

Politico Economic Consequences of Rising Wage Inequality

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Abstract

This paper uses a dynamic political economy model to evaluate whether the observed rise in wage inequality and decrease in median to mean wages can explain some portion of the relative increase in transfers to low earnings quintiles and relative increase in effective tax rates for high earnings quintiles in the U.S. over the past several decades. Specifically, we assume that households have uninsurable idiosyncratic labor efficiency shocks and consider policy choices by a median voter which are required to be consistent with a sequential equilibrium. We choose the transition matrix to match observed mobility in wages between 1978 to 1979 in the PSID dataset and then evaluate the response of social insurance policies to a new transition matrix that matches the observed mobility in wages between 1995 and 1996 and is consistent with the rise in wage inequality and the decrease in median to mean wages between 1979 to 1996. We deal with the problem that policy outcomes affect the evolution of the wealth distribution (and hence prices) by approximating the distribution by a small set of moments. We contrast these numbers with those from a sequential utilitarian mechanism, as well as mechanisms with commitment.

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1 Introduction

In this paper we ask whether the observed increase in wage inequality and the decrease in median to mean wages can explain some part of the relative increase in transfers to low earnings quintiles and relative increase in effective tax rates for high earnings quintiles in the U.S. over the past few decades. To answer this question we use a model with uninsurable, idiosyncratic shocks to labor efficiency similar to Aiyagari [1]. With incomplete markets, the rising wage dispersion generates more individual consumption dispersion and an increased role for government insurance (transfer) programs. The benefits of such transfer programs may be offset by the costs associated with financing through distortionary taxation. We use a political recursive competitive equilibrium concept pioneered in Krusell, et. al. [14]. Specifically, political outcomes are endogenously determined by a median voter who chooses a proportional tax rate that is required to be consistent with a sequential equilibrium of a competitive economy. Obviously, the difficulty in the analysis arises out of the fact that the endogenous policy outcomes and the endogenous evolution of the wealth distribution are interconnected. Idiosyncratic uncertainty greatly complicates the determination of the median voter.

The specific experiment we consider is to choose a transition matrix to match observed mobility in wages between 1978 to 1979 in the PSID dataset and show that these numbers are consistent with “low” inequality. We reparameterize the transition matrix to match the observed mobility between 1995 to 1996 and show that these numbers are consistent with “high” inequality. Then we ask what proportional tax rate the median voter would choose for each of the two parameterizations. At this new tax rate, we compute the changes in effective tax rates by quintile (normalized by the middle quintile). Since during the 1979 to 1996 period the wage data was also characterized by a sustained decrease in the median to mean wage, there are potentially important differences between proportional taxes chosen by a median voter and a utilitarian planner. We find that in general the results from the median voter model are closer to the data than those chosen from a utilitarian mechanism.

The main difference from previous work in this area is the introduction of idiosyncratic uncertainty in a political-economy model.¹ For instance, what many consider to be the canonical political economy model by Krusell and Rios-Rull [15] assumes that households are heterogeneous in their earnings but there are complete markets so that there is no

¹There are several papers which consider a social planner’s utilitarian choice of exogenous taxes with incomplete markets and idiosyncratic uncertainty. See for example, Aiyagari [2] and Domeij and Heathcote [8].

uncertainty in the present discounted value of earnings. Complete markets also implies that the differences in initial wealth between households persist indefinitely (i.e. it is possible to choose an exogenous initial wealth distribution that is consistent with a steady state which replicates itself every period from $t = 0$) which allows them to identify the median voter ex-ante. In a related paper by Azzimonti et. al. [4], the authors use a first-order approach and show that the aggregate state can be summarized by the mean and median capital holdings in a model without uncertainty. They also include a proof that their environment yields single-peaked preferences. The closest paper to ours is Aiyagari and Peled [3]. They consider a model with idiosyncratic uncertainty, however they restrict off-the-equilibrium path beliefs to be those from the steady state rather than sequentially rational beliefs.

The paper is organized as follows. The data facts are presented in section 2. The model is presented in section 3. In section 4, we discuss how we parameterize the benchmark model. In section 5 we present a quantitative experiment to study the effect of the increase in earnings volatility on tax choices. We also conduct several counterfactual experiments to assess the role of changes in the tax code versus automatic changes associated with progressivity as well as the role of idiosyncratic uncertainty in our findings. In section 6 we conduct a sensitivity analysis with regard to alternative parameterizations of the elasticity of labor as well as borrowing constraints. We conclude in section 7. An Appendix contains the algorithm we use to compute the model and a detailed discussion of our data.

2 Data Facts

It is well documented that there has been an increase in wage inequality during the past three decades. Using the Panel Study of Income Dynamics, in Figures 1 and 2 we document a substantial increase in the coefficient of variation of wages as well as a decline in the median to mean ratio of wages for heads of households between 20 and 59, and who work less than 5096 hours (see our Data Appendix for a complete description of the selection criterion we use).² We choose this selection criterion because we will work with a infinitely lived agent model. There appear to be two different regimes in Figure 1; one with low coefficient of variation until the beginning of the 1980's where the mean coefficient of variation is around 0.83 and another regime with high coefficient of variation from the mid 1980's to 1996 with mean coefficient of variation approximately equal to 1.13 (an increase of more than 35%).

²There are many papers documenting the rise in wage inequality. See, for example, Autor, et. al. [5] and Heathcote, et. al. [12].

From Figure 2, we observe that during the same period the median to mean ratio displayed a sharp decrease of around 10%.³

The Congressional Budget Office (CBO) recently published data on effective federal tax rates in the United States for the past two and a half decades. Given we are focusing on wages for households between 20 and 59, we consider effective federal tax rates for the entire population less elderly (defined as having at least one head over the age of 65 and no children under 18).⁴ The federal effective tax rate is defined to be the total tax liability of a household divided by its post transfer (but pre-tax) income. It is comprised of effective individual income tax rates, effective social insurance taxes, effective corporate income taxes, and effective excise taxes.⁵ One of the important facts that we observe is that redistribution through the tax system in the U.S. has increased after the 1980's. Figure 3 illustrates the effective tax rates paid by each income quintile (normalized by the effective tax rate paid by the middle income quintile). It is clear from the figure that while the effective tax rate for the higher income quintiles increased relative to that of the middle quintile, the effective tax paid for the lower income quintiles declined relative to that of the middle quintile. For example, the effective tax rate for the highest quintile rose from around 1.38 times the value of that paid by the middle quintile in 1979 to around 1.45 times it in 1996 (an increase of 5%). At the same time the relative effective tax rate for the lowest quintile decreased by more than 35% (from 0.5 times the value of that paid by the middle quintile to 0.32 times it).

The CBO also provides data on before-tax and after-tax income for each income quintile. As an alternative measure of redistribution, we note that pre-tax income inequality between quintiles (i.e. variance of log pre-tax income) increased from 0.5588 to 0.7670 between 1979 and 1996 while after-tax income inequality increased from 0.4474 to 0.6061 over that same period. Thus the increase in after-tax inequality is 76% of the increase in pre-tax inequality.

The relative changes in effective taxes by each quintile we see in Figure 3 could be due to several reasons. First, for given income levels, changes in the tax code may create more redistribution. Second, for a given tax rate schedule, increases in income inequality can generate more redistribution since the tax system is progressive. For example, increases

³We consider 1996 as the second regime date since that year is the last year for which the PSID provides annual data. Specifically, after 1996, the PSID provides biannual data. Since our model will be annual, calculations based on two year mobility matrices would underestimate risk.

⁴Again see our Data Appendix for a complete description of the data and the selection criterion we use.

⁵We consider the total federal tax rate rather than its components since it is difficult to separate how much government spending and transfer payments is financed by, for instance, corporate taxes versus individual income taxes (except for social security under a pure pay-as-you-go system).

in income of higher quintiles could generate increases in effective taxes because people in those quintiles move up the tax schedule facing higher marginal tax rates. The opposite could happen if lower quintiles experience declines in their income; they move down the tax schedule and face lower marginal tax rates.

In order to gain some insight into how much the changes in effective taxes in Figure 3 are due to income changes versus changes in the tax code, we follow Krueger and Perri [13] to estimate the relationship between effective tax rates and pre-tax but post-transfer income data from the CBO in Section 4.3. As we will show in Section 5, we can then use this statistical model to derive a counterfactual effective tax rate due solely from changes in income. We find that changes in income explain between 29 and 56 percent of the change in effective tax rates. Harris, et. al. [10] present independent evidence that the contribution of income changes to effective tax changes is even smaller.⁶ In Section 5, we will conduct a similar counterfactual from our structural model.

In summary, as is clear from Figures 1 through 3, changes in wage inequality may have important implications for changes in effective tax rates as part of a redistributive or social insurance mechanism. We now turn to a simple incomplete markets model like that in Aiyagari [1] where there is a role for redistribution to illustrate this mechanism.

3 Model

3.1 Environment

There is a unit measure of infinitely-lived households. Their preferences are given by:

$$E \left[\sum_{t=0}^{\infty} \beta^t u(c_t, n_t) \right] \quad (1)$$

where c_t denotes consumption, $n_t \in [0, 1]$ denotes labor supply in period t , and $\beta \in (0, 1)$ is the discount factor. We assume that the period utility function has the form introduced by Greenwood, Hercowitz and Huffman [9]:

$$u(c_t, n_t) = \frac{1}{1-\gamma} \left[c_t - \chi \frac{n_t^{1+1/\nu}}{1+1/\nu} \right]^{1-\gamma} \quad (2)$$

⁶In particular, we use the sum of the column entitled “All Income Adjustments” in Table 4 of Harris, et. al. [10] to generate a measure of the contribution of income changes to the changes in effective tax rates. We find them to be rather small (17% and 2% for the highest two quintiles) and even negative (-13% and -12% for the lowest two quintiles).

where γ is the coefficient of relative risk aversion and ν is the intertemporal (Frisch) elasticity of labor supply.

Production takes place with a constant return to scale function, whose inputs are capital and labor

$$Y_t = F(K_t, N_t) = K_t^\alpha N_t^{1-\alpha} \quad (3)$$

where capital letters denote aggregates. The final good can be used for consumption or investment. Capital depreciates at rate δ .

Each household faces an uninsurable, idiosyncratic labor efficiency shock $\epsilon_t \in E$ which evolves according to a finite state markov process $\Pi(\epsilon_{t+1} = \epsilon' | \epsilon_t = \epsilon)$. Household earnings are given by $w_t \epsilon_t$ where w_t is a competitively determined wage. An individual household can self insure by holding k_t units of capital which pays a rate of return r_t . We assume households are allowed to borrow up to an exogenous borrowing limit b . For simplicity, we assume that the interest paid on borrowings are tax deductible.

The government taxes household capital and labor income at the same proportional rate denoted τ_t , spends G_t and provides lump-sum transfers denoted T_t . The government is assumed to run a balanced budget so that

$$G_t + T_t = \tau_t [r_t K_t + w_t N_t]. \quad (4)$$

3.2 Recursive Competitive Equilibrium

Let the joint distribution of capital and efficiency levels across households be denoted $\Gamma_t(k_t, \epsilon_t)$ with law of motion $\Gamma_{t+1} = H(\Gamma_t, \tau_t)$.⁷ Then the aggregate capital stock is given by

$$K_t = \int k_t d\Gamma_t(k_t, \epsilon_t) \quad (5)$$

and aggregate labor is given by

$$N_t = \int \epsilon_t n_t d\Gamma_t(k_t, \epsilon_t). \quad (6)$$

Perfect competition in factor markets implies

$$\begin{aligned} r_t &= \alpha K_t^{\alpha-1} N_t^{1-\alpha} - \delta \\ w_t &= (1 - \alpha) K_t^\alpha N_t^{-\alpha}. \end{aligned} \quad (7)$$

⁷Since there are no other assets besides capital, the distribution of capital and the distribution of wealth are identical. We will use these definitions interchangeably.

The economy-wide resource constraint in each period is given by

$$C_t + G_t + K_{t+1} = Y_t + (1 - \delta)K_t \quad (8)$$

Letting x denote x_t and x' denote x_{t+1} , we can write the household problem recursively as⁸

$$V(k, \epsilon; \Gamma, \tau) = \max_{c, n, k'} u(c, n) + \beta \sum_{\epsilon'} \Pi(\epsilon' | \epsilon) V(k', \epsilon'; \Gamma', \tau') \quad (11)$$

s.t.

$$\begin{aligned} c + k' &= k + [r(K, N)k + w(K, N)\epsilon n] (1 - \tau) + T \\ k' &\geq -b \\ \Gamma' &= H(\Gamma, \tau) \\ \tau' &= \Psi(\Gamma, \tau) \end{aligned}$$

where the perceived law of motion of taxes is given by $\tau_{t+1} = \Psi(\Gamma_t, \tau_t)$. The solution to the individual's problem generates decision rules which we denote

$$n = \eta(k, \epsilon; \Gamma, \tau), \quad c = g(k, \epsilon; \Gamma, \tau), \quad \text{and} \quad k' = h(k, \epsilon; \Gamma, \tau).$$

Before moving to the endogenous determination of tax rates via majority voting, it is useful to state a competitive equilibrium taking as given the law of motion of taxes.

Definition (RCE). Given $\Psi(\Gamma, \tau)$, a **Recursive Competitive Equilibrium** is a set of functions $\{V, \eta, g, h, H, r, w, T\}$ such that:

⁸The utility function given in equation (2) has the convenient property that the labor supply choice is independent of the consumption-savings choice. In particular, assuming an interior solution, individual labor supply is a simple function of the after-tax labor income:

$$n = \left[\frac{w\epsilon(1 - \tau)}{\chi} \right]^\nu \quad (9)$$

It is important to note that the optimal labor supply does not depend on household wealth. This property has the useful implication that equilibrium aggregate effective labor supply depends only on the inherited aggregate capital stock, the current tax rate, and the time-invariant distribution over the set of productivity shocks:

$$N = \left[\sum_i \pi_i^* (\epsilon^i)^{1+\nu} \left(\frac{(1 - \tau)(1 - \alpha)K^\alpha}{\chi} \right)^\nu \right]^{\frac{1}{1+\alpha\nu}}. \quad (10)$$

This simplifies the solution of our problem because equilibrium prices become a function of the aggregate capital stock and tax rates only (as before). With general preferences we would need another state variable - see appendix B in Krusell and Smith [16] for that case.

- (i) Given (Γ, τ, H, Ψ) , the functions $V(\cdot), \eta(\cdot), g(\cdot)$ and $h(\cdot)$ solve the hh's problem in (11);
- (ii) Prices are competitively determined (7);
- (iii) The resource constraint is satisfied

$$\int h(k, \epsilon; \Gamma, \tau) d\Gamma(k, \epsilon) = K^\alpha N^{1-\alpha} + (1 - \delta)K - \int g(k, \epsilon; \Gamma, \tau) d\Gamma(k, \epsilon) - G$$

where K and N are defined as in (5) and (6);

- (iv) The government budget constraint (4) is satisfied;
- (v) $H(\Gamma, \tau)$ is given by

$$\Gamma'(k', \epsilon') = \int 1_{\{h(k, \epsilon; \Gamma, \tau) = k'\}} \Pi(\epsilon' | \epsilon) d\Gamma(k, \epsilon).$$

3.3 Politico Economic Recursive Competitive Equilibrium

In this section, we endogenize the tax choice. In particular, we allow households to vote on next period's tax rate τ' . Given that households are rational, a decisive voter evaluates the equilibrium effects of her choice, calculates the expected discounted utility associated with each τ' , and chooses the tax rate which gives her highest utility. Since the source of household heterogeneity arises from the idiosyncratic shocks to earnings, we do not know who the median voter is as in the papers of, for instance, Krusell and Rios-Rull [15].

Specifically, from each household choice here we generate the distribution of “most preferred” tax rates. Provided each household's derived utility is single-peaked, the median of the most preferred tax rates is chosen (i.e. it is the Condorcet winner which beats any alternative tax rate in a pairwise comparison). In this case, what the literature usually calls the median voter corresponds to the agent with capital holdings and productivity level that optimally chooses the median tax rate. It is important to appreciate that in environments with idiosyncratic uncertainty the median voter, in general, does not correspond to the agent with median capital holdings or median productivity shock.⁹

To choose the most preferred tax rate, the household must choose among alternatives. Suppose that the household starts with state vector as before $(k, \epsilon, \Gamma, \tau)$ and consider a one period deviation for next period's tax rate to τ' not necessarily given by $\tau' = \Psi(\Gamma, \tau)$ while

⁹Only in the case of idiosyncratic transitory efficiency shocks are total resources, $(1 + r(1 - \tau))k + w\epsilon(1 - \tau) + T$, sufficient to know who the median voter is.

taking as given that all future ($t + 2$) tax choices will be given by the function Ψ . In that case, the household's problem is given by

$$\tilde{V}(k, \epsilon, \Gamma, \tau, \tau') = \max_{c, n, k'} u(c, n) + \beta E_{\epsilon|\epsilon} [V(k', \epsilon', \Gamma', \tau')] \quad (12)$$

s.t.

$$\begin{aligned} c + k' &= k + [r(K, N)k + w(K, N)\epsilon n] (1 - \tau) + T \\ k' &\geq -b \\ \Gamma' &= \tilde{H}(\Gamma, \tau, \tau') \end{aligned}$$

where \tilde{H} denotes the law of motion for Γ induced by the deviation, while all future distributions evolve according to H . Note that the future value function V is given by the solution to the household problem in (12) of the definition of a Recursive Competitive Equilibrium. A solution to this problem generates

$$n = \tilde{\eta}(k, \epsilon; \Gamma, \tau, \tau'), \quad c = \tilde{g}(k, \epsilon; \Gamma, \tau, \tau') \quad \text{and} \quad k' = \tilde{h}(k, \epsilon; \Gamma, \tau, \tau').$$

It is instructive to note that at a given $k, \epsilon; \Gamma, \tau$, people save more (or dissave less) at lower tax rates τ' .

The primary reason why a solution to the politico-economic equilibrium is difficult to find is that the tax choice τ' and associated decision rule \tilde{h} induce a new sequence of distributions:

$$\begin{aligned} \Gamma' &= \tilde{H}(\Gamma, \tau, \tau') \\ \Gamma'' &= H\left(\tilde{H}(\Gamma, \tau, \tau'), \tau'\right) \\ \Gamma''' &= H\left[H\left(\tilde{H}(\Gamma, \tau, \tau'), \tau'\right), \Psi\left(\tilde{H}(\Gamma, \tau, \tau'), \tau'\right)\right] \\ &\dots \end{aligned} \quad (13)$$

Because of this difficulty, Aiyagari and Peled [3] restricted off-the-equilibrium outcomes to be steady states. Specifically, Aiyagari and Peled assume that $\Gamma'' = \Gamma^*(\tau^*)$ where Γ^* denotes the steady state distribution corresponding to tax choice τ' .

Next we define the solution concept.

Definition (PRCE) A **Politico-Economic Recursive Competitive Equilibrium** is:

- (i) a set of functions $\{V, \eta, g, h, H, \Psi, r, w, T\}$ that satisfy the definition of a RCE;
- (ii) a set of functions $\{\tilde{V}, \tilde{\eta}, \tilde{g}, \tilde{h}\}$ that solve (12), at prices which clear markets and the

govt. budget constraint, and \tilde{H} satisfying

$$\Gamma'(k', \epsilon') = \int 1_{\{\tilde{h}(k, \epsilon; \Gamma, \tau, \tau') = k'\}} \Pi(\epsilon' | \epsilon) d\Gamma(k, \epsilon)$$

with continuation values satisfying (i);

(iii) in individual state $(k, \epsilon)_i$, household i 's most preferred tax policy τ^i satisfies

$$\tau^i = \psi((k, \epsilon)_i, \Gamma, \tau) = \arg \max_{\tau'} \tilde{V}((k, \epsilon)_i, \Gamma, \tau, \tau'); \quad (14)$$

(iv) the policy outcome function $\tau^m = \Psi(\Gamma, \tau) = \psi((k, \epsilon)_m, \Gamma, \tau)$ satisfies

$$\begin{aligned} \int I_{\{(k, \epsilon): \tau^i \geq \tau^m\}} d\Gamma(k, \epsilon) &\geq \frac{1}{2} \\ \int I_{\{(k, \epsilon): \tau^i \leq \tau^m\}} d\Gamma(k, \epsilon) &\geq \frac{1}{2}. \end{aligned}$$

Condition (iv) effectively defines the median voter. That is, tax outcomes are determined by the voter whose most preferred tax rate is the median of the distribution of most preferred tax rates. To find the median voter, we sort the agents by their most preferred tax rates and then we integrate the distribution of most preferred tax rates over (k, ϵ) using $\Gamma(k, \epsilon)$.

For the existence of this type of politico economic equilibrium, preferences need to be single peaked. Generally, single-peakedness is used to establish that the median ranked preferred tax rate beats any other feasible tax rate in pairwise comparisons so that the median voter theorem applies.¹⁰ We do not have a general proof of single peakedness; however, we check that in the calibrated economy we solve numerically, the indirect utility function satisfies this property *for every* $(k, \epsilon, \Gamma, \tau)$ including those off the equilibrium path.¹¹ Single-peakedness is evident in Figure 4. There we plot the indirect utility function $\tilde{V}(k, \epsilon, \Gamma, \tau, \tau')$ over τ' for different households (k, ϵ) evaluated at $\tau = 0.433$ and the steady state distribution Γ associated with that τ . Further, for $\epsilon^1 < \dots < \epsilon^5$, Figure 4 makes clear that households with median wealth and higher wages prefer lower tax rates.

Finally, we restrict attention to steady state equilibria of the above definition. Specifically,

Definition (SSPRCE). A **Steady State PRCE** is a PRCE which satisfies $\Gamma^* = H(\Gamma^*, \tau^*)$ and $\tau^* = \Psi(\Gamma^*, \tau^*)$.

¹⁰For household i in individual state $(k, \epsilon)_i$ and aggregate state Γ, τ , preferences of voter i are *single peaked* if the following condition holds: if $\tilde{\tau} \leq \hat{\tau} \leq \tau^i$ or if $\tilde{\tau} \geq \hat{\tau} \geq \tau^i$, then $\tilde{V}((k, \epsilon)_i, \Gamma, \tau, \tilde{\tau}) \leq \tilde{V}((k, \epsilon)_i, \Gamma, \tau, \hat{\tau})$.

¹¹The papers by Azzimonti, et. al. [4] and Bassetto and Benhabib [6] have proofs of single-peakedness in nonstochastic environments.

3.4 Alternative Mechanisms

We compare our results with three alternative mechanisms. First, we analyze what would be the equilibrium tax rate if it is chosen by sequentially maximizing average welfare (the solution to a planner’s problem with no commitment). We call it the utilitarian mechanism with no commitment. In this case and identical to the equilibrium considered in the previous section, no restrictions are imposed over the evolution of tax rates. Second, we consider median voter and utilitarian mechanisms with commitment; that is where only a one time change in tax rates is allowed. More specifically, tax rates are restricted to be fixed after the first period.

3.4.1 Utilitarian Mechanism with no commitment

The planner sequentially chooses a future tax rate to maximize aggregate welfare. The definition of equilibrium is identical to that of a **PRCE** but where the condition that defines the equilibrium tax function, condition (iv), is replaced by:

$$\Psi^{un}(\Gamma, \tau) = \arg \max_{\tau'} \int \tilde{V}(k, \epsilon, \Gamma, \tau, \tau') d\Gamma(k, \epsilon).$$

with all continuation values evaluated according to the equilibrium function (e.g. $\tau'' = \Psi^{un}(\Gamma', \tau')$). As before changes in tax rates affect the evolution of the wealth distribution and viceversa.

3.4.2 Mechanisms with commitment

We consider two other tax choice mechanisms with commitment.¹² The first is a simple restriction on the PRCE defined above. In particular, the median voter chooses a future permanent tax rate. It is as if the government can commit to the future tax rate. Specifically, the only constraint on problem PRCE is that all continuation values are evaluated according to the “identity” function (that is, $\tau_{t+n+1} = \Psi(\Gamma_{t+n}, \tau_{t+n}) = \tau_{t+n}$, for all Γ_{t+n} and τ_{t+n} , $n = 1, 2, \dots$ with $\tau_{t+1} = \Psi^O(\Gamma, \tau) = \arg \max_{\tau'} \tilde{V}((k, \epsilon)_m, \Gamma, \tau, \tau')$). Note that in this case we restrict only the evolution of tax rates. The evolution of the joint distribution Γ is given by the equilibrium function $H(\Gamma, \tau)$. It is still necessary to compute the entire transition of prices for each possible tax change. We call this case the *one-time median voter tax choice*.

¹²Besides providing an interesting theoretical contrast to the sequential problem, from a computational standpoint the one-time problem is much quicker and can serve as a useful starting point for the sequential case.

Even for the one-time voting case, there is a nontrivial transition path for the wealth distribution similar to (13). Specifically, we have

$$\begin{aligned}\Gamma' &= \tilde{H}(\Gamma, \tau, \tau') \\ \Gamma'' &= H\left(\tilde{H}(\Gamma, \tau, \tau'), \tau'\right) \\ \Gamma''' &= H\left[H\left(\tilde{H}(\Gamma, \tau, \tau'), \tau'\right), \tau'\right] \\ &\dots\end{aligned}$$

Higher future tax rate choices $\hat{\tau} > \tau^*$, for example, imply aggregate capital paths that are monotonically decreasing. This is because higher future tax rates generate decreases in individual savings that are reflected in the paths to the new invariant distribution $\hat{\Gamma}(\hat{\tau})$ associated with $\hat{\tau}$. The effects of the tax change disappear slowly (about 50 model periods or years).

We also consider a *one-time utilitarian tax choice*. In this case, the planner chooses a future constant tax rate to maximize aggregate welfare:

$$\Psi^{uc}(\Gamma, \tau) = \arg \max_{\tau'} \int \tilde{V}(k, \epsilon, \Gamma, \tau, \tau') d\Gamma(k, \epsilon).$$

with all continuation values evaluated according to the “identity” function (e.g. $\tau'' = \Psi(\Gamma', \tau') = \tau' \quad \forall \Gamma', \tau'$).

4 Parameterization

We parameterize the model for the U.S. economy. We can group the parameters in three different sets: (i) preferences and technology $\{\beta, \gamma, \nu, \chi, \alpha, \delta, b\}$; (ii) the wage generating process $\{E, \Pi\}$; and exogenous government parameters $\{G, \phi\}$, where ϕ denotes the fraction of total transfers associated with the earned income tax credit.

4.1 Preference and Technology parameters

Some of the preference and technology parameters (β , γ , α , and δ) are set to standard values for the U.S. economy when using a neoclassical growth model. A model period corresponds to a year. The intertemporal Frisch elasticity ν is estimated to be between 0.1 and 0.45 for prime age males by McCurdy (1981). We take ν to be 0.3. The parameter χ is set so that

aggregate effective labor supply is equal to 0.3 in 1979 as in Heathcote [11]. We set the borrowing constraint $b = 0$.¹³ The value of the parameters are displayed in table (1).

Table 1: Preferences and Technology Parameters.

Parameter		Value
Discount Factor	β	0.96
Preferences	γ	1
	ν	0.3
	χ	100
Borrowing Constraint	b	0
Capital Share	α	0.36
Depreciation Rate	δ	0.06

4.2 Wage process

We set the number of elements in E to five since much of the effective tax rate data we consider is in terms of quintiles (so $E = \{\epsilon^1, \epsilon^2, \epsilon^3, \epsilon^4, \epsilon^5\}$ where ϵ^q refers to average wage rate of individuals in wage quintile $q \in \{1, \dots, 5\}$ ordered from lowest to highest). We use the PSID data to obtain the annual mobility matrices (transition probabilities) from 1978 to 1979 (corresponding to the low inequality regime) and from 1995 to 1996 (corresponding to the high inequality regime). We restrict our sample to household heads who are between ages 20 and 65, who work no more than 5096 hours annually, and who are in the sample for both years during the two periods for which we calculate transition matrices.¹⁴ Moreover, we use population weights when we compute our transition matrices.¹⁵ Given this we obtain the mobility matrices reported in Tables 2 and 3.¹⁶

In the raw data, our selection criterion yields an increase in the coefficient of variation from 0.93 in 1979 to 1.19 in 1996 while the median to mean ratio declines from 0.87 to 0.79. To get a sense of the approximation error for these moments from using our transition matrices, we can use those matrices to calculate the implied ratio of median to mean wages (which

¹³As it turns out, weakening the constraint has very little effect on our results and would actually help us match the level of effective tax rates better.

¹⁴5096 hours of work a year corresponds to a person that worked 14 hours a days, 7 days a week during the 52 weeks of the year. Therefore, the limit on the number of hours worked is set to avoid data collection errors since a higher value seems unfeasible.

¹⁵The Appendix provides a complete description of the way we compute the transition matrices.

¹⁶For instance, in Table 2, the ϵ^q corresponds to the average of the values in 1978 and 1979 for quintile q .

Table 2: Transition Matrix for 1978-1979.

	ϵ^1	ϵ^2	ϵ^3	ϵ^4	ϵ^5
ϵ^1 (2.60)	0.732	0.189	0.048	0.015	0.015
ϵ^2 (9.01)	0.165	0.553	0.222	0.048	0.009
ϵ^3 (13.42)	0.038	0.188	0.527	0.190	0.055
ϵ^4 (18.52)	0.034	0.050	0.160	0.556	0.198
ϵ^5 (35.43)	0.029	0.019	0.041	0.193	0.716

Table 3: Transition Matrix for 1995-1996.

	1	2	3	4	5
ϵ^1 (1.75)	0.731	0.148	0.051	0.033	0.034
ϵ^2 (7.92)	0.145	0.558	0.219	0.056	0.021
ϵ^3 (11.90)	0.055	0.207	0.505	0.208	0.022
ϵ^4 (17.03)	0.040	0.045	0.191	0.575	0.147
ϵ^5 (35.98)	0.029	0.036	0.033	0.126	0.774

are 0.85 and 0.79 in 1979 and 1996, respectively) and the implied coefficient of variation of wages (which are 0.70 and 0.78 in 1979 and 1996, respectively). Since we are grouping individuals in wage brackets, it is expected that the level and changes in these inequality measures implied by these transition matrices are smaller. While the approximation error is quite small for the median to mean ratio, it is between 25 and 34 percent smaller for the coefficient of variation. This means the model results for redistribution should be considered as a lower bound for what is in the data.

The mobility matrices we obtain from the data imply certain properties for an autoregressive representation of the data. In particular, one can compute the autocorrelation of the logged labor efficiency shock process ϵ_t (i.e. $\log(\epsilon_{t+1}) = \rho \log(\epsilon_t) + u_{t+1}$ where u_{t+1} is iid mean zero and variance given by $(1 - \rho^2)\sigma^2$ where $\sigma^2 \equiv \text{var}(\log(\epsilon_{t+1}))$). Table 4 provides the implied values for this process. This suggests that “mobility”, as measured by ρ , has risen slightly while “inequality”, as measured by σ^2 , has risen substantially.

4.3 Government Parameters

We next set certain parameters in the government budget constraint (4). Since our model abstracts from retirement and the reasons for federal government spending like defense, we

Table 4: Autoregressive Representation

	1979	1996	% Δ
ρ	0.77	0.75	-2.6
σ^2	0.75	1.01	35.0

include social security transfers as part of government purchases (i.e. it is a resource lost on agents not in the model). Using this categorization for 1979, 5.2% of GDP was associated with social security and 9.1% of GDP was associated with government purchases yielding $G_{1979} = 9.1 + 5.2 = 14.3$. In 1996, 7% of GDP was associated with social security and 5.3% of GDP was associated with government purchases yielding $G_{1996} = 5.3 + 7 = 12.3$.¹⁷

To take the theoretical marginal tax rate τ to the data, we use the CBO's definition of effective tax rates, which we denote e . As mentioned previously, it is defined to be the amount of total tax liability divided by pre-tax income including transfers. In the data, the total tax liability is reported net of earned income tax credit (EITC) and this is not included in the transfer measure. That is, from the total transfer T some fraction $\phi \in [0, 1]$ is computed as a credit in income taxes and the rest $(1 - \phi)$ is finally distributed as a pure transfer. Thus, for accounting reasons, let $\Upsilon = \phi T$ denote the EITC and $T^f = (1 - \phi)T$ denote pure transfers. In the context of our model, the effective income tax rate is given by:

$$e = \frac{\tau \int (rk + nw\epsilon) d\Gamma(k, \epsilon) - \Upsilon}{\int (rk + nw\epsilon) d\Gamma(k, \epsilon) + T^f}. \quad (15)$$

The parameter ϕ is chosen as follows. At the given parameters, $\{\beta, \sigma, \alpha, \delta, E, \Pi\}$, we obtain the equilibrium marginal tax rate τ . We then choose ϕ to match the ratio of Total Earned Income Tax Credit to GDP ($\phi T/Y$) in 1996. The IRS reports that the Total Earned Income Tax Credit is \$22.1 billion. Nominal GDP from the NIPA tables is \$7816.9 billion. To make a fair comparison between the different mechanisms and because each mechanism generates a different marginal tax rate (and transfers), ϕ varies insignificantly from one mechanism to the other. For example, we find $\phi = 0.0103$ for the sequential median voter mechanism and $\phi = 0.0108$ for the sequential utilitarian mechanism.

¹⁷The data comes from Table 15.5 (Total Government Expenditures by Major Category of Expenditure as Percentages of GDP: 1948–2006) on the U.S. Government Printing Office web page under Budget of the United States Government: Historical Tables Fiscal Year 2008. The link to the table is <http://www.gpoaccess.gov/usbudget/fy08/sheets/hist15z5.xls>.

Equation (15) implies that the effective tax rate in our model increases with income (i.e. even though τ is independent of income, effective taxes are progressive). To see this let $\int (rk + nw\epsilon)d\Gamma^q(k, \epsilon) = I^q$ be the pre-tax, pre-transfer average income for quintile q . Then from (15) the effective tax rate for quintile q can be written as

$$e^q = a + b \cdot \frac{1}{I^q + T^f} \quad (16)$$

where $a = \tau$ and $b = -(\tau T^f + \Upsilon)$. That is, a system with a constant marginal tax rate a and a fixed deduction b . Krueger and Perri fit a regression to (16). In particular, they regress effective tax rate data on pre-tax, post-transfer average income for each quintile in a given year t , yielding estimates of \hat{a}_t and \hat{b}_t that we present in Table 5 with standard errors in parentheses. The high R^2 leads Krueger and Perri [13] to state (p.41) “the progressive tax system used in the last section (which is similar to ours) is almost perfectly approximated by a tax system with a constant marginal tax rate of 25% and a fixed deduction of 9.6% of mean per adult earnings.”

Table 5: Estimated Tax System

Year	Estimates	\hat{a}_t	\hat{b}_t	R^2
1979		0.2672 (0.017)	-3059 (536)	0.92
1996		0.2725 (0.017)	-3667 (551)	0.94

5 Findings

To assess the quantitative significance of the change in inequality for changes in effective taxes, we feed the transition matrix for wage rates from 1978 to 1979 into the model to deliver a steady state effective tax rate in the initial regime. Then we feed the transition matrix for wage rates from 1995 to 1996 into the model to deliver a steady state effective tax rate in the final regime.

After solving the saving decision problem of the household we can solve problem (14) in the definition of PRCE to obtain the tax rate that maximizes each agent’s utility. In Figure 5 we observe the most preferred tax rates as a function of k for different levels of ϵ . The

feasible set of tax rates is restricted to the interval $[0.17, 1]$.¹⁸ For a fixed level of wealth k , the function $\tau' = \psi(k, \epsilon, K, \tau)$ is decreasing in ϵ . That is, for a given level of assets, an agent with the lowest efficiency level ϵ^1 will vote for a higher tax rate than an agent with higher efficiency levels ϵ^2 to ϵ^5 . This implies that the fraction of households in each efficiency level is critical for the determination of the optimal tax rate.

Clearly if two households have equal efficiency levels at the time of the tax reform, but different levels of wealth k , the wealthier household has more to lose from an increase in tax rates. This effect is seen as a movement along $\tau' = \psi(k, \epsilon, K, \tau)$ for a given ϵ in Figure 5. The figure shows that the optimal tax rate is decreasing in the level of wealth for a given level of labor productivity. Wealthier agents receive a large portion of their income from the return on capital and therefore changing the tax rate affects their expected net return. In general, this effect offsets the effect of the increase in the government transfers mentioned above.

Finally, Figure 5 shows that it is possible for households with two different (k, ϵ) to choose the same tax rate τ' (this is seen as a horizontal slice). For instance, it is evident that a household with $(1.08, \epsilon^3)$, one with $(2.11, \epsilon^2)$ and one with $(3.07, \epsilon^1)$ choose the same tax rate $\tau' = 0.433$.

We can summarize the tax choice of a typical agent as follows:

1. For a given (k, Γ, τ) , $\psi(k, \epsilon, \Gamma, \tau)$ is decreasing in ϵ ; that is, a household with a lower wages will choose a higher τ' .
2. For a given $(\epsilon^i, \Gamma, \tau)$, $\psi(k, \epsilon, \Gamma, \tau)$ is decreasing in k ; that is, a household with a lower wealth will choose a higher τ' .
3. For a given (Γ, τ) , there may be households with different wealth and wages who choose the same τ' .

There is an observational difference between our work and the previous political economy models mentioned in the introduction. Previous models that do not incorporate idiosyncratic uncertainty were calibrated to generate a direct relation between wealth and preferred tax rates; that is, households with more wealth than the median level always vote for lower taxes and the opposite is true for households with lower than median wealth. On the contrary, our model endogenously generates heterogeneity in voting outcomes. As evident in Figure

¹⁸ $\tau = 0.17$ is the lowest tax rate such that government revenues can pay for government expenditures.

5, households with different levels of wealth k may vote for the same τ' . After solving for the optimal tax rate we locate the capital holdings of the median voter k^m (as well as his earnings). We can sort households based on their level of capital relative to k^m to form two groups: those with $k \geq k^m$ and those with $k \leq k^m$. Finally in each of these two groups, agents can be separated between those who prefer a higher tax rate and those who prefer a lower tax rate than the median voter. We find that for agents with lower wealth k than the median voter only 63% vote for higher taxes (either those with lower earnings or those with extremely low capital and higher earnings) while 37% vote for lower taxes than the median voter (those with higher earnings). By comparison with previous papers, this would be 100% and 0% respectively.¹⁹ Furthermore, for agents with higher wealth k than the median voter only 50% vote for higher taxes (those with lower earnings level) while the other half vote for lower taxes than the median voter (either those with higher earnings or those with extremely high capital and lower earnings).

Table (6) presents the changes in effective income tax rates by income quintile when normalized by the middle quintile, the analogue of our Figure 3. The sequential median voter model is capable of explaining nearly half of the observed changes in normalized effective tax rates for low quintiles ($q = 1$ and 2) but tends to overpredict changes in the high quintiles ($q = 4$ and 5). Further, the sequential median voter model actually matches the levels of normalized effective tax rates better than the utilitarian model in 1996. This is sensible since the model should work better when the median to mean ratio is the farthest from one. We also note that all models tend to overestimate the average level of effective taxes.²⁰ However, the sequential median voter model is the only one which gets close to matching the change in the level of average effective tax rates (i.e. 3% in the data versus 4% in the sequential median voter model while all other models actually predict decreases). Finally, we note that the sequential models predict higher average levels of tax rates than models with commitment since the decisive agent takes into account the entire future direct distortion when setting one-time taxes.

Since pre-tax income is crucial for voting outcomes, as a test of the model we compare some measures of income inequality from the data with those produced by the Sequential Median Voter in the 1996 equilibrium in Table 7.²¹ We observe that the model does a fairly

¹⁹Of course, it is possible for the previous papers without idiosyncratic uncertainty to calibrate differently and obtain heterogeneity in voting similar to ours.

²⁰The corresponding theoretical marginal tax rate for the sequential median voter model is 0.43 in 1979 and 0.47 in 1996, while they are 0.388 in 1979 and 0.394 in 1996 for the sequential one-time median voter model.

²¹For income measures, we use the income data provided from the CBO that does not include elderly

Table 6: Effective Income Tax Rate, Average Levels and Income Quintiles (Normalized by Middle Quintile)

Effective Tax Rates		1979	1996	% Δ
Data	Average level	0.22	0.23	3.15
	quintile 1	0.499	0.320	-35.91
	quintile 2	0.823	0.776	-5.76
	quintile 4	1.116	1.117	0.05
	quintile 5	1.383	1.454	5.08
Seq. Median Voter	Average level	0.356	0.372	4.27
	quintile 1	0.578	0.491	-15.04
	quintile 2	0.878	0.848	-3.48
	quintile 4	1.084	1.113	2.60
	quintile 5	1.194	1.271	6.43
Seq. Utilitarian	Average level	0.371	0.364	-1.71
	quintile 1	0.560	0.498	-11.01
	quintile 2	0.870	0.851	-2.17
	quintile 4	1.065	1.109	1.52
	quintile 5	1.212	1.261	4.05
One-time Median Voter	Average level	0.330	0.328	-0.46
	quintile 1	0.614	0.541	-11.83
	quintile 2	0.893	0.873	-2.34
	quintile 4	1.071	1.089	1.65
	quintile 5	1.163	1.212	4.25
One-time Utilitarian	Average level	0.338	0.331	2.08
	quintile 1	0.602	0.538	-10.53
	quintile 2	0.889	0.871	-1.96
	quintile 4	1.075	1.090	1.37
	quintile 5	1.173	1.216	3.66

good job in matching the data on income inequality measures.

Table 7: Income Inequality by Income Quintiles

Measures (hh's sorted by Income Quintile)	Data	Model
Ratio Average Income to Middle Quintile	1.34	1.24
Top 10% to Middle Quintile	4.43	2.80
First Quintile (Lowest) to Middle Quintile	0.30	0.46
Second Quintile to Middle Quintile	0.65	0.74
Fourth Quintile to Middle Quintile	1.41	1.35
Fifth Quintile (Highest) to Middle Quintile	3.16	2.63
Gini Wealth	0.80	0.51

As suggested in Section 2, rising inequality by itself could potentially generate a rise in effective tax rates without any change in the marginal tax rate τ owing to the effect of changes in labor income working through a progressive tax system. To assess this issue, we can use the statistical model in Section 4.3 to determine how much of the change in effective taxes are due only to changes in income given the simple progressive tax system we employ. Specifically, in Table 8 under the heading “K-P Estimates” we provide the change in effective taxes due solely to changes in income based upon the counterfactual

$$e_{1996}^{q,inc} = \hat{a}_{1979} + \hat{b}_{1979} / (I_{1996}^q + T_{1979}^f).$$

The CBO does not separately report I_t^q or T_t^f in any year but only the sum of the two. However, to conduct the counterfactual above we need I_t^q or T_t^f for the years 1979 and 1996. To obtain an estimate of these numbers, we use data on federal transfers and compute the ratio of EITC to total transfers (which corresponds to $\Upsilon / (T^f + \Upsilon)$ in our model) for the years 1979 and 1996. In 1979, this ratio is equal to 0.3% while in 1996 it is 2%. Given these ratios and using the estimates for $b(-(\tau T^f + \Upsilon))$ for each year from Table 5, we can solve for T_{1979}^f and T_{1996}^f which implies that $T_{1996}^f - T_{1979}^f = \1228 . Adding this to the CBO pretax post-transfer data ($I_{1996}^q + T_{1996}^f$) we obtain $I_{1996}^q + T_{1979}^f$ that we use to obtain the counterfactual tax rates from the equation above. For example, as Table 8 suggests, changes in income explain between 29 and 56 percent of the change in effective tax rates.

We can also run a counterfactual to decompose how much of the change in effective tax rates in 1996 is attributable to changes solely in the wage process using our model.

households (as in our calibration). The source of the wealth data is the Survey of Consumer Finances of 1998 and includes retirees.

Specifically, we impose the sequential equilibrium marginal tax rate chosen by the median voter τ in the low inequality (1979) regime into a competitive equilibrium from the high inequality (1996) regime.²² This gives us a counterfactual set of effective tax rates for the 1996 regime that are attributable only to changes in the wage process. We then use these tax rates to obtain effective tax rates across quintiles and normalize them as we did earlier. Then we calculate the percentage changes in these counterfactual normalized tax rates. This gives us the percentage change in normalized tax rates due to the change in the wage process. Then we compute the ratio of the percentage change in counterfactual normalized effective tax rates to the percentage change in actual normalized effective tax rates to obtain the numbers in Table 8. As evident in the table, the sequential mechanism attributes much less change in effective tax rates due to wage changes than the utilitarian mechanism. Thus the results from the sequential mechanism are closer to the data than the results from the utilitarian mechanism.

Table 8: Fraction of changes in normalized effective tax rates due only to changes in wages

Income Quintiles	K-P Estimates	Sequential	Utilitarian
quintile 1	56%	72%	101%
quintile 2	39%	60%	99%
quintile 4	35%	57%	100%
quintile 5	29%	62%	101%

Next we use the model to determine the relative importance of mobility and inequality in explaining the increase in redistribution. For example, in order to assess the contribution of changes in mobility (i.e changes in ρ) we compare the results in Table 6 for the one-time median voter model with one where we solve for an equilibrium using the levels of the efficiency shocks in 1979 (i.e. E_{1979}) and the transition matrix corresponding to the calibration in 1996 (i.e. Π_{1996}). In this case, the measure of inequality (σ^2) remains virtually unchanged but the measure of mobility in 1996 (i.e. ρ) decreases by 2.6%. In order to assess the contribution of changes in inequality (i.e changes in σ^2) we compare the results in Table 6 with one where we solve for an equilibrium using the transition matrix for 1979 (i.e. Π_{1979}) and the levels of efficiency shocks corresponding to the calibration in 1996 (i.e. E_{1996}). In this case, the measure of mobility (ρ) remains constant, but the measure of inequality in 1996 (i.e. σ_2) increases by 33%. As Table 9 shows, the observed change in mobility generates

²²In other words, we simply solve an Aiyagari [2] economy calibrated to 1996 with τ set at the level implied by our SEQ for 1979.

very small percentage changes in effective tax rates while the observed change in inequality generates large percentage changes in effective tax rates. Thus, this provides evidence that a significant portion of the increase in redistribution is due to an increase in inequality.

Table 9: Changes in normalized effective tax rates from the one-time median voter model attributable to changes in mobility or inequality

Income Quintiles	Total % Δ	% Δ from mobility	% Δ from inequality
quintile 1	-11.83	-2.03	-11.03
quintile 2	-2.34	-0.33	-2.34
quintile 4	1.65	0.28	1.61
quintile 5	4.25	0.87	3.86

A special case of our model is one where there is no idiosyncratic uncertainty (i.e. where the transition matrix $\Pi = I$ (the identity matrix)). This is the case, for instance, in the paper by Krusell and Rios-Rull [15]. To assess the role that such uncertainty plays for redistribution and the average level of effective taxes, we recompute the sequential model with $\Pi_{1979} = \Pi_{1996} = I$ but with efficiency levels given by E_{1979} and E_{1996} in Table 10.²³

Table 10: Counterfactual tax rates with no idiosyncratic uncertainty.

Effective Tax Rates		1979	1996	% Δ
	Average level	0.39	0.40	2.56
Seq. Median Voter	quintile 1	0.54	0.47	-13.53
	quintile 2	0.86	0.84	-3.11
	quintile 4	1.10	1.13	2.41
	quintile 5	1.23	1.30	5.94

²³In this environment the interest rate is equal to the intertemporal discount rate and the distribution of assets is indeterminate. In particular, for each τ there is only one possible steady state aggregate capital stock but any asset distribution that satisfies this condition corresponds to a competitive equilibrium. In order to solve the model without uncertainty and compare it to our benchmark idiosyncratic uncertainty model, we assume that the distribution of assets is the one derived from a an incomplete markets competitive equilibrium with idiosyncratic shocks but where asset holdings are normalized so that aggregate capital satisfies the equilibrium conditions of a complete markets economy without uncertainty.

As evident in the table, the average effective tax rate is about 10% higher than in our benchmark case and thus considerably higher than in the data. As for redistribution across quintiles, the relative changes in normalized tax rates are between 7-10% smaller than in the benchmark model so that except for the fourth quintile, they are also further from the data than our benchmark model.

6 Sensitivity Analysis

Here we conduct two experiments to assess the sensitivity of our results. In the first case, we consider a higher Frisch elasticity of labor by setting ν to be 0.7 in Table 11. This requires an adjustment to the parameter χ , namely $\chi = 8$, so that aggregate effective labor supply is equal to 0.3 in 1979 as in the benchmark model. As evident in the table, this lowers the average effective tax rate by 10% relative to the benchmark case in Table 6, but still higher than in the data. For the bottom quintiles, the relative changes are also closer to the data than in the benchmark model but higher than the benchmark for the top quintiles.

Table 11: Effective tax rates with higher Frisch elasticity of labor

Effective Tax Rates		1979	1996	% Δ
	Average level	0.32	0.33	5.22
Seq. Median Voter	quintile 1	0.55	0.45	-18.36
	quintile 2	0.87	0.83	-4.82
	quintile 4	1.08	1.12	3.21
	quintile 5	1.19	1.29	8.06

The second experiment is to weaken the borrowing constraint. In particular we set $b = -\frac{\epsilon_1 n(\epsilon_1, \bar{\tau}) w(K(\bar{\tau}), N(\bar{\tau}))}{r(K(\bar{\tau}), N(\bar{\tau}))}$, where $\bar{\tau} = 0.50$ is the maximum point in the tax grid (this maximum point in the tax grid is not binding, so the equilibrium tax is always lower than $\bar{\tau}$), and $K(\bar{\tau}), N(\bar{\tau})$ correspond to the equilibrium aggregate capital and labor at $\tau = \bar{\tau}$. Table 12 shows that the borrowing constraint has very little effect on the average effective tax rate but brings the results closer to the data for lower quintiles while doing poorer on the top quintiles.

Table 12: Effective tax rates with weaker borrowing constraint

Effective Tax Rates		1979	1996	% Δ
	Average level	0.35	0.37	6.58
Seq. Median Voter	quintile 1	0.54	0.43	-20.88
	quintile 2	0.88	0.84	-4.40
	quintile 4	1.09	1.12	3.39
	quintile 5	1.19	1.27	7.28

7 Concluding Remarks

Our paper is one of the first to incorporate idiosyncratic uncertainty into a dynamic, incomplete markets model where taxes are chosen by a median voter. It provides a framework to answer questions about the impact of mobility and inequality on consumption volatility. The sequential median voter model is able to predict roughly half of the increase in redistribution to households in the lowest wage quintiles as a consequence of exogenous changes in the wage process. Since the mobility matrices we construct from the data underestimate the coefficient of variation of wages, it is not surprising that we underpredict redistribution. At the same time, the model overpredicts the average effective tax rate. Since the median voter model assumes all agents vote, this is also not surprising. That is, evidence shows that voter turnout is positively correlated with an agent's position in the income distribution. Hence one would expect that a model which matches this observation would in principle yield lower taxes. Simultaneously matching both observations is a goal of future research.

References

- [1] Aiyagari, R. (1994) “Uninsured Idiosyncratic Risk and Aggregate Saving”, *Quarterly Journal of Economics*, 109(3), pp. 659-84.
- [2] Aiyagari, R. (1995) “Optimal capital income taxation with incomplete markets, borrowing constraints and constant discounting,” *Journal of Political Economy*, 103, pp. 1158-1175.
- [3] Aiyagari, R. and D. Peled (1995) “Social insurance and taxation under sequential majority voting and utilitarian regimes,” *Journal of Economic Dynamics and Control*, 19, pp. 1511-28.
- [4] Azzimonti, m., E. de Francisco, and P. Krusell (2006) “The political economy of labor subsidies,” manuscript.
- [5] Autor, D., L. Katz, and M. Kearney (2005) “Rising Wage Inequality: The Role of Composition and Prices”, NBER Working Paper #11628.
- [6] Basetto, M. and J. Benhabib (2006) “Redistribution, Taxes, and the Median Voter”, Federal Reserve Bank of Chicago WP#2006-02.
- [7] Congressional Budget Office Study (2001) “Effective Federal Tax Rates, 1979-1997”, <http://www.cbo.gov/ftpdocs/30xx/doc3089/EffectiveTaxRate.pdf>.
- [8] Domeij, D. and J. Heathcote (2004) “On the distributional effects of reducing capital taxes,” *International Economic Review*, 45, pp. 523-554.
- [9] Greenwood, J., Hercowitz, Z. and Huffman, G. (1988) “Investment, capacity utilization, and the real business cycle,” *American Economic Review*, 78, pp. 402-417.
- [10] Harris, E., D. Weiner, and R. Williams (2003) “The Effects of the Changing Distribution of Income and Tax Laws on Effective Federal Income Tax Rates, 1979-2000”, *Proceedings of 96th Annual Conference on Taxation of the National Tax Association*, pp. 266-274.
- [11] Heathcote, J. (2005), “Fiscal Policy with Heterogeneous Agents and Incomplete Markets,” *Review of Economic Studies*, January, 72, p. 161-188.
- [12] Heathcote, J., K. Storesletten, and G. Violante (2006) “Insurance and Opportunities: The Welfare Implications of Rising Wage dispersion ,” mimeo.
- [13] Dirk Krueger and Fabrizio Perri (2005) “Public versus Private Risk Sharing,” mimeo.

- [14] Krusell, P., V. Quadrini and V. Ríos Rull (1997) “Politico-economic equilibrium and economic growth,” *Journal of Economic Dynamics and Control*, 21, pp. 243-272.
- [15] Krusell, P. and V. Ríos Rull (1999) “On the Size of U.S. Government: Political Economy in the Neoclassical Growth Model,” *American Economic Review*, 89, pp. 1156-1181.
- [16] Krusell, P. and A. Smith (1998) ”Income and Wealth Heterogeneity in the Macroeconomy,” *Journal of Political Economy*, 106, p. 867-96.

8 Appendix

8.1 Data Description for Wage Process

Here we describe the data and steps we use to construct labor earnings transition matrices: one for transitions from 1978 to 1979 and another from 1995 to 1996. There are five states in each year. Household heads in the first state have the lowest real hourly wages and those in the fifth state have the highest real hourly wages. The publicly available data set we use is the Panel Study of Income Dynamics (PSID). To make it more convenient for anyone who wants to replicate our results, the specific PSID variable names are included. The weight variables we use are the 1979 weight (V7451) and the 1996 weight (ER12084).²⁴

1. The nominal hourly wages of household heads are calculated by taking the nominal annual labor earnings divided by annual work hours. The nominal annual labor earnings of household heads (V6767, V7413) and annual work hours of household heads (V6336, V6934) are readily given for 1978 and 1979. To obtain these two measures for the years 1995 and 1996, the following extra steps need to be taken:
 - Add up labor earnings from various sources to obtain nominal annual labor earnings of household heads: wages (ER8256, ER11150), bonuses (ER8263, ER11157), commissions (ER8266, ER11160), overtime (ER8264, ER11158), professional practice or trade (ER8270, ER11163), tips (ER8265, ER11159), market gardening (ER8286, ER11179), roomers or boarders (ER8302, ER11195), and extra jobs (ER8318, ER11211).
 - If household heads are currently working in the year when surveyed, the annual work hours in the previous year are the number of weeks worked per year for main jobs (ER7317, ER10231) times the number of hours worked per week for main jobs (ER7320, ER10232) plus the number of weeks worked per year for extra jobs (ER7327, ER10239) times the number of hours worked per week for extra jobs (ER7328, ER10240). If the household heads are not currently working, all the above variables are coded zero.
 - If the household heads are not currently working in the year when surveyed, the annual work hours in the previous year can be obtained similarly by taking the the number of weeks worked per year for main jobs (ER7562, ER10470) times

²⁴We note that the surveys asked households the history of previous year instead of the year in which the surveys were conducted.

the number of hours worked per week for main jobs (ER7565, ER10471) plus the number of weeks worked per year for extra jobs (ER7572, ER10478) times the number of hours worked per week for extra jobs (ER7573, ER10479). If the household heads are currently working, all the above variables are coded zero.

- The annual work hours not conditional on current working status for a household head is the larger number of the two calculations above because by construction the smaller number will be zero. Note that hours worked per week should be treated as missing values if coded as 998 or 999. The weeks worked per year should be treated as missing values if coded as 98 or 99.

2. Next, nominal hourly wages are adjusted to be in 1992 dollars. The nominal hourly wages are either deflated or inflated using the Consumer Price Index - All Urban Consumer (CPI-U) from U.S. Department of Labor, Bureau of Labor Statistics.
3. The sample selection criteria are: (1) the age of the household head (V6462, V7067, ER7006, and ER10009) is between 20 and 59, (2) the household head works for no less than 520 hours and no more than 5096 hours annually, (3) the nominal hourly wage of the household head is greater than half of the federal minimum wage rate (available from U.S. Department of Labor, Employment Standards Administration Wage and Hour Division), (4) the nominal annual labor earnings of the household head are less than \$99999 for the years 1978 and 1979 and less than \$999996 for the years 1995 and 1996, (5) the household satisfies all of the above criteria in both years 1978 and 1979 and/or in both years 1995 and 1996.
4. For the households who satisfy all the sample selection criteria, the state they are in can now be assigned for each year. If the real hourly wage earned by the household head is higher than at least $20^{*(i-1)}\%$ but no more than $20^*i\%$ of the samples, this household is in the i th state, $i \in \{1, 2, 3, 4, 5\}$.
5. Finally, we are ready to build the 5-by-5 transition matrix Π for the year 1978-79. Each row or column represents a state. The frequencies of each cell in the matrix are counted. If a household is in the i th state in 1978 and in the j th state in 1979, then he will be counted one in cell $\Pi(i, j)$. For each cell, we divide the counts by total counts of the entire row the cell is in to get the sample proportions conditional on the state of year 1978. The transition matrix is completed when the frequencies are replaced by the conditional sample proportions for all cells. Repeat to get the transition matrix for the year 1995-96.

8.2 Data Description for Federal Effective Tax Rates

The effective tax rate measures the percentage of household income going to the federal government from taxes. The income measure is comprehensive household income, which comprises pretax cash income plus income from other sources. Pretax cash income is the sum of wages, salaries, self-employment income, rents, taxable and nontaxable interest, dividends, realized capital gains, cash transfer payments, and retirement benefits plus taxes paid by businesses (corporate income taxes; the employer’s share of Social Security, Medicare, and federal unemployment insurance payroll taxes); and employees’ contributions to 401(k) retirement plans. Other sources of income include all in-kind benefits (Medicare, Medicaid, employer-paid health insurance premiums, food stamps, school lunches and breakfasts, housing assistance, and energy assistance). Households with negative income are excluded from the lowest income category but are included in totals.

We calculate federal effective taxes for nonelderly households. To do that we use Table 2C and 4C from from “Effective Federal Tax Rates for All Households” from

<http://www.cbo.gov/showdoc.cfm?index=7000&type=1>. Table 2C reports the number of households, average pretax income, and average after-tax income for each income quintile for households with children, i.e. a household that has at least one member under age 18. Table 4C reports the same statistics for nonelderly childless households, i.e. a household headed by a person under age 65 and with no member under age 18. The two groups make up all nonelderly households plus elderly households with children under 18. The CBO does not provide data that would allow us to exclude elderly households with children under 18. However, the size of the elderly households with children under 18 group is rather small and is unlikely to affect our calculations. Therefore, we combine the two groups to represent nonelderly households. Using number of households, average pre-tax income, and average after-tax income for each quintile in each group, we calculate total pre-tax income and total tax liability (pre-tax income minus after-tax income) for each quintile in each group and use these to compute the total pre-tax income and total tax liability of the combined group. Then we divide total tax liability of each quintile by the total pre-tax income of that quintile in the combined group to get the effective taxes by quintile for the combined group.

8.3 Computational Algorithm

We now outline our algorithm for computing equilibria numerically. As in Krusell and Smith [16], we deal with the high dimensionality of the distribution by approximating Γ by

a finite set of moments. One moment is the aggregate (or mean) capital stock K since this determines prices households face. The other moment is median after-tax income denoted γ defined by $(1 - \tau)[rk + w\epsilon]$ since this helps forecast the decisive voter and the evolution of the endogenous tax rate. Agents thus perceive the law of motion for K' , γ'_m and τ' to be given by the functions $H(K, \gamma, \tau)$, $G(K, \gamma, \tau)$ and $\Psi(K, \gamma, \tau)$ respectively. Using this approximation we can re-formulate the household problem in an RCE as:

$$V(k, \epsilon, K, \gamma, \tau) = \max_{c, k'} u(c) + \beta \sum_{\epsilon'} \Pi(\epsilon'|\epsilon) V(k', \epsilon', K', \gamma', \tau') \quad (17)$$

s.t.

$$\begin{aligned} c + k' &= k + (1 - \tau) [r(K)k + w(K)\epsilon] + T(K, \tau) \\ K' &= H(K, \gamma, \tau) \\ \gamma' &= G(K, \gamma, \tau) \\ \tau' &= \Psi(K, \gamma, \tau) \end{aligned}$$

The solution to this problem are the functions $h(k, \epsilon, K, \gamma, \tau)$ and $V(k, \epsilon, K, \gamma, \tau)$.

The one period deviation problem in (12) can be similarly redefined.

$$\tilde{V}(k, \epsilon, K, \gamma, \tau, \tau') = \max_{c, k'} u(c) + \beta E_{\epsilon|\epsilon} [V(k', \epsilon', \Gamma', \tau')] \quad (18)$$

s.t.

$$\begin{aligned} c + k' &= k + [r(K)k + w(K)\epsilon] (1 - \tau) + T, \\ K' &= \tilde{H}(K, \gamma, \tau, \tau'), \\ \gamma' &= \tilde{G}(K, \gamma, \tau, \tau'). \end{aligned}$$

The solution to this problem yields functions $\tilde{h}(k, \epsilon, K, \gamma, \tau, \tau')$ and $\tilde{V}(k, \epsilon, K, \gamma, \tau, \tau')$.

The distribution Γ is a probability measure on (S, β_S) where $S = [0, \bar{k}] \times E$ and β_S is the Borel σ -algebra. Thus, for $B \in \beta_S$, $\Gamma(B)$ indicates the mass of agents whose individual state vectors lie in B . For reference, here we also defined the operator $\Phi : M(S) \rightarrow M(S)$ where $M(S)$ is the space of probability measures on (S, β_S) :

$$(\Phi\Gamma)(k', \epsilon') = \int 1_{\{h(k, \epsilon, K, \gamma, \tau) = k'\}} \Pi(\epsilon'|\epsilon) d\Gamma(k, \epsilon). \quad (19)$$

An SSPRCE must be contained in the following set of stationary equilibria. Let $\tau_j \in \{\tau_1, \dots, \tau_J\}$ be a grid of tax rates in $[0, 1]$ and let $\Gamma^{ss}(\tau_j)$ be an associated stationary distribution which solves RCE for $\tau' = \tau = \tau_j$. This procedure generates a set of stationary distributions and associated tax rates $SS = \{\Gamma^{ss}(\tau_j), \tau_j\}_{j=1}^J$. Simply put, this is like solving for the steady state of an Aiyagari [1] model for a grid of exogenous constant taxes.

1. Let $\Psi^n(K, \gamma, \tau)$ be the tax function at iteration n . For $n = 1$, we set this equal to a constant.
2. Given $\Psi^n(K, \gamma, \tau)$, solve a RCE. That is, let $H^s(K, \gamma, \tau)$ and $G^s(K, \gamma, \tau)$ be the functions associated with the law of motion for aggregate capital and median after tax income at iteration s . For $s = 1$ we set these to a constant.
 - (a) solve for household decision rules (in particular saving $h^s(k, \epsilon, K, \gamma, \tau)$) in problem (17).
 - (b) use the operator Φ defined in (19) and $\Psi^n(K, \gamma, \tau)$ to generate a joint sequence of transitional distributions Γ_η and tax rates τ_η for $\eta = 1, \dots, \Upsilon$ starting from $\Gamma_0 = \Gamma^{ss}(\tau_j)$ and $\tau_0 = \tau_j$ for each of the $j = 1, \dots, J$ possible tax rates. We take Υ large enough to ensure that $(\Gamma_\Upsilon, \tau_\Upsilon) \in SS$.
 - (c) Use the J sequences of transitional distributions and taxes $\{\Gamma_\eta, \tau_\eta\}_{\eta=1}^\Upsilon$ to generate a sequence of $\{K_\eta, \gamma_\eta, \tau_\eta\}_{n=1}^{J \times \Upsilon}$. Run a linear regression on this sequence to update H^s and G^s as in Krusell and Smith [16]. If the updated H^s and G^s are close enough to the previous iteration, go to step 3, otherwise set $s = s + 1$ and go to step 2 with the updated functions.
3. Solve a PRCE.
 - (a) From step 2, we know $V(k, \epsilon, K, \gamma, \tau)$ which depends on $\Psi^n(K, \gamma, \tau)$ since it is in the constraint set in (17). Given this, we solve the one period deviation problem (18) starting from $\Gamma_0 = \Gamma^{ss}(\tau_j)$ and $tau_0 = \tau_j$ for each of $j = 1, \dots, J$ in order to generate τ_1 . Using the operator Φ evaluated at decision rules $\tilde{h}(k, \epsilon, K_0, \gamma_0, \tau_0, \tau_1)$ obtain Γ_1 where K_0 and γ_0 are obtained from Γ_0 . The next period's distribution and tax rate, (Γ_2, τ_2) , are obtained by repeating the same steps starting at (Γ_1, τ_1) . Continue in this way to compute the transitional sequence $\{\Gamma_\eta, \tau_\eta\}_{\eta=0}^\Upsilon$.
 - (b) Use $\{\Gamma_\eta, \tau_\eta\}_{\eta=0}^\Upsilon$ to generate the sequence $\{K_\eta, \gamma_\eta, \tau_\eta\}_{n=1}^{J \times \Upsilon}$. Run a linear regression on this sequence to update Ψ^n . If the updated Ψ^n is close enough to the previous iteration, go to step 4, otherwise set $n = n + 1$ and go to step 1 with the updated functions.
4. Having solved for the functions H, G , and Ψ , solve for steady state K^*, γ^* , and τ^* that

solves the three equations:

$$\begin{aligned} K^* &= H(K^*, \gamma^*, \tau^*) \\ \gamma^* &= G(K^*, \gamma^*, \tau^*) \\ \tau^* &= \Psi(K^*, \gamma^*, \tau^*). \end{aligned}$$

One-time voting simply restricts $\tau_\eta = \tau_1$ for all $\eta > 1$ in step 3a and uses (17) to generate the sequence $\{\Gamma_\eta, \tau_\eta\}_{\eta=0}^\infty$ with $\tau_\eta = \tau_1$ for all $\eta > 1$.

8.4 Computed Equilibrium

In this section we present the computed median voter sequential equilibrium for the Final Steady State calibration. We approximated the evolution of the wealth distribution on and off-the-equilibrium by a finite number of moments: mean capital, a measure of the median and the tax rate. In particular, the laws of motion we consider are:

- Law of motion of aggregate capital, function H

$$K' = a_0 + a_1 K + a_2 z_m + a_3 \tau \quad (20)$$

- Law of motion of median total resources, function G

$$z'_m = b_0 + b_1 K + b_2 z_m + b_3 \tau \quad (21)$$

- Law of motion of taxes, function Ψ

$$\tau' = d_0 + d_1 K + d_2 z_m + d_3 \tau \quad (22)$$

where

$$z_i = k + [r(K)k + w(K)\epsilon_i](1 - \tau) + T \quad (23)$$

In Table (13) we display the parameter values for the laws of motion. The equilibrium income effective steady state tax rate from this sequential equilibrium is 0.4562.

To illustrate the importance of using another moment like median resources, we solved the PRCE equilibrium without the law of motion (21) and with $a_2 = 0$ in (20) and $d_2 = 0$ in (22). Notice that the goodness of fit (measured by R^2) falls substantially for the law of motion of taxes (22) in Table (14).

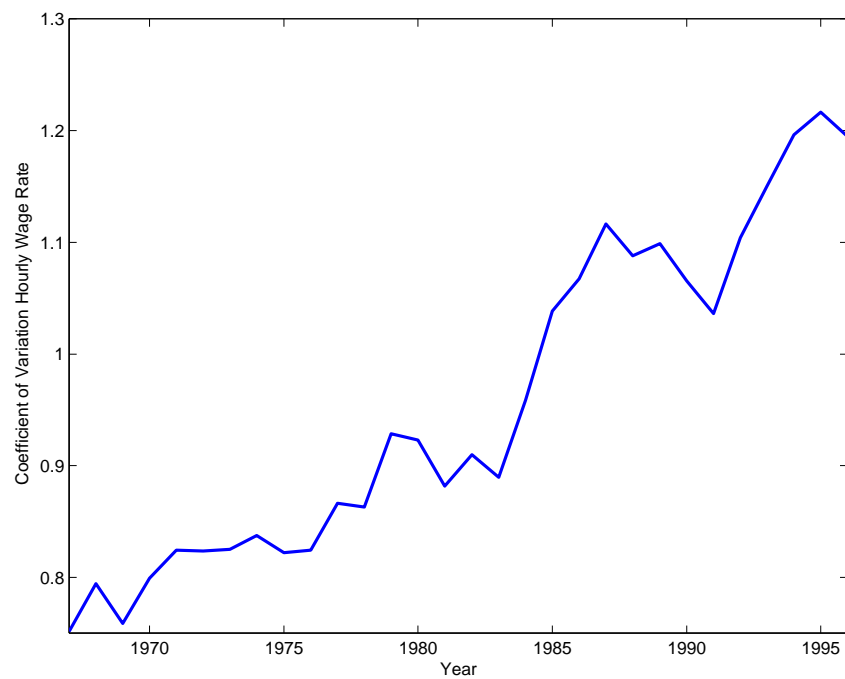
Variable	K'	z'	τ'
Constant	0.14 (3.45e-08)	0.15 (6.10e-05)	0.37 (2.87e-05)
K	0.94 (9.41e-07)	0.16 (1.66e-04)	-0.04 (9.20e-05)
z	-1.21e-02 (1.34e-07)	0.73 (2.36e-04)	0.12 (1.30e-04)
τ	-7.15e-02 (6.73e-08)	8.07e-03 (1.19e-04)	-3.36e-02 (4.97e-05)
R^2	0.999	0.998	0.948

Table 13: Equilibrium Laws of Motion

Variable	K'	τ'
Constant	0.15 (9.17e-07)	0.29 (1.35e03)
K	0.92 (2.93e-07)	0.12 (4.44e-04)
τ	-7.88e-02 (4.12e-06)	0.21 (6.10e-03)
τK	5.50e-03 (1.31e-03)	-0.15 (2.00e-03)
R^2	0.999	0.867

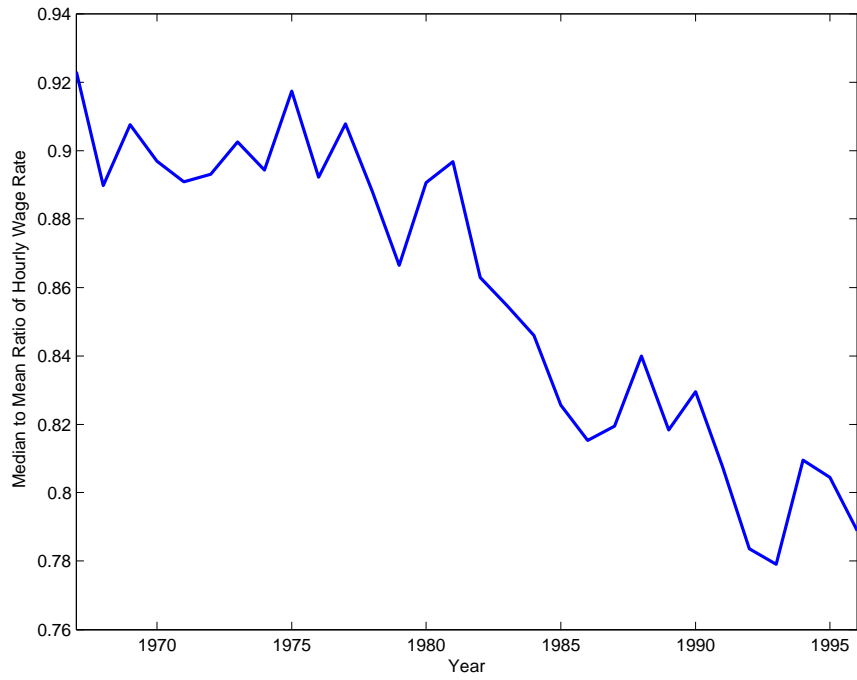
Table 14: Imperfect Equilibrium Laws of Motion

9 Figures



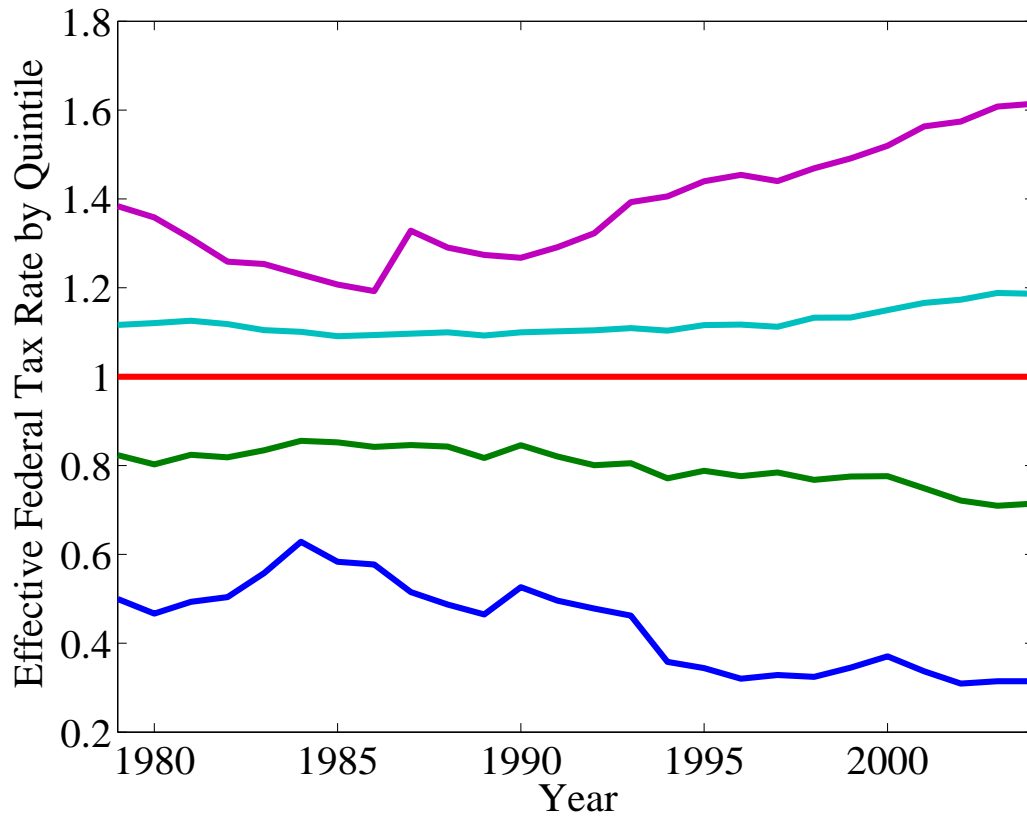
Source: Panel Study of Income Dynamics.

Figure 1: Increase in wage inequality 1966 – 1996.



Source: Panel Study of Income Dynamics.

Figure 2: Decrease in median to mean ratio of log wages 1967 – 1996.



Source: Congressional Budget Office.

Figure 3: Effective Federal Tax Rate by quintiles 1979 – 2004.

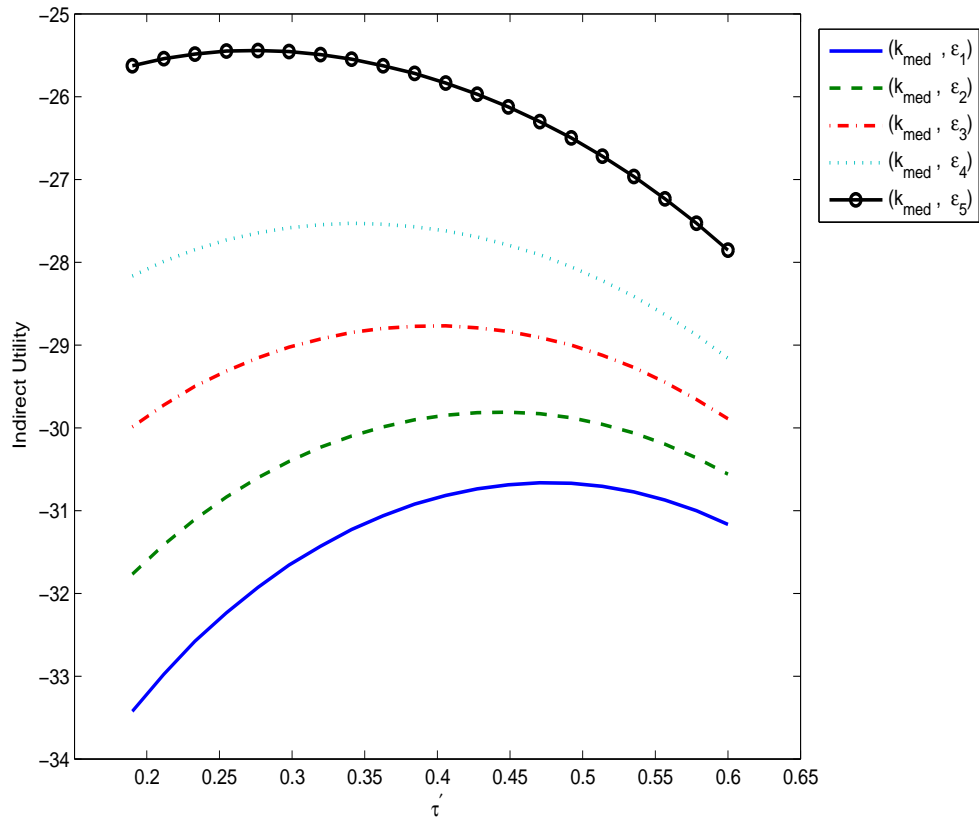


Figure 4: Single Peaked Preferences.

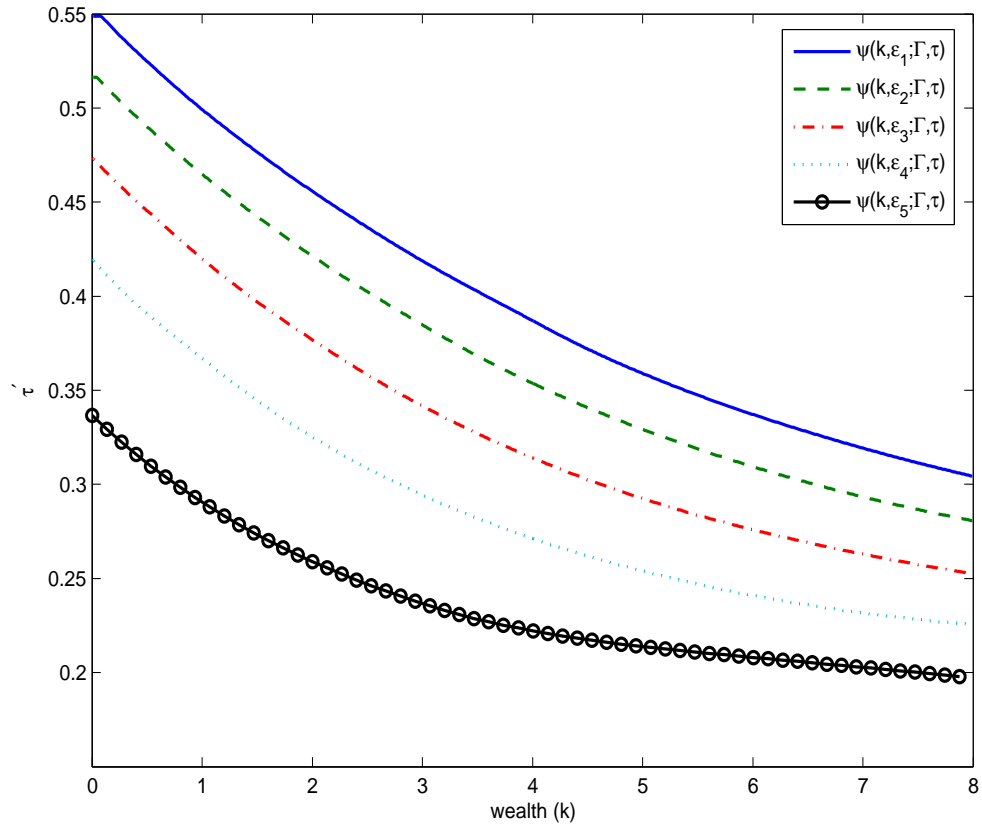


Figure 5: Most Preferred Tax Rate.