

Politico Economic Consequences of Rising Wage Inequality* (Preliminary and Incomplete)

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Abstract

This paper uses a dynamic political economy model to evaluate whether the observed rise in wage inequality can explain an increase in transfers and effective tax rates in the U.S. over the past two 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 deal with the problem that policy outcomes affect the evolution of the wealth distribution by approximating the distribution by a small set of moments. We calibrate the model to match properties of the U.S. earnings distribution and effective tax rates in 1983 and then evaluate the response of the social insurance policies to the observed rise in wage inequality over the next decade and a half. This increase in wage dispersion is capable of explaining over two-thirds of the increase in effective taxes observed in the data while a utilitarian approach would explain only one-third³¹ of the change.

1 Introduction

In this paper we ask whether the observed increase in wage inequality in the U.S. can explain the rise in effective tax rates observed in the data. 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. [10]. Specifically, political outcomes are endogenously determined by a median voter who chooses a proportional tax rate that

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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 calibrate the initial wage process using moments from Heathcote, et. al. [9] in 1983. Then we re-calibrate the economy to match only the increase in the variance of log wages fifteen years later and ask what tax the median voter would choose. While the model overestimates the starting level of effective taxes by about $1/3$, we find that using a median voter mechanism explains about $2/3$ of the observed increase in effective tax rates while using a utilitarian mechanism would explain only about $1/3$ of the rise.

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 [11] assumes that households are heterogeneous in their earnings but there are complete markets so that there is no 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 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 the off-the-equilibrium path beliefs are restricted 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 calibrate the benchmark model. In section 5 we present a quantitative experiment to study the effect of the increase in earnings volatility on tax choices. An Appendix contains the algorithm we use to compute the model.

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, Heathcote et.al. [9] documented the substantial increase in the variance of the log-wage in

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].

Table 1.² Specifically, the variance of log-wages rises by 11 percentage points from 1983-1996, representing an increase of 22%, with most of the increase taking place in the 1980s but continuing with an upward trend during the nineties. Figure 1 provides a graphical portrait of these facts. In Section 4, we calibrate our model to their findings.

The Congressional Budget Office (CBO) recently published data on the effective tax rates paid by households in the United States for the past two decades.³ The effective tax rate is defined to be the total tax liability of a household divided by its post transfer (but pre-tax) income.⁴ We choose to look at the federal effective tax because looking at any one particular tax, say the federal income tax, can give a misleading picture of the overall distribution of taxes paid across income groups. More importantly, the effective tax rate includes a measure of transfers that is at the heart of our paper. The effective tax rate rose from 20.2 % in 1983 to 22.7% in 1996.⁵

As is clear from Figures 1 and 2 wage inequality and effective tax rates present a similar trend. Explaining and quantifying the relation between the increase in inequality and effective tax rates in a democracy is the main objective of this project.

3 Model

3.1 Environment

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

$$E \left[\sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma} - 1}{1-\sigma} \right] \quad (1)$$

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

³The data comes from Table 1A in "Effective Federal Tax Rates for All Households" from <http://www.cbo.gov/showdoc.cfm?index=7000&type=1>.

⁴The effective tax rate measures the percentage of household income going to the federal government from all sources of taxation, including payroll taxes, individual income taxes, corporate taxes, excise taxes, etc. 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 express the effective tax rate below in terms of the model in equation (17).

⁵Rising inequality by itself could potentially generate a rise in effective tax rates without any change in the marginal tax rate τ through the effect of $w\bar{e}$ on T through the government budget constraint. However, quantitatively the change in $w\bar{e}$ explains only a 0.54 percent rise in the effective tax rate.

where c_t denotes consumption in period t and $\beta \in (0, 1)$ is the discount factor. Production takes place with a constant return to scale function, whose inputs are capital and labor:

$$Y_t = F(K_t, N_t) = K_t^\alpha N_t^{1-\alpha} \quad (2)$$

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 risk free rate of return r_t . No borrowing is permitted, which limits the ability of low-wealth households to smooth consumption.

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

$$T_t = \tau_t [r_t K_t + w_t N_t]. \quad (3)$$

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 $\Gamma_{t+1} = H(\Gamma_t, \tau_t)$.⁶ Then the aggregate capital stock is given by

$$K_t = \int k_t d\Gamma_t(k_t, \epsilon_t) \quad (4)$$

and aggregate labor is given by

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

since preferences are such that households supply their time endowment inelastically. More specifically, given our assumptions, aggregate labor is simply given by

$$N_t = \sum_{\epsilon_t \in E} \bar{\Pi}(\epsilon_t) \cdot \epsilon_t (\equiv \bar{\epsilon})$$

where $\bar{\Pi}(\epsilon_t)$ denotes the invariant distribution of efficiency levels associated with the markov process $\Pi(\epsilon_{t+1} = \epsilon' | \epsilon_t = \epsilon)$. Perfect competition in factor markets implies

$$\begin{aligned} r_t &= \alpha K_t^{\alpha-1} N_t^{1-\alpha} - \delta \\ w_t &= (1 - \alpha) K_t^\alpha N_t^{-\alpha}. \end{aligned} \quad (6)$$

⁶Since 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

$$C_t + K_{t+1} = Y_t + (1 - \delta)K_t \quad (7)$$

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

$$V(k, \epsilon; \Gamma, \tau) = \max_{c, k'} u(c) + \beta \sum_{\epsilon'} \Pi(\epsilon'|\epsilon) V(k', \epsilon'; \Gamma', \tau') \quad (8)$$

s.t.

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

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

$$\begin{aligned} c &= g(k, \epsilon; \Gamma, \tau) \quad \text{and} \\ k' &= h(k, \epsilon; \Gamma, \tau). \end{aligned}$$

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 $\{V, g, h, \Gamma, H, r, w, T\}$ such that:

- (i) Given (Γ, τ, H, Ψ) , the functions $V(\cdot), g(\cdot)$ and $h(\cdot)$ solve the hh's problem in (8);
- (ii) Prices are competitively determined (6);
- (iii) The resource constraint is satisfied

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

where K and N are defined as in (4) and (2);

- (iv) The government budget constraint (3) is satisfied
- (v) $H(\Gamma, \tau)$ is given by

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

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 [11], we follow an alternative approach.⁷ From each household choice we generate the distribution of "most preferred" tax rates and 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.

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 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

$$\tilde{V}(k, \epsilon, \Gamma, \tau, \tau') = \max_{c, k'} u(c) + \beta E_{\epsilon|\epsilon} [V(k', \epsilon', \Gamma', \tau')] \quad (9)$$

s.t.

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

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 (8) of the definition of a Recursive Competitive Equilibrium. A solution to this problem generates

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

It is instructive to understand how the savings choice varies across individual capital holdings and future tax rates for the evolution of the wealth distribution. Note that in Figure 3 higher future tax rates for a given k induce a lower level of savings.⁸ More importantly, note that for a high level of future tax rates,

⁷Only 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.

⁸The figure plots $k' = \tilde{h}(k, \epsilon; \Gamma, \tau, \tau')$ for $\epsilon = 0.4427$, $\tau = 0.42$, all evaluated at the steady state distribution Γ associated with τ .

low wealth households are borrowing constrained which further compresses the wealth distribution.

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:

$$\begin{aligned}\Gamma' &= \tilde{H}(\Gamma, \tau, \tau') \\ \Gamma'' &= H\left(\tilde{H}(\Gamma, \tau, \tau'), \tau'\right) \\ \Gamma''' &= H\left[H\left(\tilde{H}(\Gamma, \tau, \tau'), \tau'\right), \Psi\left(\tilde{H}(\Gamma, \tau, \tau'), \tau'\right)\right] \\ &\dots\end{aligned}\tag{10}$$

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 $\{V, g, h, H, \Psi, r, w, T\}$ that satisfy the definition of a RCE;
- (ii) a set of functions $\{\tilde{V}, \tilde{g}, \tilde{h}\}$ that solve (9), 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

$$\tau^i = \psi((k, \epsilon)_i, \Gamma, \tau) = \arg \max_{\tau'} \tilde{V}((k, \epsilon)_i, \Gamma, \tau, \tau');\tag{11}$$

- (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.⁹ Single-peakedness simply says that there is an alternative τ^i that represents a peak of satisfaction and, moreover, satisfaction increases as we approach this peak. 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.¹⁰ Graphically we can see the importance of this condition from 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 $\tau = 0.42$ and the steady state distribution Γ associated with that τ . If there were equal measures of each type of household graphed in the figure, then the median tax rate corresponding to $\tau^* = 0.4$ clearly beats any other tax rate in pairwise comparison. 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.

In our environment, the median voter identity is endogenous. In models without uncertainty or with complete markets, an agent with mean capital holdings would choose zero redistribution. However, in our model, even agents with the mean capital holding will vote for a positive tax rate for insurance reasons. A higher government transfer allows agents with low wealth to smooth consumption. There are also general equilibrium considerations. As τ increases, the household decision rule implies lower capital accumulation which results in a higher interest rate and lower wage rate. If the latter effect dominates, the distribution will compress.

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 $\tau^* = \Psi(\Gamma^*, \tau^*)$.

3.4 Tax Choice Mechanisms with Commitment

We consider two other tax choice mechanisms with commitment. 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 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

⁹For 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 $\tilde{V}((k, \epsilon)_i, \Gamma, \tau, \tilde{\tau}) \leq \tilde{V}((k, \epsilon)_i, \Gamma, \tau, \hat{\tau})$.

¹⁰The papers by Azzimonti, et. al. [4] and Bassetto and Benhabib [6] have proofs of single-peakedness in nonstochastic environments.

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 *median voter one-time tax choice*.

Even for the one-time voting case, there is a nontrivial transition path for the wealth distribution similar to (10). Specifically, we have

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

Figure 5 displays the transition paths of aggregate capital for different one-time changes in tax rates.¹¹ The starting point is the aggregate capital corresponding to the invariant distribution $\Gamma^*(\tau^*)$ with constant taxes for the initial SS calibration. Higher future tax rate choices $\hat{\tau} > \tau^*$ imply aggregate capital paths that are monotonically decreasing. Higher future tax rates generate decreases in individual savings that are reflected in these 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). Obviously, the transition is longer than the 16 years from 1983 to 1996.

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

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

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

4 Calibration

We calibrate the model to the U.S. economy. We can group the parameters in two different sets: (i) preferences and technology parameters $\{\beta, \sigma, \alpha, \delta\}$; and (ii) the wage generating process $\{E, \Pi\}$. The former group is calibrated to match long-run moments. In particular we calibrate these parameters to match the observed average of wealth to output ratio, the capital share of total output and the depreciation rate from NIPA during the last 40 years. The second set of parameters is calibrated so that the model generates the observed variance of log-wages, the autocorrelation of log-wages and the median to mean ratio of log-wages in 1983. Once the model is fully calibrated we can perform our

¹¹This corresponds to point (3.b) in the computational algorithm and the discussion immediately following for one-time tax changes in the appendix.

| Parameter | Value | Moment |
|-----------|-------|-------------------------------|
| β | 0.96 | wealth to output ratio (NIPA) |
| α | 0.36 | Capital share (NIPA) |
| σ | 1.0 | log utility function |
| δ | 0.06 | depreciation rate (NIPA) |

Table 1: Preferences and Technology Parameters.

quantitative exercise. We re-calibrate the wage generating process to match the increase in the dispersion of wages. After that we are able to compute the equilibrium tax rate again to answer the main question of the paper, that is how much of the increase in effective the tax rate we can explain with the observed increase in wage inequality.

4.1 Preference and Technology parameters

The first set of parameters are calibrated to match the standard moments from the U.S. economy when using a neoclassical growth type of model. The value of the parameters are displayed in table (1). The time period chosen for the model is one year.

4.2 Earnings process

The idiosyncratic uncertainty generated by the labor efficiency shocks is a crucial element because it defines how agents vote over redistribution policies. Our main focus is on a model economy calibrated so that the market allocation generates an earnings and wealth distribution like the one in the U.S. Moreover, we want to evaluate how the changes in wage inequality affects the political outcomes, so we calibrate the earnings process to two different point in time 1983 and 1996.

We model the log-wage process as an AR(1). The equation governing log-wages is given by:

$$\log(w\epsilon_t) = \rho \log(w\epsilon_{t-1}) + \eta_t$$

The innovation η_t has zero mean and variance σ_η^2 and the autocorrelation parameter is ρ . This specification is broadly used in the literature and it seems to capture the main features of income dynamics we observe in the data. Assuming stationarity of the wage process

$$var(\log \epsilon_t) = \frac{\sigma_\eta^2}{1 - \rho^2}. \quad (12)$$

We set the number of elements in E to three, so $E = \{\epsilon_1, \epsilon_2, \epsilon_3\}$ and we normalize ϵ_2 to make $\sum_i \pi_i^* \log(\epsilon_i) = 0$ where π_i^* is the unconditional probability of ϵ_i for $i = 1, 2, 3$. We choose the transition matrix to reproduce the moments in the data with the least number of parameters. Moreover, as in Domeij and

| | Initial SS (1983) | | Final SS (1996) | |
|---|-------------------|-------|-----------------|-------|
| | Data | Model | Data | Model |
| $var(\log \epsilon)$ | 0.328 | 0.328 | 0.399 | 0.399 |
| $\frac{\epsilon_{med}}{\bar{\epsilon}}$ | 0.878 | 0.878 | 0.756 | 0.756 |
| Autocorrelation (ρ) | 0.90 | 0.90 | 0.90 | 0.90 |

Table 2: Wage Distribution Moments.

Heathcote [8] we assume that households cannot move between the high and low productivity levels directly. We set Π to

$$\Pi = \begin{bmatrix} p & 1-p & 0 \\ \frac{1-p}{2} & p & \frac{1-p}{2} \\ 0 & 1-p & p \end{bmatrix}. \quad (13)$$

Then, the total number of free parameters is three: the transition probability p and two of the labor efficiency levels ϵ_1 and ϵ_3 .

The moments we are interested in are:

1. the variance of log wages

$$var(\log(\epsilon)) = \sum_i \pi_i^* (\log(\epsilon_i) - \overline{\log(\epsilon)})^2 \quad (14)$$

2. the autocorrelation of log wages

$$\rho_{\log(\epsilon)} = \frac{Cov(\log(\epsilon'), \epsilon)}{Var(\log(\epsilon))} \quad (15)$$

3. given that $\pi_1^* + \pi_2^* \geq \frac{1}{2} \geq \pi_1^*$, the median to mean wage

$$\frac{median(\epsilon)}{\bar{\epsilon}} = \frac{\epsilon_2}{\bar{\epsilon}} \quad (16)$$

Expressions (14)-(16) provide three equations in three unknowns $(\epsilon_1, \epsilon_3, p)$ that we use to calibrate the the model. The data provides us with three moments in 1983 and 1996 summarized in Table 2. We associate the 1983 moments with an “initial steady state” and 1996 with a “final steady state”. The final calibrated values and the moments from the data are reported in Table 3.¹²

This set of parameters implies that $\pi_1^* = \pi_3^* = 0.25$ and $\pi_2^* = 0.5$ in the initial and in the final steady states.

¹²The values of $var(\log \epsilon)$, $\frac{\epsilon_{med}}{\bar{\epsilon}}$ are from the Panel Study of Income Dynamics and are taken from Heathcote et.al. [9].

| Parameter | Initial SS | Final SS |
|--------------|------------|----------|
| ϵ_1 | 0.43342 | 0.44272 |
| ϵ_3 | 2.1894 | 2.6141 |
| p | 0.900 | 0.901 |

Table 3: Wage process parameters.

| | Initial SS | (1983) | Final SS | (1996) |
|-----------------------|------------|--------|----------|--------|
| | Data | Model | Data | Model |
| Wealth Gini | 0.80 | 0.55 | 0.828 | 0.5948 |
| Median to Mean Income | 0.82 | 0.83 | 0.75 | 0.725 |

Table 4: Wealth and Income Distribution Moments.

5 Quantitative Exercise

The “effective tax rate” applied to labor and capital earnings is defined to be the amount of tax liability divided by pre-tax income including transfers. In the context of our model, the effective tax rate is given by:

$$ETR = \int \frac{\tau(rk + w\epsilon)}{(rk + w\epsilon) + T} d\Gamma(k, \epsilon). \quad (17)$$

To assess the quantitative significance of the change in inequality for changes in effective taxes, we calibrate $(\epsilon_1, \epsilon_3, p, q)$ to match the variance of log wages, median to mean ratio of wages and the autocorrelation in 1983 and then recalibrate the same parameters to match those moments in 1996. The model then delivers a new equilibrium effective tax rate that we compare to the initial steady state effective tax rate. At this preliminary stage, we simply report results for the one-time voting exercise.

To measure the empirical success of the model, as an over-identification test we present different measures of the level of concentration in the economy in Table 4. The first one is the wealth gini. The other one is the ratio of mean to median income where household income in the model corresponds to $rk + w\epsilon$.¹³

Even though the final distributions are positively skewed (the median is lower than the mean), the wealth inequality predicted by the model and measured by the gini coefficient does not correspond exactly to the one observed in the U.S. data.¹⁴ A possible explanation is that we do not incorporate enough heterogeneity across agents. The model does well explaining differences in the income distribution of households. In the initial steady state the model mean

¹³The value of the wealth gini and median to mean income are taken from Wolff [13] Tables 1 and 2.

¹⁴In the initial SS the gini coefficient is around 70% of that in the data and in the final steady state it is almost 72%.

to median income ratio is only 1.22 percent higher than in the data and in the final steady state it is about 3 percent lower.

After solving the saving decision problem of the household we can solve problem (11) in the definition of PRCE to obtain the tax rate that maximizes each agent's utility. In Figure 6 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 $[0, 1]$. 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 productivity ϵ_1 will vote for a higher tax rate than an agent with higher productivity levels ϵ_2 or ϵ_3 . This implies that the fraction of households in each productivity level is critical for the determination of the optimal tax rate. High productivity agents receive a larger fraction of their income from wages and are usually saving. On the other hand the low productivity level agents receive a larger fraction of their income from capital gains and more importantly choose to decrease their capital holdings in equilibrium so have much more to gain from increases in the income tax and the resulting increment in government transfers.

Clearly if two households have equal productivity 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 6. 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 the expected net return. In general, this effect offsets the effect of the increase in the government transfers mentioned above.

Finally, Figure 6 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 $(2.4192, \epsilon_2)$ and a household with $(19.4136, \epsilon_1)$ to choose the same tax rate $\tau' = 0.4$.

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' .

Table (5) displays the main result of the paper. While the model overestimates the level of the tax rate in 1983 by 36%, it does well in matching the consequence of the change in wage inequality. Specifically, as we increase the dispersion of log-wages, to match the variance of log-wages and the median to mean ratio in 1996, the model generates a change that explains 67.7% of that observed in the data. The increase in the tax rate is 7.63% in the model where in the data is around 11.27%.

| | Initial SS | Final SS | Change |
|--------------------------------|------------|----------|----------------|
| Data | | | |
| Total Effective Tax Rate | 0.204 | 0.227 | +11.27% |
| Utilitarian | | | |
| Total Effective Tax Rate | 0.274 | 0.283 | +3.28% |
| One-time Median Voter | | | |
| Total Effective Tax Rate | 0.2765 | 0.2976 | +6.13% |
| Sequential Median Voter | | | |
| Total Effective Tax Rate | n.a. | n.a. | n.a. |

Table 5: Optimal Tax Rates

The table also shows that the utilitarian mechanism generates an increase in the optimal tax rate that represents only 31% of the U.S. data. If our assumptions about the political mechanism are correct this points to the misleading results that could be obtained when analyzing exogenous taxes.

The increase in wage inequality leads the median voter to choose more redistribution (and insurance). Note that the increase in τ generates an increase in government transfers but also a decrease in the variance of after-tax income. The inefficiencies associated with the increase in the marginal tax rate are surpassed by the positive effects of redistribution. The greater is the need for insurance the higher are the optimal tax rates under our median voter scheme.

There is one key observational difference between our work and the previous political economy models mentioned in the introduction. Models that do not incorporate idiosyncratic uncertainty 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 other hand, as evident in Figure 6, households with different levels of wealth k may vote for the same τ' . Figure 7 shows how agents vote in our model for different levels of wealth relative to the median voter. The figure is constructed as follows. After solving for the optimal tax rate we know the capital holdings of the median voter k_m (as well as his earnings). Then households are sorted 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 are separated between those who prefer a higher tax rate and those who prefer a lower tax rate than the median voter. The figure reports the normalized (relative to the number of households in the $k \geq k_m$ group and the $k \leq k_m$ groups) fraction who prefer higher or lower tax rates.

The panel on the left of Figure 7 shows the portion of agents with **lower** wealth k than the median voter. From this group only 61% vote for higher taxes (either those with lower earnings or those with extremely low capital and higher earnings) while 39% vote for lower taxes than the median voter (those with higher earnings). The panel on the right shows the portion of agents with

higher capital than the median voter. In this case, only 6% vote for higher taxes (those with lower earnings level) while 94% vote for lower taxes than the median voter (either those with higher earnings or those with extremely high capital and lower earnings). As mentioned before, except for the iid case, total resources $(1 + r(1 - \tau))k + w\epsilon(1 - \tau) + T$ are not a sufficient statistic for voting decisions.¹⁵

5.1 Other Experiments

We are in the process of computing a sequential version of the above experiment. We present the results for the iid case in the appendix.

It would also be interesting to compute the equilibrium transition path for taxes from an initial steady state in 1983 to a new steady state using the direct changes in the wage process. The idea would be to introduce a finite path of changes in the wage process to match the level and the trend of wage inequality between 1983 and 1996 documented in section 2; assuming that this change is unforeseen by agents before 1983, but that all future changes are fully learned once the first change has occurred. This change induces a transition path from the initial to a final stationary equilibrium corresponding to the wage process that prevails once the path of wage dispersion changes has been completed. At the period corresponding with the year 1996, we would solve the one time voting problem to obtain the equilibrium tax rate. Note that at that point in time the wealth distribution does not coincide with the stationary distribution which is what we are assuming above.

¹⁵Specifically, in the iid case, if we had sorted on the basis of total resources then the left hand panel would have been 100% voting for higher taxes and the right hand panel would have been 100% voting for lower taxes. Using total resources in the persistent case would have generated a figure similar to that in Figure 7.

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6 Appendix

6.1 Computational Algorithm

We now outline our algorithm for computing equilibria numerically. As in Krusell and Smith [12], 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:

$$V(k, \epsilon, K, \gamma, \tau) = \max_{c, k'} u(c) + \beta \sum_{\epsilon'} \Pi(\epsilon' | \epsilon) V(k', \epsilon', K', \gamma', \tau') \quad (18)$$

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 (9) can be similarly redefined.

$$\tilde{V}(k, \epsilon, K, \gamma, \tau, \tau') = \max_{c, k'} u(c) + \beta E_{\epsilon' | \epsilon} [V(k', \epsilon', \Gamma', \tau')] \quad (19)$$

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) :

$$(\Phi\Gamma)(k', \epsilon') = \int \mathbf{1}_{\{h(k, \epsilon, K, \gamma, \tau) = k'\}} \Pi(\epsilon' | \epsilon) d\Gamma(k, \epsilon). \quad (20)$$

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 (18).
 - (b) use the operator Φ defined in (20) 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 [12]. 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 (18). Given this, we solve the one period deviation problem (19) 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 (18) to generate the sequence $\{\Gamma_\eta, \tau_\eta\}_{\eta=0}^\infty$ with $\tau_\eta = \tau_1$ for all $\eta > 1$.

6.2 iid Sequential Voting example

In the iid case, the future employment probabilities are the same for all individuals regardless of their current employment status. This implies that two individuals with the same after tax-transfer current period resources will have the same decision rules and value functions. Hence, we do not need to carry employment status as a state variable and, as in Aiyagari [1], we can reduce the individual state variable from (k, ϵ) to z where z is the current period after tax resources available to an individual:

$$z = k + [r(K)k + w(K)\epsilon](1 - \tau) + T.$$

In this case, we can rewrite the one-period deviation problem of an individual as¹⁶

$$\tilde{V}(z, \Gamma, \tau, \tau') = \max_{c, k'} u(c) + \beta E[V(z', \Gamma', \tau')]$$

s.t.

$$c + k' = z \tag{21}$$

$$z' = k' + [r(K')k' + w(K')\epsilon'](1 - \tau') + T' \tag{22}$$

$$\Gamma' = \tilde{H}(\Gamma, \tau, \tau'). \tag{23}$$

The optimal tax rate chosen by individual of type z_i is given by

$$\tau^i = \psi(z_i, \Gamma, \tau) = \arg \max_{\tau'} \tilde{V}(z_i, \Gamma, \tau, \tau').$$

Although we do not have a formal proof, we numerically confirm that $\psi(z, \Gamma, \tau)$ is a monotonically decreasing function of z . The monotonic relation between z and individual's tax choices implies that the median tax rate chosen in equilibrium corresponds to the tax rate chosen by the agent with median z . Hence,

$$\tau^m = \Psi(\Gamma, \tau) = \psi(z_m, \Gamma, \tau)$$

¹⁶The economic equilibrium for a given tax function $\tau' = \Psi(\Gamma, \tau)$ is obtained by evaluating the value function and individual decision rules at $\tau' = \Psi(\Gamma, \tau)$ in the problem above.

where z_m is the median after-tax-transfer resources.

Using this insight, we set $\gamma = z_m$ in the quantitative exercise. We conjecture that the equilibrium laws of motion for aggregate capital, median resources and the equilibrium tax rate take the following form:

- Law of motion of aggregate capital, function H

$$K' = a_0 + a_1K + a_2z_m + a_3\tau + a_4\tau K + a_5\tau z_m \quad (24)$$

- Law of motion of median total resources, function G

$$z'_m = b_0 + b_1K + b_2z_m + b_3\tau + b_4\tau K + b_5\tau z_m \quad (25)$$

- Law of motion of taxes, function Ψ

$$\tau' = d_0 + d_1K + d_2z_m + d_3\tau + d_4\tau K + d_5\tau z_m. \quad (26)$$

Given these laws of motion, an individual's problem can be written as:

$$V(z, K, z_m, \tau) = \max_{c, k'} u(c) + \beta E [V(z', K', z'_m, \tau')]$$

s.t. (21),(22),(24)-(26).

The one period deviation problem in (19) can be similarly redefined:

$$\tilde{V}(z, K, z_m, \tau, \tau') = \max_{c, k'} u(c) + \beta E [V(z', K', z'_m, \tau')]$$

s.t. (21),(22), and

$$\begin{aligned} K' &= \tilde{H}(K, z, \tau, \tau') \\ z'_m &= \tilde{G}(K, z, \tau, \tau') \end{aligned}$$

where \tilde{H} and \tilde{G} are calculated using the Φ operator.

In Table (6) we display the parameter values for the laws of motion after the computation of an iid shock PRCE equilibrium where many parameters are the same as in Section 4 except that we assume a 4 year period (so $\beta = 0.85$ and $\delta = 0.22$ reflect that change) and ($\epsilon_1 = 0.79, \epsilon_2 = 1, \epsilon_3 = 1.63$) were calibrated to match the variance of log wages and the median to mean ratio in 1983. The reason we chose to lower β is that it made the transition shorter. The equilibrium effective steady state tax rate from this sequential equilibrium is 0.122. We also computed the one-time voting equilibrium for the same parameters and found that the steady state effective tax rate was 0.130 (i.e. 6.5% higher).

To illustrate the importance of using another moment like median resources, we solved the PRCE equilibrium without the law of motion (25) and with $a_2 = a_5 = 0$ in (24) and $d_2 = d_5 = 0$ in (26). Notice that the goodness of fit (measured by R^2) falls substantially for the law of motion of taxes (26) in Table (7).

| Variable | K' | z' | τ' |
|----------|-----------------------|-----------------------|-----------------------|
| Constant | 1.7557 (0.0001) | 1.3558 (0.0000) | -1.0620 (0.0056) |
| K | 0.7707 (0.0001) | -0.0097 (0.0000) | -0.3559 (0.0038) |
| z | -1.1314 (0.0002) | 0.0275 (0.0000) | 1.1125 (0.0065) |
| τ | -1.9980 (0.0049) | 0.0907 (0.0000) | 3.0099 (0.3255) |
| τK | -3.0927 (0.0032) | 0.1009 (0.0000) | 3.0645 (0.1228) |
| τz | 2.7395 (0.0053) | -0.1055 (0.0000) | -4.1596 (0.3036) |
| R^2 | 0.998184 | 0.999997 | 0.999600 |

Table 6: Equilibrium Laws of Motion

| Variable | K' | τ' |
|----------|-----------------------|-----------------------|
| Constant | 0.7497 (0.0000) | -0.2212 (0.0003) |
| K | -0.1126 (0.0000) | 0.3866 (0.0006) |
| τ | -0.1872 (0.0002) | 1.7689 (0.0134) |
| τK | 0.0930 (0.0003) | -1.6207 (0.0273) |
| R^2 | 0.952124 | 0.684470 |

Table 7: Equilibrium Laws of Motion

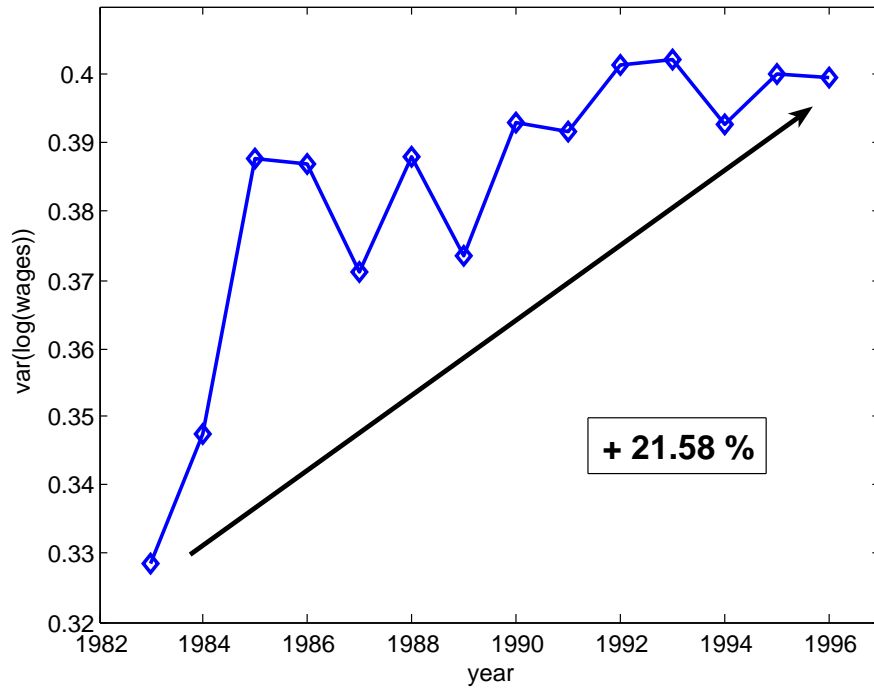


Figure 1: Increase in wage inequality 1983 – 1996.
Source: Heathcote, Storesletten and Violante (2005).

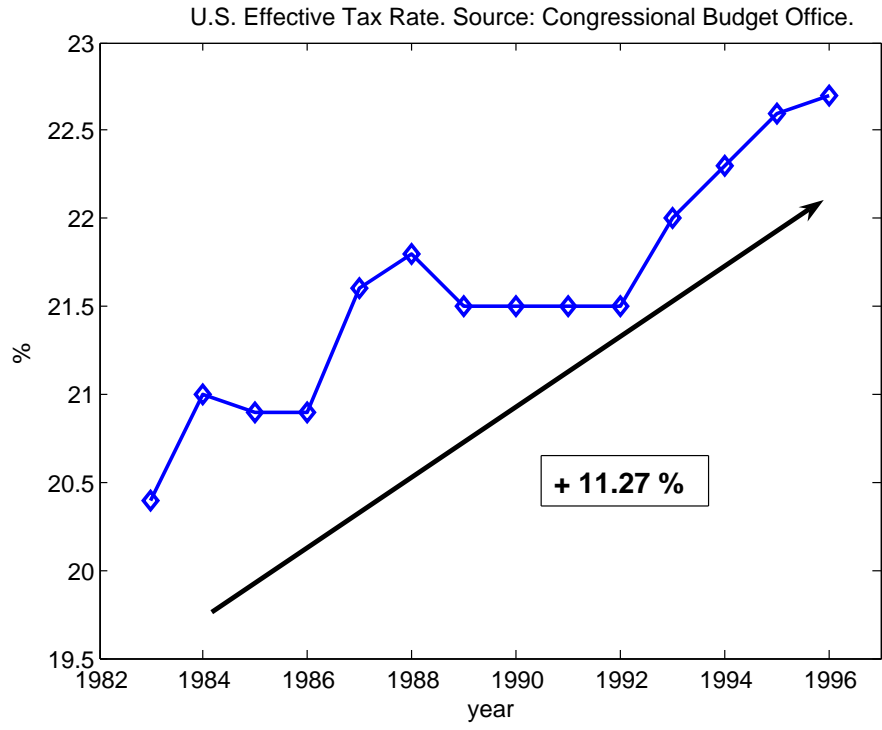


Figure 2: Total Effective Federal Tax Rate for all Households 1983 – 1996.
 Source: Congressional Budget Office.

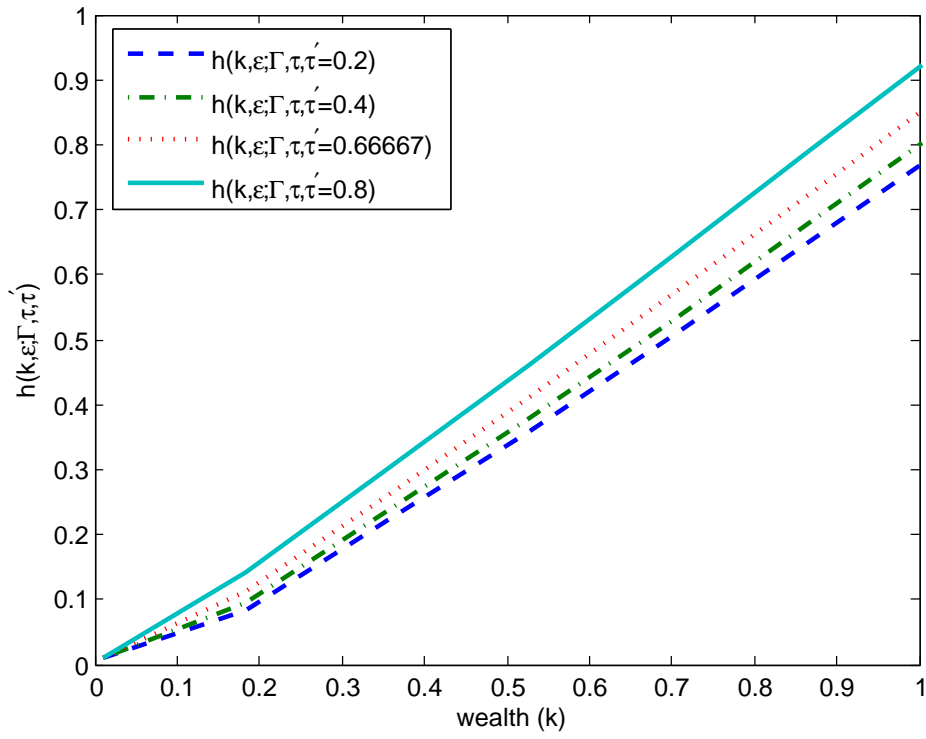


Figure 3: Decision rules over wealth for different levels of τ' .

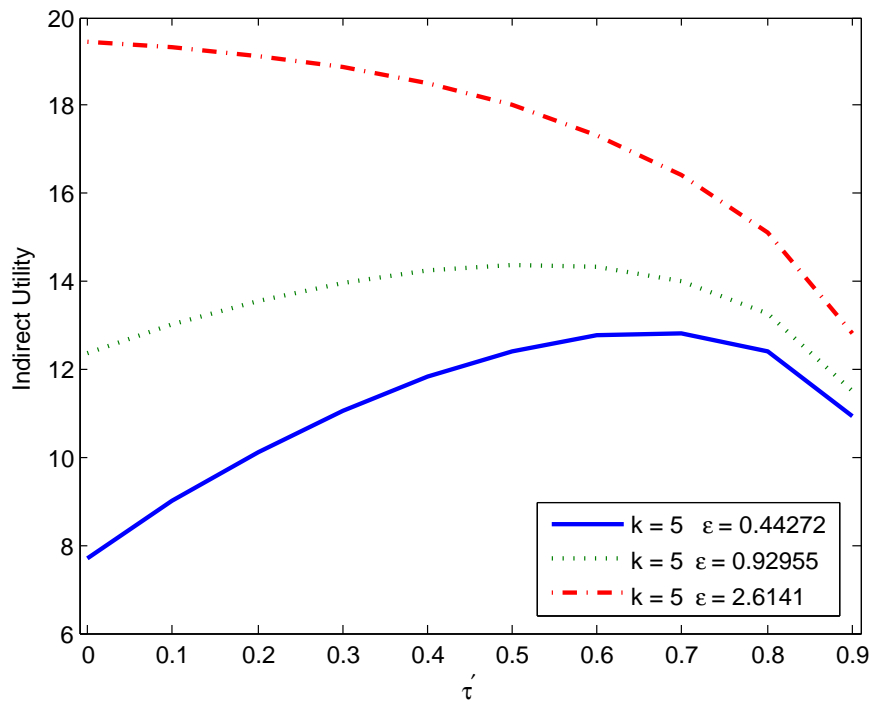


Figure 4: Single Peaked Preferences.

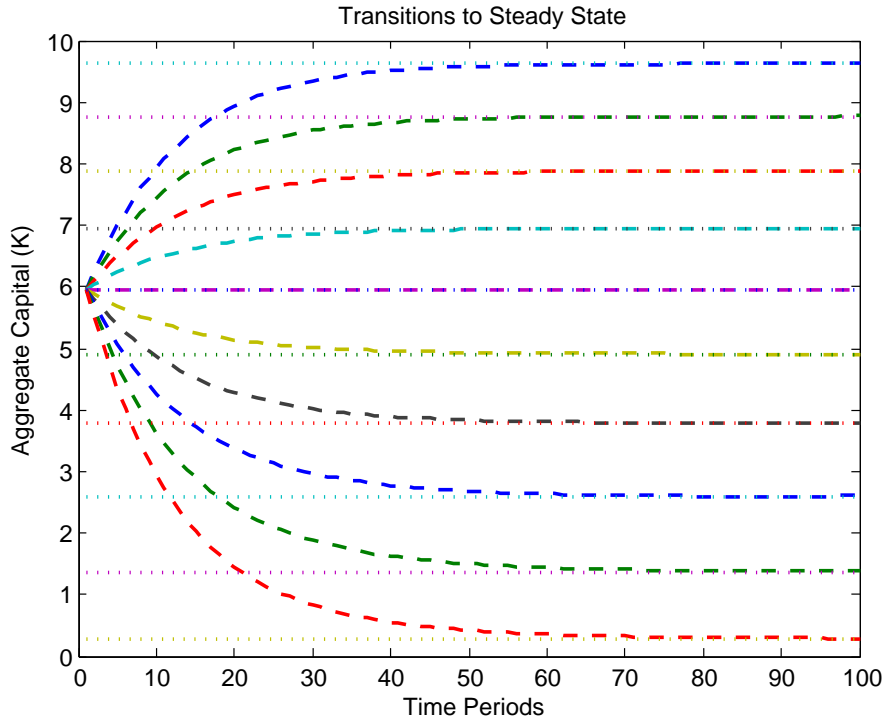


Figure 5: Transitions at initial steady state τ

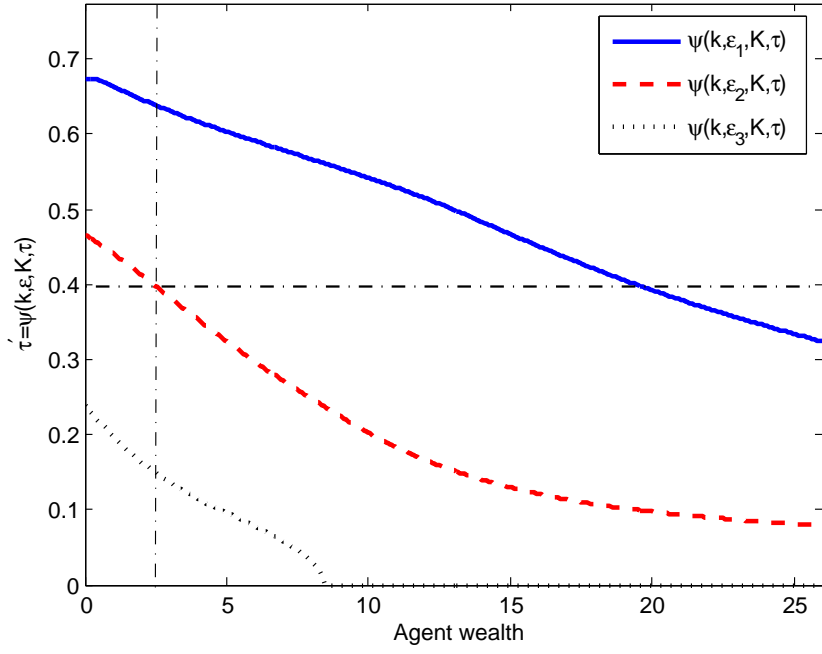


Figure 6: Most Preferred Tax Rate.

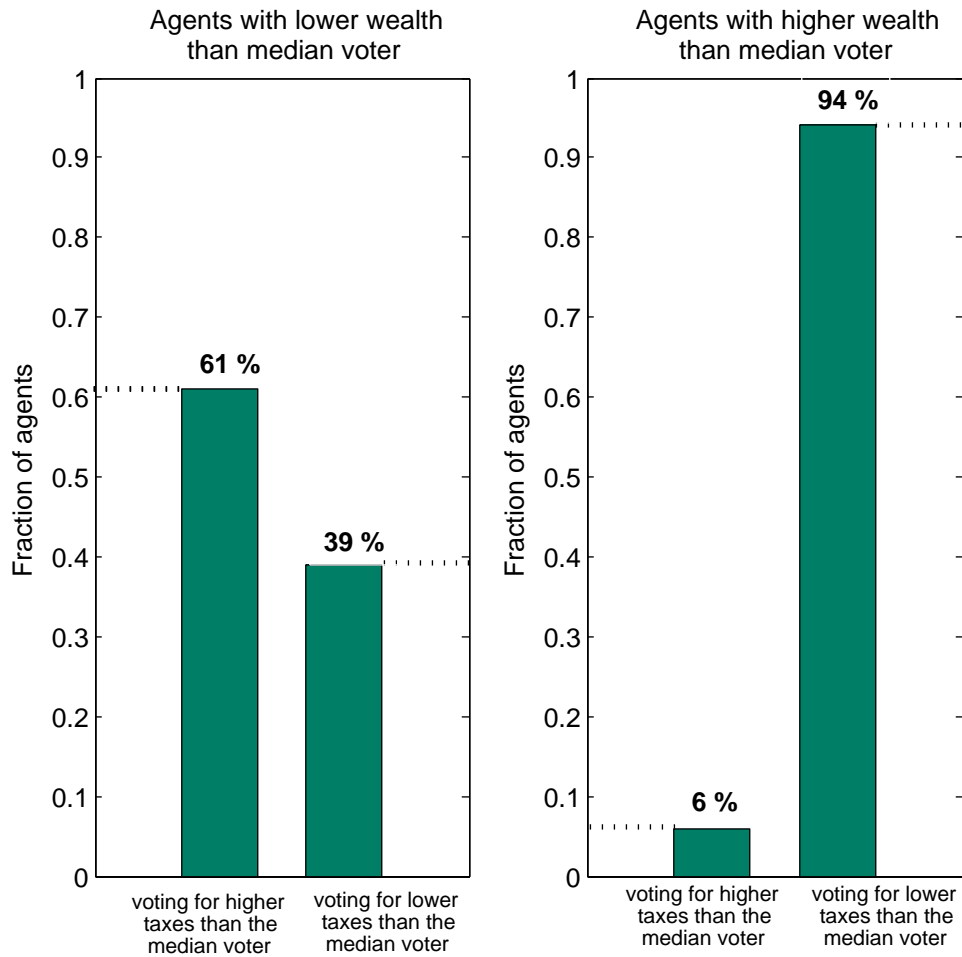


Figure 7: Distribution of Wealth and Tax Choices.

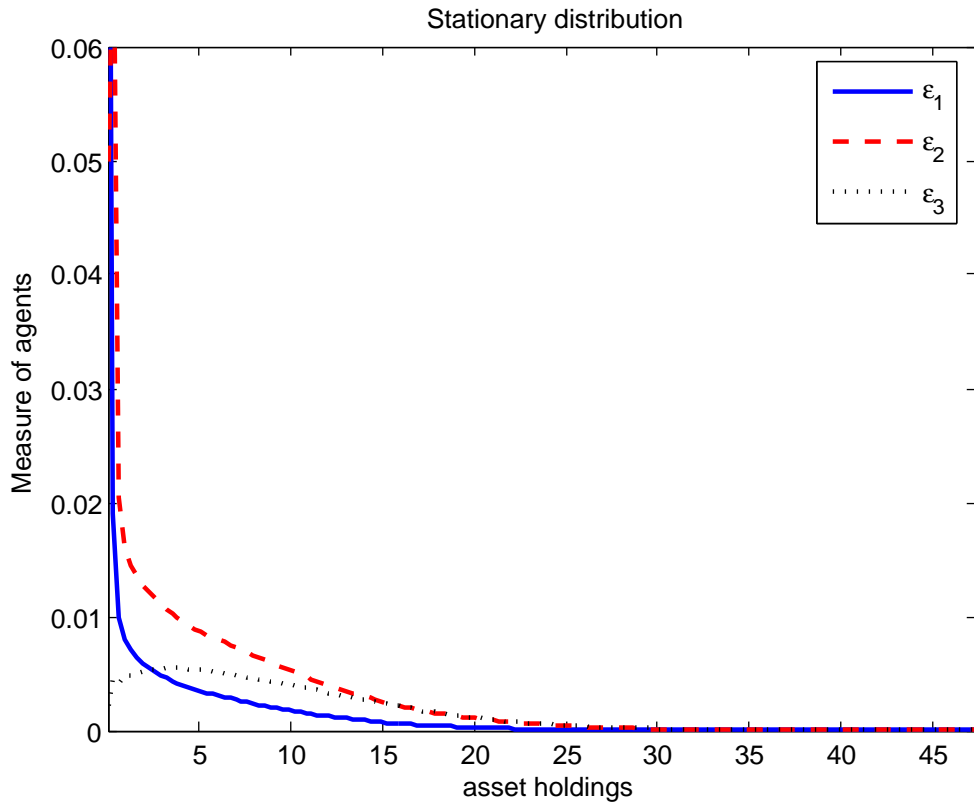


Figure 8: Distribution of Wealth at Initial SS.

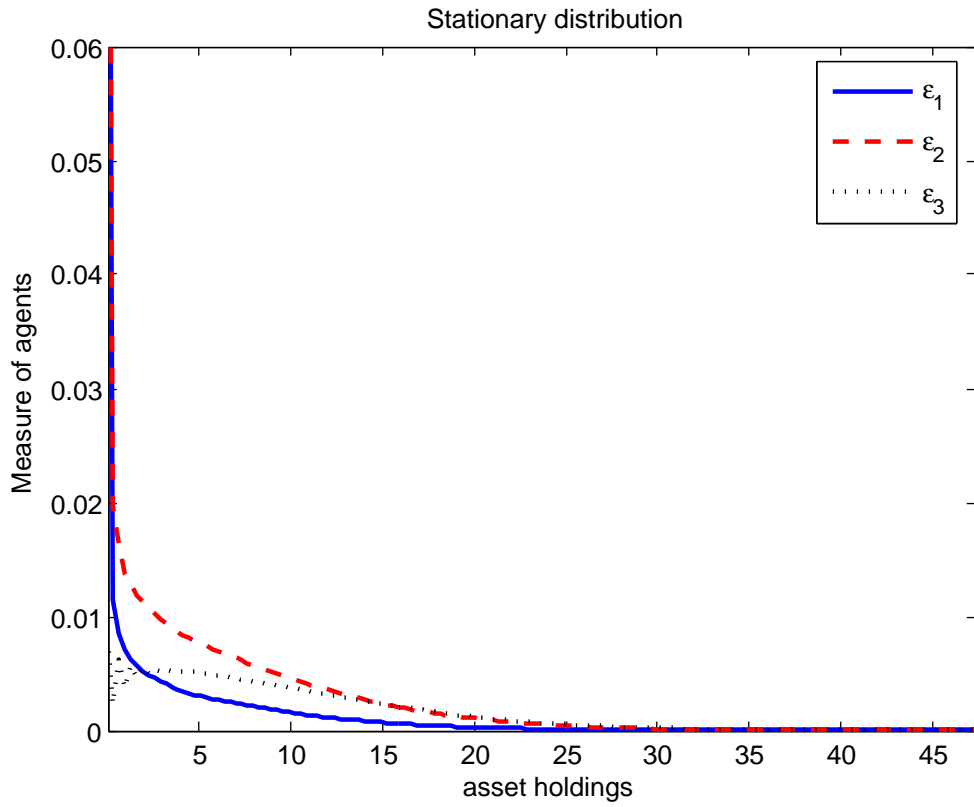


Figure 9: Distribution of Wealth at Final SS.