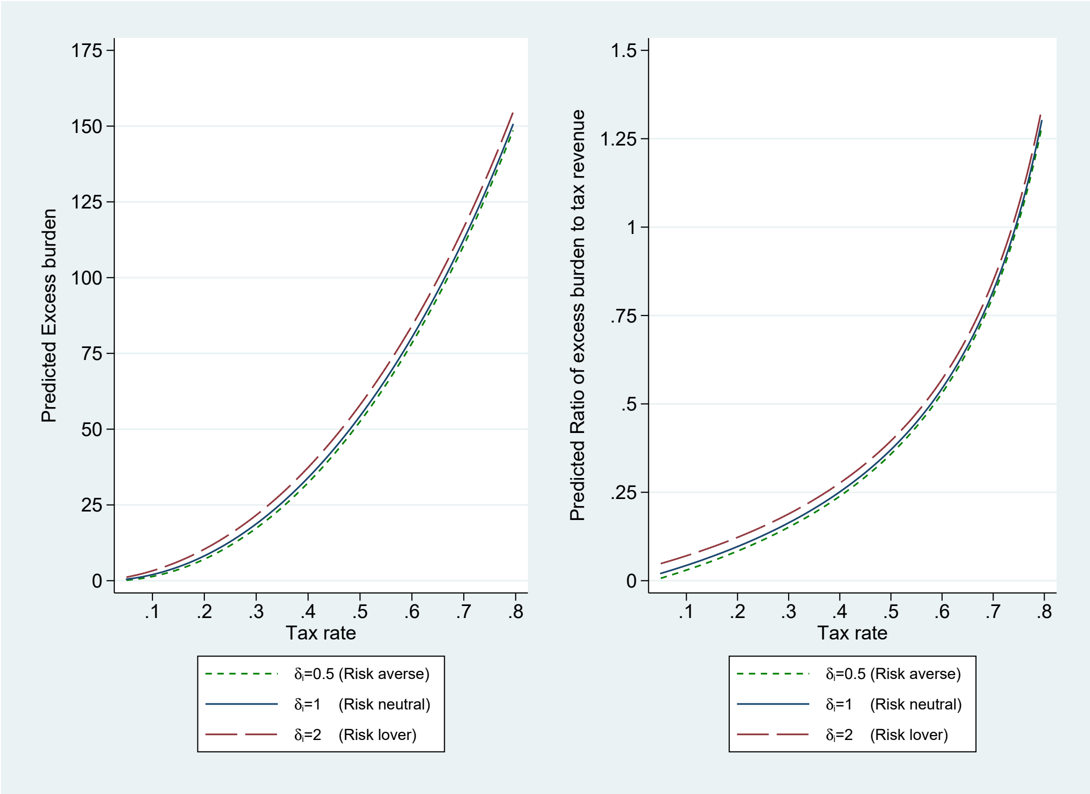


Figure 19 shows the trajectory of the predicted excess burden of taxation and that of the ratio of the excess burden to tax revenue in function of tax rates. The excess burden of taxation increases very rapidly with the tax rate. The same applies to the ratio of excess burden to tax revenue. At tax rate of 0.56 that maximizes tax revenue, the excess burden of taxation represents more than 65% of tax revenue.These patterns hold irrespective of risk preferences. These results advocates for a broad-based and low tax rate system.

Figure 19: Predicted daily excess burden of average worker : Model 3



14 Discussion and conclusions

Field experiment studies on the disincentive effects of labor taxation are quite rare due to their complexity and high cost. This study succeeds in implementing one that is both affordable and realistic in an environment where work intensities (productivity in terms of effort) can be accurately measured. The experiment introduced a proportional wage tax by reducing the firm's piece rate offered to the workers. This exogenous variation in taxes enabled us to measure tax-induced effects and evaluate the excess burden of taxation. We developed a structural model that generated analytical expressions of worker incentive effects and the social cost of taxation. Our experimental data served to identify and estimate the model. The estimated structural model is then used to evaluate the excess burden of taxation and generalize our results. Our approach allowed us to account for base-wage (income) effects and risk preferences.

Our results demonstrate that taxes reduce incentives to work and consequently productivity. For an average daily production of 2000 trees per worker and an initial tax rate of 15%, an increase of 10% of the tax rate will induce a decrease in daily production of 28 trees per worker. This increases to 39 and 52 trees for initial tax rates of 20% and 25% respectively. These estimates are reduced by 4.5 when we disregard base wage effects. The impact of risk preference on our results is however modest. Daily average excess burden on experimental observations represents 0.12 of the collected tax revenue with substantial heterogeneity across workers. We generalize our results to tax rates beyond those observed in our experiment and observe that the ratio of the excess burden to tax revenue increases disproportionately with the tax rate. It is above 0.65 when tax revenue is maximized at the tax rate of 0.56. This study advocates for a broad-based and low tax rate system. Indeed any policy which increases the tax base but reduces the tax rate will generate a lesser excess burden.

The results of our study also suggest interesting areas for future research. Our experiment is a one-shot experiment which introduced exogenous taxes. Taxes, however, have the feature of being a permanent or at least a long-lived policy. Several authors have evoked the possibility of behavioral differences between short-run (hot) and long-run (cold) decision making (Orcutt and Orcutt; 1968; Loewenstein; 2000; Shearer; 2003; Ferrall; 2003; Loewenstein; 2005; Gneezy and List; 2006; Levitt and List; 2007; Prendergast; 2015). This has fostered keen interest on the relevance of predicting the effects of permanent policy changes from such short-term changes. Shearer (2003) and Ferrall (2003, 2012) propose structural modeling to address these issues. In our context, this will involve the development of a structural dynamic model of effort. We leave this for future research. Another interesting area for future research is to investigate how the use of tax revenue (public expenditure, direct transfer payment) affects the productivity of workers. A recent study from Keser et al. (2020) provides laboratory evidence that the labor supply of individuals is influenced by how their taxes are used and reflowed back to them. It will be interesting to investigate how their findings generalize on the field with real workers.

References

Akerlof, G. A. and Yellen, J. L. (1988). Fairness and unemployment, *The American Economic Review* **78**(2): 44–49.

Akerlof, G. A. and Yellen, J. L. (1990). The fair wage-effort hypothesis and unemployment, *The Quarterly Journal of Economics* **105**(2): 255–283.

Alpert, A. and Powell, D. (2020). Estimating intensive and extensive tax responsiveness, *Economic Inquiry* **58**(4): 1855–1873.

Anderson, P. M. and Meyer, B. D. (1997). The effects of firm specific taxes and government mandates with an application to the us unemployment insurance program, *Journal of Public Economics* **65**(2): 119–145.

Anderson, P. M. and Meyer, B. D. (2000). The effects of the unemployment insurance payroll tax on wages, employment, claims and denials, *Journal of public Economics* **78**(1-2): 81–106.

Azmat, G. (2019). Incidence, salience, and spillovers: The direct and indirect effects of tax credits on wages, *Quantitative Economics* **10**(1): 239–273.

Banerjee, A. V., Chassang, S. and Snowberg, E. (2017). Decision theoretic approaches to experiment design and external validity, *Handbook of Economic Field Experiments*, Vol. 1, Elsevier, pp. 141–174.

Bellemare, C. and Shearer, B. (2013). Multidimensional heterogeneity and the economic importance of risk and matching: evidence from contractual data and field experiments, *RAND Journal of Economics* **44**(2): 361–389.

Blomquist, S., Newey, W. K., Kumar, A. and Liang, C.-Y. (2021). On bunching and identification of the taxable income elasticity, *Journal of Political Economy* **129**(8): 2320–2343.

Blundell, R. (1992). Labour supply and taxation: a survey, *Fiscal Studies* **13**(3): 15–40.

Blundell, R., Duncan, A. and Meghir, C. (1992). Taxation in empirical labour supply models: lone mothers in the uk, *The Economic Journal* **102**(411): 265–278.

Blundell, R., Duncan, A. and Meghir, C. (1998). Estimating labor supply responses using tax reforms, *Econometrica* pp. 827–861.

Blundell, R., Meghir, C., Symons, E. and Walker, I. (1988). Labour supply specification and the evaluation of tax reforms, *Journal of Public Economics* **36**(1): 23–52.

Bozio, A., Breda, T. and Grenet, J. (2017). Incidence of social security contributions: evidence from france, *Paris School of Economics Working Paper* .

Charness, G., Cooper, M. and Reddinger, J. L. (2020). Wage policies, incentive schemes, and motivation, *Handbook of labor, human resources and population economics* pp. 1–33.

Chetty, R. (2009). Is the taxable income elasticity sufficient to calculate deadweight loss? the implications of evasion and avoidance, *American Economic Journal: Economic Policy* **1**(2): 31–52.

Cobo-Reyes, R., Lacomba, J. A., Lagos, F. and Levin, D. (2017). The effect of production technology on trust and reciprocity in principal-agent relationships with team production, *Journal of Economic Behavior & Organization* **137**: 324–338.

Cohn, A., Fehr, E. and Goette, L. (2015). Fair wages and effort provision: Combining evidence from a choice experiment and a field experiment, *Management Science* **61**(8): 1777–1794.

Coviello, D., Deserranno, E. and Persico, N. (2022). Minimum wage and individual worker productivity: Evidence from a large us retailer, *Journal of Political Economy* **130**(9): 2315–2360.

Creedy, J. and Mok, P. (2022). *Tax and Transfer Policy Using Behavioural Microsimulation Modelling: Design and Evaluation*, Edward Elgar Publishing.

Cruces, G., Galiani, S. and Kidyba, S. (2010). Payroll taxes, wages and employment: Identification through policy changes, *Labour economics* **17**(4): 743–749.

DellaVigna, S., List, J. A., Malmendier, U. and Rao, G. (2020). Estimating social preferences and gift exchange with a piece-rate design.

Deslauriers, J., Dostie, B., Gagné, R. and Paré, J. (2021). Estimating the impacts of payroll taxes: Evidence from canadian employer–employee tax data, *Canadian Journal of Economics/Revue canadienne d'économique* **54**(4): 1609–1637.

Dickinson, D. L. (1999). An Experimental Examination of Labor Supply and Work Intensities, *Journal of Labor Economics* **17**(4): 638–670.

Dupuit, J. (1844). On the measurement of the utility of public works, *International Economic Papers* **2**(1952): 83–110.

Eissa, N. and Liebman, J. B. (1996). Labor supply response to the earned income tax credit, *The Quarterly Journal of Economics* **111**(2): 605–637.

Ferrall, C. (2003). Estimation and inference in social experiments, *Queen's University Working Paper* .

Ferrall, C. (2012). Explaining and forecasting results of the self-sufficiency project, *Review of Economic Studies* **79**(4): 1495–1526.

Finkelstein, A. and Hendren, N. (2020). Welfare analysis meets causal inference, *Journal of Economic Perspectives* **34**(4): 146–67.

Gneezy, U. and List, J. A. (2006). Putting behavioral economics to work: Testing for gift exchange in labor markets using field experiments, *Econometrica* **74**(5): 1365–1384.

Goerg, S. J., Kube, S. and Radbruch, J. (2019). The effectiveness of incentive schemes in the presence of implicit effort costs, *Management Science* **65**(9): 4063–4078.

Gruber, J. (1997). The incidence of payroll taxation: evidence from chile, *Journal of labor economics* **15**(S3): S72–S101.

Hafenbrädl, S., Waeger, D., Marewski, J. N. and Gigerenzer, G. (2016). Applied decision making with fast-and-frugal heuristics, *Journal of Applied Research in Memory and Cognition* **5**(2): 215–231.

Hansen, E. (2021). Optimal income taxation with labor supply responses at two margins: When is an earned income tax credit optimal?, *Journal of Public Economics* **195**: 104365.

Harrison, G. W. and List, J. A. (2004). Field experiments, *Journal of Economic Literature* **42**(4): 1009–1055.

Heckman, J. J. (1993). What has been learned about labor supply in the past twenty years?, *The American Economic Review* **83**(2): 116–121.

Holt, C. A. and Laury, S. K. (2002). Risk Aversion and Incentive Effects, *American Economic Review* **92**(5): 1644–1655.

Holter, H. A., Krueger, D. and Stepanchuk, S. (2019). How do tax progressivity and household heterogeneity affect laffer curves?, *Quantitative Economics* **10**(4): 1317–1356.

Iskhakov, F. and Keane, M. (2021). Effects of taxes and safety net pensions on life-cycle labor supply, savings and human capital: The case of australia, *Journal of Econometrics* **223**(2): 401–432.

Kahneman, D., Knetsch, J. L. and Thaler, R. H. (1991). Anomalies: The endowment effect, loss aversion, and status quo bias, *Journal of Economic perspectives* **5**(1): 193–206.

Keane, M. P. (2011). Labor Supply and Taxes: A Survey, *Journal of Economic Literature* **49**(4): 961–1075.

Keane, M. P. (2021). Recent research on labor supply: Implications for tax and transfer policy, *Labour Economics* p. 102026.

Keane, M. and Rogerson, R. (2012). Micro and macro labor supply elasticities: A reassessment of conventional wisdom, *Journal of Economic Literature* **50**(2): 464–76.

Keane, M. and Rogerson, R. (2015). Reconciling micro and macro labor supply elasticities: A structural perspective, *Annu. Rev. Econ.* **7**(1): 89–117.

Keser, C., Masclet, D. and Montmarquette, C. (2020). Labor supply, taxation, and the use of tax revenues: A real-effort experiment in canada, france, and germany, *Public Finance Review* **48**(6): 714–750.

Killingsworth, M. R. (1983). *Labor supply*, Cambridge university press Cambridge.

Ku, H. (2022). Does minimum wage increase labor productivity? evidence from piece rate workers, *Journal of Labor Economics* **40**(2): 325–359.

Kugler, A. and Kugler, M. (2009). Labor market effects of payroll taxes in developing countries: Evidence from colombia, *Economic development and cultural change* **57**(2): 335–358.

Levitt, S. D. and List, J. A. (2007). Viewpoint: On the generalizability of lab behaviour to the field, *Behavioral & Experimental Economics eJournal* .

List, J. A. and Reiley, D. (2008). Field Experiments in Economics: Palgrave Entry, *IZA Discussion Papers 3273*, Institute for the Study of Labor (IZA).

Loewenstein, G. (2000). Emotions in economic theory and economic behavior, *American economic review* **90**(2): 426–432.

Loewenstein, G. (2005). Hot-cold empathy gaps and medical decision making., *Health psychology* **24**(4S): S49.

MaCurdy, T., Green, D. and Paarsch, H. (1990). Assessing empirical approaches for analyzing taxes and labor supply, *Journal of Human resources* pp. 415–490.

Martinez, I. Z., Saez, E. and Siegenthaler, M. (2021). Intertemporal labor supply substitution? evidence from the swiss income tax holidays, *American Economic Review* **111**(2): 506–46.

Meghir, C. and Phillips, D. (2010). Labour supply and taxes, *Dimensions of tax design: The Mirrlees review* pp. 202–74.

Meyer, B. D. and Rosenbaum, D. T. (2001). Welfare, the earned income tax credit, and the labor supply of single mothers, *The quarterly journal of economics* **116**(3): 1063–1114.

Orcutt, G. H. and Orcutt, A. G. (1968). Incentive and disincentive experimentation for income maintenance policy purposes, *The American Economic Review* **58**(4): 754–772.

Paarsch, H. J. and Shearer, B. S. (1999). The response of worker effort to piece rates: Evidence from the british columbia tree-planting industry, *Journal of Human resources* pp. 643–667.

Prendergast, C. (2015). The empirical content of pay-for-performance, *The Journal of Law, Economics, & Organization* **31**(2): 242–261.

Riley, R. and Bondibene, C. R. (2017). Raising the standard: Minimum wages and firm productivity, *Labour Economics* **44**: 27–50.

Robins, P. K. (1985). A Comparison of the Labor Supply Findings from the Four Negative Income Tax Experiments, *Journal of Human Resources* **20**(4): 567–582.

Saez, E., Schoefer, B. and Seim, D. (2019). Payroll taxes, firm behavior, and rent sharing: Evidence from a young workers' tax cut in sweden, *American Economic Review* **109**(5): 1717–63.

Saez, E., Slemrod, J. and Giertz, S. H. (2012). The Elasticity of Taxable Income with Respect to Marginal Tax Rates: A Critical Review, *Journal of Economic Literature* **50**(1): 3–50.

Shearer, B. (2003). Compensation policy and worker performance: identifying incentive effects from field experiments, *Journal of the European Economic Association* **1**(2-3): 503–511.

Shearer, B. (2004). Piece Rates, Fixed Wages and Incentives: Evidence from a Field Experiment, *Review of Economic Studies* **71**(2): 513–534.

Sliwka, D. and Werner, P. (2017). Wage increases and the dynamics of reciprocity, *Journal of Labor Economics* **35**(2): 299–344.

Sumiya, K. and Bagger, J. (2022). Income taxes, gross hourly wages, and the anatomy of behavioral responses: Evidence from a danish tax reform, *IZA Discussion Paper* (15502).

Tversky, A. and Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases: Biases in judgments reveal some heuristics of thinking under uncertainty., *science* **185**(4157): 1124–1131.

Xiao, W. (2022). Understanding probabilistic expectations–a behavioral approach, *Journal of Economic Dynamics and Control* **139**: 104416.

Zhao, N. and Sun, M. (2021). Effects of minimum wage on workers' on-the-job effort and labor market outcomes, *Economic Modelling* **95**: 453–461.

Zubrickas, R. (2022). Loss aversion, labor supply, and income taxation, *The Scandinavian Journal of Economics* **124**(2): 579–598.

Appendices

A Contract Choice Experimental design

You have before you a decision sheet. Your decision sheet shows 15 decisions listed on the left. For each decision, we would like you to choose between "Option A" and "Option B.", marking your choice with an X in the appropriate column. For each of the 15 decisions, you must choose Option A or Option B, but not both. While you will make 15 choices, only one of these choices will be used to determine your contract and earnings. Before you start making your 15 choices, please let me explain how these choices will affect your contract and earnings.

Here are 15 chips that will be used to determine earnings. These poker chips are numbered from 1 to 15. After you have made all of your choices, you will pick one of the 15 chips out of a bag. The chip you draw will select which of the 15 Decisions will be used to calculate your contract. For example, if you draw the chip with the number 3, then your choice for Decision 3 will determine your contract. If you draw the chip with the number 8, then your choice for Decision 8 will determine your contract. Again, even though you will make 15 Decisions, only one of these will end up determining your contract. However, each Decision has an equal chance of being selected.

Now, please look at Decision 1 at the top of the decision sheet. Option A pays your regular piece rate contract of 16 cents per tree. Option B denotes a base wage contract paying 20 dollars per day plus 12 cent per tree contract. This means that if the chip that you draw is numbered 1 and you chose option A for decision 1, then you will be paid 16 cents for each tree that you plant over the next 2 days. However, if the chip that you draw is numbered 1 and you chose option B for that decision, then you will be paid 20 dollars plus 12 cents for each tree that you plant over the next 2 days. The other Decisions are similar, the piece rate contract is always the same but as you move down the table, the Option B contract pays a higher base-wage with the same piece rate of 12 cents per tree. For example, if the first chip you draw selects Decision 5 and you selected Option A for that Decision, then you will be paid 16 cents for each tree planted. However, if the first chip you draw selects Decision 5 and you selected Option B for that Decision, then you will be paid 100 dollars plus 12 cents for each tree. For Decision 14, in the bottom row, your choice is between a piece rate contract paying 16 cents per tree and a base-wage of 280 dollars per day plus 12 cents per tree.

To summarize, you will make 15 choices: for each row in the table you will have to choose between Option A and Option B. You may choose Option A for some decision rows and Option B for other rows. When you are finished, you will come one by one to our table and draw a chip out of a hat to select which of your 15 Decisions will be used. So, for example, if the chip you draw selects Decision 2, then you will be paid 16 cents for each tree that you plant if you chose Option A for Decision 2, or $100 per day plus 12 cents per tree planted if you chose Option B. However, if the chip you draw selects Decision 8, then you will be paid 16 cents per tree planted if you chose Option A for Decision

8, or \$225 per day plus 12 cents per tree planted if you chose Option B for Decision 8.

DATE : ___________________

NAME: ______________________________ Regular rate: __________

	Option A		My Choice is A	Option B		My Choice is B
	Base Wage	Piece Rate		Base Wage	Piece Rate	
Decision 1	0	Regular rate		$20	Regular rate - $.04	
Decision 2	0	Regular rate		$40	Regular rate - $.04	
Decision 3	0	Regular rate		$60	Regular rate - $.04	
Decision 4	0	Regular rate		$80	Regular rate - $.04	
Decision 5	0	Regular rate		$100	Regular rate - $.04	
Decision 6	0	Regular rate		$120	Regular rate - $.04	
Decision 7	0	Regular rate		$140	Regular rate - $.04	
Decision 8	0	Regular rate		$160	Regular rate - $.04	
Decision 9	0	Regular rate		$180	Regular rate - $.04	
Decision 10	0	Regular rate		$200	Regular rate - $.04	
Decision 11	0	Regular rate		$220	Regular rate - $.04	
Decision 12	0	Regular rate		$240	Regular rate - $.04	
Decision 13	0	Regular rate		$260	Regular rate - $.04	
Decision 14	0	Regular rate		$280	Regular rate - $.04	

The minimum base wage that I am willing to accept in order to take a 4 cents reduction in my piece rate is ___________.

DATE : ____________________

NAME: ______________________________ Regular rate: __________

	Option A		My Choice is A	Option B		My Choice is B
	Base Wage	Piece Rate		Base Wage	Piece Rate	
Decision 1	0	Regular rate		$20	Regular rate - $.06	
Decision 2	0	Regular rate		$40	Regular rate - $.06	
Decision 3	0	Regular rate		$60	Regular rate - $.06	
Decision 4	0	Regular rate		$80	Regular rate - $.06	
Decision 5	0	Regular rate		$100	Regular rate - $.06	
Decision 6	0	Regular rate		$120	Regular rate - $.06	
Decision 7	0	Regular rate		$140	Regular rate - $.06	
Decision 8	0	Regular rate		$160	Regular rate - $.06	
Decision 9	0	Regular rate		$180	Regular rate - $.06	
Decision 10	0	Regular rate		$200	Regular rate - $.06	
Decision 11	0	Regular rate		$220	Regular rate - $.06	
Decision 12	0	Regular rate		$240	Regular rate - $.06	
Decision 13	0	Regular rate		$260	Regular rate - $.06	
Decision 14	0	Regular rate		$280	Regular rate - $.06	
Decision 15	0	Regular rate		$300	Regular rate - $.06	
Decision 16	0	Regular rate		$320	Regular rate - $.06	
Decision 17	0	Regular rate		$340	Regular rate - $.06	

The minimum base wage that I am willing to accept in order to take a 6 cents reduction in my piece rate is ___________.

B Lottery Experimental design

Lottery instructions

You have before you a decision sheet. Your decision sheet shows ten decisions listed on the left. For each decision, we would like you to choose between "Option A" and "Option B.", marking your choice with an X in the appropriate column. For each of the ten decisions, you must choose Option A or Option B, but not both. While you will make 10 choices, only one of these choices will be used to determine your earnings. Before you start making your ten choices, please let me explain how these choices will affect your earnings.

Here are 10 chips that will be used to determine earnings. These poker chips are numbered from 1 to 10. After you have made all of your choices, you will twice pick one of the ten chips out of a bag. The first chip you will draw will be replaced in the bag before you draw the second chip. Your first draw will select which of the 10 Decisions will be used to calculate your earnings. For example, if your first draw is a chip with the number 3, then your choice for Decision 3 will determine your earnings. The second chip you draw will determine, for the particular decision selected, what your payoff is for the Option you chose, Option A or Option B. Again, even though you will make ten Decisions, only one of these will end up determining your earnings. However, each Decision has an equal chance of being selected.

Now, please look at Decision 1 at the top of the answer sheet. Option A pays \$80.00 if the second chip you draw is numbered 1, and pays \$64.00 if the second chip you draw is numbered 2-10. This means that if the first chip you draw selects Decision 1 and you selected Option A for that decision, then you have 1 chance out of 10 to win \$80.00, and 9 chances out of 10 to win \$64.00. Option B yields \$154.00 if the second chip you draw is numbered 1, and it pays \$4.00 if the second chip you draw is numbered 2-10. This means that if the first chip you draw selects Decision 1 and you selected Option B for that decision, then you have 1 chance out of 10 to win \$154.00, and 9 chances out of 10 to win \$4.00. The other Decisions are similar, the payoffs are the same but as you move down the table, the chances of the higher payoff for each option increase. For example, if the first chip you draw selects Decision 5 and you selected Option A for that Decision, then you have an equal chance of winning \$80.00 or \$64.00 when drawing the second chip. If the first chip you draw selects Decision 5 and you selected Option B for that Decision, then you have an equal chance of winning \$154.00 or \$4.00 when drawing a chip a second time. In fact, for Decision 10 in the bottom row, there is no need to draw a second chip since each option pays the highest payoff for certain, so your choice here is between \$80.00 or \$154.00.

To summarize, you will make ten choices: for each row in the table you will have to choose between Option A and Option B. You may choose Option A for some decision rows and Option B for other rows. When you are finished, you will come one by one to our table and draw a chip out of a hat to select which of your ten Decisions will be used. You will then draw a chip a second time again to determine your money earnings for the Option you chose for that Decision. So, for example, if the first chip you draw selects Decision 1 and the second chip you draw is numbered 1, then you will receive earnings of $80.00 if you chose Option A, or $154.00 if you chose Option B. However, if the first chip you draw selects Decision 1, but the second chip you draw is numbered from 2 to 10, you will receive earnings of $64.00 if you chose Option A, or $4.00 if you chose Option B.

	Option A	Choice is A	Option B	Choice is B
Decision 1	$80.00 if chip is 1 $64.00 if chip is 2 to 10		$154.00 if chip is 1 $4.00 if chip is 2 to 10	
Decision 2	$80.00 if chip is 1 to 2 $64.00 if chip is 3 to 10		$154.00 if chip is 1 to 2 $4.00 if chip is 3 to 10	
Decision 3	$80.00 if chip is 1 to 3 $64.00 if chip is 4 to 10		$154.00 if chip is 1 to 3 $4.00 if chip is 4 to 10	
Decision 4	$80.00 if chip is 1 to 4 $64.00 if chip is 5 to 10		$154.00 if chip is 1 to 4 $4.00 if chip is 5 to 10	
Decision 5	$80.00 if chip is 1 to 5 $64.00 if chip is 6 to 10		$154.00 if chip is 1 to 5 $4.00 if chip is 6 to 10	
Decision 6	$80.00 if chip is 1 to 6 $64.00 if chip is 7 to 10		$154.00 if chip is 1 to 6 $4.00 if chip is 7 to 10	
Decision 7	$80.00 if chip is 1 to 7 $64.00 if chip is 8 to 10		$154.00 if chip is 1 to 7 $4.00 if chip is 8 to 10	
Decision 8	$80.00 if chip is 1 to 8 $64.00 if chip is 9 to 10		$154.00 if chip is 1 to 8 $4.00 if chip is 9 to 10	
Decision 9	$80.00 if chip is 1 to 9 $64.00 if chip is 10		$154.00 if chip is 1 to 9 $4.00 if chip is 10	
Decision 10	$80.00 if chip is 1 to 10		$154.00 if chip is 1 to 10	

C Proofs of results of Structural model

Proof. Result 10

Maximum expected utility of the risk neutral worker under the standard piece rate contract $E_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})|_{\delta_i=1}]$ and under the base wage contract with taxes $E_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})|_{\delta_i=1}]$ are linked by the relation :

$$E_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})|_{\delta_i=1}] = b_{i\tau} + \frac{(1-\tau)^{\gamma+1}}{\exp^{\gamma\alpha_i b_{i\tau}}} E_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})|_{\delta_i=1}]$$

Hence we also always have

$$E_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})|_{\delta_i=1}] > E_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})|_{\delta_i=1}] \quad \text{whenever} \quad \gamma\alpha_i b_{i\tau} < (\gamma+1)\log(1-\tau)$$

■

Proof. Result 11

Let us assume $\gamma\alpha_i b_{i\tau} \geq (\gamma+1)\log(1-\tau)$ and pose

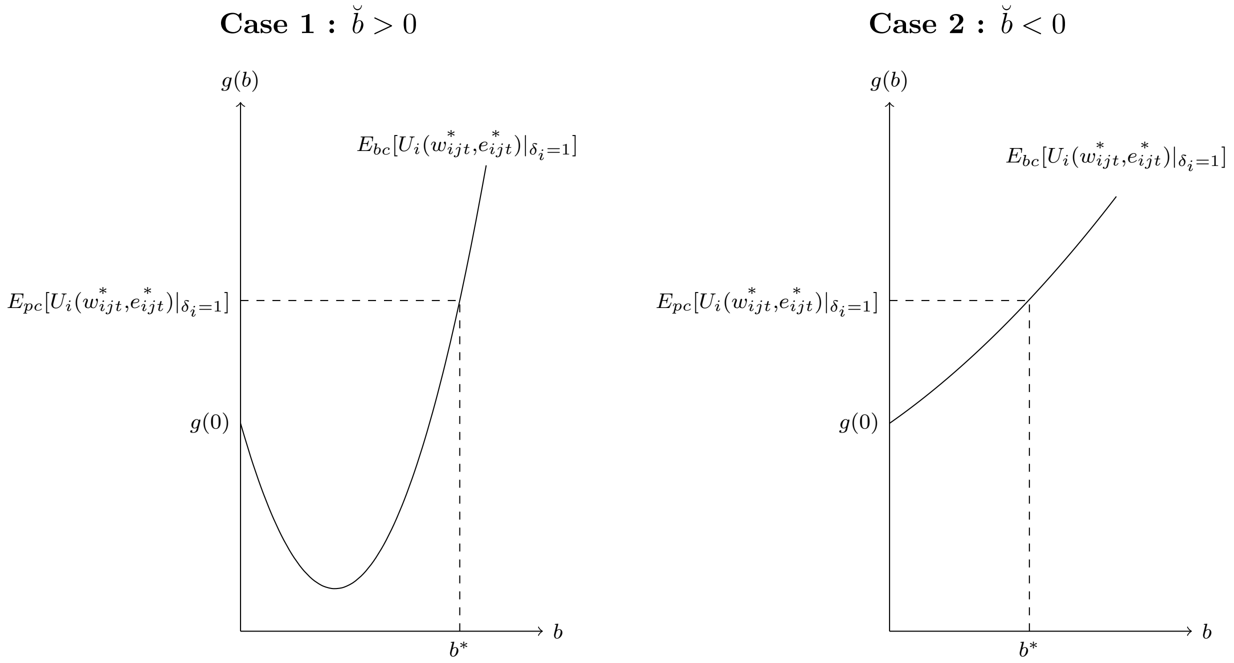
$$g(b) = E_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})|_{\delta_i=1}] = b + (1-\tau)^{\gamma+1}\bar{w}\exp^{\gamma(\lambda_h-\lambda_i)+\frac{1}{2}(\gamma+1)^2(1-\delta_h)\sigma_j^2-\gamma\alpha_i b}$$

The first derivative of $g(b)$ relatively to b is given by

$$g'(b) = 1 - \gamma\alpha_i(1-\tau)^{\gamma+1}\bar{w}A\exp^{-\gamma\alpha_i b+\frac{1}{2}(\gamma+1)^2(1-\delta_h)\sigma_j^2} \quad \text{with} \quad A = d_t^{\gamma+1}\exp^{\gamma(\lambda_h-\lambda_i)}$$

1. If $\alpha_i \leq 0$, then $g'(b) > 0$, $g(b)$ is a strictly increasing function in b and thus bijective. This implies that there is a unique value of b that equates $g(b) = E_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$ when $\frac{(\gamma+1)\log(1-\tau)}{\gamma b} \leq \alpha_i \leq 0$. Indeed we have $g(0) < E_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})|_{\delta_i=1}] < g(E_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})|_{\delta_i=1}])$.

2. If $\alpha_i > 0$, then g has an U shape with a minimum at $\breve{b}$. It is strictly increasing for $b > \breve{b}$ as depicted by the graphs below. There is a unique strictly positive $\tilde{b}$ such that $g(\tilde{b}) = E_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})|_{\delta_i=1}]$. Recall that in the study, we focus on positive lump-sum ($b \geq 0$).



■

Proof. Result 12

The expected utility under the base wage contract is given by :

$$E_{bc}[U_i(w^*_{ijt}, e^*_{ijt})] = \frac{1}{\delta_i} E\Big[\Big(\underbrace{b_{i\tau} + s_{ij}^{\gamma+1}\upsilon}_{X}\Big)^{\delta_i}\Big] \quad \text{where} \quad \upsilon = \bar{w}d_t^{\gamma+1}(1-\tau)^{\gamma+1}\exp^{\gamma(\lambda_h-\lambda_i)-(\gamma+1)\mu_j-\frac{1}{2}(\gamma+1)^2\delta_h\sigma_j^2-\gamma\alpha_i b_{i\tau}}$$

There is no closed-form for this expression when δ_i is different from 1 (case of risk-neutrality). Let us pose

$$\Lambda(X) = \frac{1}{\delta_i}X^{\delta_i} \quad \text{then} \quad E_{bc}[U_i(w^*_{ijt}, e^*_{ijt})] = E_{bc}[\Lambda(X)]$$

- if $\delta_i > 1$ (risk lover) , $\Lambda(X)$ is convex and expected maximum utility of individual under the base wage contract is denoted $E^l_{bc}[U_i(w^*_{ijt}, e^*_{ijt})]$
- if $\delta_i < 1$ (risk averse) , $\Lambda(X)$ is concave and expected maximum utility of individual under the base wage contract is denoted $E^a_{bc}[U_i(w^*_{ijt}, e^*_{ijt})]$
- if $\delta_i = 1$ (risk neutral) , $\Lambda(X)$ is identity and expected maximum utility of individual under the base wage contract is denoted $E^n_{bc}[U_i(w^*_{ijt}, e^*_{ijt})]$

The jensen inequality enables to establish for the risk averse individual for $\delta_i < 1$:

$$E_{bc}[\Lambda(X)_{\delta_i<1}] \leq \Lambda[E(x)] \iff E^a_{bc}[U_i(w^*_{ijt}, e^*_{ijt})] \leq \frac{1}{\delta_i}\Big(E^n_{bc}[U_i(w^*_{ijt}, e^*_{ijt})]\Big)^{\delta_i} \tag{43}$$

The jensen inequality enables to establish for the risk lover individual for $\delta_i > 1$:

$$\Lambda[E(x)] \leq E_{bc}[\Lambda(X)_{\delta_i>1}] \iff \frac{1}{\delta_i}\Big(E^n_{bc}[U_i(w^*_{ijt}, e^*_{ijt})]\Big)^{\delta_i} \leq E^l_{bc}[U_i(w^*_{ijt}, e^*_{ijt})] \tag{44}$$

While it is not possible to have a closed-form for $E^l_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$ and $E^a_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$, we can however compute analytically $E^n_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$

$$\begin{aligned}
E^n_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})] &= b_{i\tau} + (1-\tau)^{\gamma+1}\bar{w}d_t^{\gamma+1}\exp^{-\gamma\alpha_i b_{i\tau}+\gamma(\lambda_h-\lambda_i)+\frac{1}{2}(\gamma+1)^2(1-\delta_h)\sigma_j^2} \\
&= b_{i\tau} + (1-\tau)^{\gamma+1}\bar{w}d_t^{\gamma+1}\exp^{-\gamma\alpha_i b_{i\tau}+\gamma(\lambda_h-\lambda_i)+\frac{1}{2}(\gamma+1)^2(1-\delta_i+\delta_i-\delta_h)\sigma_j^2} \\
&= b_{i\tau} + (1-\tau)^{\gamma+1}\bar{w}d_t^{\gamma+1}\exp^{-\gamma\alpha_i b_{i\tau}+\frac{1}{2}(\gamma+1)^2(1-\delta_i)\sigma_j^2}\exp^{\gamma(\lambda_h-\lambda_i)+\frac{1}{2}(\gamma+1)^2(\delta_i-\delta_h)\sigma_j^2}
\end{aligned}$$

For a given $b_{i\tau} \geq 0$ and $\delta_i > 1$, we can re-arrange the terms and deduce

$$\begin{aligned}
\frac{1}{\delta_i}\Big(E^n_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})] - b_{i\tau}\Big)^{\delta_i} &= \frac{1}{\delta_i}\Big((1-\tau)^{\gamma+1}\bar{w}d_t^{\gamma+1}\exp^{-\gamma\alpha_i b_{i\tau}+\frac{1}{2}(\gamma+1)^2(1-\delta_i)\sigma_j^2}\exp^{\gamma(\lambda_h-\lambda_i)+\frac{1}{2}(\gamma+1)^2(\delta_i-\delta_h)\sigma_j^2}\Big)^{\delta_i} \\
&= (1-\tau)^{\delta_i(\gamma+1)}\exp^{-\delta_i\gamma\alpha_i b_{i\tau}+\frac{1}{2}(\gamma+1)^2(1-\delta_i)\sigma_j^2\delta_i} \times \underbrace{\frac{1}{\delta_i}\bar{w}^{\delta_i}d_t^{\delta_i(\gamma+1)}\exp^{\delta_i\gamma(\lambda_h-\lambda_i)+\frac{1}{2}\delta_i(\gamma+1)^2(\delta_i-\delta_h)\sigma_j^2}}_{E^l_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]} \\
&= (1-\tau)^{\delta_i(\gamma+1)}\exp^{-\delta_i\gamma\alpha_i b_{i\tau}+\frac{1}{2}(\gamma+1)^2(1-\delta_i)\sigma_j^2\delta_i} \times E^l_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]
\end{aligned}$$

Note that $E^l_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$ is the expected maximum utility of the risk lover individual under the standard piece rate. It follows from the precedent equation that

$$\begin{aligned}
(1-\tau)^{\delta_i(\gamma+1)}\exp^{-\delta_i\gamma\alpha_i b_{i\tau}+\frac{1}{2}(\gamma+1)^2(1-\delta_i)\sigma_j^2\delta_i} > 1 &\iff (\gamma+1)\log(1-\tau) + \frac{1}{2}(\gamma+1)^2(1-\delta_i)\sigma_j^2 > \gamma\alpha_i b_{i\tau} \\
&\iff \alpha_i\gamma b_{i\tau} + \frac{1}{2}(\gamma+1)^2(\delta_i-1)\sigma_j^2 < (\gamma+1)\log(1-\tau) \\
&\implies \frac{1}{\delta_i}\Big(E^n_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})] - b_{i\tau}\Big)^{\delta_i} > E^l_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]
\end{aligned}$$

Hence we can deduce for $b_{i\tau} \geq 0$

$$\begin{aligned}
&\frac{1}{\delta_i}\Big(E^n_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]\Big)^{\delta_i} \geq \frac{1}{\delta_i}\Big(E^n_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})] - b_{i\tau}\Big)^{\delta_i} > E^l_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})] \\
&\text{if} \quad \gamma\alpha_i\gamma b_{i\tau} + \frac{1}{2}(\gamma+1)^2(\delta_i-1)\sigma_j^2 < (\gamma+1)\log(1-\tau)
\end{aligned} \tag{45}$$

From equations (44) and (45), we can then establish

$$E^l_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})] > E^l_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})] \quad \text{whenever} \quad \gamma\alpha_i\gamma b_{i\tau} + \frac{1}{2}(\gamma+1)^2(\delta_i-1)\sigma_j^2 < (\gamma+1)\log(1-\tau)$$

■

Proof. Result 13

Let us assume $\alpha_i\gamma b_{i\tau} + \frac{1}{2}(\gamma+1)^2(\delta_i-1)\sigma_j^2 \geq (\gamma+1)\log(1-\tau)$ and pose

$$\begin{aligned}
h(b)|_{\delta_i>1} = \frac{1}{\delta_i}\Big(E^n_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]\Big)^{\delta_i} &= \frac{1}{\delta_i}\Big(b + (1-\tau)^{\gamma+1}\bar{w}d_t^{\gamma+1}\exp^{\gamma(\lambda_h-\lambda_i)+\frac{1}{2}(\gamma+1)^2(1-\delta_h)\sigma_j^2-\gamma\alpha_i b_{i\tau}}\Big)^{\delta_i} \\
&= \frac{1}{\delta_i}\Big(g(b)\Big)^{\delta_i}
\end{aligned}$$

The first derivative of $h(b)|_{\delta_i>1}$ relatively to b is given by

$$h'(b)|_{\delta_i>1} = g'(b)\Big(g(b)\Big)^{\delta_i-1}$$

Noting that $g(b)$ is positive, the sign of $h'(b)|_{\delta_i>1}$ is given by the sign of $g'(b)$. Hence we can deduce as shown previously when examining $g'(b)$

1. If $\alpha_i \leq 0$, then $g'(b) > 0$ and consequently $h'(b)|_{\delta_i>1} > 0$, $h(b)|_{\delta_i>1}$ is a strictly increasing function in b and thus bijective. This implies that there is a unique value of b that equates $h(b)|_{\delta_i>1} = E^l_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$ when $(\gamma+1)\log(1-\tau) - \frac{1}{2}(\gamma+1)^2(\delta_i - 1) \leq \gamma b\alpha_i \leq 0$ with $\delta_i > 1$. Indeed we have $h(0)|_{\delta_i>1} < E^l_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})] < h(E^l_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})])|_{\delta_i>1}$. It appears quite straightforward to show that $E^l_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})] < h(E^l_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})])|_{\delta_i>1}$. Notice that :

$$h(0)|_{\delta_i>1} = (1-\tau)^{\delta_i(\gamma+1)} \exp^{\frac{1}{2}(\gamma+1)^2(1-\delta_i)\sigma_j^2\delta_i} E^l_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$$

Since $\delta_i > 1$ and $0 < t < 1$, it follows that $h(0)|_{\delta_i>1} < E^l_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$ as stated above.

2. If $\alpha_i > 0$, $h(b)|_{\delta_i>1}$ has the same U shape as $g(b)$ with a minimum at $\breve{b}$. It is strictly increasing for $b > \breve{b}$.

   There is a unique strictly positive $\hat{b}_{i\tau}$ such that $h(\hat{b}_{i\tau})_{\delta_i>1} = E^l_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$. It is straightforward to show that

$$(\gamma+1)\log(1-\tau) = \gamma\alpha_i\hat{b}_{i\tau} + \frac{1}{2}(\gamma+1)^2(\delta_i-1)\sigma_j^2 + \log\left[1 - \frac{\hat{b}_{i\tau}}{\bar{w}A\exp^{\frac{1}{2}(\gamma+1)^2(\delta_i-\delta_h)\sigma_j^2}}\right] \text{ with } \delta_i > 1,\ A = d_t^{\gamma+1}\exp^{\gamma(\lambda_h-\lambda_i)}$$

These two points help to establish that there is an unique strictly positive $\hat{b}_{i\tau}$ such that $h(\bar{b})_{\delta_i>1} = E^l_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$ when $\alpha_i\gamma b_{i\tau} + \frac{1}{2}(\gamma+1)^2(\delta_i-1)\sigma_j^2 \geq (\gamma+1)\log(1-\tau)$. Knowing this and recalling from the Jensen inequality in equation 44 that

$$h(b)|_{\delta_i>1} = \frac{1}{\delta_i}\Big(E^n_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]\Big)^{\delta_i} \leq E^l_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$$

It follows that $E^l_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$ cuts $E^l_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$ at least at one point $b^l_{i\tau}$ when $\alpha_i\gamma b_{i\tau} + \frac{1}{2}(\gamma+1)^2(\delta_i-1)\sigma_j^2 \geq (\gamma+1)\log(1-\tau)$. It is straightforward to show that $E^l_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]|_{b=0} = (1-\tau)^{\delta_i(\gamma+1)}E^l_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})] < E^l_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$. It also follows that where $E^l_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$ cuts $E^l_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$ in $b^l_{i\tau}$, we have $b^l_{i\tau} \leq \hat{b}_{i\tau}$. ■

Proof. Result 14

Let us assume $\frac{1}{2}(\gamma+1)^2(\delta_i-1)\sigma_j^2 > (\gamma+1)\log(1-\tau)$ and pose

$$\begin{aligned} h(b)|_{0<\delta_i<1} = \frac{1}{\delta_i}\Big(E^n_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]\Big)^{\delta_i} &= \frac{1}{\delta_i}\Big(b + (1-\tau)^{\gamma+1}\bar{w}d_t^{\gamma+1}\exp^{\gamma(\lambda_h-\lambda_i)+\frac{1}{2}(\gamma+1)^2(1-\delta_h)\sigma_j^2-\gamma\alpha_i b_{i\tau}}\Big)^{\delta_i} \\ &= \frac{1}{\delta_i}\Big(g(b)\Big)^{\delta_i} \end{aligned}$$

Notice that $h(b)|_{0<\delta_i<1}$ and $h(b)|_{\delta_i>1}$ studied previously display similar behaviors.

1. If $\alpha_i \leq 0$, then $h'(b)|_{0<\delta_i<1} > 0$, consequently $h(b)|_{0<\delta_i<1}$ is a strictly increasing function in b and thus bijective.

   Notice that $h(0)|_{0<\delta_i<1} = (1-\tau)^{\delta_i(\gamma+1)}\exp^{\frac{1}{2}(\gamma+1)^2(1-\delta_i)\sigma_j^2\delta_i} E^a_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$. It follows the relation

$$\frac{1}{2}(\gamma+1)^2(\delta_i-1)\sigma_j^2 > (\gamma+1)\log(1-\tau) \Longleftrightarrow h(0)|_{0<\delta_i<1} < E^a_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})] \quad \text{when} \quad \delta_i < 1$$

On the hand, we can also show that $E^a_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})] < h(E^a_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})])|_{0<\delta_i<1})$. Thus, there is a unique value of b that equates $h(b)|_{0<\delta_i<1} = E^a_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$ when $\frac{1}{2}(\gamma+1)^2(\delta_i-1)\sigma_j^2 > (\gamma+1)\log(1-\tau)$.

Indeed, we have $h(0)|_{0<\delta_i<1} < E^a_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})] < h(E^a_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})])|_{0<\delta_i<1}$ when $\frac{1}{2}(\gamma+1)^2(\delta_i-1)\sigma_j^2 > (\gamma+1)\log(1-\tau)$ and $h(b)|_{0<\delta_i<1}$ is strictly bijective.

2. If $\alpha_i > 0$, $h(b)|_{0<\delta_i<1}$ has the same U shape as $h(b)|_{0<\delta_i<1}$ with a minimum at $\breve{b}$. It is strictly increasing for $b > \breve{b}$. There is an unique strictly positive $\hat{b}_{i\tau}$ such that $h(\hat{b}_{i\tau})|_{0<\delta_i<1} = E^a_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$. It is straightforward to show that

$$(\gamma+1)\log(1-\tau) = \gamma\alpha_i\hat{b}_{i\tau} + \frac{1}{2}(\gamma+1)^2(\delta_i-1)\sigma_j^2 + \log\left[1 - \frac{\hat{b}_{i\tau}}{\bar{w}A\exp^{\frac{1}{2}(\gamma+1)^2(\delta_i-\delta_h)\sigma_j^2}}\right] \text{ with } \delta_i < 1,\ A = d_t^{\gamma+1}\exp^{\gamma(\lambda_h-\lambda_i)}$$

These two points imply an unique strictly positive $\hat{b}_{i\tau}$ such that $h(\bar{b})|_{0<\delta_i<1} = E^a_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$ when $\frac{1}{2}(\gamma+1)^2(\delta_i-1)\sigma_j^2 > (\gamma+1)\log(1-\tau)$. Knowing this and recalling from the Jensen inequality in equation (43) that $h(b)|_{0<\delta_i<1} = \frac{1}{\delta_i}\Big(E^n_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]\Big)^{\delta_i} \geq E^a_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$, it follows that $E^a_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$ cuts $E^a_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$ at least at one point $b^a_{i\tau}$ when $\frac{1}{2}(\gamma+1)^2(\delta_i-1)\sigma_j^2 > (\gamma+1)\log(1-\tau)$.

Indeed, under the condition $\frac{1}{2}(\gamma+1)^2(\delta_i-1)\sigma_j^2 > (\gamma+1)\log(1-\tau)$ and assuming δ_i positive, we can also verify that for very important values of b, $E^a_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})] > E^a_{pc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$. It also follows that where $E^a_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$ cuts $E^a_{bc}[U_i(\overset{*}{w}_{ijt}, \overset{*}{e}_{ijt})]$ in $b^l_{i\tau}$, we have $b^a_{i\tau} \geq \hat{b}_{i\tau}$. ■