DIVISION OF THE HUMANITIES AND SOCIAL SCIENCES
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA 91125

Equilibrium Tax Rates and Income Redistribution: A Laboratory Study

Thomas R. Palfrey
California Institute of Technology

Marina Agranov
California Institute of Technology

SOCIAL SCIENCE WORKING PAPER 1385
January 2014

Equilibrium Tax Rates and Income Redistribution: A Laboratory Study[1]

Marina Agranov[2] and Thomas R. Palfrey[3]

First Version: September 2012. This Version: January 31, 2014

Abstract

This paper reports results from a laboratory experiment that investigates the Meltzer-Richard model of equilibrium tax rates, inequality, and income redistribution. We also extend that model to incorporate social preferences in the form of altruism and inequality aversion. The experiment varies the amount of inequality and the collective choice procedure to determine tax rates. We report four main findings. First, higher wage inequality leads to higher tax rates. The effect is significant and large in magnitude. Second, the average implemented tax rates are almost exactly equal to the theoretical ideal tax rate of the median wage worker. Third, we do not observe any significant differences in labor supply or average implemented tax rates between a direct democracy institution and a representative democracy system where tax rates are determined by candidate competition. Fourth, we observe negligible deviations from labor supply behavior or voting behavior in the directions implied by altruism or inequality aversion.

[1]The financial support of the National Science Foundation (SES-0962802) and the Gordon and Betty Moore Foundation is gratefully acknowledged. We are grateful for comments from seminar audiences at the NBER, Caltech, Chicago, UCSB, University of Zurich, ETH, EUI, Berkeley, USC, Higher School of Economics Moscow, SAET, especially Ernesto Dal Bo, John Londregan, and Thomas Romer. Kirill Pogorelskiy provided excellent research assistance.
[2]Division of the Humanities and Social Sciences, California Institute of Technology, Mail Code 228-77, Pasadena, CA 91125. Email: magranov@hss.caltech.edu.
[3]Division of the Humanities and Social Sciences, California Institute of Technology, Mail Code 228-77, Pasadena, CA 91125. Email: trp@hss.caltech.edu.

1 Introduction

In the US and other democratic countries, taxes are decided by a democratic political process, and income tax policy in particular has enormous redistributive consequences. Much of the expenditures that are financed by income taxes are either almost entirely redistributive, such as Food Stamps or Aid to Families with Dependent Children, or have significant redistributive components, such as subsidies to education (college loans, head start, work study), public transit, and health insurance. These expenditures are generally aimed at benefiting lower income members of society, while the costs of these programs are borne in proportion to income (or, under progressive taxation, more than proportionally to income). However, standard economic analysis implies that, unless the elasticity of labor supply with respect to after-tax wages is zero for all individuals, this redistribution comes at a cost. Thus, on the one hand, income taxes reduce inequality, which is generally regarded to be a positive improvement to society, but on the other hand, taxes may negatively affect efficiency of the economy through distortions in the labor market. This fundamental equity-efficiency tradeoff drives much of the political debate and polarization over economic policy, which is considered by most political scientists to be the primary dimension of political competition in modern democracies.[1]

There is now a rather well developed and rigorous, equilibrium-based theory addressing the positive question of how the level of income taxes are determined in the democratic society, starting with the work of Romer (1975), Roberts (1977) and Meltzer and Richard (1981). These models are based on the median voter theory developed by Black (1958) and Downs (1957).[2] The equity-efficiency tradeoff in these models is captured by a distortion to labor supply created by a gap between the after-tax wage and a worker's marginal productivity. The heterogeneity in the agents' productivities is the driving force behind inequality in the pre-tax incomes in these models, as it is in the model we study in the present paper. While the theoretical implications of these models have potentially enormous economic consequences, both in terms of inequality level in society and economic efficiency, as an empirical matter, these theories are extremely difficult to test using macro field and historical data sets.

Not only is such data relatively limited, but there are open methodological issues about the extent to which these studies enable one to draw causal conclusions, as well as the deeper problem of endogeneity of the economic and political variables using historical or contemporary data. For example, one basic implication of these median voter models of tax policy is that, all else equal, greater pre-tax inequality will lead to higher taxes. At the same time the model predicts that, all else equal, higher taxes will lead to a decline in aggregate output. Besides causality issues, it is hard to pin down exactly which policies are redistributive, or more precisely, how much redistribution is associated with various policies. Moreover, the key variables, inequality, taxes, and income are all endogenous and causally intertwined. For cross-national studies, political institutions vary across countries, and in none of the systems are tax rates determined by "pure" majority rule vote. Rather there are a variety of ways of deciding taxes, ranging from decisions made by elected representatives to highly decentralized systems that more closely resemble referenda.

There have been a number of careful studies that acknowledge these difficulties and attempt to overcome them. Unfortunately, taken collectively, these studies have led to ambiguous, and sometimes conflicting conclusions. Several studies attempt to test the median voter tax hypothesis, which states that the tax rate and/or government expenditures in democracies will correspond to the ideal level of public expenditure of the median voter. Meltzer and Richard (1983) test this with data on their categorization of redistributive expenditures in the U.S. between 1936 and 1977, excluding expenditures on public goods such as public safety, defense, and infrastructure. They don't find direct evidence for

[1] See, for example, McCarty, Poole and Rosenthal (2006).

[2] The present paper focuses primarily on behavioral and positive questions about the political-economic equilibrium that determines tax policy, rather than normative concerns about optimal tax rates. Thus we explore a different set of questions than is addressed in the literature on incentive efficient tax schemes, pioneered by Mirlees (1971).

the hypothesis, but find that purely redistributive expenditures are positively correlated with the ratio of mean to median income. Milanovic (2000), in a cross-sectional study of 24 democracies, also finds that income redistribution to the poor correlates with measures of income inequality, but finds little support for the median voter hypothesis. On the other hand, Perotti (1996), in his cross-sectional study of 67 countries, does not find significant evidence for a positive relationship between inequality and middle class tax rates. Thus, the overall picture is one of mixed empirical findings. While some of the findings are suggestive of a link that would be consistent with the median voter hypothesis, the link is tenuous and does not help identify the mechanism by which the median voters preferences are implemented in the political process.

In spite of the inconclusive empirical evidence, there is a widespread consensus about the importance of the interdependence between agents' behavior in economical and political domains. Indeed, labor supply crucially depends on the amount of taxation imposed by the political process and, vice-versa, indirect preferences of an agent for the level of taxation and redistribution crucially depend upon the agent's beliefs about labor market behavior of other agents. For instance, low income agents might prefer lower tax rates if they believe that richer agents might drastically reduce labor when taxes are higher. While the theoretical literature has long recognized the necessity to study the interplay between market behavior of heterogeneous agents and their indirect preferences for redistribution expressed in the political arena, empirical studies of this interdependence are inconclusive.[3]

The experiment we report in this paper explores questions about the equity-efficiency tradeoff vis-a-vis redistributive taxation, the equilibrium effect of wage inequality on income tax rates, and the median voter hypothesis about the political economy consequences of voting over taxes. Our laboratory environment is designed to correspond to the Meltzer-Richard model. The individuals participating in our experiment operate in two interconnected environments: a political environment, where the level of taxation is determined, and a labor market (economic environment), in which, given an income tax schedule, individuals with varying wage rates choose labor supply that generates pre-tax income. Because of the redistributive effect of income taxation and because individuals differ in their productivities and hence their incomes, individuals in our experiment have different indirect preferences for the level of taxation and these preferences depend upon the distribution of productivities in the economy. Political institutions are the means by which these heterogeneous preferences are aggregated into a public decision on the tax rate. However, because the tax rate in turn affects the amount of income that is generated by the private economy, agents' preferences for redistribution themselves are endogenous and depend on aggregate labor supply responses to taxes.

The experiment is motivated by three primary considerations. The first was summarized above: the large empirical literature devoted to studying these questions about the equity-efficiency tradeoff and in particular the median voter hypothesis that implies greater inequality leads to higher taxes, has not succeeded in coming to any consensus about any of the important questions raised by the theoretical political models of redistributive taxation. Our experiment can address these theoretical issues by providing data from a simple environment where preferences, technology, and the political process are tightly controlled, leading to sharp theoretical predictions. This enables us to measure directly the labor supply effects, and by exogenously controlling the level of inequality, we can address the causal question of how the degree of inequality in the economy affects the level of redistributive taxation.

The second consideration concerns the role of the specific mechanism that implements democratic outcomes. One of the shortcomings of the classic political economy models of income taxation is that they are completely silent about the mechanics of the political process by which a tax rate is chosen. The models simply assume that the tax rate preferred by the median voter will emerge, as if by an invisible political hand. However more recent work in theoretical political economy and game theory clearly show that the institutional details of a democratic system cannot be ignored, as small differences in the game form can lead to substantially different outcomes, and that those outcomes do

[3]See, for example, Keane's (2011) detailed survey of the effect of taxes on labor supply.

not necessarily correspond to the ideal point of the median voter. With this in mind, our experimental design compares the tax rates that emerge under two different majoritarian political processes: *direct democracy* and *representative democracy*. In the direct democracy mechanism, the median voter's preferred policy is elicited directly[4], while in the representative democracy system voters choose in an election between two office-motivated candidates who compete by choosing tax rates as their platforms.

The third consideration is the question of *direct preferences for redistribution*. The standard political economy models approach is to characterize indirect preferences for redistribution based on the assumption that voters are completely selfish and only care about their own after tax income and their own labor leisure tradeoff. There is a substantial empirical literature on direct preferences for redistribution, largely addressing questions of cross-cultural differences in preferences for equality, tolerance of inequality, or interdependent preferences (see Alesina and Giuliano (2011)). There is also abundant evidence from laboratory experiments suggesting a potentially important role of direct preferences over redistribution, or *social preferences*, in economic decision making where inequality is a key aspect of the final allocations.[5] Redistributive taxation is an almost ideal environment where social preferences can strongly influence behavior and outcomes.

To address this, we characterize the equilibrium effects of social preferences on labor supply and indirect preferences over tax rates, for two different models of social preferences: *altruism* and *inequality aversion*. Altruism leads to systematically higher labor supply for any tax rate, and reduces the ideal tax rate for all voters, regardless of their productivity. Inequality aversion leads to systematically higher labor supply for high income workers and systematically lower labor supply for low income workers. Under standard conditions on the level of inequality and the parameters of the Fehr-Schmidt model, inequality aversion increases the ideal tax rate of the median voter. Hence, this characterization provides plausible and testable alternative hypotheses to the standard theoretical hypotheses that are derived under the assumption that individuals are selfish.

We have several main results. The first set of results address qualitative hypotheses based on the first two considerations above, all of which hold regardless of the assumptions about social preferences. First, higher inequality leads to significantly more income redistribution through higher taxation. Second, we observe strong labor supply effects. Higher tax rates lead to lower aggregate labor supply and lower total income, so there is the predicted equity-efficiency tradeoff. Third, the equilibrium tax rates are largely determined by the voting behavior of the median productivity worker, which is consistent with the median voter hypothesis. Observation of choice behavior of voters in each political mechanism (direct and representative democracy) allows us to back out estimates of the revealed ideal points of different voter types. Our fourth result confirms the monotonic relationship between ideal tax rates of agents and productivities. As predicted, these revealed ideal points are ordered by productivity, with less productive (low wage) individuals preferring higher taxes. Fifth, the above results are robust to the political mechanism: we observe very similar behavior and outcomes under direct democracy and representative democracy.

A second set of results addresses specific quantitative hypotheses about labor supply decisions, revealed preferences over tax rates, and equilibrium tax rates. As explained above, these quantitative predictions strongly depend on social preferences. First, we find that the average observed tax rates are very close to the predicted tax rates under the standard model without social preferences. Second, we observe that labor supply decisions are very close to what is predicted by the standard model, with one important exception: when inequality is very high, the very rich individuals tend to undersupply labor. However, this deviation from the standard model cannot be accounted for by the social preference model that predict exactly the opposite effect: rich workers should supply more than what is predicted by the standard model if they are altruistic or inequality averse. The effect of social preferences on

[4]This mechanism has been used in tax referendums in the U.S. See Holcombe (1977) and Holcombe and Kenny (2007,2008).

[5]Andreoni and Miller (2002), Bolton and Ockenfels (2000), Fehr and Schmidt (1999), Fisman et al. (2007), Palfrey and Rosenthal (1988).

voting behavior is difficult to assess in the data using simple descriptive statistics. Therefore we estimate the parameters of the altruism and inequality aversion models, using the data on voting decisions. We cannot reject the hypothesis that the social preference parameters are equal to zero, and conclude that social preferences do not play an important role in either labor supply responses to taxes, or preferences over redistribution. While we hesitate to extrapolate these findings to the much more complex environments of voting over taxes in mass economies and electorates, the results in our small carefully-controlled environment are quite sharp.

We see experiments as a valuable tool for advancing our understanding of the political economy of redistribution and taxation. Indeed, these controlled laboratory experiments provide a clean test of the theoretical models in very simple environments, while preserving key incentives and tradeoffs that people face outside of the laboratory. Hence, data created from a carefully controlled setting that can be used toward the development of better models. Further, our paper can be seen as one of the first attempts to study the interaction between labor market and political behavior, while keeping all the remaining details (political institution and distribution of productivities) constant and varying one parameter at a time. For these purposes, experiments have a significant advantage over empirical research using historical time-series or cross-sectional data.

The paper is structured as follows. In the remainder of this section, we discuss some related experimental literature. Section 2 presents the theoretical model where we characterize the equilibrium under three alternative assumptions about social preferences: purely selfish preferences, altruistic preferences, and inequality averse preferences. These serve as the basis for hypotheses about the results of our experiment. Section 3 discusses the experimental design and procedures. The results are presented in Section 4, and Section 5 offers some brief conclusions.

1.1 Related Literature

There is an extensive experimental literature in economics aimed at measuring preferences for redistribution. Some papers concentrate entirely on examination of two motives - self-interest versus fairness - and abstract away from efficiency concerns.[6] Other more recent studies (e.g., Andreoni and Miller (2002), Fisman et al. (2007)) investigate whether and how efficiency affects participants' social preferences by exogenously allowing the size of the total pie to vary as a function of the shares. Bolton and Ockenfels (2006) conduct a series of voting games, in which subjects are confronted with two distributions of incomes: one that promotes efficiency and a second that promotes equity. Tyran and Sausgruber (2006) offer evidence that inequality averse social preferences may explain voting behavior over non-distortionary redistribution, in an experiment where subjects were endowed with one of two different income levels (there is no labor market) and vote on a fixed amount of redistribution. Hochtl et al. (2012) report a followup experiment and provide evidence that the ability of inequality aversion to explain voting behavior on redistribution may depend on the pre-tax distribution of income. In all the papers described above, the amount of resources to be distributed is fixed exogenously and participants can only decide how to reallocate this surplus. In our experiments subjects' labor market decisions determine the total surplus generated, so both the total size of the pie and the distribution of income is endogenous and is a function of the tax rate. Moreover, while measuring preferences for redistribution is not the main focus of our paper, our design allows us to detect the presence of social preferences through analyzing both labor market decisions of agents as well as their voting patterns.

There are two recent studies that are more closely related to our paper. The first is Durante et al. (2014), a laboratory experiment to study how preferences for redistribution vary with social preferences, risk aversion, self-interest and the source of pre-tax inequality. In particular, that paper focuses on whether preferences for redistribution are affected by: (1) the way the distribution of pre-tax endowments are determined: by luck, or earned in the sense that they are based on the score obtained in an unrelated skill task; and (2) whether the person choosing the level of redistribution is affected

[6] See, for example, Forsythe et al. (1994) and many other studies of the dictator game.

by this redistribution process him/herself or is merely a disinterested observer. Among other things, the authors document that most subjects prefer a more equal distribution of final wealth; however, this preference for redistribution decreases substantially when the initial distribution of endowments is determined based on the task performance rather than randomly.[7] Similarly to the literature discussed above, the main goal of the Durante et al. study is to measure subjects' preferences for redistribution and how they are affected by various factors. Consistent with this goal, the authors use random dictator method to elicit subjects' preferences and abstract away from the details of political process that determine taxation level as well as strategic behavior of subjects in the political sphere, which is what we do in our study. Put differently, our focus is on the equilibrium behavior of agents in both economical and political markets and how this behavior is affected by various political institutions used to determine taxes in the democratic societies.

A second recent paper is Grosser and Reuben (2013), which reports the results of two laboratory experiments. In the first experiment, subjects first earn their income by trading in a double auction market and the profits generated in the market are redistributed according to one of several exogenously fixed rules (including zero redistribution). The goal of this experiment is to see whether equal-share redistribution effects trading efficiency. In a competitive equilibrium there should be no such effect, and they observed only small effects, and only when the redistribution rule is essentially equal sharing, which they attribute to out-of-equilibrium dynamics. The second experiment investigates endogenous redistribution by introducing competition between two candidates who propose the level of redistribution as in our study. Because the taxes are non-distortionary and the median voter has low income, the theoretical equilibrium tax rate is 100%, which is close to what is observed.[8]

2 Model and Theoretical Predictions

In this section we first lay out the primitives of the model and derive equilibrium under the assumption that agents are purely selfish. We then extend the analysis to consider two alternative models of social preferences, altruism and inequality aversion, and characterize the equilibrium in each of these models.

2.1 Model with Selfish Agents

The economy consists of $n > 1$ agents. Agents operate in a perfectly competitive and frictionless labor market and also participate in a democratic political process that determines taxes which in turn affect labor decisions. To simplify exposition, we describe here the setup with the utility function we implement in the experiments.

We start by discussing the decision problem of an agent in the labor market assuming that the tax rate is fixed. Then we characterize the majority rule equilibrium tax rate, by deriving the induced preferences of voters, assuming rational expectations about how aggregate labor supply responds to changes in the income tax rate.

The Labor Market. Agent i is endowed with productivity w_i. Individuals are identical in all other respects. The difference in choice of labor and consumption arise solely because of the differences in productivity. An agent with productivity w_i who supplies x_i units of labor earns pre-tax income $y_i = w_i x_i$ and bears an effort cost of $\frac{1}{2}x_i^2$ which represents the tradeoff between labor and leisure. Income and costs are measured in units of consumption. In addition, each agent pays a fraction t of

[7]In our experiment, one's rank on the income scale is determined entirely by luck and there is no social mobility. So their finding, together with similar findings from survey research on preferences for redistribution (Alesina and Giuliano (2011)) suggest the likelihood of a significant role of social preferences in our experiment.

[8]The timing of voting is also different from our study. Voting over tax rates occurs after subjects make their market decision. They also include a treatment where voters can offer non-binding bribes to the candidates, with no significant effect.

earned income in taxes. Tax revenues are redistributed in equal shares.[9] Thus the payoff U_i of agent i consists of three parts: after-tax disposable income, cost of labor, and an equal share of collected taxes, where the latter depends on the entire profile of productivities, $w = (w_1, ..., w_n)$ and labor supply decisions $x = (x_1, ..., x_n)$:

$$U_i(w_i, x_i, t) = (1-t) \cdot w_i x_i - \frac{1}{2} x_i^2 + \frac{1}{n} \sum_{j=1}^{n} t \cdot w_j x_j \tag{1}$$

Given the tax rate t, agent i chooses labor supply x_i that maximizes (1) above, taking x_{-i} as given. The utility function is concave, and the unique optimal labor supply for individual i is characterized by the first order condition:

$$x_i^*(w_i, t) = \left(1 - \frac{n-1}{n} t\right) w_i \tag{2}$$

Thus, all productive agents (i.e., $w_i > 0$) have positive labor supply for all tax rates, $t \in [0, 1]$. Labor supply is declining in the tax rate and is proportional to a worker's productivity. Hence, pre-tax income is proportional to the square of productivity.

The Political Process. Tax rates are determined by a political process. There are many possible voting procedures, and each may produce a different outcome. Here we focus on majoritarian political institutions, derive the indirect preferences of agents over tax rates, and characterize the majority rule equilibrium.

The equilibrium payoff of agent i when the tax rate t is implemented and all other agents follow the behavior prescribed by the equilibrium in the labor market is:

$$U_i^*(w_i, t) = \frac{1}{2} \left((1-t)^2 - \frac{t^2}{n^2} \right) w_i^2 + \frac{t}{n} \left(1 - \frac{n-1}{n} t\right) Z \tag{3}$$

where $Z = \sum_j w_j^2$ denotes the aggregate income of the economy if the tax rate is $t = 0$.

Our first result, Proposition 1, characterizes preferences of agents over tax rates and derives the tax rate that will emerge in equilibrium.[10]

PROPOSITION 1:

Agents' preferences over tax rates satisfy the following properties:[11]

1. Single-peakedness: for any w_i, there exists $t_i^* \in [0, 1]$ such that

$$U_i^*(w_i, t) < U_i^*(w_i, t') \text{ for all } t < t' \leq t_i^*$$

$$U_i^*(w_i, t) < U_i^*(w_i, t') \text{ for all } t_i^* \geq t' > t$$

2. Ideal points are ordered by productivity:

$$t_i^* \leq t_j^* \Leftrightarrow w_i > w_j$$

[9]Equivalently, taxes are used to finance a level of public good, $y = \frac{1}{n} \sum_{j=1}^{n} t \cdot w_j x_j$, and all agents value the public good according to the function $V(y) = y$, which corresponds to the last term of equation (1).

[10]We refer the reader to Appendix A for the proofs of all results.

[11]These properties are central in the theoretical literature that studies the political economy of redistributive taxation. Romer (1975) assumes that agents have Cobb-Douglas preferences over consumption and leisure and derives conditions under which the preferences of agents are single-peaked in the tax rate. Roberts (1977) derives a more general condition that guarantees that ideal points are inversely ordered by income. Meltzer and Richard (1981) assume the regularity condition of Roberts (1977).

3. The median ideal tax rate, t_m^*, is given by:

$$t_m^* = \begin{bmatrix} \frac{n^2}{n^2-1} \cdot \frac{\frac{1}{n}Z - w_m^2}{\frac{2}{n+1}Z - w_m^2} & \text{if} \quad w_m^2 \leq \frac{1}{n}Z \\ 0 & \text{if} \quad w_m^2 > \frac{1}{n}Z \end{bmatrix} \tag{4}$$

The intuition for this characterization is straightforward. Agents with lower productivity prefer higher taxes, because they enjoy substantial redistributive benefits which for the most part come from the tax payments of the higher productivity, and hence higher income, agents. In contrast, agents with higher productivity prefer lower taxes (or no taxes at all), because they end up subsidizing the large portion of the tax revenues from which they receive back only a small part in benefits. Specifically, voters with below average income prefer positive tax rates, while voters with above average income prefer zero tax rates.

Single-peakedness and monotonicity of ideal tax rates with respect to productivities, combined with the majority rule, imply that the agent with the median productivity (median voter) is decisive. Put differently, the tax rate specified in equation (4), which is the tax rate most preferred by the median voter, is the unique tax rate that is majority preferred to any other tax rate, and is therefore a Condorcet winner. This result echoes the median voter theorem from the spatial model of electoral competition.

Notice that total income in equilibrium is $\sum_{i=1}^n U_i^*(w_i, t) = \frac{1}{2}\left(1 - \frac{(n-1)^2}{n^2}t^2\right)\sum_{i=1}^n w_i^2$ and it is maximized when $t = 0$ since taxes are distortionary.

A natural next question that arises in this setup is: How do tax rates compare across economies that differ in the distribution of productivity levels of its agents? The following corollary to Proposition 1 provides an answer to this question.

Corollary. Consider two economies with n individuals, which differ only in the profile of productivities: w^A in economy A and w^B in economy B, and suppose that $w_m^A = w_m^B$. Then,

$$\begin{array}{lll} t^{*A} = t^{*B} = 0 & \text{if and only if} & w_m^2 > \frac{1}{n}Z^A > \frac{1}{n}Z^B \\ t^{*A} > t^{*B} = 0 & \text{if and only if} & \frac{1}{n}Z^A > w_m^2 > \frac{1}{n}Z^B \\ t^{*A} > t^{*B} > 0 & \text{if and only if} & \frac{1}{n}Z^A > \frac{1}{n}Z^B > w_m^2 \end{array}$$

The corollary can be interpreted in terms of inequality in productivities as measured approximately by the variance of worker productivities. To see this, notice that in the special case where the median productivity equals the *mean* productivity, $\frac{1}{n}Z$ is approximately equal to the variance of w_i, with the approximation being arbitrarily close for large n. In this case, an increase in the variance that leaves the mean unchanged will lead to a higher equilibrium tax rate. The tax rate chosen by the median voter will be higher in the economy in which the productivity levels are more unequal as captured by this variance-related measure, $\frac{1}{n}Z$. Also, if the distribution of productivities in economy A is more skewed than the one in economy B then $\frac{1}{n}Z^A > \frac{1}{n}Z^B$ and we would expect (weakly) higher taxes in economy A than in economy B. The intuition for this result comes from the fact that tax revenues are rebated back to all agents in equal shares. When higher productivity agents become more productive, they supply more labor and, thus, contribute more to the total tax revenues. Therefore, the median voter would prefer higher taxes and more redistribution since an increase in the tax rebate associated with an increase in tax rates outweighs the decrease in after-tax disposable income.

2.2 Social Preferences

This model is a natural one for considering the effects of other-regarding preferences. Indeed, in this framework social preferences of almost any kind will affect both labor supply decisions of agents as well as their indirect preferences over tax rates. In this section we extend our theoretical analysis to characterize how labor supply and equilibrium taxes are affected by social preferences. This extension is also important for generating alternative hypotheses about the behavior in our experiment. In particular, findings from many prior experimental studies, such as dictator games, public goods games, and ultimatum games suggest that social preferences may play a key role. If this is indeed the case in our environment, then theoretical predictions derived in the previous section are not the relevant ones. The analysis in this section provides hypotheses about the economic and political behavior that are relevant alternative hypotheses to those implied by the standard homo-economicus model. We explore in depth two commonly used social preferences models: altruism and inequality aversion.[12]

Preferences for altruism. Denote by $U_i^A(w,x,t)$ the altruistic utility function of agent i, where:

$$U_i^A(w,x,t) = U_i(w_i,x_i,t) + A\frac{1}{n-1}\sum_{j\neq i} U_j(w_j,x_j,t)$$

where parameter $A \geq 0$ measures i's altruism, i.e., the weight i puts on the average payoff of others in the society, and for each i, $U_i(w_i,x_i,t)$ is defined as before by equation (1). The standard model without social preferences is nested in our altruism model, and corresponds to $A = 0$.

Fehr-Schmidt Preferences. Order agents according to their productivity from the lowest $i = 1$ to the highest $i = n$. Denote by $U_i^{FS}(w,x,t)$ the Fehr-Schmidt utility function of agent i, where

$$U_i^{FS}(w,x,t) = U_i(w_i,x_i,t) - \frac{\alpha}{n-1}\cdot\sum_{j=1}^{n}\max(U_j(w_j,x_j,t) - U_i(w_i,x_i,t),0) - \\ - \frac{\beta}{n-1}\cdot\sum_{j=1}^{n}\max(U_i(w_i,x_i,t) - U_j(w_j,x_j,t),0)$$

where the second term measures utility loss from disadvantageous inequality in payoffs and the third term measures utility loss from advantageous inequality in payoffs. The standard assumption in the literature is that $0 \leq \beta \leq \alpha \leq 1$, i.e. individuals experience greater utility loss from inequality when their payoff is below average than when their payoff is above average. The standard model without social preferences is nested in the inequality aversion model and corresponds to $\alpha = \beta = 0$.

2.2.1 Labor supply effects of social preferences.

In this subsection, we characterize the effects of altruism and inequality aversion on individual labor supply decisions, for any given tax rate. Proposition 2 below establishes two results. First, altruism leads to higher labor supply compared to the selfish model, for all values of A and for all productivity levels. Second, inequality aversion leads to higher individual labor supply if and only if an individual's productivity rank is sufficiently high. Thus, for any tax rate, relatively high productivity inequality averse individuals will supply more labor than a selfish individual, while relatively low productivity workers will supply less labor.

Proposition 2:

1. The optimal labor supply of an individual with productivity w_i and altruism parameter A is

$$x_i^{\mathrm{A}}(w_i,t) = \left[1 - t + \frac{(1+A)t}{n}\right] w_i$$

[12] In order to avoid some special sub-cases, we assume throughout the analysis in this section that individual productivities are distinct. This restriction is consistent with the experimental parameters and shortens the proofs for inequality averse preferences by avoiding some special cases. The results are easily extended.

The more agent i cares about the average payoff of other agents the more labor he will supply for a given tax rate t:

$$x_i^{\mathrm{A}}(w_i,t) > x_i^*(w_i,t) \text{ and } \frac{dx_i^{\mathrm{A}}(w_i,t)}{dA} > 0 \text{ for all } A \geq 0$$

2. The optimal labor supply of an individual with productivity w_i and Fehr-Schmidt parameters α and β is:

$$x_i^{FS}(w_i,t) = \left(1 - t + \frac{1}{\mu_i} \cdot \frac{t}{n}\right) w_i$$

where $\mu_i = 1 + \frac{\alpha(n-i)-\beta(i-1)}{n-1} > 0$ for all $i \in \{1, 2, ..., n\}$. Inequality averse agents with high productivity supply more labor than their selfish counterparts. Inequality averse agents with low productivity supply less:

$$\text{if } i > \frac{\alpha n + \beta}{\alpha + \beta} \Rightarrow \mu_i < 1 \Rightarrow x_i^{FS}(w_i,t) > x_i^*(w_i,t)$$

$$\text{if } i < \frac{\alpha n + \beta}{\alpha + \beta} \Rightarrow \mu_i > 1 \Rightarrow x_i^{FS}(w_i,t) < x_i^*(w_i,t)$$

There are several implications of this proposition. First, as in the case of selfish preferences, the optimal labor supply of either altruistic or inequality averse individuals does not depend on the labor supply choices of other individuals because of the additively separable specification of payoffs, even though agents care about inequality. Second, labor supply and income remain ordered by productivity, for any tax rate, in both social preference models.

Third, there are some clear comparative statics properties about how labor supply changes as social preferences become more intense. If social preferences are altruistic, then greater altruism leads unambiguously to greater labor supply, and hence redistributive taxes are less distortionary in a world of altruistic individuals. The intuition is clear. At the selfish level of labor supply the marginal private benefit from supplying the next unit is equal to the marginal cost, but the marginal private benefit to the other individuals of supplying that extra unit is positive.

The comparative statics for the inequality aversion model are more complicated because it is a two-parameter model, but we can still say quite a bit. An increase in the envy parameter, α, increases μ_i, and hence decreases labor supply. The opposite is true for the guilt parameter, β. An increase in β, decreases μ_i, and hence decreases labor supply. Simultaneously increasing α and β by a constant will reduce output by all individuals below the median and will increase output by all voters above the median. A related property of the inequality aversion model is that in the special case where $\alpha = \beta > 0$ the critical rank below which inequality averse individuals supply less labor and above which inequality averse individuals supply more labor is precisely equal to the median productivity level. More generally, $\mu_m = \frac{2+\alpha-\beta}{2} > 1$ if and only if $\alpha > \beta$, and therefore the median individual with inequality averse preferences will never supply more labor than a selfish individual, under the standard assumption that $\alpha \geq \beta$. Furthermore, for any α and β, for large societies, the critical rank is $\frac{\alpha}{\alpha+\beta}$, which corresponds to an individual above the median productivity level as long as $\alpha \geq \beta$. One can also show that a proportionate increase in inequality aversion $((1+\epsilon)\alpha, (1+\epsilon)\beta)$ increases total income if the median is less than the mean.

2.2.2 Equilibrium tax effects of social preferences.

Altruism and inequality aversion affect equilibrium taxes in opposite ways. A society of altruists prefers lower taxes, as everyone is concerned, at least to some degree with efficiency, which declines when taxes increase. Thus, a small increase in altruism will result in a lower ideal tax rate for each individual (unless the individual's ideal tax rate was already equal to 0). With inequality aversion, because $\mu_m > 1$, at the margin the median voter is more concerned about reducing the payoff of higher productivity workers than increasing the payoff of lower productivity workers, even if this means lowering her own payoff. There are some minor equilibrium effects that can go the other way, but we are able to show in the proposition below that under some fairly weak conditions the other effects are small enough for the main intuition to hold.

Proposition 3. Assume $n > 3$ and $w_m^2 < \frac{1}{n}Z$.

1. If individuals are altruistic and $0 < A \leq 1$, then the ideal tax rate of the median productivity individual is strictly lower than that individual's ideal tax rate would be if $A = 0$, i.e.

$$t_m^A < t_m^*$$

2. If individuals have inequality averse preferences such that $0 < \beta \leq \alpha \leq \bar{\alpha}(\beta, n)$, then the ideal tax rate of the median productivity individual is strictly higher than that individual's ideal tax rate would be if $\alpha = \beta = 0$, i.e.

$$t_m^{FS} \geq t_m^*$$

At this point we briefly discuss the assumptions about the social preference parameters. First, given that the question being addressed is redistribution of income on a society-wide level, the requirement that $n > 3$ does not seem to rule out interesting cases. Second, the assumption that $w_m^2 < \frac{1}{n}Z$ is needed in order for positive income taxes to be an equilibrium phenomenon. If the median income is above the mean income, then there will be no income redistribution. That case is not empirically relevant. Third, the assumption that $0 < A \leq 1$ in the altruism model is natural since weighting the per capita payoffs higher than one's own payoff seems implausible. The assumption that $\alpha \geq \beta$ is standard in the inequality aversion literature, but could be relaxed. The results for labor supply do not depend on that assumption, but if $\alpha < \beta$ then the cutoff rank for inequality aversion to have a positive effect on labor supply will be below the median voter. The result that inequality aversion leads to higher taxes can fail if α is very large and β is very small because then too few individuals exhibit a positive labor supply effect from inequality aversion. For example, if $\beta < \frac{\alpha}{n}$ then there is a positive labor supply effect only on the highest productivity worker. Thus, if α is too large relative to β, the amount of extra redistribution that occurs is outweighed by the income distortion resulting from higher taxes. That is why Proposition 3 imposes $\alpha \leq \bar{\alpha}(\beta, n)$.

3 Experimental Design

Our design considers two very different competitive democratic institutions for determining the tax rate. In a world with perfect information and perfect optimization by all agents, both regimes theoretically will produce the same tax rate outcome, which will correspond to the median voter ideal point. The two institutions we consider are *direct democracy* and *representative democracy*.

Direct democracy (DD) was implemented by simply allowing every individual voter an equal say in the outcome, without introducing candidates or representatives. Under the direct democracy mechanism, each voter proposes a tax rate, and the median proposal is directly implemented. It is well known (Moulin (1985)) that under this mechanism every voter has a *dominant strategy* to propose his or her ideal tax rate. Because it is a dominant strategy, as long as voters have rational expectations about how the tax rate affects the labor supply decisions of the other voters, this should lead unambiguously to tax rate outcomes corresponding to equation (4), without any additional assumptions about information or beliefs held by the players in the game.

Representative democracy (RD) was implemented as Downsian candidate competition, by introducing two additional players into the game, both of whom are purely office-motivated candidates, with no private preferences over tax rates. This leads to a three stage game. In the first stage, the two candidates simultaneously propose (binding) tax rates, which they will impose if they are elected to represent the voters. In the second stage, voters simultaneously vote for one of the two candidates, with no abstention. In the third stage, after the representative is elected, the voters make their labor supply decisions, taking as given the tax rate of the winning candidate. In this regime, if candidates have rational expectations about how each voter will vote between every pair of proposed tax rates, *and in addition* voters have rational expectations about how tax rates affect labor supply decisions, then the equilibrium is for both candidates to propose the ideal tax rate of the median voter.

According to theory, the median voter's ideal tax rate is the equilibrium in both regimes. However, the informational requirements for the equilibrium are more difficult to achieve in the RD regime. Not only must voters have rational expectations about labor supply distortions, but in addition the candidates must also have rational expectations about how voters choose between pairs of tax rates. In contrast, in the first stage of the DD regime, each voter has a dominant strategy to propose his or her ideal tax rate, regardless of their beliefs about the proposal strategies of the other voters. Thus, a priori, the RD regime, which more closely resembles a democratic process we observe, provides a tougher test for the theory.

Moreover, in order to test whether a more unequal distribution of income leads to greater income redistribution via higher equilibrium tax rates (which is one of the main predictions of the theoretical papers on equilibrium tax rates) we also have two distributional treatments, which we call Low inequality and High inequality. The productivity of the median voter is the same in both treatments ($w_m^{\text{Low}} = w_m^{\text{High}}$), but the relevant inequality measure is higher in High than Low ($Z^{\text{Low}} < Z^{\text{High}}$). Both have interior equilibrium tax rates, so that $0 < t^{*\text{Low}} < t^{*\text{High}} < 1$.

Table 1 specifies the values used in each treatment and lists the ideal tax rates for all agents, assuming selfish preferences. The only difference between parameters in the High and Low inequality treatments is the productivity of the most productive agent. We next describe in more detail the procedures used in each experiment.

Table 1: Parameters and Equilibrium Tax Rates

High Inequality Treatment		
Agent	Productivity	Ideal Tax Rate
1	2	0.62
2	6	0.59
3	10	0.**53**
4	14	0.37
5	35	0.00
Low Inequality Treatment		
Agent	Productivity	Ideal Tax Rate
1	2	0.62
2	6	0.54
3	10	0.**28**
4	14	0.0
5	18	0.0

3.1 Experimental Procedures

All the experiments were conducted at the CASSEL (California Social Science Experimental Laboratory) using students from the University of California, Los Angeles. Subjects were recruited from a database of volunteer subjects.[13] Eleven sessions were run, using a total of 228 subjects. No subject participated in more than one session. We used a between subjects design, so each subject participated in only one treatment. Table 2 summarizes the sessions.

The experimental currency was called tokens. Each token a subject earned was converted to dollars at an exchange rate of \$1 = 200 tokens.[14] Total earnings for a subject was the sum of earnings across all periods in the session, plus a \$10 show up fee. Average earnings, including the show up fee, were approximately \$32 with a standard deviation of \$7.8. Sessions lasted approximately two hours on average.

Table 2: Experimental Design

Regime	High Inequality	Low Inequality
DD	2 sessions (60 subjects; 12 groups)	3 sessions (70 subjects; 14 groups)
RD	2 sessions (49 subjects; 7 groups)	2 sessions (49 subjects; 7 groups)

Upon arrival to the laboratory, subjects were divided into groups of five or seven agents: five in the DD sessions and seven in the RD sessions. Five subjects in each group performed the role of agents and two additional subjects in the RD sessions performed the role of the candidates. Each agent in a group was assigned one of the five productivities (see Table 1). Productivity assignments and the group assignments were fixed for the whole duration of the session. At the very beginning of the session each agent was told their own productivity, but also told the productivity of each of the other four agents.

There were two parts in each session. In the first part, which lasted for 10 periods, subjects gained experience with the labor market. In the second part of the experiment, which also lasted for 10 periods, depending on the session subjects participated in either the DD or the RD game. Instructions for the second part of the session were given to the participants only after they finished the first part.[15] We will now describe the specific experimental procedures that were common to all the sessions and then describe how different political regimes were implemented.

In the first part of a session, at the beginning of each period agents were informed of the tax rate for that period. Then they chose how much labor to supply without knowing what other subjects in their group chose.[16] Labor supply decisions were allowed to be any number between 0 and 25 with up to two decimal places.[17] After all five agents had made their choice, subjects received feedback that specified the labor supply of each agent in their group, and an agent's own payoff was displayed on the screen, broken down into three parts: after-tax income, the quadratic cost of labor, and their tax rebate (equal share of collected taxes). After the period was over, the group moved on to the next

[13]The software for the experiment was developed from the open source Multistage package, available for download at http://software.ssel.caltech.edu/.

[14]The exchange rate was higher (\$1 = 100 tokens) for the Low inequality treatment because the potential theoretical earnings were lower.

[15]Appendix B contains the instructions for the DD High inequality treatment.

[16]The terminology in the experiment avoided reference to work, effort, productivity or other terms associated with labor markets. The individual labor supply decision was called the "investment level" and productivities/wages were called "values". Pre-tax labor income was called "investment earnings".

[17]Recall that the optimal choice of labor given the tax rate is $x_i(w_i, t) = (1 - \frac{n-1}{n}t) \cdot w_i = (1 - 0.8t) \cdot w_i$. Thus, for all agents and for all tax rates, the theoretically optimal choice of labor is away from the boundaries (strictly below 25 and strictly above 0), except for the agent with highest productivity in High inequality treatment ($w_i = 35$). Agent with $w_i = 35$ should choose $x_i(35, t) = 25$ for any tax rate below 0.375. In equilibrium, the upper bound of 25 is not binding for either parameter set.

period which was identical to the previous one except for the tax rate imposed at the beginning of the period. In this training part of the session, subjects went through different possible tax rates, in the following order: 0.50, 0.15, 0.70, 0.62, 0.35, 0.05, 0.27, 0.75, 0.90, 0.20.

To help subjects calculate hypothetical earnings from different labor supply choices, they were provided with a built-in calculator that appeared on their monitors. To use the calculator, subjects had to enter two numbers: a labor supply decision and a guess for the total taxes collected from the other members in their group. Then, the calculator computed the payoff of the subject in this hypothetical scenario taking into account the current tax rate in this training period and the wage assigned to the subject.

Experimental protocol specific for Direct Democracy. In the second part of the DD sessions, at the beginning of each period each agent was asked to submit a proposal for the tax rate. The median proposal (third lowest tax rate) was announced to all subjects and implemented in that period. After the tax rate was determined, subjects chose their labor supply as in the first training part. Again, after the tax rate was determined, subjects could use the on-screen calculator to evaluate different hypothetical scenarios before they submitted their labor supply decision. This two-stage process was repeated 10 times (10 periods).

Experimental protocol specific for Representative Democracy. The first (training) 10 periods of the RD sessions were the same as the ones in the DD sessions except that the two subjects in the role of candidates were also given a task. In order to focus the candidates' attention during these periods, in each period each candidate was randomly assigned one of the agents, was told the agent's productivity and the tax rate for that period, and then was asked to guess the labor supply of that agent. In each of the first ten periods, a candidate earned 100 tokens for guessing correctly and 0 tokens for guessing incorrectly, where the correct guess was defined as within 2 points of the actual labor supply decision of that agent in that period. At the end of each period, the candidates observed all the labor choices of all five agents in their group.

Each of the 10 periods of the second part of the RD sessions had three stages. In the first stage, the two candidates simultaneously submitted tax rate proposals. In the second stage, all agents in a group observed the two candidates' tax rate proposals and voted for one of the candidates, with no abstention. The tax rate proposal submitted by the candidate who received a majority of three or more votes was implemented for that period. In the third stage, the process was the same as in the DD sessions: agents observed the tax rate, chose how much to work and then got feedback for that period. The only source of earnings for the candidates in the last 10 periods was winning elections: the winning candidate in a period earned 200 tokens and the loser earned 0 tokens. This payoff structure aimed to incentivize candidates to propose the ideal tax rate of the median voter, since, in theory, it defeats any other proposed tax rate if all agents are choosing their labor supply decisions optimally. As in the DD regime, once the tax rate for the period was determined, agents could use the built-in calculator to evaluate hypothetical scenarios before submitting the final labor decision.[18]

[18] Additional RD sessions were also conducted with an alternative protocol that was problematic because it eliminated the learning phase and limited comparability with the DD sessions. Those sessions exhibited slower convergence to the theoretically predicted tax rates, but were otherwise similar.

4 Results

We organize the results of the experiment in four sections following the questions posed in the introduction. In Section 4.1 we test the main predictions of the theoretical model presented in Section 2 combining the data from both political regimes. In particular, in this section we investigate the median voter hypothesis, the effect of inequality on redistribution, aggregate labor market behavior, and the equity-efficiency tradeoff. The second set of results, presented in Section 4.2, focuses on the effects of political institutions on the behavior of agents in both economic and political domains. We start that section by comparing taxes that each political regime implements. We then back out revealed ideal tax rates for agents with different productivities and test whether there is a monotonic relationship between revealed tax rates and productivities. Finally, we compare whether the two political institutions have an indirect effect on the labor market behavior. In the third set of results, presented in Section 4.3, we investigate whether our data suggest the presence of social preferences for redistribution both in the labor market and in the political domain. In the fourth section, we investigate the linkage between variation in implemented tax rates across groups and differences in labor supply across groups.

4.1 Main theoretical predictions

In this section we analyze the main predictions of the theory presented in Section 2. To do that we pool together the data from both political regimes.

4.1.1 Implemented Taxes

The theoretical results of Section 2 imply the hypothesis that greater inequality leads to higher taxes. Hence, we should observe higher tax rates in our High inequality treatment than in our Low inequality treatment. The data strongly support this hypothesis. Table 3 presents summary statistics of implemented taxes in each inequality treatment focusing on the last 10 periods (Part II) of the experiment. Figure 1 shows the evolution of the average implemented tax for the same part of the game.

Table 3: Implemented Tax Rates

	High Inequality, $t^* = 0.53$		Low Inequality, $t^* = 0.28$	
	mean (st err)	median	mean (st err)	median
Implemented Taxes	0.50 (0.03)	0.55	0.26 (0.03)	0.25

Note. Robust standard errors are in parentheses, clustered by group.

As Table 3 shows, taxes are higher in the High Inequality treatment than in the Low Inequality treatment, and the effect is highly significant. This result is also confirmed statistically by regressing the implemented tax rates on a dummy variable for the High inequality treatment. The estimated coefficient is positive and statistically significant: $\beta = 0.24$ ($p < 0.01$).[19]

Figure 2 presents the CDF of the implemented tax rates in each inequality treatment. A Kolmogorov-Smirnov test rejects the null hypothesis that taxes implemented in the High inequality treatment come from the same distribution as the ones implemented in the Low inequality treatment ($p < 0.01$).[20]

[19] In fact, as Figure 1 clearly shows, in every single period tax rates are higher in the High inequality treatment than in the Low Inequality treatment. Using a Wilcoxon rank-sum test performed period-by-period, the taxes in the High Inequality treatment are significantly higher ($p < 0.05$) than those in the Low Inequality treatment in 9 out of 10 periods.

[20] The figures also show that, while average implemented tax rates converge to the theoretically predicted ones, there is heterogeneity on the group-level data. We return to the analysis of this heterogeneity in Section 4.4 where we investigate

Figure 1: Implemented Taxes, dynamics

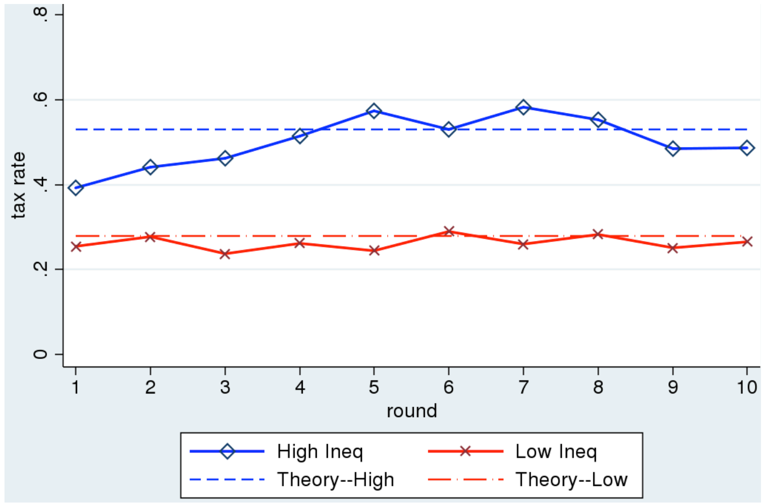
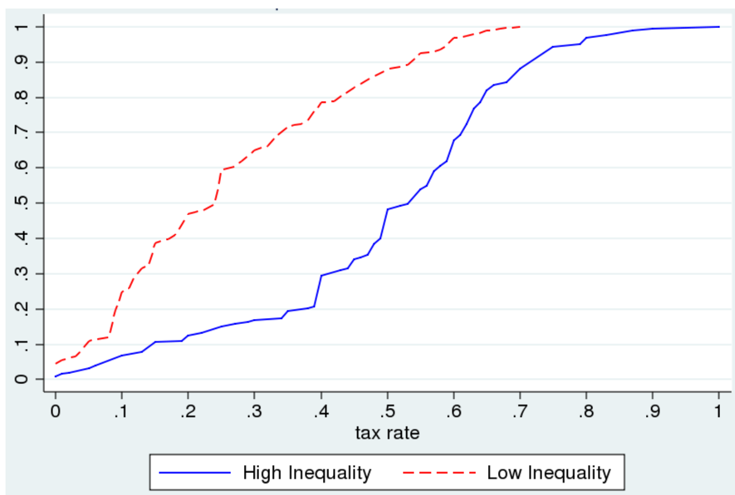


Figure 2: CDF of Implemented Tax Rates



Result 1a: Tax rates are significantly higher when inequality is high.

The second prediction of the theory is the median voter hypothesis, that for both inequality treatments the ideal tax rate of the median productivity agent will be implemented. Our data also provide support for this hypothesis. As evident from Figure 1, on average, in both inequality treatments taxes converge to the ones predicted by the theory almost exactly. This is confirmed statistically for each inequality treatment separately, based on the means and standard errors reported in Table 3, and also by a Wilcoxon Rank-sum median test $p > 0.05$.

Result 1b: The ideal tax rate of the median voter is implemented in both inequality treatments.

---

the link between this heterogeneity and the variation of labor supply across different groups.

4.1.2 Labor Supply

Table 4 reports the mean difference between actual labor choices of agents and the predicted ones, broken down by the productivity levels and treatments. The data show that behavior of agents in the labor market is close to that predicted by theory. However, in general agents with low productivity somewhat oversupply labor, while agents with high productivity somewhat undersupply it. This undersupply of labor is especially pronounced for agents with the highest productivity of 35 in the High Inequality treatments in both regimes: these agents on average supplied labor by about 3 units too low.

Table 4: Mean Differences Between Observed and Predicted Labor Supply

	High Inequality		Low Inequality	
	first 10 periods	last 10 periods	first 10 periods	last 10 periods
Productivity 2	1.083 (0.360)	0.589 (0.376)	0.705 (0.298)	0.301 (0.244)
Productivity 6	0.765 (0.384)	0.088 (0.132)	0.731 (0.331)	-0.001 (0.183)
Productivity 10	0.593 (0.234)	0.344 (0.335)	0.264 (0.184)	0.315 (0.175)
Productivity 14	0.515 (0.343)	0.184 (0.116)	0.274 (0.335)	0.042 (0.243)
Productivity 18			-0.360 (0.239)	-0.397 (0.371)
Productivity 35	-2.555 (1.130)	-2.670 (1.105)		

Note. Robust standard errors are in parentheses, clustered by individual.

Both the undersupply by high wage workers and the oversupply by low wage workers contradict some of the main implications of the social preference models for our environment. Indeed, as we have shown in Section 2, the model of inequality aversion by Fehr-Schmidt predicts that high wage workers will oversupply labor and low wage workers will undersupply labor relative to the standard case. Alternatively, the model of agents with altruistic preferences predicts that all agents will oversupply labor relative to the standard case. While one might expect to observe behavior consistent with other-regarding preferences in our setup (indeed, subjects are endowed with very different productivities and can reduce this inequality by adjusting their labor supply), the first look at the data suggests that this is not the case. We return to this observation in Section 4.3 with a more rigorous statistical estimation of the parameters altruism and inequality aversion implied by labor supply data.

To estimate the labor supply functions of the agents, we define the normalized labor supply function, L(t), as: $L(t) \equiv \frac{x_i^*(w_i,t)}{w_i} = 1 - \frac{n-1}{n}t$. Table 13 reports the Tobit estimates obtained by regressing observed normalized labor supply ($\frac{x_i}{w_i}$) on a constant and the tax rate. We do this separately for each productivity level. Because we have 40 groups and 20 observations per group, this gives us 800 observations for each of the four lower productivity levels is (which are the same in both High and Low inequality treatments) and 400 observations for the high productivity voters (which are different in the High and Low inequality treatments). For the highest productivity worker in the High inequality treatment ($w_i = 35$), the constraint $x_i \leq 25$ is binding if the tax rate is sufficiently low ($t \leq 0.375$). So we run separate regressions for $t \leq 0.375$ and $t > 0.375$ for this one class of worker-voters. Thus, the table reports the estimates of the constant term α and the coefficient on the tax rate β for a total of seven different regressions. According to the theoretical normalized labor supply equation derived for selfish agents, the estimates for the first six (unconstrained) regressions are predicted to be $\alpha = 1$ and $\beta = -\frac{n-1}{n} = -0.8$. For the constrained regression reported in the last row, the predicted estimates were $\alpha = 0.71$ and $\beta = 0$.

The results reported in Table 13 are largely consistent with the theory without social preferences. With only one exception the estimated coefficients are not significantly different from the predicted values at the 5% level. The one exception is the estimated slope of the response to the tax rate for the highest productivity worker when constraint $x_i \leq 25$ is binding. The estimated slope is significantly

Table 5: Estimated Normalized Labor Supply Functions

Productivity	α	p-value	β	p-value
2	1.17 (0.15)	0.26	-0.46 (0.19)	0.07
6	1.04 (0.05)	0.38	-0.74 (0.08)	0.43
10	1.01 (0.02)	0.46	-0.74 (0.05)	0.21
14	1.02 (0.02)	0.47	-0.79 (0.03)	0.88
18	0.97 (0.03)	0.30	-0.76 (0.05)	0.46
35 ($t > 0.375$)	0.98 (0.08)	0.77	-0.84 (0.10)	0.72
35 ($t < 0.375$)	0.65 (0.04)	0.11	-0.73 (0.09)	0.02

Note. Robust standard errors are in parentheses, clustered by individual.

negative, which reflects the undersupply of labor by the highest productivity workers, as reported in the last row of Table 4.

Result 2: Labor supply decisions by agents are approximately optimal and consistent with the theoretical model with selfish agents.

4.1.3 Welfare

There are two dimensions to consider in the welfare analysis of redistributive taxation: equity (or related notions of distributive justice) and efficiency. There is a tradeoff between these two dimensions, and both are jointly determined by the tax rate in the political sector and the labor supply decisions made in the economic sector. Thus, the welfare analysis must consider the combined political economy effects in the two sectors. The tradeoff is explicitly modeled in the theoretical framework we use: the more pre-tax income is going to be redistributed, the less labor will be supplied. Assuming that each worker chooses his labor supply optimally given the tax rate, we can construct an equity-efficiency frontier, for any particular measure of equity and efficiency. We use one minus the post-tax Gini coefficient as our measure of equity, and total income as the measure of efficiency.[21] Using these measures, we define the equity-efficiency frontier as the locus of points in this two dimensional space corresponding to after tax equity-efficiency pairs that would arise from optimal labor supply behavior as we vary tax rates from 0 to 1. We use this as a benchmark with which to compare the actual equity-efficiency tradeoff that is observed in the experiment.

Figure 3 displays all the equity-efficiency pairs for all group outcomes in the low inequality and high inequality treatments, respectively. The solid line in the figures marks the frontier with the upper left of the frontier corresponding to $t = 1$ and the lower right of the frontier corresponding to $t = 0$.[22] Table 6 below gives the averages across all the equity-efficiency pairs for the two treatments, with standard errors in parentheses (clustered by group).

From a slightly different perspective, Figure 4 plots the Laffer curve for each inequality treatment, with total tax revenues displayed as a function of the tax rate t. The solid line represents the theoretical Laffer curve, derived under the assumption that all agents supply labor optimally given the tax rate, while the data observed in the experiments are marked as the circles. This graph is essentially a different projection of the three-dimensional picture that summarizes the relation between tax rates, efficiency and equality in the economy.

[21] There are alternative measures as well, such as the variance of the income distribution to measure inequality or netting out the effort costs of labor in the measure of efficiency. These alternative measures lead to similar conclusions.

[22] The frontier as we have defined it does not represent the boundary of feasible equity-efficiency pairs. In principle, workers are free to supply 25 units of labor for any tax rate, but doing so is not consistent with equilibrium in our labor market.

Figure 3: Equity-Efficiency Frontier

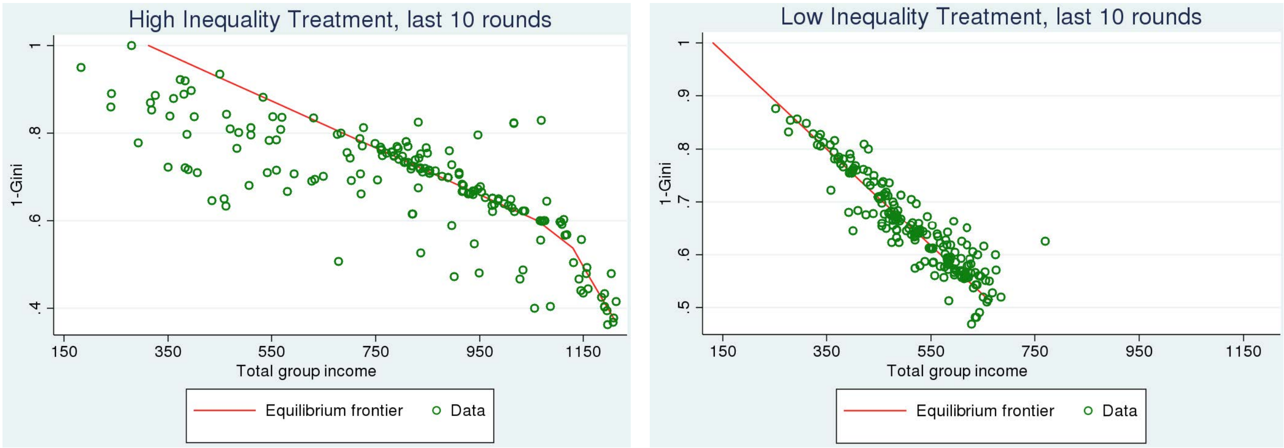
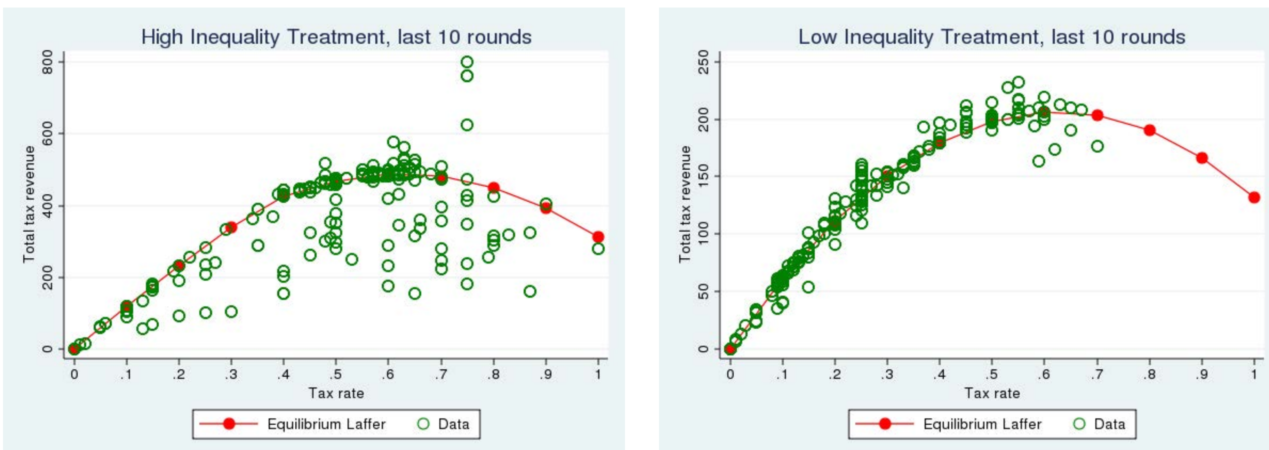


Figure 4: Laffer Curves



Several observations can be made about the data displayed in these figures. First, Figure 3 shows that, consistent with the theoretical equity-efficiency tradeoff, higher tax rates lead to lower aggregate labor supply and lower total income in both inequality treatments. Second, deviations from the theoretical frontiers in Low inequality treatment are minimal, balanced between points above and below the frontiers and are not correlated with the tax rate (as seen from the right panels of Figures 3 and 4). The picture is different in the High inequality treatment, in which deviations from the efficiency-equity frontier and from the theoretically predicted Laffer curve are much more pronounced, in a negative direction. Most of these deviations are on the side of undersupply of labor for a given tax rate (left panel of Figure 4), since most of the data points are below the predicted tax revenues. The undersupply of aggregate labor in the high inequality treatment is driven mainly by the undersupply of labor by the highest productivity agent (that with productivity $w_i = 35$), reported in Table 4. However, there is no clear pattern of these deviations with respect to different tax rates: undersupply of aggregate labor is observed for both high and low tax rates.

Result 3a: Higher tax rates lead to lower total income irrespectively of the inequality level, as predicted by the efficiency-equity tradeoff.

Result 3b: In the Low inequality treatment, the data closely track the efficiency-equity frontier and theoretical Laffer curve, while in the High inequality treatment the deviations from these frontiers are sizable and negative.

Table 6: Equity-Efficiency Tradeoff

	High Inequality treatment				
	$t = 0$	$t^{*} = 0.53$	$t = 1$	mean observed	(st err)
Gini coefficient	0.628	0.313	0.000	0.315	(0.019)
Total group income	1211	899.14	312.20	818.32	(40.99)
	Low Inequality treatment				
	$t = 0$	$t^{*} = 0.28$	$t = 1$	mean observed	(st err)
Gini coefficient	0.485	0.349	0.000	0.350	(0.015)
Total group income	660	512.16	132	518.98	(16.40)

Note. Robust standard errors in the parentheses are clustered by group.

4.2 Effects of Political Institutions

In this section we compare how the two political regimes, direct democracy (DD) and representative democracy (RD), affect the implemented tax rates, voting behavior, and labor supply.

4.2.1 Implemented Taxes

Table 7 summarizes the implemented tax rates in each political regime in each inequality treatment. The results of a regression analysis confirm that in each political regime, higher inequality leads to significantly higher level of redistribution. Specifically, for each political regime separately, we regress implemented taxes on a dummy variable for the High inequality treatment. Estimated coefficients are positive and highly significant ($p < 0.01$): $\beta = 0.21$ for DD regime and $\beta = 0.27$ for RD regime.

Moreover, there is no significant difference between the average or median implemented taxes in the DD and RD regimes, for each inequality treatment. To reach this conclusion we regress implemented taxes on a dummy variable for the RD regime, for each inequality treatment separately, clustering observations by group. The estimated coefficient is not statistically different from zero for either inequality treatment ($p > 0.05$).[23] This is further confirmed by a Wilcoxon Rank-sum test that does not reject the hypothesis that median implemented taxes are equal in the DD and RD regimes, in both High and Low inequality treatments ($p > 0.05$).

Result 4: In both political regimes, higher inequality leads to higher taxation as predicted by the theory. The mean and median implemented tax rates are the same in the two regimes, for both inequality treatments.

Table 7: Implemented Taxes in each Regime

	High Inequality, $t^{*} = 0.53$		Low Inequality, $t^{*} = 0.28$	
	mean (st err)	median	mean (st err)	median
DD	0.474 (0.04)	0.50	0.259 (0.03)	0.25
RD	0.536 (0.03)	0.565	0.267 (0.07)	0.225

Note. Robust standard errors are in parentheses, clustered by group.

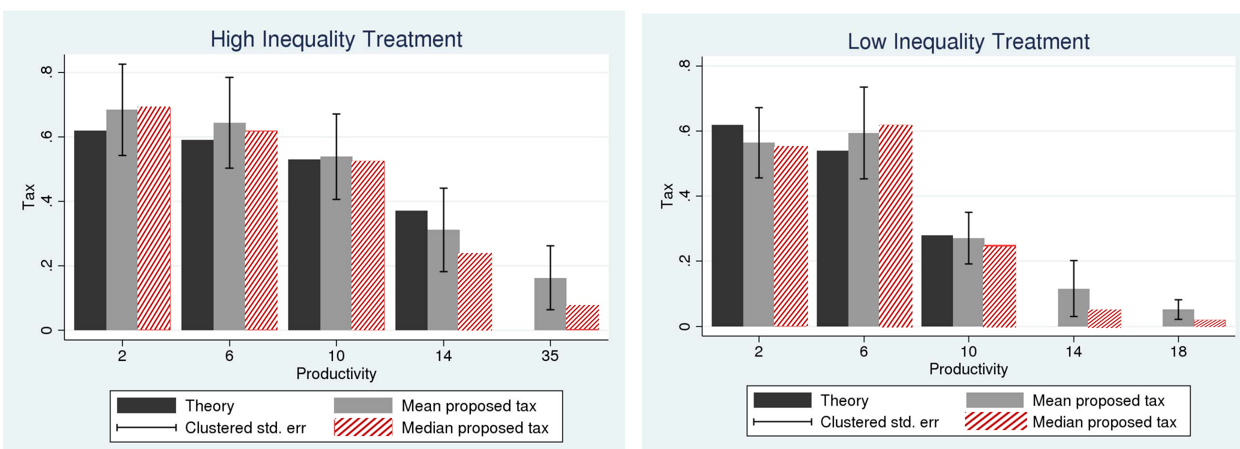
[23] The small difference in the average implemented tax rates in DD and RD regimes in the High inequality treatment (0.474 vs. 0.536) is entirely due to differences in the first few rounds of the game. By the end of the experiment (last 5 rounds) the average implemented tax rate in the High inequality treatment in both the DD and the RD regimes is exactly equal to 0.53.

4.2.2 Voting Behavior

Besides the predictions about equilibrium tax rates as a function of the distribution of wage rates, the model also makes more specific predictions about voter behavior in the two institutional regimes. Specifically, in DD, all voters, regardless of productivity, have a dominant strategy to propose their most preferred tax rate, assuming all voters supply labor optimally conditional on any tax rate. Similarly, in RD, voters have a dominant strategy to vote for the candidate who proposed the more preferred of the two candidates' tax rates, once again under the assumption that all voters supply labor optimally. In this section, we investigate voters' behavior relative to these two benchmarks.

Tax Proposals in DD. Figure 5 displays the median and average proposed tax rates, by productivity type, in the DD-High and DD-Low treatments, pooling across all groups for the last 10 periods, and compares it with the theoretical peak of the induced voter preferences. In all cases the observed mean or median proposals match up closely with the theory. In particular, the average proposals by the median voter, with a productivity of 10 is almost exactly equal to the predicted proposal (0.54 vs. 0.53 in DD-high and 0.27 vs. 0.28 in DD-low). There are a two minor discrepancies that are worth noting. First, for high productivity voters who are predicted to propose zero tax, on average the proposal is for a tax rate of about 0.10. Second, in DD-high, the mean proposals are not perfectly ordered by productivity. The second lowest productivity worker has a higher average proposed tax rate than the lowest productivity voters (0.59 vs. 0.56), but this difference is not statistically significant. We also note that while the *average* observed tax proposals match the theoretical ideal tax rates, there is considerable variance in the proposals (as is evident from the relatively large standard errors).

Figure 5: Proposed Tax Rates, by productivity.



Voting Behavior in RD. Table 8 summarizes voting behavior in each inequality treatment in the RD regime broken down by productivity level, pooling across all groups for the last 10 periods. The second column lists the fraction of correct votes: a vote is labeled correct if the candidate the voter voted for proposed a tax rate that theoretically would yield at least as high a payoff as the proposed tax rate of the other candidate. The third column indicates the number of correct votes, with the number of cases where both candidates proposed the same tax rate in parentheses. The fourth and fifth columns list the number of mistakes separated into two categories: the mistakes in which participants voted for a higher of the two proposed taxes, in column four, and the mistakes in which the vote was cast for the lowee of the two proposed taxes, in column five. Table 8 shows that, for all productivity levels, most votes cast in the RD treatment were "correct", with somewhat more accurate voting behavior observed in the Low than in the High inequality treatment. An interesting observation from these graphs is that incorrect votes in the High inequality treatment tend to be votes for too high a tax rate.

Table 8: Voting Behavior in the RD regime

		High Inequality		
Productivity	% correct	# correct (indiff)	# voted higher	# voted lower
2	0.71	50 (6)	15	5
6	0.61	43 (6)	20	7
10	0.71	50 (6)	13	7
14	0.73	51 (6)	14	5
35	0.89	62 (6)	8	0
		Low Inequality		
Productivity	% correct	# correct (indiff)	# voted higher	# voted lower
2	0.80	56 (13)	7	7
6	0.69	48 (13)	9	13
10	0.67	47 (13)	11	12
14	0.91	64 (13)	6	0
18	0.91	64 (13)	6	0

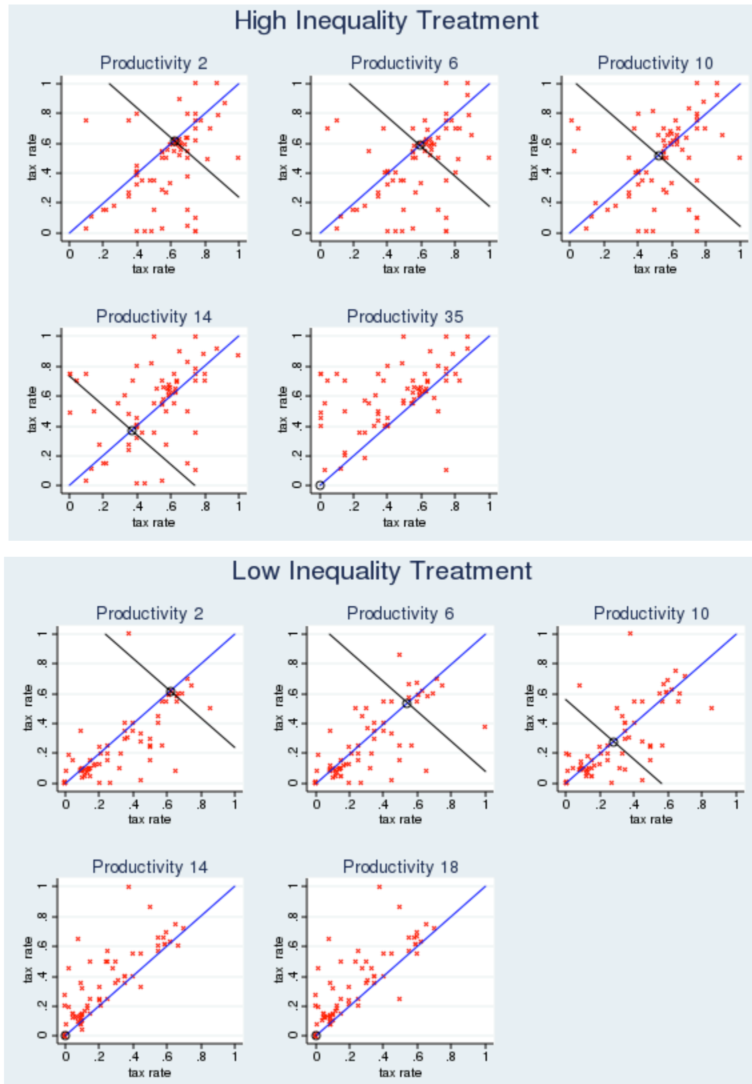
Figure 6 provides a more complete description of voting behavior in the RD sessions, again broken down by productivity level. Each panel in the figure displays simultaneously the two proposals that are offered in each election and the proposal the voter of that productivity voted for. The horizontal axis represents the tax rate proposed by the candidate the voter voted for, and the vertical axis corresponds to the tax rate proposed by the other candidate. Each panel also has two crossing line segments. Those line segments represent pairs of tax proposals that the voter in theoretically indifferent between. One of the segments, the upward sloping one, obviously is the diagonal. The other, downward sloping line represent pairs that are equidistant from the voter's ideal tax rate. The two lines intersect at the ideal tax rate of the voter. Therefore, correct votes are in north and south quadrants. Incorrect votes are in the east and west quadrants.[24] Most of the incorrect votes lie fairly close to one of the two indifference-pair line segments.

Finally, we use the classification of votes introduced in Figure 6 to estimate the empirical ideal tax rates in the RD sessions in two ways. The first method finds, for each productivity, the tax rate (or the range of the tax rates) that minimizes the number of mistakes, i.e. the number of points in the east and west quadrants of Figure 6. The second method computes the tax rate that minimizes utility loss from the voting mistakes, where utility loss is defined as the shortest distance from a point in the east or west quadrant to the closest indifference line. Table 9 summarizes inferred ideal tax rates in both political regimes along with the theoretically predicted ones. The main observation that emerges from this table is clear: except for the small discrepancies in the DD-High treatment, inferred ideal tax rates of agents are monotonically decreasing in agents' productivities in both political regimes.

Result 5: In both political regimes and in both inequality treatments, empirical ideal tax rates are ordered by agent productivities.

[24]For high productivity voters whose ideal point is zero tax, the west and south quadrants do not exist, reflecting the fact that it is always optimal for these voters to vote for the lower tax rate.

Figure 6: Voting Behavior in the RD regime.



4.2.3 Labor Supply

We conclude this section by noting that the labor supply behavior in both political regimes is very similar. The results of the regression analysis of normalized labor supply performed separately for each political regime and each inequality treatment produce estimates similar to those given in Table 5 for the pooled regression (see Table 13 in Appendix C).

Result 6: In both political regimes, observed labor supply decisions are consistent with the predictions of the theory with selfish agents, with the exception of undersupply of labor by the highest productivity workers when tax rates are very low.

4.3 Estimating Social Preference Models

In this section we address the question of whether our data provide evidence of the presence of other-regarding preferences in the labor market and/or in the political domain. As observed in Section 4.1, we cannot reject the hypothesis that labor supply choices and implemented taxes are statistically

Table 9: Ideal Tax Rates, by productivity

		Low Inequality treatment		
	Theory	DD	RD	RD
productivity		mean (median)	min # mistakes	min utility loss
2	0.62	0.56 (0.55)	[0.73,1)	0.71
6	0.54	0.59 (0.62)	[0.73,1)	0.70
10	0.28	0.27 (0.25)	[0.36,0.39]	0.39
14	0.00	0.12 (0.05)	0.00	0.07
18	0.00	0.05 (0.02)	0.00	0.01
		High Inequality treatment		
	Theory	DD	RD	RD
productivity		mean (median)	min # mistakes	min utility loss
2	0.62	0.68 (0.69)	[0.74,1)	0.62
6	0.59	0.64 (0.62)	[0.78,0.90]	0.58
10	0.53	0.54 (0.53)	0.56	0.43
14	0.37	0.31 (0.24)	[0.31,0.36]	0.41
35	0.00	0.16 (0.08)	[0.00,0.18]	0.29

different from the predictions of the theory with selfish agents. However, this does not mean that voters necessarily have selfish preferences. In order to reach this conclusion, we need to investigate whether our data might also be compatible with other-regarding preferences, based on the theoretical results developed in Section 2.

4.3.1 Labor Supply

We start with the labor market and do the following exercise. For each inequality treatment, we estimate the altruism parameter $A \in [0, 1)$ by finding the value of A that minimizes the sum of squared deviations of the observed labor decisions from the theoretically predicted ones for that value of A. We use a similar method to estimate the two inequality aversion parameters, (α, β). Table 10 presents the results of this estimation. We also report estimates based on the full dataset, pooling across the two inequality treatments. The estimates that are not marked with an asterisk are not significantly different from zero at any reasonable significance level, based on a chi-squared test. The estimates marked with an asterisk are statistically different from zero ($p < 0.05$).

Table 10: Estimation results for altruism and inequality aversion effects on labor supply.

Treatment	Altruism parameter A		Inequality Aversion (α, β)	
	all rounds	last 10	all rounds	last 10
High Inequality	0	0	(0,0)	(0,0)
Low Inequality	0.07*	0.05*	(0,0)	(0,0)
Pooled Treatments	0	0	(0,0)	(0,0)

Notes. Data pooled across both RD and DD regimes.

This estimation reveals no social preference effects on labor supply in the high inequality treatments. We cannot reject the null that $\alpha = \beta = 0$ in *all* treatments, in both all rounds of the experiment as well as in the last 10 rounds of the experiment. With respect to altruism, we measure only a very small positive value of A in the Low Inequality treatment.

4.3.2 Proposal Behavior

Social preferences would also affect the preferences of agents over the tax schedules. The data from the DD regime is perfectly suited for testing it because the median proposal mechanism is specifically designed to directly elicit each voter's ideal tax rate. Similar to what we did for the labor supply data, we estimate the altruism parameter, A, and the inequality aversion parameters, (α, β), by minimizing the sum of square distances between the observed tax proposals and the optimal tax proposals for each productivity type, conditional on the parameters. The results are reported in Table 11. Again, our estimates indicate almost no social preference effects in the observed ideal tax rates, as revealed in the proposal data. We estimate a small and insignificant altruism coefficient ($A = 0.01$) in the low inequality economies, and a very small and insignificant envy parameter ($\alpha = 0.01$) for the high inequality treatment. In all other cases the best fitting parameters equal 0.

Table 11: Estimation results for altruism and inequality aversion effects on DD voting.

Treatment	Altruism parameter A	Inequality Aversion (α, β)
High Inequality	0	(0.01,0)
Low Inequality	0.01	(0,0)
Pooled Treatments	0	(0,0)

Result 7: Social preference effects on both labor supply and revealed ideal tax rates are negligible. There is evidence only of a small amount of altruism based on labor supply behavior in the DD low treatment, and no evidence of inequality aversion.

4.4 Empirical Equilibrium

The results so far paint a picture of the aggregate data as being close to the theory based on selfish preferences with respect to (1) the qualitative comparative statics; (2) average and median implemented tax rates; (3) the individual labor supply responses to tax rates (except for the $w_i = 35$ workers); (4) the aggregate labor supply effect of taxes; and (5) voting behavior. However there is some variance across groups in the data, as one can infer from Figures 2 and 3. In this section we take a closer look at this variation, and in particular explore the possibility that deviations from the equilibrium tax rates may be driven by variation across groups with respect to expectations about labor supply responses to taxes.

Theoretically, deviations from equilibrium labor supply responses to tax rates, if correctly anticipated by voters, will lead to distortions in the political equilibrium tax rates. That is, the equilibrium tax rates in High and Low Inequality treatments derived in Section 2 were based on the assumption that all agents make optimal labor decisions at all tax rates, and all voters correctly anticipate this. However, to the extent that we find actual aggregate labor supply functions to be different from the theoretical ones, if these deviations vary systematically across groups, then one might expect rational candidates to propose different tax rates in the RD regime and agents to offer different tax proposals in the DD regime. Therefore, in this section we will connect the analysis of the labor and political markets and ask whether the variation in the labor supply across different groups is linked in this way to the variation in the implemented tax rates. We refer to tax rates that constitute an equilibrium relative to the empirical labor supply functions as an *empirical equilibrium*.

To do this, we construct three alternative models of "empirical equilibrium" (EE) tax rates that differ according to the method used to estimate the labor supply functions in a group. That is, we estimate empirical labor supply functions of each agent in each group, and then compute the empirical equilibrium tax rate for that group based on the estimated labor supply functions. The challenge is to obtain good estimates of the labor supply functions. To deal with this issue, rather than choosing one particular method to estimate labor supply, we apply three different alternative models to do this estimation. The first, EE1, uses only the data from the first 10 periods to estimate the labor supply functions of each group member, and uses this estimate to compute an adjusted median voter's ideal tax rate as the basis for the empirical equilibrium tax rate. The second, EE2, is similar, but uses the labor supply data from all 20 periods. The third model, EE3, takes a different approach. For each group EE3 is based only on the *earnings* of the median productivity worker across the ten trial tax rates in the first 10 periods; the EE3 tax rate is the one of these for which that agent experienced the highest earnings.

Table 12 shows the results of regressing predicted against observed tax rates, using all 400 observations from the 40 groups in the experiment. The observed tax rate in each group equals the median of that group's ten implemented taxes in periods 11-20. The predicted tax rate is calculated for each of the models EE1, EE2 and EE3 described above, as well as for the theoretical model based on individually optimal labor supply, derived in Section 2.

Table 12: Regressions of predicted against observed tax rates.

	constant	slope	R^2
Theory	-0.00 (0.07)	0.94 (0.17)	0.28
EE1	0.23* (0.06)	0.12** (0.13)	0.31
EE2	0.23* (0.07)	0.11** (0.13)	0.31
EE3	0.12* (0.06)	0.32** (0.14)	0.35

Notes. Robust standard errors reported in the parentheses are clustered by group. * is significantly different from 0, ** is significantly different from 1.

The first model based on the theoretical labor supply functions nails the coefficients almost exactly. The theoretical equilibrium model has an intercept equal to 0.00 and a slope equal to 0.94, and we cannot reject the hypothesis that they equal 0 and 1, respectively. Based on the coefficient estimates, all three EE models reject that hypothesis. In fact, for EE1 and EE2, one cannot even reject the hypothesis that the slope equals 0. In terms of model fit, the R^2 is slightly higher for the three EE models than the theoretical equilibrium model, but this does not take into account that we are implicitly burning some degrees of freedom by estimating the labor supply curves for each group and then feeding those estimates into each of the EE models.

5 Conclusion

This article presents the results from an experiment to explore the median voter theory of equilibrium income tax rates that produce distortions in labor supply. The experiment is novel in a number of ways, including combining a labor market with a political market, where preferences in the political market are endogenous and are determined by expectations about labor supply responses to taxes. The central focus was on four main questions. Does greater inequality ex ante lead to higher tax rates and more income redistribution? Are the implemented tax rates driven by the induced preferences of the median income voter? Do the implemented tax rates depend on the institutional rules governing the collective choice procedure? Do social preferences have a significant impact on labor supply responses to tax rates or to indirect voter preferences over tax rates?

The answer to the first question is unambiguously yes. Higher ex ante inequality in terms of worker wage rates leads to higher tax rates. The effect is significant and large in magnitude. The answer to the second question is related to the first: the implemented tax rates in both inequality treatments are almost exactly equal to the theoretical ideal tax rate of the median wage worker. The answer to the third question is negative. We do not observe any significant differences in labor supply or average implemented tax rates between the direct democracy institution and a representative democracy where tax rates are determined by candidate competition. While there are many other possible democratic collective choice procedures that one could examine, this third finding is at least suggestive of a robustness with respect to the finer details of majoritarian democratic choice procedures. The answer to the fourth question is also negative. We do not observe significant deviations from labor supply behavior or voting behavior of the sort that are implied by models of altruism or inequality aversion. The one exception is the labor market behavior under the DD-low treatment, where we estimate a significant altruism effect. However, even there, the effect we estimate is very small in magnitude ($A = 0.05$).

The findings from the experiment lead to some strong conclusions, but leave open a number of more difficult questions that are beyond the scope of the analysis presented here. There are at least two intriguing unanswered questions about behavior in these experiments. First there is the surprising result about undersupply of labor by the highest productivity workers in the high inequality treatment. Such behavior is inconsistent with selfish behavior as well as altruistic or inequality averse behavior. Second, we observe some variation in tax rates across different groups and across periods.

More general questions concern the robustness of our findings to richer environments. The findings are suggestive of rather general phenomena, but as a first exploration of these phenomena in the laboratory, our experimental environment was necessarily very stark. What happens if there are more agents, more complicated political institutions involving multiple layers and branches of government, progressive tax structures, or dynamic considerations such as income mobility or investment in human capital? The taxes we consider are purely redistributional, but many government expenditures are not purely redistributional and involve investments in public infrastructure, social insurance, and other categories that have a significant public good component. There are also interesting questions about the effect of tax rates on tax compliance, an issue that is beyond the scope of the present study. All of these issues are important to understand the relationships between public finance and political economy more deeply, and some of them are already being explored theoretically and empirically. We are hopeful that this paper opens the door for further investigation of these issues using laboratory experiments as a complement to theoretical and empirical studies.

References

[1] Alesina, A. and P. Giuliano. 2011. Preferences for Redistribution. in Jess Benhabib, Matthew O. Jackson and Alberto Bisin editors: *Handbook of Social Economics, Vol. 1A*. Amsterdam: North-Holland, 93-131.

[2] Andreoni, J. and J. Miller (2002) Giving According to GARP: An Experimental Test of the Consistency of Preferences for Altruism. *Econometrica.* 70(2): 737-753.

[3] Black, D. 1958. *The Theory of Committees and Elections.* Cambridge: Cambridge University Press.

[4] Bolton, G. and A. Ockenfels (2000) ERC: A Theory of Equity, Reciprocity, and Competition. *American Economic Review.* 90: 166-93.

[5] Bolton, G. and A. Ockenfels (2006) Inequality Aversion, Efficiency, and Maximin Preferences in Simple Distribution Games: Comment. *American Economic Review.* 96: 1906-11.

[6] Carbonell-Nicolau, O. and E. Ok (2007). Voting over Income Taxation. *Journal of Economic Theory* 134: 249-86.

[7] Coughlin, P. (1992) *Probabilistic Voting Theory.* Cambridge University Press: Cambridge.

[8] Downs, A. 1957. *An Economic Theory of Democracy.* New York: Harper and Row.

[9] Durante, R., Putterman, and J. Van der Weele (2014). Preferences for Redistribution and Perception of Fairness: An Experimental Study. *Journal of the European Economic Association*, in press.

[10] Fehr, E. and K. Schmidt (1999) "A Theory of Fairness, Competition, and Cooperation." *Quarterly Journal of Economics*, 114(3): 817-68.

[11] Fisman, R., S. Kariv, and D. Markovits (2007). Individual Preferences for Giving. *American Economic Review.* 97(5): 1858-76.

[12] Forsythe, R., J. Horowitz, N. Savin, and M. Sefton (1994). Fairness in Simple Bargaining Games. *Games and Economic Behavior.* 6: 347-69.

[13] Grosser, J. and E. Reuben. 2013. Redistribution and Market Efficiency: An Experimental Study. *Journal of Public Economics* 101: 39-52.

[14] Hinich, M. (1977) Equlibrium in Spatial Voting: The Median Voter Result is an Artifact. *Journal of Economic Theory.* 16: 208-19.

[15] Hochtl, W., J.-R. Tyran, and R. Sausgrubeer (2012). Inequality Aversion and Voting on Redistribution, *European Economic Review*, 56:1406-21.

[16] Holcombe, R. (1977) The Florida System: A Bowen Equilibrium Referendum Process. *National Tax Journal.* 30: 77-84.

[17] Holcombe, R. and L. Kenny (2007) Evidence on Voter Prefernces from Unrestricted Choice Referendums. *Public Choice.* 131: 197-215.

[18] Holcombe, R. and L. Kenny (2008) Does Restricting Choice in Referenda Enable Governments to Spend More? *Public Choice.* 136: 87-101.

[19] Konrad, K. and F. Morath (2011). Social Mobility and Redistributive Taxation. *Working paper #2011-2*, Max Planck Institute for Tax Law and Public Finance, Munich.

[20] Krawczyk, M. (2010). A Glimpse Through the Veil of Ignorance: Equality of Opportunity and Support for Redistribution. *Journal of Public Economics*, 94:131-41.

[21] Ledyard, J. (1984) "The Pure Theory of Large Two-Candidate Elections," *Public Choice*, 1984, 44(1), 7-41.

[22] McCarty, N., K. Poole, and H. Rosenthal (2006) *Polarized America The Dance of Ideology and Unequal Riches.* Cambridge: MIT Press.

[23] Meltzer, A. H., and Richard, S. F. (1981). A rational theory of the size of government. *Journal of Political Economy* 89 (Oct.): 914-927.

[24] Meltzer, A. H., and Richard, S. F. (1983). Tests of a rational theory of the size of government. *Public Choice*, 41, 403–418.

[25] Milanovic, B. (2000) The median-voter hypothesis, income inequality, and income redistribution: an empirical test with the required data. *European Journal of Political Economy*, 16, 367-410.

[26] Mirlees, J. (1971) An Exploration in the Theory of Optimum Income Taxation. *Review of Economic Studies* 38: 175-208.

[27] Palfrey, T. and H. Rosenthal (1988) Private incentives in social dilemmas: The effects of incomplete information and altruism. *Journal of Public Economics.* 35: 309-32.

[28] Perotti, R., 1996. Growth, income distribution, and democracy: what the data say. *Journal of Economic Growth* 1, 149–187.

[29] Roberts, K. W. S. (1977). Voting over income tax schedules. *Journal of Public Economics* 8:329-340.

[30] Romer, T. (1975). Individual welfare, majority voting and the properties of a linear income tax. *Journal of Public Economics*, 4, 163–185.

[31] Tyran, J.-R. and R. Sausgruber. (2006) A Little Fairness may Induce a Lot of Redistribution in Democracy, *European Economic Review* 50(2): 469-85.

Appendix A. Proofs of Propositions 1-3

Proof of Proposition 1. Single-peakedness is established in two steps. Clearly, if $\frac{d^2U_i^*(w_i,t)}{dt^2} < 0$ in the region $t \in [0,1]$, then single peakedness in the policy space follows immediately. From equation 3, we get:

$$\begin{aligned}\frac{dU_i^*(w_i,t)}{dt} &= -w_i^2\left(1-t+\frac{t}{n^2}\right)+\frac{1}{n}Z\left(1-2\frac{n-1}{n}t\right)\\ \frac{d^2U_i^*(w_i,t)}{dt^2} &= \frac{n-1}{n^2}\left((n+1)w_i^2-2Z\right)\end{aligned}$$

Thus, single-peakedness is guaranteed by concavity of U_i^* for all individuals whose productivity is sufficiently low ($w_i^2 < \frac{2}{n+1}Z$). For relatively high productivity workers ($w_i^2 > \frac{2}{n+1}Z$), it is easy to show that $\frac{dU_i^*(w_i,t)}{dt} < 0$ for all values of $t \in [0,1]$:

$$-w_i^2\left(1-t+\frac{t}{n^2}\right)+\frac{1}{n}Z\left(1-2\frac{n-1}{n}t\right) < 0 \Leftrightarrow w_i^2 > Z\cdot\frac{n(1-2t)+2t}{n^2(1-t)+t}$$

The last inequality is satisfied for all $w_i^2 > \frac{2}{n+1}Z$ since $\frac{2}{n+1} > \frac{n(1-2t)+2t}{n^2(1-t)+t}$.
The second and third properties follow immediately. **QED**

Proof of Proposition 2. As in Proposition 1, we obtain the optimal labor supply of altruistic individuals by differentiating with respect to x:

$$\frac{dU_i^A(w,x,t)}{dx_i} = (1-t+\frac{t}{n})w_i - x_i + \frac{A}{n-1}\cdot(n-1)\frac{t}{n}w_i \leq 0$$

$$x_i^{\text{altruism}}(w_i,t) = \left(1-t+\frac{(1+A)t}{n}\right)w_i > \left(1-t+\frac{t}{n}\right)w_i = x_i^*(w_i,t)$$

$$\frac{dx_i^{\text{altruism}}(w_i,t)}{dA} = \frac{t}{n}w_i > 0$$

To obtain the labor supply function of an inequality averse individual, we re-write the Fehr-Schmidt utility functions based on the productivity rank of the individual:

$$U_i^{FS}(w,x,t) = \mu_i\cdot U_i(w_i,x_i,t) - \frac{\alpha}{n-1}\cdot\sum_{j=i+1}^{n}U_j(w_j,x_j,t) + \frac{\beta}{n-1}\cdot\sum_{j=1}^{i-1}U_j(w_j,x_j,t)$$

where

$$\mu_i = \frac{n-1+\alpha(n-i)-\beta(i-1)}{n-1}$$

We can further simplify $U_i^{FS}(w,x,t)$ as follows:

$$\begin{aligned}U_i^{FS}(w,x,t) =&\mu_i\cdot\left[(1-t)w_ix_i-\frac{1}{2}x_i^2\right]-\frac{\alpha}{n-1}\cdot\sum_{j=i+1}^{n}\left[(1-t)w_jx_j-\frac{1}{2}x_j^2\right]+\\ &+\frac{\beta}{n-1}\cdot\sum_{j=1}^{i-1}\left[(1-t)w_jx_j-\frac{1}{2}x_j^2\right]+\frac{t}{n}\cdot\sum_{j=1}^{n}w_jx_j\end{aligned}$$

$$\frac{dU_i^{FS}(w,x,t)}{dx_i} = \mu_i\cdot[(1-t)w_i-x_i]+\frac{t}{n}w_i = 0 \Rightarrow x_i^{FS} = w_i\cdot\left[1-t+\frac{1}{\mu_i}\cdot\frac{t}{n}\right]$$

$$\text{where } \mu_i = 1 + \frac{\alpha(n-i) - \beta(i-1)}{n-1} > 0 \text{ for all } i \in \{1, 2, ..., n\}$$

Therefore, the value of μ_i determines the relation between $x_i^*(w_i, t)$ and $x_i^{FS}(w_i, t)$ as specified in the second part of the proposition. **Q.E.D.**

Proof of Proposition 3. Consider first case of altruistic preferences, $A \geq 0$. To establish the equilibrium tax rate in this society we first re-write the utility of individual i, adjusting for the labor supply effects of A:

$$\begin{aligned} U_i^A(w, x, t)^* &= \frac{1}{2} w_i^2 \left[(1-t)^2 - \frac{(A+1)^2}{n^2} t^2 \right] + \frac{t}{n} \left(1 - t + \frac{A+1}{n} t \right) \sum_j w_j^2 + \\ &+ \frac{A}{2(n-1)} \left[(1-t)^2 - \frac{(A+1)^2}{n^2} t^2 \right] \sum_{j \neq i} w_j^2 + A \frac{t}{n} \left(1 - t + \frac{A+1}{n} t \right) \sum_j w_j^2 = \\ &= \frac{1}{2} w_i^2 \left[(1-t)^2 - \frac{(A+1)^2}{n^2} t^2 \right] \left(1 - \frac{A}{n-1} \right) + \\ &+ Z \cdot \left(1 - t + \frac{A+1}{n} t \right) \left(\frac{t}{n} + \frac{A}{2(n-1)} \left(1 - t - \frac{A+1}{n} t \right) + A \frac{t}{n} \right) \end{aligned}$$

$$\Rightarrow \frac{dU_i^A(w, x, t)^*}{dt} = \frac{n-1-A}{n^2(n-1)} \cdot \left[Z \cdot (n - (2+A)(n-1-A)t) - w_i^2 \cdot (n^2(1-t) + (1+A)^2 t) \right]$$

$$\frac{d^2 U_i^A(w, x, t)^*}{dt^2} = -\frac{(n-1-A)^2}{n^2(n-1)} \cdot \left[(2+A)Z - (n+1+A) w_i^2 \right]$$

Single peakedness is easily verified, and we obtain the optimal tax for each level of productivity:

$$t^{\text{A}}(w_i) = \begin{cases} \frac{n^2}{n^2-(1+A)^2} \cdot \frac{\frac{1}{n}Z - w_i^2}{\frac{2+A}{n+1+A}Z - w_i^2} & \text{if} \quad w_i^2 < \frac{1}{n}Z \\ 0 & \text{if} \quad w_i^2 > \frac{1}{n}Z \end{cases}$$

We now compare this with the ideal tax rate of the median productivity individual if $A = 0$. The equilibrium tax is positive, $t_m^* > 0$, because $w_m^2 < \frac{1}{n}Z$:

$$\frac{n^2}{n^2 - (1+A)^2} \cdot \frac{\frac{1}{n}Z - w_m^2}{\frac{2+A}{n+1+A}Z - w_m^2} < \frac{n^2}{n^2 - 1} \cdot \frac{\frac{1}{n}Z - w_m^2}{\frac{2}{n+1}Z - w_m^2} \Leftrightarrow \frac{n^2 - 1}{n^2 - (1+A)^2} < \frac{\frac{2+A}{n+1+A}Z - w_m^2}{\frac{2}{n+1}Z - w_m^2}$$

The last inequality is satisfied for all $A \in [0, 1)$ as long as $n > 3$ and $w_m^2 < \frac{1}{n}Z$, which completes the proof of the first half of the proposition.

Consider next the case of inequality averse preferences, with Fehr-Schmidt parameters satisfying $0 < \beta \leq \alpha \leq \bar{\alpha}(\beta, n)$. Given the labor supply functions derived in Proposition 2, we can rewrite the utility of the median individual m as:

$$\begin{aligned} U_m^{FS}(w, x, t) &= \frac{1}{2} w_m^2 \left((1-t)^2 - \frac{t^2}{\mu_m^2 n^2} \right) + \frac{t}{n} \cdot \sum_{j=1}^{n} w_j^2 \left(1 - t + \frac{t}{\mu_j n} \right) - \\ &- \frac{\alpha}{2(n-1)} \cdot \sum_{j>m} \left[w_j^2 \left((1-t)^2 - \frac{t^2}{\mu_j^2 n^2} \right) - w_m^2 \left((1-t)^2 - \frac{t^2}{\mu_m^2 n^2} \right) \right] - \\ &- \frac{\beta}{2(n-1)} \cdot \sum_{j<m} \left[w_m^2 \left((1-t)^2 - \frac{t^2}{\mu_m^2 n^2} \right) - w_j^2 \left((1-t)^2 - \frac{t^2}{\mu_j^2 n^2} \right) \right] \end{aligned}$$

The first-order condition becomes:

$$\frac{dU_m^{FS}(w,x,t)}{dt} = -(1-t)w_m^2 - \frac{t}{n^2}\cdot\frac{w_m^2}{\mu_m^2} + \frac{1}{n}\cdot\sum_{j=1}^{n} w_j^2 - \frac{2t}{n}\cdot\sum_{j=1}^{n} w_j^2 + \frac{2t}{n^2}\cdot\sum_{j=1}^{n}\frac{w_j^2}{\mu_j}$$
$$+\frac{\alpha(1-t)}{n-1}\cdot\sum_{j>m} w_j^2 + \frac{\alpha t}{n^2(n-1)}\cdot\sum_{j>m}\frac{w_j^2}{\mu_j^2} - \frac{\alpha(1-t)}{2}w_m^2 - \frac{\alpha t}{2n^2}\cdot\frac{w_m^2}{\mu_m^2}+$$
$$+\frac{\beta(1-t)}{2}w_m^2 + \frac{\beta t}{2n^2}\cdot\frac{w_m^2}{\mu_m^2} - \frac{\beta(1-t)}{n-1}\cdot\sum_{j<m} w_j^2 - \frac{\beta t}{n^2(n-1)}\cdot\sum_{j<m}\frac{w_j^2}{\mu_j^2} =$$
$$= \left(\frac{1}{n}Z - \mu_m w_m^2\right) + \left(\frac{\alpha}{n-1}\sum_{j>m} w_j^2 - \frac{\beta}{n-1}\sum_{j<m} w_j^2\right) - t\cdot\left[\frac{2}{n}Z - \mu_m w_m^2 + \frac{w_m^2}{n^2\mu_m} - \frac{2}{n^2}\sum_{j=1}^{n}\frac{w_j^2}{\mu_j}\right]$$
$$- t\cdot\left[\left(\frac{\alpha}{n-1}\sum_{j>m} w_j^2 - \frac{\beta}{n-1}\sum_{j<m} w_j^2\right) - \left(\frac{\alpha}{n^2(n-1)}\sum_{j>m}\frac{w_j^2}{\mu_j^2} - \frac{\beta}{n^2(n-1)}\sum_{j<m}\frac{w_j^2}{\mu_j^2}\right)\right] \le 0$$

where $\mu_m = \frac{2+\alpha-\beta}{2}$ and $Z = \sum_{j=1}^{n} w_j^2$. Thus, the ideal tax rate of the median individual can be written as

$$t_m^{FS} = \begin{cases} \frac{\frac{1}{n}Z - w_m^2 + C}{\frac{2}{n}Z - w_m^2 - \frac{2}{n^2}\sum_{j=1}^{n}\frac{w_j^2}{\mu_j} + D} & \text{if} \quad w_m^2 \le \frac{1}{n}Z + C \\ 0 & \text{if} \quad \text{otherwise} \end{cases}$$

where

$$C = \left(\frac{\alpha}{n-1}\sum_{j>m} w_j^2 - \frac{\beta}{n-1}\sum_{j<m} w_j^2\right) - \frac{\alpha-\beta}{2}w_m^2 > 0$$

$$D = \left(\frac{\alpha}{n-1}\sum_{j>m} w_j^2 - \frac{\beta}{n-1}\sum_{j<m} w_j^2\right) - \left(\frac{\alpha}{n^2(n-1)}\sum_{j>m}\frac{w_j^2}{\mu_j^2} - \frac{\beta}{n^2(n-1)}\sum_{j<m}\frac{w_j^2}{\mu_j^2}\right) + w_m^2\cdot\left[\frac{1}{n^2\mu_m} - \frac{\alpha-\beta}{2}\right]$$

We next show that the median ideal tax rate is higher than the baseline model with standard preferences, the latter given by:

$$t_m^* = \begin{cases} \frac{\frac{1}{n}Z - w_m^2}{\frac{2}{n}Z - w_m^2 + \frac{1}{n^2}w_m^2 - \frac{2}{n^2}Z} & \text{if} \quad w_m^2 \le \frac{1}{n}Z \\ 0 & \text{if} \quad \text{otherwise} \end{cases}$$

Since $C > 0$ for $n \ge 3$, we will focus on interior (t_m^{FS}, t_m^*) and show that $t_m^{FS} > t_m^*$:

$$\frac{\frac{1}{n}Z - w_m^2 + C}{\frac{2}{n}Z - w_m^2 - \frac{2}{n^2}\sum_{j=1}^{n}\frac{w_j^2}{\mu_j} + D} > \frac{\frac{1}{n}Z - w_m^2}{\frac{2}{n}Z - w_m^2 + \frac{1}{n^2}w_m^2 - \frac{2}{n^2}Z} \Leftrightarrow$$

$$\left(\frac{1}{n}Z - w_m^2\right)\left(\frac{2}{n}Z - w_m^2\right) + \left(\frac{1}{n}Z - w_m^2\right)\frac{w_m^2}{n^2} - \left(\frac{1}{n}Z - w_m^2\right)\frac{2}{n^2}Z + C\left(\frac{2}{n}Z - w_m^2 + \frac{w_m^2}{n^2} - \frac{2}{n^2}Z\right) >$$
$$> \left(\frac{1}{n}Z - w_m^2\right)\left(\frac{2}{n}Z - w_m^2\right) - \left(\frac{1}{n}Z - w_m^2\right)\frac{2}{n^2}\sum_{j=1}^{n}\frac{w_j^2}{\mu_j} + D\left(\frac{1}{n}Z - w_m^2\right) \Leftrightarrow$$

$$C\left(\frac{2}{n}Z - w_m^2 + \frac{w_m^2}{n^2} - \frac{2}{n^2}Z\right) + \left(\frac{1}{n}Z - w_m^2\right)\frac{w_m^2}{n^2} + \frac{2}{n^2}\left(\frac{1}{n}Z - w_m^2\right)\sum_{j=1}^{n} w_j^2\left(\frac{1}{\mu_j} - 1\right) > D\left(\frac{1}{n}Z - w_m^2\right)$$

Notice that $C > 0$ and $\frac{2}{n}Z - w_m^2 + \frac{w_m^2}{n^2} - \frac{2}{n^2}Z > \frac{1}{n}Z - w_m^2$ for $n \geq 3$. Therefore, it is enough to show that

$$C + \frac{w_m^2}{n^2} + \frac{2}{n^2}\sum_{j=1}^{n} w_j^2\left(\frac{1}{\mu_j} - 1\right) > D \Leftrightarrow$$

$$\left(\frac{\alpha}{n-1}\sum_{j>m} w_j^2 - \frac{\beta}{n-1}\sum_{j<m} w_j^2\right) - \frac{\alpha-\beta}{2}w_m^2 + \frac{w_m^2}{n^2} + \frac{2}{n^2}\sum_{j=1}^{n} w_j^2\left(\frac{1}{\mu_j} - 1\right) >$$

$$> \left(\frac{\alpha}{n-1}\sum_{j>m} w_j^2 - \frac{\beta}{n-1}\sum_{j<m} w_j^2\right) - \left(\frac{\alpha}{n^2(n-1)}\sum_{j>m}\frac{w_j^2}{\mu_j^2} - \frac{\beta}{n^2(n-1)}\sum_{j<m}\frac{w_j^2}{\mu_j^2}\right) + w_m^2 \cdot \left[\frac{1}{n^2\mu_m} - \frac{\alpha-\beta}{2}\right]$$

$$\left(\frac{\alpha}{n^2(n-1)}\sum_{j>m}\frac{w_j^2}{\mu_j^2} - \frac{\beta}{n^2(n-1)}\sum_{j<m}\frac{w_j^2}{\mu_j^2}\right) + \frac{2}{n^2}\sum_{j=1}^{n} w_j^2\left(\frac{1}{\mu_j} - 1\right) > w_m^2 \cdot \left[\frac{1}{n^2\mu_m} - \frac{1}{n^2}\right]$$

We establish the last inequality in two steps.

<u>Step 1:</u>

$$\frac{\alpha}{n^2(n-1)}\sum_{j>m}\frac{w_j^2}{\mu_j^2} \geq \frac{\beta}{n^2(n-1)}\sum_{j<m}\frac{w_j^2}{\mu_j^2}$$

If $\frac{\alpha}{\beta} < \frac{n+1}{n-3}$, then all individuals above the median have $\mu_j < 1$, while all individuals below or equal to the median have $\mu_j \geq 1$, where $\mu_j = 1 + \frac{\alpha(n-j)-\beta(j-1)}{n-1}$. Therefore, cutoff value $\bar{\alpha}(\beta, n)$ will satisfy $\bar{\alpha}(\beta, n) < \beta \cdot \frac{n+1}{n-3}$. In this case there are the same number of individuals with productivity above and below the median, and we get

$$\frac{\alpha}{n-1}\sum_{j>m}\frac{w_j^2}{\mu_j^2} \geq \frac{\alpha}{n-1}\sum_{j>m}\frac{w_m^2}{\mu_m} = \frac{\alpha}{2}\cdot\frac{w_m^2}{\mu_m} \geq \frac{\beta}{2}\cdot\frac{w_m^2}{\mu_m} \geq \frac{\beta}{n-1}\sum_{j<m}\frac{w_j^2}{\mu_j^2}$$

<u>Step 2:</u>

$$\sum_{j=1}^{n} w_j^2\left(\frac{1}{\mu_j} - 1\right) > \frac{1}{2}w_m^2 \cdot \left[\frac{1}{\mu_m} - 1\right] \Leftrightarrow$$

$$\sum_{j>m} w_j^2\left(\frac{1}{\mu_j} - 1\right) - \sum_{j<m} w_j^2\left(1 - \frac{1}{\mu_j}\right) > \frac{w_m^2}{2}\cdot\left[1 - \frac{1}{\mu_m}\right] = w_m^2 \cdot \frac{\alpha-\beta}{2(2+\alpha-\beta)} \Leftrightarrow$$

$$\sum_{j>m} w_j^2\left(\frac{1}{\mu_j} - 1\right) - \sum_{j<m} w_j^2\left(1 - \frac{1}{\mu_j}\right) > w_m^2 \cdot \left[\sum_{j>m}\left(\frac{1}{\mu_j} - 1\right) - \sum_{j<m}\left(1 - \frac{1}{\mu_j}\right)\right] \Leftrightarrow$$

Thus, it is enough to show that

$$\sum_{j>m}\left(\frac{1}{\mu_j} - 1\right) - \sum_{j<m}\left(1 - \frac{1}{\mu_j}\right) > \frac{\alpha-\beta}{2(2+\alpha-\beta)}$$

Since there are an equal number of individuals with productivity above and below the median, one can pair them in the following way: $\left(\frac{n+3+2k}{2}, \frac{n-1-2k}{2}\right)$ for $k = 0, ..., \frac{n-3}{2}$. So there are $\frac{n-1}{2}$ pairs. We rewrite the inequality above as follows:

$$\sum_{k=0}^{\frac{n-3}{2}} \left(\frac{n-1}{n-1+\alpha n+\beta - \frac{n+3+2k}{2}(\alpha+\beta)} + \frac{n-1}{n-1+\alpha n+\beta - \frac{n-1-2k}{2}(\alpha+\beta)} - 2 \right) > \frac{\alpha-\beta}{2(2+\alpha-\beta)}$$

The left-hand side of the inequality is increasing in k, therefore, the smallest difference for all the k-pairs is the one when $k = 0$, that is, it is enough to show that

$$\frac{n-1}{2} \cdot \left[\frac{n-1}{n-1+\alpha n+\beta - \frac{n+3}{2}(\alpha+\beta)} + \frac{n-1}{n-1+\alpha n+\beta - \frac{n-1}{2}(\alpha+\beta)} - 2 \right] > \frac{\alpha-\beta}{2(2+\alpha-\beta)}$$

The last inequality is satisfied for $\alpha = \beta \in (0, 1)$. It is straightforward to show that for any parameter $\beta \in (0, 1)$ and any $n \geq 3$, there exists $\beta < \bar{\alpha}(\beta, n) < \beta\frac{n+1}{n-3}$ such that inequality above is satisfied for all $\alpha \in [\beta, \bar{\alpha}(\beta, n)]$, which completes the proof. **QED**

Appendix B. Instructions for DD-High treatment.

Welcome

You are about to participate in an experiment on decision-making and you will be paid for your participation in cash privately at the end of the session.

The currency in this experiment is called tokens. All payoffs are denominated in this currency. Tokens that you earn during the experiment will be converted into US dollars using the rate 200 Tokens = \$1. In addition, you will be paid a \$10 participation fee if you complete the experiment. The money you earn will depend on your decisions and the decisions of others.

Do not talk to or attempt to communicate with other participants during the session. Please take a minute and turn off all electronic devices, especially phones. During the experiment you are not allowed to open or use any other applications on these laboratory computers, except for the interface of the experiment.

The experiment consists of two parts. Each part is self-contained and consists of 10 rounds. Before the beginning of each part, we will read out loud detailed instructions about that part and the computer interface will be explained.

Part I: There will be 10 rounds in Part 1.

Before the first round begins, all participants will be randomly divided into groups of 5 participants each. In addition, each participant will be assigned a value V. Your group assignment and your assigned value will stay the same V for all 10 rounds of Part I.

There are 5 possible values of V: V = 2, V=6, V=10, V=14 and V=35. One member in each group will be assigned V = 2, one member V=6, one member V=10, one member V=14 and one member V=35. The computer will do the assignments randomly. Your assigned value will be displayed on your computer screen.

Your task in each round is to choose an investment level. Your investment can be any number between 0 and 25 (up to two decimal places). If you choose investment X and your value is V, this will generate your total investment earnings equal to V*X. For example, if V = 10 and X=4, then your total investment earnings in that round are computed by 10*4=40 tokens.

However, investment is not free. The cost to you of investing X is equal to $0.5 * X^2$ In the example just given, the investment of X=4 costs you 8 tokens. These costs are subtracted from your earnings at the end of the round.

A portion of your investment earnings for the round will be taxed. If the tax rate is T%, then your taxes will equal T% of your investment earnings, and you will keep the remaining (100-T)% of your investment earnings. The amount you keep after taxes is called your after tax investment earnings. Recall the example just given, where V = 10 and X=4, and your total investment earnings is 40 tokens. If the tax rate is 50% then your taxes equal 20 tokens and your after tax investment earnings, which are yours to keep, equal 20 tokens.

The taxes everyone in your group pays are not thrown away. Rather, the total taxes collected from all members of your group are rebated to the group members in equal shares at the end of each round. For example, if the total amount collected as taxes from all members of the group equals 200 tokens, then each member will receive back one fifth of this amount, or 40 tokens. Note that all members of the group are taxed at the same tax rate in a round, and all group members share equally the total taxes collected in the group.

To summarize up, your payoff in a round depend on the value V assigned to you at the beginning of round 1, your investment X, tax rate T and the tax rebate, which is determined by the total taxes collected from all members in your group. Your total earnings in a round consist of three parts

Total Earnings = Your After Tax Investment Earnings - Your Cost of Investment + Tax Rebate

Thus, your total earnings for the round in this example would be equal to 20 - 8 + 40 = 52 tokens.

At the beginning of each round a tax rate T will be displayed on your screen. This tax rate is the same for all members in your group. However, your group's tax rate may change from round to round. After observing your group's tax rate, you and all other members of your group will be asked to independently choose your investment levels, which can be any non-negative number between 0 and 25 up to two decimal places.

The screen has a calculator to assist you in deciding how much to invest in each round. The first row of the calculator displays your group's tax rate. You can calculate your hypothetical earnings for a round by entering two different numbers. Enter a hypothetical investment level choice in the second row and a hypothetical total taxes from the other four members of your group in the third row. You can use the up and down buttons to try different hypothetical levels. The fourth row then displays what your total earnings for the round would be if those hypothetical amounts were the actual amounts in that round. (If you enter these manually instead of using the buttons, you will need to press "Enter" for the calculator to work.) The numbers you enter in the calculator are just hypothetical and do not affect your actual earnings. Remember that your tax rebate consist of one fifth of the taxes collected from your investment earnings and one fifth of the taxes collected from the other members of the group.

After everyone has entered their investment decision and clicked on the "submit button", the computer will display your investment decision as well as the investment decisions made by all the other members of your group. It will appear in a table that also shows their values. All of your own information is highlighted in Red on the table. It will also show your earnings for the round, in tokens, broken down into its three components: after tax investment income, cost of investment, and tax rebate. All of this information is also summarized at the bottom of your screen in the history panel. The history panel will keep track of everything that has happened in your group in all rounds, highlighting your own information in red.

When round 1 is finished, we will move on directly to the next round. The next round will be identical to the previous round except your group's new tax rate T will be posted on your screen.

Summary of Part I:

- Part I of the experiment consists of 10 rounds.
- Before the beginning of round 1, participants are divided into groups of 5 members each.
- Each member of the group is assigned value V: one member gets V=2, one gets V=6, one gets V=10, one gets V=14 and one gets V=35.
- The assignment of values and the group assignments are fixed for all 10 rounds of Part I.
- In each round, a tax rate T is displayed on the screen. All members of the same group observe the same tax rate T.
- Each member chooses an investment X (number between 0 and 25 with up to two decimal places).
- Decisions and earnings for that round are displayed on your screen and recorded in the history panel

Part II: Part II of the experiment also consists of 10 rounds. The group assignments do not change. They are exactly the same as in Part I. Everyone also keeps the same assigned value as in Part I. Just to remind you, there is one member in your group who was assigned V = 2, one member V=6, one member V=10, one member V=14 and one member V=35.

Each round in Part II is similar to rounds in Part I of the experiment, except that at the beginning of each round all members of the group are asked to submit a proposal for the tax rate T.

While you are deciding what tax rate you wish to propose, the screen has a calculator to assist you in deciding. You can calculate your hypothetical earnings for a round by entering three different numbers. Enter a hypothetical group tax rate in the first row of the calculator. Enter a hypothetical investment decision of yours in the second row and a hypothetical total taxes from the other four members of your group in the third row. You can use the up and down buttons to try different hypothetical levels. The fourth row then displays what your total earnings for the round would be if those hypothetical amounts were the actual amounts in that round. (If you enter these manually instead of using the buttons, you will need to press "Enter" for the calculator to work.) The numbers you enter in the calculator are just hypothetical and do not affect your actual earnings. Remember that your tax rebate consist of one fifth of the taxes collected from your investment earnings and one fifth of the taxes collected from the other members of the group.

After each member of your group has submitted a proposed tax rate, the third highest of the five proposed tax rates is implemented as your group's tax rate for that round. The chosen tax rate will be clearly posted on your screen and is the same for everyone in your group. You will then be asked to choose an investment decision (as you did in the Part I of the experiment). Your investment decision can be any number between 0 and 25 up to two decimal places. You may use the calculator to explore different hypothetical scenarios, as you did in part I.

Once everyone in your group submits their investments, your payoff will be determined and we move on to the next round of the experiment.

As before, your payoff in a round depend on the value V assigned to you at the beginning of round 1, your investment X, tax rate T and the tax return, which is determined by the total taxes collected from all members in your group.

More precisely, your Payoff in a round consist of three parts:

Total Earnings = Your After Tax Investment Earnings - Your Cost of Investment + Tax Rebate

Appendix C.

Table 13: Estimates of the Regression Analysis of the Labor Supply Functions of Agents

Productivity	α	p-value	β	p-value
		DD regime		
2	1.21 (0.19)	0.30	-0.56 (0.25)	0.33
6	1.03 (0.06)	0.65	-0.67 (0.10)	0.19
10	1.01 (0.03)	0.69	-0.74 (0.08)	0.36
14	1.00 (0.03)	0.98	-0.76 (0.04)	0.28
18	0.94 (0.05)	0.21	-0.70 (0.07)	0.17
35 ($t > 0.375$)	0.93 (0.09)	0.39	-0.76 (0.10)	0.71
35 ($t < 0.375$)	0.64 (0.06)	0.23	-0.26 (0.12)	0.03
		RD regime		
2	1.11 (0.20)	0.57	-0.31 (0.23)	0.04
6	1.06 (0.08)	0.44	-0.84 (0.12)	0.74
10	1.02 (0.02)	0.38	-0.76 (0.02)	0.03
14	1.05 (0.03)	0.18	-0.86 (0.06)	0.31
18	1.01 (0.01)	0.12	-0.87 (0.03)	0.03
35 ($t > 0.375$)	1.06 (0.14)	0.64	-0.96 (0.20)	0.43
35 ($t < 0.375$)	0.66 (0.04)	0.22	-0.18 (0.13)	0.17

Notes. Estimates are based on all 20 rounds of the game. Robust standard errors in the parentheses are clustered by individual. p-values are from individual Wald tests of the null hypothesis that each coefficient equals its predicted value.