On the Size of U.S. Government: Political Economy in the Neoclassical Growth Model

By Per Krusell and José-Víctor Ríos-Rull*

We study a dynamic version of Meltzer and Richard's median-voter model of the size of government. Taxes are proportional to total income, and they are redistributed as equal lump-sum transfers. Voting takes place periodically over time, and each consumer votes for the tax rate that maximizes his equilibrium utility. We calibrate the model to U.S. data. Key elements in the calibration are the income and wealth distribution and the parameters governing the leisure and consumption choices. The total size of transfers predicted by our political-economy model is quite close to the size of transfers in the data. (*JEL* E60, H11, P16)

Countries differ widely in their public policy choices. For example, among the OECD countries, 1983 marginal tax rates on capital income varied between −90 and 49.5 percent; the average labor income tax varied between 24 and 63 percent; and the net total tax burden as measured by public expenditures varied between 26 and 54 percent of GNP.[1] Even larger differences would be revealed if one included countries on a lower level of development. Similarly, large differences in policies can also be recorded within given countries over time. To the extent one thinks actual policy outcomes affect economic performance, it seems an important task for economists to explore the origins of these wide disparities.

One way of building a positive theory of policy is to assume that policies are chosen optimally. If they are indeed, then the large observed policy differences can only depend on differences in economic primitives such as preferences and technology. In contrast, the political-economy paradigm seeks to analyze how different policy-selection procedures/collective choice mechanisms affect policy outcomes. With this approach, differences in policy outcomes depend not only on mentioned primitives and on differences in population characteristics, but they also depend on the details of the procedure by which policies are selected.

In this paper we set out to develop a macroeconomic model that can be used for quantitative theoretical analysis of political economy. Our framework of analysis in this paper is a dynamic extension of Alan H. Meltzer and Scott F. Richard's (1981) study of the size of government. There, the median voter has lower-than-average labor productivity, and thus a proportional tax on labor used for making lump-sum subsidies implies a net transfer to this agent. Since labor supply is elastic, the political equilibrium tax rate is chosen by this agent so as to equate his marginal utility benefit from the transfer to his marginal utility loss from the tax distortion.

Our version of Meltzer and Richard's analysis has inequality not only in labor income but also in wealth, and wealth—capital income—can be taxed. This feature seems important to consider in a quantitative analysis for two reasons. First, the wealth distribution is much more skewed than the labor income distribution, and the upper tail of the distribution is an ample source for the median voter to potentially redis-

* Krusell: Department of Economics, Harkness Hall, University of Rochester, Rochester, NY 14627, Institute for International Economic Studies (Stockholm), and Centre for Economic Policy Research (e-mail: pekr@troi.cc.rochester.edu); Ríos-Rull: Department of Economics, University of Pennsylvania, 3718 Locust Walk, Philadelphia, PA 19104, and National Bureau of Economic Research (e-mail: vr0j@anaga.sas.upenn.edu). We thank seminar attendants for feedback and Torsten Persson, Vincenzo Quadrini, Richard Rogerson, and two anonymous referees for particularly helpful comments. Both authors gratefully acknowledge support from the National Science Foundation. Krusell also gratefully acknowledges support from the Bank of Sweden Tercentenary Foundation.

[1] See Michael J. McKee et al. (1986) for data sources.

tribute from. Second, taxing wealth accumulation is particularly distortionary, as we have learned from the literature on dynamic optimal taxation. The population is thus heterogeneous in two respects: labor productivity and asset wealth. The joint distribution of labor productivity, which we calibrate to U.S. data, is a key determinant of the equilibrium transfer level. Our setup also includes government consumption. We maintain the one-issue nature of voting assumed by Melter and Richard and consider voting over a common tax rate on all sources of income.

The quantitative assessment of the costs of redistributive taxation rests in part on assumptions about the key elasticities in the model: those governing the labor-leisure choices, and those determining the consumption-savings choices. For this, we select parameters in line with studies using similar macroeconomic models. The costs of redistributive taxation also depend on the level of government consumption, which we treat as exogenous here. We divide the different items of the government budget into those which can be considered transfers and those which cannot, and calibrate government consumption in the model accordingly.

Given our calibration, the political equilibrium transfer level turns out to be quite close to that in the data: measured as a percentage of GDP, the equilibrium transfer level is within a few percentage points of its observed value. Relatedly, the income tax rate is close to that observed: around 30 percent. For comparison, we also solve a calibrated static model, and we find that equilibrium taxes and transfers there are much too high (e.g., the tax rate is close to 60 percent). The dynamic model is quite robust to changes in parameter values—economic and political ones—and to changes in the interpretation of what constitutes transfers in the data.

The extension to a dynamic framework is not only important for incorporating the consumption-savings distortion and the redistribution of asset income into the quantitative considerations of the median voter. The dynamic model also allows us to analyze several normative experiments which have important dynamic elements. Although the political framework in this paper is quite rudimentary, it admits some nontrivial constitutional experiments. In particular, we consider changes in the frequency of elections/policy reevaluations and implementation lags for policy. But it is clear that an explicitly dynamic framework is also necessary for investigating such constitutional features as a balanced-budget rule, Social Security legislation, and so on. Although we do not study these issues here, since they would involve a different population structure, the methods we develop in this paper can be used for such analyses.

Another important purpose of our work is to develop tools that can be used for analyzing a broader set of dynamic models of political economy with maximizing agents. In general, such models are much harder to study than the corresponding static models, and they are also an order of magnitude more complex than standard dynamic models without political-economy elements. The main complication is introduced by dynamic voting. In particular, when agents vote, they need to rationally predict the effects of current policy alternatives (i) on current and future prices, and (ii) on future policies. In political science theory, there are similar analyses where voters make correct forecasts and are fully rational [see Arthur T. Denzau and Robert J. Mackay (1981) for a two-period model, and Dennis N. Epple and Joseph B. Kadane (1990) for a multiperiod setup with uncertainty]. It has been stressed in these contexts that Condorcet cycles may occur due to a violation of single-peakedness of preferences. Our framework has the added features that the preferences over the policy are induced via the economic equilibrium and not considered primitives, and that the time horizon is infinite. The requirement that voters make rational forecasts and that policy preferences be derived explicitly in an infinite-horizon equilibrium model clearly complicates the analysis, but we view these features as unavoidable if one wishes to address our types of questions in quantitatively reasonable macroeconomic settings. Our approach, therefore, is to proceed with numerical analysis.[2] A natural part of the paper is therefore our

[2] Other recent dynamic political-economy models [for example, Gerhard Glomm and Balasubrahmanian Ravikumar (1992), Giuseppe Bertola (1993), Roberto Perotti (1993), Gilles Saint-Paul and Thierry Verdier (1993), Alberto Alesina and Dani Rodrik (1994), and Torsten Persson and Guido Tabellini (1994)] make one of several simplify-

reporting throughout of how the choice of model parameters affects the results.

The outline of the rest of the paper is as follows. The first two sections are theoretical. Section I describes the economic framework and discusses the determination of steady states and dynamics under the assumption that policy is exogenous. Section II then introduces politics, and shows how policy endogeneity changes the findings in the previous section. The quantitative analysis is contained in Section III. In our calibration section, Section III, subsection A, we first characterize U.S. data on income and wealth. We then discuss choices of constitutional parameters and of preference and technology parameters. The results from our baseline specification are then presented in Section III, subsection B. We start with the static version of the model—a calibrated Meltzer and Richard model—and proceed to the dynamic version. Section IV describes comparative statics with respect to both economic and political parameters; the latter are our constitutional experiments. Conclusions can be found in Section V. The Appendix contains formal equilibrium definitions, our computational algorithm, and a simple example.

I. Neoclassical Growth with Income and Wealth Distribution

We consider a straightforward extension of Meltzer and Richard's (1981) static model to a dynamic macroeconomic setup. In this section, we describe the economics of the model, and in the next section we lay out the politics.

Agents are infinitely lived, derive utility from streams of consumption and leisure, and have access to competitive borrowing and lending markets in order to allocate resources over time. There is no uncertainty. Production takes place with constant returns to scale to labor and capital inputs, and the final output can be used one for one for either consumption or investment; capital depreciates geometrically. Each agent has one unit of time available for either leisure or work, but the productivity at work may differ across agents.

Agents obtain their income from three sources: capital income, wage income, and a government transfer. Capital and labor income are taxed at a common, proportional rate (capital income is taxed net of depreciation), and the transfer is lump-sum and the same for all agents. We also assume that the government budget is balanced in all periods.

A typical agent thus faces the following maximization problem:

$$\max \sum_{t=0}^{\infty} \beta^t u(c_t, l_t) \text{ s.t.}$$

$$c_t + a_{t+1} = a_t(1 + r_t(1 - \tau_t)) + w_t\varepsilon_t(1 - l_t)(1 - \tau_t) + T_t,$$

where c denotes consumption, l leisure, a asset holdings, r the rental rate of capital, w wage per efficiency unit of labor, τ the income tax rate, and T the government transfer. The parameter β is assumed to be in (0, 1), and $\varepsilon > 0$ is the individual's productivity parameter. We furthermore assume that $u(c, l) = ((c^\alpha l^{1-\alpha})^{1-\sigma} - 1)/(1 - \sigma)$.[3] As we shall show below, this utility function gives rise to aggregation if economic policy is exogenous.

We assume that the heterogeneity in the population is of two kinds. First, agents differ in initial asset holdings; and second, they differ in labor productivity. We assume for simplicity that there is a discrete number I of types of agents with a measure μ_i of type i agents. Each type of agent i is thus associated with an initial asset holding a_{i0} and a labor productivity level ε_i. We normalize so that $\sum_{i=1}^I \mu_i = \sum_{i=1}^I \mu_i\varepsilon_i = 1$. In the theoretical section below, we will work with two agents, since it is not necessary to use more than two agents to

ing assumptions: they consider intertemporal models which are not fully dynamic, i.e., where rational agents do not need to be forward looking, they restrict voting to a subset of the population which is not concerned about the future, or they assume that voters are not fully rational when predicting the effects of changes in current policy. The analysis in Krusell and Ríos-Rull (1996) is fully dynamic and analytical, but it assumes a small number of agents to limit the size of the state space. For a discussion of these issues, see Krusell et al. (1997).

[3] We restrict σ to be less than 1. When $\sigma = 0$, the utility function can be written $\alpha \log c + (1 - \alpha) \log l$.

illustrate the main workings of the model. In the applied section, we will work with three types of agents, since this allows us to capture some of the key features of the income and wealth distributions in a parsimonious way.

The government budget constraint reads:

$$g_t + T_t = \tau_t(K_t r_t + N_t w_t),$$

where g_t is government consumption and K_t and N_t are the aggregate inputs of capital and labor in efficiency units, respectively. We take g_t as given exogenously throughout the paper, and we do not model how agents benefit from it.[4]

The resource constraint is

$$C_t + K_{t+1} - K_t(1-\delta) + g_t = F(K_t, N_t),$$

where C_t is aggregate consumption, $\delta \in (0, 1)$ is the depreciation rate, and F is the aggregate production function.

Given perfect competition, the rental rate and the wage rate are given by

$$r_t = F_1(K_t, N_t) - \delta \quad \text{and}$$

$$w_t = F_2(K_t, N_t).$$

A. *Steady States, Exogenous Policy*

One of the main reasons for studying a model with complete markets and infinely lived agents is that it allows us flexibility in matching the income and wealth distributions observed in U.S. data: under quite weak assumptions, this kind of framework allows any relative asset and labor income distributions as a steady state with constant policy. To see this, note that with a standard neoclassical production function, the steady-state equations can be summarized as follows.

First, the Euler equation for asset accumula-tion, which is the same for all agents given that they have the same discount factor and face the same rate of return on savings, reads

$$(1) \qquad \frac{1}{\beta} = 1 + r(1-\tau).$$

This equation pins down the rental rate and therefore the capital-labor ratio as well as the wage rate.

Further, the labor-leisure choice is characterized by

$$u_1(c_i, l_i)w\varepsilon_i(1-\tau) = u_2(c_i, l_i)$$

for all i. The steady-state version of the budget constraint for each agent can be used to eliminate c_i for all i. This leaves $I + 1$ equations in $2I$ unknowns: (a_i, l_i) for all i.[5] Thus, the set of steady-state income and wealth distributions is typically of dimension $I - 1$.

Some specific examples are useful for illustration. First, if leisure is not valued, the above equations reduce to $\sum_{i=1}^{I} \mu_i a_i = K^*$, where K^* solves the rate-of-return equation. Thus, there is only one possible capital stock, and any relative asset distribution is possible. Furthermore, by choice of the individual productivity parameters, the distribution of labor income can be chosen independently of the wealth distribution.

Second, because $u(c, l)$ is homothetic in our particular case, the equation system is linear in asset and leisure levels, and although the capital-labor ratio is pinned down, the total capital stock depends on the distribution and is generically indeterminate as well. More specifically, for any period utility function which can be written $u(c, l) = \tilde{u}(c^{\alpha}l^{1-\alpha})$ for some increasing and concave $\tilde{u}$, the capital stock is pinned down independently of the distribution: it is given jointly with the total amount of labor effort by (i) the rate-of-return requirement on the capital-labor ratio from above, and (ii) the aggregate version of the first-order condition for labor choice:

$$(2) \qquad \alpha(1-N_t)F_2(K_t, N_t)(1-\tau) = (1-\alpha)(F(K_t, N_t) - \delta K_t - g_t).$$

[4] The issue of how agents benefit from g_t would be an important one if g_t were regarded as endogenous.

[5] The statement follows from replacing prices and transfers with known functions of the a_i's and the l_i's, using market clearing in capital and labor and the government's budget.

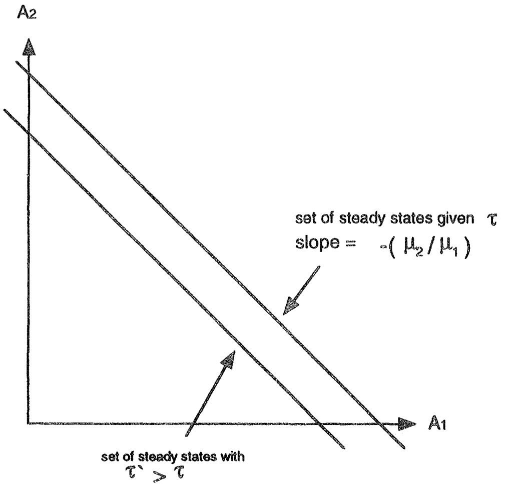

FIGURE 1. EXOGENOUS TAXES

Hence, our steady-state theory imposes no restrictions at all on the relative distributions of wealth and labor income.

For the purpose of graphical illustration, assume that there are two types of agents in the economy. Then Figure 1 describes the set of steady-state asset distributions.

The set of steady states is linear, with slope $-\mu_1/\mu_2$ and an intercept indicating the capital stock which, along with a value for the total labor supply, solves the rate-of-return equation (1) and the aggregate version of the labor-leisure first-order condition, equation (2). Negative values for assets are possible, provided consumption is nonnegative for each type of agent. The figure illustrates clearly that any relative distribution of asset wealth is possible. Moreover, notice that we can select a_1 and a_2 independently of ε_1 and ε_2. Therefore, any steady-state correlation between asset and labor income wealth is possible.

Changes in the exogenous tax rate will change the capital stock (capital-labor ratio), and will hence shift the steady-state line up or down, with unchanged slope. Changes in the exogenous tax rate thus does not change the set of relative wealth distributions that can arise as steady states. One of the main purposes of the ensuing analysis is to determine the set of steady-state asset distributions for this setup when taxes are endogenous.

How general is the result that there is a large set of steady states? First, the result continues to hold if agents have differences in their period utility functions.[6] It does not hold, however, when discount factors differ among agents or when preferences are nonadditive. Second, the fact that the time horizon is infinite is important for the result. Overlapping-generations structures without altruism do not give rise to the kind of steady-state Euler equation characterizing steady states in this economy.[7] Third, the result requires that agents face the same return on savings. The return on savings might differ because of an incompleteness in asset markets (so that agents may be constrained in their use of assets), because of transaction costs, or because taxes are not proportional. Fourth, the result continues to hold in the presence of individual uncertainty, as long as market completeness is maintained.[8]

B. *Aggregation, for Exogenous Policy*

The main focus of our analysis is on the political determination of the tax and transfer sequence. We analyze an environment where, absent the endogeneity of policy variables, an aggregation theorem applies. In particular, we will make assumptions on preferences such that aggregate outcomes do not depend on the distribution of earnings abilities nor on the initial distribution of asset holdings when policies are exogenous. This means that heterogeneity per se is inconsequential for aggregate outcomes: any effect on aggregates from changes in the distribution of wealth is solely due to politics. The present section establishes this fact.

Consider therefore an arbitrary sequence of

[6] If there is long-run growth and agents have different period utility functions, the result does not hold.

[7] The same is true for overlapping-generations models where altruism is either restricted or of the nature that different generations of the same family have different preferences over the same consumption baskets.

[8] For examples of models with unique steady states based on (i) differences in (endogenously determined) discount factors, see John H. Boyd, III (1996); (ii) progressive taxes with differences in discount factors, see Pierre-Daniel G. Sarte (1997); (iii) nondynastic populations, see Alan J. Auerbach and Laurence J. Kotlikoff (1987) and Ríos-Rull (1996); and idiosyncratic, partially uninsurable risk, see Ayse İmrohoroğlu (1989), S. Rao Aiyagari and Mark Gertler (1991), Javier Díaz-Gimenez et al. (1992), Mark Huggett (1993), Aiyagari (1994), or Huggett (1997).

taxes, transfers, and government expenditures. It is easy to show that the static optimal consumption and leisure choice satisfies

$$\varepsilon_i l_{it} = \frac{1-\alpha}{\alpha} \frac{c_{it}}{w_t(1-\tau_t)}. \tag{3}$$

That is, the supply of labor in efficiency units is $\varepsilon_i(1-l_i)$, and it is linear in consumption, with an intercept which is different for agents with different productivity levels and a slope coefficient which is the same for all agents. Using this condition, the present-value budget can be rewritten as follows:

$$\sum_{s=t}^{\infty} \frac{p_s}{p_t} c_{is} = \alpha \Bigg(a_{it}(1 + r_t(1-\tau_t)) + \sum_{s=t}^{\infty} \frac{p_s}{p_t} (w_s \varepsilon_i (1-\tau_s) + T_s) \Bigg) \equiv \alpha \omega_{it},$$

where p_s denotes the price of consumption good at t in terms of the numeraire, consumption at 0 ($p_0 = 1$). The variable ω_{it} is thus defined as the lifetime wealth of agent i, i.e., the present value of his current and future human wealth (which we define as the market value of the time endowment of the agent) and transfers together with the current holding of capital (nonhuman wealth).

Again employing the consumption-leisure first-order condition, the intertemporal Euler equation can be expressed in terms of consumption at t and $t+1$:

$$\left(\frac{c_{i,t+1}}{c_{it}}\right)^{\sigma} = \beta \frac{p_t}{p_{t+1}} \left(\frac{w_t(1-\tau_t)}{w_{t+1}(1-\tau_{t+1})}\right)^{(1-\alpha)(1-\sigma)}.$$

Here, $c_{i,t+1}$ can be solved for as a function of c_{it}: the relationship between these two variables is linear, and the slope coefficient does not depend on individual-specific variables (such as ε_i or a_i). Thus, future values of consumption can be successively substituted into the budget constraint, and consumption and leisure at date t can be solved for:

$$c_{it} = e_c(\mathbf{z}_t)\omega_{it}$$

and

$$\varepsilon_i l_{it} = e_l(\mathbf{z}_t)\omega_{it},$$

where $\mathbf{z}_t$ is defined as an infinite vector of current and future (as of t) prices and taxes and the e's are functions thereof.[9] Furthermore, in our formulation,

$$\frac{p_t}{p_{t+1}} = 1 + (f'(k_{t+1}) - \delta)(1-\tau_{t+1}), \tag{4}$$

where k is the capital-labor ratio and $Nf(k) \equiv F(K, N)$. Similarly, the wage rate equals $f(k) - kf'(k)$.

We know that the wage and rental rates are functions only of the capital-labor ratio. This capital-labor ratio, in turn, equals

$$k_t = \frac{K_t}{\sum_{i=1}^{I} \mu_i \varepsilon_i (1-l_i)} = \frac{K_t}{1 - e_l(\mathbf{z}_t)\Omega_t}, \tag{5}$$

where Ω_t is total wealth, i.e., $\Sigma_{i=1}^{I} \mu_i \omega_{it}$. Furthermore, total wealth satisfies

$$\Omega_t = \sum_{i=1}^{I} \mu_i \Bigg(a_{it}[1 + (f'(k_t) - \delta)(1-\tau_t)] + \sum_{s=t}^{\infty} \frac{p_s}{p_t}((f(k_s) - k_s f'(k_s))(1-\tau_s)\varepsilon_i + T_s)\Bigg),$$

which allows us to write

[9] More precisely, $e_c(\mathbf{z}_t) \equiv \alpha/\Sigma_t$ and $e_l(\mathbf{z}_t) \equiv (1-\alpha)/(w_t(1-\tau_t)\Sigma_t)$, where $\Sigma_t \equiv \Sigma_{s=0}^{\infty} \beta^{s/\sigma}[(p_t/p_{t+s})(w_t(1-\tau_t)/(w_{t+s}(1-\tau_{t+s})))^{1-\alpha}]^{(1-\sigma)/\sigma}$.

$$(6)\quad \Omega_t = K_t[1 + (f'(k_t) - \delta)(1 - \tau_t)] + \sum_{s=t}^{\infty} \frac{p_s}{p_t}((f(k_s) - k_s f'(k_s)) \times (1 - \tau_s) + T_s),$$

where $T_s = \tau_s(K_s(f'(k_s) - \delta) + (K_s/k_s)(f(k_s) - k_s f'(k_s))) - g_s$. Finally, the economy's resource constraint reads

$$(7)\quad K_t f(k_t)/k_t - K_{t+1} + (1 - \delta)K_t - g_t = C_t = \sum_{i=1}^{I} \mu_i e_c(\mathbf{z}_t)\omega_{it} = e_c(\mathbf{z}_t)\Omega_t.$$

We now have a system of equations that completely determines the equilibrium evolution of aggregate variables. This system of equations consists of, for each t, (i) the aggregate resource constraint (7); (ii) the equation determining the capital-labor ratio (5); (iii) the equation determining total wealth (6); and (iv) the equation for relative prices at t and $t + 1$ (4).[10] These equations embody consumer and firm optimization and market clearing.

It is clear at this point that aggregation obtains: no relative wealth or labor income variables enter in this equation system. Individual consumption, leisure, and asset levels are solved for recursively: given a solution to the above equation system for aggregate capital and the capital-labor ratio, and given an initial asset position for consumer i, we can determine all we need to know about this consumer.[11]

In graphical terms, what the aggregation result means is indicated in Figure 2. Suppose that taxes are given by a constant sequence $\tau_t = \tau$, so that the steady-state line is described as in the figure. An initial condition with total capital K_0 is a point (a_{10}, a_{20}) such that $\mu_1 a_{10} + \mu_2 a_{20} = K_0$ (the line t—t in the figure); this is

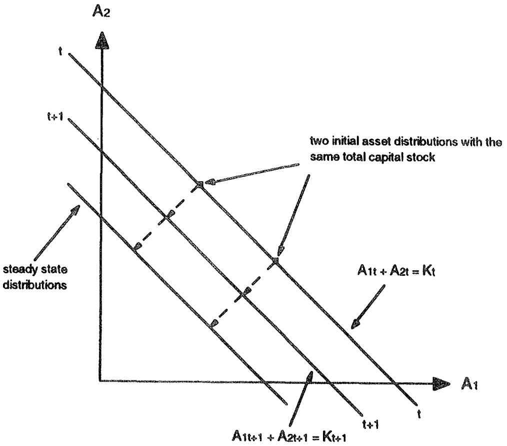

FIGURE 2. AGGREGATION WITH EXOGENOUS TAXES

a line which is parallel to the steady-state line. Equilibrium implies consumption choices among agents implying a next period's capital stock K_1 and an asset distribution (a_{11}, a_{21}) depicted on line t + 1—t + 1 in the graph. The content of the aggregation theorem is to dictate that the location of this line is *independent* of the distribution of the initial capital stock K_0 among agents. An alternative initial distribution, say $(\tilde{a}_{10}, \tilde{a}_{20})$, that is also on line t—t will move the economy to a new distribution $(\tilde{a}_{11}, \tilde{a}_{21})$ with the same total capital stock as (a_{11}, a_{21}), i.e., to a point on the line t + 1—t + 1. Moreover, although two economies that only differ in the initial distribution of a given amount of total capital will have identical time paths for prices and aggregates, their asset distributions will remain different and, if total capital converges, the asset distributions will converge to different points on the steady-state line. In other words, there is not enough equalization of incomes and wealth in this model over time so as to eliminate the importance of initial relative wealth levels. This fact also helps us interpret the large set of steady states in this model.[12]

[10] We omit transversality conditions for simplicity. For the present purpose they can be omitted, since they are either met for no agent or for all agents.

[11] Aggregation obtains also for a more general preference structure. For details, see Krusell and Ríos-Rull (1997).

[12] Satyajit Chatterjee (1994) investigates the implications of different initial capital stocks on the behavior of the distribution of wealth, where wealth is interpreted in present-value terms and as a sum of human and nonhuman wealth. Francesco Caselli and Jaume Ventura (1996) explore the evolution of asset wealth and labor income in the same kind of framework.

II. Political Equilibrium

We now introduce the political element of the model. The goal of the exercise is to describe a way in which τ_t, and thus T_t, the size of the government transfer program, are determined at all points in time. The mechanism of collective choice which we consider here is the same as that in Meltzer and Richard's paper: agents vote on the size of taxes, and tax outcomes coincide with those preferred by the median voter. It should be pointed out that other collective choice mechanisms have been considered in similar models. For example, a recent paper by Gene M. Grossman and Elhanan Helpman (1998) considers an overlapping-generations setup with two alternative choice mechanisms: one with a government with preferences over consumption of currently young and old agents, and one where in addition young and old agents can lobby the government regarding its tax policy choice. We chose the median-voter setup mainly to concord as closely as possible with Meltzer and Richard, but we agree with the view that this political mechanism only captures the political process imperfectly. It should prove fruitful to extend our analysis to alternative political contexts.

Our quantitative analysis below describes a setup in which taxes are voted on every two periods, with a period representing one year, and in which taxes are kept constant in between votes. To facilitate presentation of the political equilibrium mechanism in this section, however, we discuss a simpler framework: there is a vote every period on the income tax to be applied next period.[13]

To derive the agents' preferences over tax rates, we follow Meltzer and Richard by assuming that agents think through the equilibrium effects of each tax policy and calculate their associated utility levels. Agents then vote for the tax rate that gives them the highest equilibrium utility. It is important to note that to follow Meltzer and Richard's analysis in spirit in a dynamic model is quite demanding: the agents in the model need to rationally think through all the consequences of different tax choices, and these consequences extend into the infinite future. Nevertheless, this is the route we follow. The derived utility functions over the tax rate currently voted on are not single-peaked in general. However, in our calibrated economy, which we solve numerically, we find that single-peakedness is satisfied. This means that in our setup, tax outcomes will be determined by the voter whose most preferred tax rate is the median in the distribution of most preferred tax rates.

A. *Recursive Political Equilibrium*

We will rely on recursive methods in defining and computing equilibria for this economy. In this section, we discuss the key elements of our equilibrium definition, and the next section discusses how the endogeneity of policy alters the equilibrium characterization compared to when taxes are exogenous. The full statement of the equilibrium definition is made in the Appendices, where we also describe the numerical method we use for computing equilibria and go through a simple example along the lines of subsection B.

The calculation of the indirect preference over tax rates proceeds in the following way. We restrict attention to equilibria which satisfy a Markov property: the voting outcome in period t only depends on the "minimum state variable." By this we mean any information that would be necessary in order to compute a dynamic equilibrium were taxes exogenously chosen.[14] The key state variable is the current distribution of asset wealth, i.e., the distribution of the initial capital stock. From here on, we denote this variable $\mathbf{A}_t$, which is an I-dimensional vector whose ith element represents the beginning of time t asset holding of a type i agent. In addition, we need to include the current tax rate, since different values for the current tax rate imply different posttax wealth distributions. Thus, our equilibrium tax rate next period will be a function, Ψ, of the state variable: $\tau_{t+1} = \Psi(\mathbf{A}_t, \tau_t)$. Similarly, the evolution of asset holdings will be given by a

[13] If the choice were over the current tax, capital income taxation would be nondistortionary.

[14] Equivalently, this information is what a Ramsey planner with preferences over different types of agents would need in order to calculate an optimal plan by choosing sequences of tax rates.

function $\mathbf{H}$: $\mathbf{A}_{t+1} = \mathbf{H}(\mathbf{A}_t, \tau_t)$. The function $\mathbf{H}$ is determined from economic equilibrium conditions (utility and profit maximization and market clearing) given that taxes follow the function Ψ. The determination of $\mathbf{H}$ is nontrivial but standard.[15] The main objective of our paper is to solve for the function Ψ, which requires solving jointly for $\mathbf{H}$.

Given the equilibrium law of motion for taxes, consider an agent who contemplates a current vote. This agent needs to compare all possible tax choices τ_{t+1}. For this, the agent needs to have a view on how both current and future events are affected by the choice of τ_{t+1}. These events include the evolution of prices, capital, and asset holdings of the different types of agents as well as the evolution of tax rates. Our assumption here amounts to subgame-perfectness or, in macro terminology, time consistency of equilibrium: by varying the tax currently under consideration, the agent takes into account the equilibrium response of all future variables. This equilibrium response has both an economic and a political part: future asset holdings (and total capital) respond to τ_{t+1} as dictated by (forward-looking) equilibrium savings behavior on the part of all agents, and future taxes respond to equilibrium votes as given by Ψ. In particular, when an agent thinks about a specific vote, the agent does not view it as possible to consider any future tax paths, but is restricted to those which will arise as equilibrium responses to each current tax choice.

To be more specific, two different tax choices τ^1_{t+1} and τ^2_{t+1} would lead to different current and future savings, $\{\mathbf{A}^1_{t+1}, \mathbf{A}^1_{t+2}, \cdots\}$ and $\{\mathbf{A}^2_{t+1}, \mathbf{A}^2_{t+2}, \cdots\}$, and to different future taxes $\{\tau^1_{t+1}, \Psi(\mathbf{A}^1_{t+1}, \tau^1_{t+1}), \Psi(\mathbf{A}^1_{t+2}, \Psi(\mathbf{A}^1_{t+1}, \tau^1_{t+1})), \cdots\}$ and $\{\tau^2_{t+1}, \Psi(\mathbf{A}^2_{t+1}, \tau^2_{t+1}), \Psi(\mathbf{A}^2_{t+2}, \Psi(\mathbf{A}^2_{t+1}, \tau^2_{t+1})), \cdots\}$, where the the evolution of the asset distribution in each case occurs taking as given the corresponding evolution of tax rates. In particular, on the equilibrium path, the asset distribution evolves according to $\mathbf{A}' = \mathbf{H}(\mathbf{A}, \tau)$, and on the paths where taxes are arbitrary for one period (which the voters need contemplate to form their political preferences), the assets evolve according to an alternative function $\tilde{\mathbf{H}}$ during the first period, $\mathbf{A}' = \tilde{\mathbf{H}}(\mathbf{A}, \tau, \tau')$, and according to $\mathbf{H}$ thereafter. Thus, the equilibrium evolution of taxes and assets can be completely described by applying the functions $\mathbf{H}$, $\tilde{\mathbf{H}}$, and Ψ to any initial asset distribution and tax rate.

The forward-looking aspect of the dynamic political equilibrium makes computation nontrivial, and few analytical results can be obtained in this kind of model. Numerical characterization of equilibrium, however, is feasible.

B. *Equilibrium Characterization: Steady States and Dynamics*

What are the properties of equilibria when taxes are endogenous? First, consider the problem of determining the set of steady states. In terms of equations, we need to add the condition that taxes be constant over time:

$$\tau = \Psi(\mathbf{A}, \tau). \tag{8}$$

This equation, together with the rate-of-return equation (1), the aggregate labor-supply equation (2), and asset market clearing ($\sum_{i=1}^{I} \mu_i A_i = K$), determines the set of steady states. The unknowns are $\mathbf{A}$, N, K, and τ, i.e., $I + 3$ variables, and there are four equations. So provided the Ψ function exhibits nontrivial, nongeneric dependence on the $\mathbf{A}$ vector, the dimension of the set of steady states is the same as before (where we had one less equation but where τ was exogenous).

For illustration, consider an economy with two types of agents and no differences in labor efficiency. It is easy to show for this case that equal asset wealth and $\tau = 0$ is a steady state.[16] This is because there can be no transfer gain from taxation in such a situation, and any deviation from nondistortionary taxes is bad for both agents [more generally, $\Psi(\mathbf{A}, \tau) = 0$ has to hold whenever $A_1 = A_2$, including off the steady-state path]. Suppose furthermore that $\mu_2 > \mu_1$, so that agent 2 is the median voter.

Consider first the set of steady states when

[15] The determination of $\mathbf{H}$ given Ψ is different than in, say, the real-business-cycle literature: changes in the distribution of savings trigger changes in tax rates. However, standard methods can be used to solve for $\mathbf{H}$.

[16] For details, see an earlier version of this paper, Krusell and Ríos-Rull (1994).

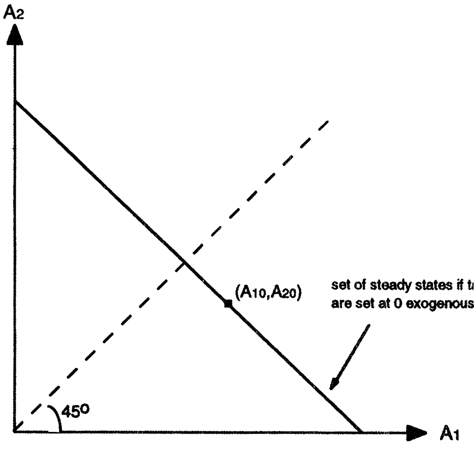

FIGURE 3A. SET OF STEADY STATES WHEN TAXES ARE ZERO EXOGENOUSLY

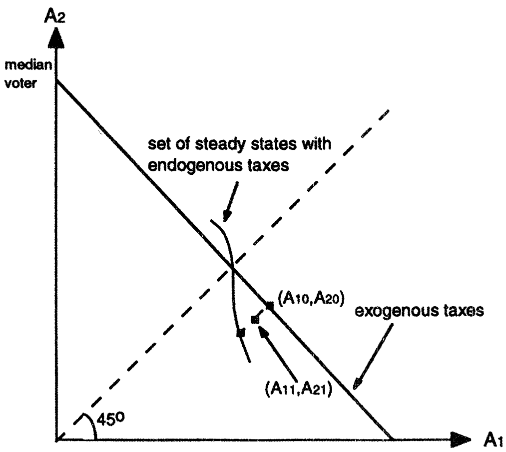

FIGURE 3B. SET OF STEADY STATES WITH ENDOGENOUS TAXES

taxes are zero exogenously, as depicted by the straight line with negative slope in Figure 3A. Is any point on this line also part of the political equilibrium steady-state set? Yes: the point where $A_1 = A_2$—on the 45-degree line—must be, since we just pointed out that a zero tax has to be chosen when agents have equal asset holdings.

Is any other point on the line also a political equilibrium steady state? No. Consider a point (A_{10}, A_{20}) on the steady-state line such that $A_{20} < A_{10}$. This point will not be a steady state when taxes are chosen, since it will benefit the median voter to impose a positive tax: the median voter, who is poor in relative terms, sees an advantage in departing from a zero tax to a positive one.[17] The positive tax will discourage saving and move the economy away from the steady-state line given zero taxes to a lower level of capital. That is, from (A_{10}, A_{20}) the economy moves to a point such as (A_{11}, A_{21}), which is southwest of the steady-state line with zero taxes. Moreover, assuming that the economy will converge to a steady state, and assuming monotonicity of the new path, this path can be represented by the dotted line starting at (A_{10}, A_{20}). The path ends up at a point on the new steady-state line, as shown in Figure 3B. The steady state with endogenous taxes achieved starting from (A_{10}, A_{20}) is thus associated with a positive tax and a lower total capital stock. A symmetric argument applies when $A_{20} > A_{10}$.

In summary, in the case where the type 2 agent is politically pivotal, the steady-state line with endogenous taxes has a steeper slope than the corresponding steady-state line with exogenously set zero taxes. (Conversely, when type 1 is the median agent, the slope is flatter.) The issue, of course, in our quantitative section is how much steeper the steady-state line is. More precisely, and still expressed in terms of the two-agent example, we will take as given a relative wealth ratio $(A_2/A_1)^*$ given by the one observed in recent U.S. time-series data, interpret it as a steady state, and ask what tax rate supports it. This means that we will use a "reasonably" parameterized version of our model and ask what point on the steady-state line is intersected by the line $A_2 = (A_2/A_1)^*A_1$. That point defines a level of the total capital stock, and we can then use the steady-state equations to find the corresponding tax rate and size of government.

[17] A somewhat more detailed, heuristic argument for this would go as follows: ignoring the effect a potential change in taxes has on transfers, the median voter would choose a zero tax, as taxes are distortionary. However, the net transfer to the median voter is strictly increasing in the tax rate when $A_{20} < A_{10}$. Thus, the benefits from a tax increase must exceed the costs, since costs are of second order. Of course, these arguments are heuristic because in order to support any steady state, alternative equilibrium paths—with all their transitional economic and political dynamics—need to be calculated.

III. Quantitative Analysis of the Size of Government

In this section we use the model developed above to analyze the transfers actually implemented in the U.S. economy. To do this we use a version of the model discussed above. In terms of the mapping between model and data, note that the model implicitly treats households as part of integrated dynasties, i.e., they are altruistic towards their descendants. We base the choice of an infinitely lived agent economy on the arguments in Laurence J. Kotlikoff and Lawrence H. Summers (1981); they find that a very small fraction of the economy's wealth can be accounted for by life-cycle savings motives. Note also that we are using a balanced-budget assumption, and that transfers are lump-sum and equal for all agents. In the United States, a large part of transfers consist of social security payments. Given the progressivity built into this system, we find this simplifying assumption a reasonable one.[18]

A. *Calibration*

We now describe in detail how we choose a specific parameterization of the model economy so that it reproduces certain features of the U.S. economy. We begin with the properties of the joint distribution of wealth and earnings, and we then move on to the constitutional parameters and to preferences and technology parameters.

1. *The Distribution of Earnings and Wealth.*—The distribution of earnings and wealth is a central variable in our analysis. The median household's decision of how much to tax depends on how it differs from the other households; if it is much poorer than the mean in terms of assets, for example, the median has an argument for choosing a high income tax rate, since it receives a net transfer from the capital income base. Moreover, the voters do not only care about the size of the transfer (net of taxes) and the magnitude of the intertemporal distortion that the policies generate, but they also care about the relative price of labor and capital. For this reason, the relative composition of income matters. As an example, suppose that the efficiency to wealth ratio of a voter is higher than the economy's average. Then this voter would like to see higher wages relative to rental rates of capital than would the average agent, and as a consequence the voter would favor policies which discourage others from working.

Our calibration of wealth and earnings is nontrivial. First, we need to choose a small number (I) of groups, since computational complexity is substantial and is increasing in the number of groups. We also need select the size of each of the I groups. Second, the sample we have from the U.S. economy—we use the 1992 Survey of Consumer Finances; see Díaz-Gimenez et al. (1997) for details—covers a large number of households, and there are many ways of mapping the data into asset-earnings pairs of the I groups. Third, our model assumes a dynasty structure, whereas data are only reported for physically separate households. Our model implicitly assumes that young households form an alliance with some middle-aged and old households (their parents and grandparents); the data, however, does not allow us to connect households this way. Moreover, age is a very important determinant of wealth and earnings—for life-cycle savings reasons, wealth tends to be low for young agents and high for old agents; earnings rise over the life cycle until retirement and are very low thereafter. Therefore, it may not be appropriate to treat each household as representative of their dynasty.

We first briefly describe the method we use for connecting model and data: how we partition the data into dynasties and into I wealth-earnings groups. We then describe the data and discuss the issues that are important in the calibration of the wealth-earnings distribution.

1(a) *Chosen Method.*—We assume that I is 3, and that the fractions in each group are 49, 2, and 49 percent, respectively. We determine the wealth and earnings of each of the three groups in two different ways, and present results for each of these. We first sort agents according to their wealth, draw the 49-2-49 partition according to this sorting, and compute the average earnings in each of the three resulting groups; we then make a similar partition, but where the sorting is according to earnings. We use as a

[18] See Luis Manuel Cubeddu (1995) for an analysis of the Social Security system.

basis for our partitions only "middle-aged" households (between 41 and 65 years of age), thus discarding households outside this age bracket.

1(b) *The Data, and Discussion of Our Method*

1(b1) *The Number and Sizes of Groups.*—First, the dynamic model we use is significantly more complicated to solve numerically than standard dynamic macroeconomic models. There are two reasons for this: (i) in order to solve the political fixed-point problem and support a given voting outcome, we need to compare different dynamic equilibrium paths: in order to compare two tax rates, the voter needs to solve for the two dynamic paths resulting from each tax rate; and (ii) the distribution of earnings and assets matters in the political equilibrium, so the state variable is increasing in the number of groups we have. For this reason, we choose the smallest number of groups that allows us to identify a median and a group below and above the median: 3. A small number of groups also means that there are large differences in asset and earnings across groups, which makes it very unlikely that the median voter will change identity over time (which could in principle happen in our model). Our 49-2-49 partition is simply designed to make the median group small, allowing a precise identification of the political preferences of the pivotal voter.[19]

1(b2) *The Data.*—Given the three groups, we need to assign each of a large number of households in our sample to one of the three groups. As mentioned, households notably differ in wealth, earnings, and age. In order to describe the wealth and earnings inequality in the whole population in terms of three groups, we first sort into groups according to wealth: we assign the 49 percent of all the households (independently of age) with the lowest wealth to the first group, the next 2 percent to the middle group, and the final 49 percent to the third group, and then compute average wealth and average earnings of each of these groups.[20] We also produce a similar partition with sorting according to earnings. As will be seen, the two procedures do lead to different joint asset/earnings distributions, and our numerical findings will tell how these differences matter for policy outcomes. By construction, the sorting according to wealth makes wealth inequality the most extreme possible, and similarly the sorting according to earnings makes earnings inequality the most extreme possible.

TABLE 1—DISTRIBUTIONAL STATISTICS FOR THE U.S. ECONOMY: ALL HOUSEHOLDS

Household type	1	2	3
Percentiles involved	0–49	49–51	51–100
Sorted by wealth			
Per household wealth	0.30	1	4.78
Per household earnings	0.57	1	1.91
Sorted by earnings			
Per household wealth	0.55	1	2.93
Per household earnings	0.24	1	2.94

Table 1 shows the per capita amounts of wealth and earnings (normalized so that the middle group has wealth and earnings of 1) for the three groups of households for each of our two sorting criteria.

Next, Table 2 shows the same kind of statistics for household in different age brackets. We have chosen three age groups (according to the age of the household): up to 40 years of age, 41 to 65, and older than 65 (the earnings-based old group is excluded, since most of the households in this group are retired and have zero earnings).

Note from the above tables that the differences in earnings and wealth dispersion between the different life-cycle groups are nontrivial. Moreover, we have as pointed out, there are differences in earnings and wealth levels between groups: compare Tables 1 and 2. Given this information, what procedure should be followed for partitioning households into groups?

1(b3) *Forming Dynasties.*—If we knew what dynasty each household belonged to (and the

[19] We could not make the median group much smaller, since that would introduce large sampling errors when measuring this group's earnings and wealth from the Survey of Consumer Finances.

[20] The data comes from the 1992 Survey of Consumer Finances. For details, see Díaz-Gimenez et al. (1997).

TABLE 2—DISTRIBUTIONAL STATISTICS FOR THE U.S. ECONOMY: SELECTED AGE-GROUPS

	Young: 0–40			Middle:41–65			Old:66 and older		
Percentiles	0–49	49–51	51–100	0–49	49–51	51–100	0–49	49–51	51–100
				Sorted by wealth					
Wealth	0.25	1	4.36	0.34	1	4.97	0.37	1	4.97
Earnings	0.77	1	2.14	0.60	1	2.15	0.67	1	3.07
				Sorted by earnings					
Wealth	0.59	1	2.32	0.62	1	3.70			
Earnings	0.45	1	2.23	0.34	1	2.54			

data set was large enough to have several members of each dynasty included), age would not be an issue. Unfortunately, our data set, as most other data sets, does not provide information about relatives. Moreover, from the little data we do have, the attempts to estimate intergenerational earnings correlations [see, e.g., Nancy L. Stokey (1996) and John Knowles (1999)] cover a wide range; while estimates center around 0.5 or somewhat less, some estimates are much higher and others much lower. In addition, we have no information about intergenerational correlations in wealth, or intergenerational cross-correlations between earnings and wealth. Therefore, existing studies do not suggest how to impute earnings and wealth of missing members of each dynasty, or how to construct dynasties in our data set by synthetically connecting households of different ages.

Lacking direct quantitative information, life-cycle savings and earnings facts however do suggest that young and old households within a given dynasty are special; the young have the lowest wealth, and the old the highest, and the old have the lowest earnings. Given this, letting a young household in the data set represent its dynasty and an old represent its dynasty seems a poor way to proceed, as one would expect an artificially large recorded dispersion in wealth and income this way. Moreover, since the correlation in at least earnings across generations is significantly smaller than one, there is some averaging, and this provides another reason why treating all households as representative of their dynasties is probably not the best way to proceed. Our procedure in the baseline calibration is to discard data from households outside the 41–65-year age bracket. This may underestimate dispersion in that it discards extreme values for earnings and wealth, since the young and the old tend to be at extremes. On the other hand, since we do not do any averaging across households, we may overestimate dispersion for this reason. Since we only know that these two biases should work in opposite directions, and for completeness, we also report results from alternative calibrations (using other age-groups or all households).

1(b4) *Partitioning the Sample of Dynasties into the Three Groups.*—Being left with a large set of representatives of dynasties, how should these dynasties be partitioned into three groups? In particular, assuming that households have single-peaked indirect preferences over tax rates, who in the large remaining sample is the median agent, in terms of most preferred tax rates? A priori, this is impossible to know, as the answer is model-dependent: how one's wealth holdings and one's earnings determine one's tax choice depends, among other things, on prices, which in turn depend on equilibrium tax rates.

To organize the thinking, it may be useful to first imagine the "first-best" solution to this calibration problem: we could simply have solved a model with as many households as in the sample. This would trivially tell us how to calibrate the earnings and wealth distribution in the model: it should coincide exactly, agent by agent, with that in the data sample. The next step would be to derive indirect utility functions over tax rates (in equilibrium) for each group, and then to rank agents according to their most preferred tax rate. The median in this ranking would then be chosen as the outcome. Although this procedure is conceptually straightforward, it is, as we have indicated, not computationally feasible with current technology.

Our choice of using two alternative sortings—one according to wealth and one according to earnings—may be a way of bracketing the set of possible results. The idea is as follows: one of the sortings makes earnings dispersion the largest possible, and the other makes it artificially small (and vice versa for wealth inequality). This is true unless the correlation between earnings and wealth is 1, in which case the two sortings would produce identical partitions. So if, for example, the earnings turn out to be quantitatively the most important determinant of an agent's tax preferences, the sorting according to earnings should provide a good idea of the key characteristics of the median voter and of the agents below and above the median. If, on the other hand, wealth is more important quantitatively, the sorting according to wealth should provide a better picture of the relevant aspects of the distribution. Hence, we believe that the tax preferences of the "true median voter" in our sample of dynasties is likely located between those resulting from our two ways of sorting.

Finally, we calibrate the distribution of wealth, **A** (recall that in this model differences in wealth across agents are perpetuated) and the distribution of efficiency units of labor, ε, so that equilibrium wealth and earnings of the model economy reproduce the properties of Tables 1 and 2. For the distribution of wealth, this is trivial, since the model economy's wealth distribution is an initial condition and in this sense exogenous. The earnings distribution is slightly more complicated, since it involves each agent's choice of how many hours to work.

2. *Constitutional Characteristics.*—In this model we set the length of time in between elections to two years. This is a potentially important variable. For our baseline calculations we take the length of time between renewals of the House of Representatives (given its budgetary powers) as the appropriate time interval. In each period there is a vote over next period's tax rate, i.e., the policy implementation lag is one year.

3. *Preferences and Technology.*—The economic period is set to one year, so that it coincides with our baseline voting frequency. The choice of functional forms for preferences is an important one here, since it will determine the elasticities that in effect determine the distortionary costs of taxation. As regards intertemporal substitution, we employ additive time separability, which simplifies the structure and allows a direct identification of the key elasticities. We assume a period utility function which allows balanced growth: a function with constant relative risk aversion. The elasticity with intertemporal relevance is governed by the parameter σ, and it will be important in determining the distortions from capital taxation.

The distortions from taxing labor involve the labor-supply elasticity. Furthermore, the importance of wealth effects in labor supply cannot be understated in our model: to the extent labor supply is decreasing in wealth, a tax on labor works as an indirect subsidy to wealth. The applied macro literature has tended to use the type of period utility we employ here.[21] This formulation is useful for matching an important growth fact: hours worked have remained roughly constant over a long period of time. For the "macro preferences," with consumption and real wages growing at the same rate, the choice of hours worked is constant [this fact follows directly from equation (3)]. This result comes from substitution and wealth effects which cancel each other out: increasing wages makes leisure more expensive in relative terms, so people work more; on the other hand, higher wages make people richer, so they work less. The fact that substitution and wealth effects cancel out is also useful for matching the cross-sectional distribution of hours: although hours worked are higher for workers with higher wages, the effect is not quantitatively large.

We have also experimented with a different period utility function for aggregating consumption and leisure, since the Cobb-Douglas form has only one parameter, α (the share on consumption), and this parameter is tied down by calibrating working time. That is, the Cobb-Douglas specification does not allow us to vary the degree of substitutability between consumption and leisure without also changing hours worked. The natural extension is $u(c, l) = (\alpha c^{\rho} + (1 - \alpha)l^{\rho})^{1/\rho}$. Different measures of

[21] An important exception is Jeremy Greenwood et al. (1988), who use a formulation without wealth effects on labor supply.

labor-supply elasticity are available; a convenient one for our functional form is to compute $d \log(1 - l)/d \log w$ keeping consumption constant. This gives, using the first-order conditions for the labor-leisure choice, an elasticity of $(l/(1 - l))/(1 - \rho)$. That is, with $\rho = 0$ (Cobb-Douglas) and $l = 2/3$, the elasticity is 2; this calibration is standard in the macroeconomic literature. Although $\rho \neq 0$ is inconsistent with a balanced supply of hours in the presence of growth (unless one adds a growing constant multiplying l in the utility function), microeconomic studies do suggest that this number is high [see, e.g., Mark R. Killingsworth and James J. Heckman (1986) and John H. Pencavel (1986)]. The latter studies would be more consistent with an elasticity of around 0.5. We use different values of ρ, maintaining $l = 2/3$ by choice of α, in our robustness analysis.

Turning to technology, we choose a Cobb-Douglas production function, $y = K^{\theta}N^{1-\theta}$, for standard reasons: it allows us to obtain a balanced growth path in a growing version of the model economy with constant input shares.

The calibration of preferences and technology parameters involves the choice of the discount rate, β, the risk aversion parameter, σ, the consumption share, α, the share of capital income, θ, and the depreciation rate, δ. To calibrate these five parameters and the size of government consumption, g, we impose five aggregate conditions that the model economy has to satisfy, and we use a coefficient of risk aversion of 4 (which is a commonly used value in the real-business-cycle literature). The five conditions that we impose on our yearly model are:

1. A wealth-to-output ratio of 2.6.
2. A rate of return (before taxes) of around 6 percent.
3. A consumption-to-GDP ratio of 0.65 (the 1960–1995 average was 0.64, and between 1990 and 1995 it was 0.68).
4. A government expenditure-to-GDP ratio of 0.19.
5. An average time allocation to market activities of around one-third of the total time endowment.

A few of these statistics require discussion. The time allocation, and its relation to the labor-supply elasticity, has already been discussed.

Second, the government expenditure-to-GDP ratio was calculated as follows, with 1995 as an example year. In 1995 total current expenditures from the government, consolidating its federal, state, and local components, amounted to 32.2 percent of GDP. Of this, net interest on public debt amounted to 2.5 percent of GDP. This leaves 29.7 percent of GDP, which is spent either on pure transfers or on goods and services. Since some of transfers take the form of goods and services, we chose to measure g "indirectly": we distinguish different kinds of transfers, and then measure g as whatever is left after these transfers are deducted. We thus define transfers as consisting of two components: (i) those which are received lump-sum by all households (where, as in our theory, a household is a dynastic construct), T_1, and those which can be regarded as income security, T_2. The main components of each of these are as follows. T_1 consists of Medicare and Social Security, which are largely not means-tested or income-dependent, and amounts to 6.8 percent of GDP. T_2 consists of state and local transfers labeled public assistance—estimated to 2.7 percent of GDP—and federal government programs for Medicaid and income security purposes net of grants to the states, which amounts to 1.1 percent of GDP. Thus, we have

$$\text{government outlays} - \text{interest on debt}$$
$$= g + T_1 + T_2 = 29.7 \text{ percent}$$

with $T_1 = 6.8$ percent and $T_2 = 2.7 + 1.1 = 3.8$ percent. This leads to an estimate for g of 19.1 percent.[22] The exclusion of T_2 from g has the drawback of implying that the total exogenous tax pressure in the model is slightly too low. On the other hand, including it as part of g would be a misrepresentation. An alternative is to include T_2 explicitly in the model as a transfer to the lowest income/wealth group only (it would thus be a lump-sum payment which depends on "type," which is not endogenous). In this alternative, the level of T_2, or its relation to total transfers or to GDP, would be treated as

[22] These calculations build on the 1997 *Economic Report of the President* and the 1996 *Statistical Abstract of the United States*.

TABLE 3—PARAMETERS AND STEADY-STATE PROPERTIES FOR THE BASELINE ECONOMY

β	α	σ	δ	θ
0.96	0.429	4	0.05	0.36
$\Sigma_i \mu_i A_i / Y$	r	C/Y	g/Y	N
3.3	0.060	0.638	0.199	0.34

TABLE 4—TRANSFERS AND TAXES (IN PERCENT) IN THE STATIC MODEL

Model economy	T/Y	τ
Baseline: wealth sorting	20.6	51.7
Earnings sorting	28.6	64.9
No asset inequality	12.5	38.8
$1.05A_r$	20.8	52.0
$1.05\varepsilon_r$	21.5	53.2
$\rho = -3$	51.6	88.1
$\rho = 0.5$	11.8	39.1

exogenous. We report results for this alternative specification in subsection C below. Note, finally, that our identification of transfers makes education in the form of public schooling part of g. There are two specific arguments for this. First, schooling can be regarded as a public good more than a direct income transfer and therefore fits better in g. Second, funding is local and people choose where to live, which means that public schooling in many ways is close to a private good (i.e., the net transfer is small in practice, and may mainly occur across households with and without schoolchildren). For comparison, however, we also report results in subsection C for the case where public-schooling expenditures are regarded as pure transfers.

In summary, for our baseline model the calibrated parameters and key steady-state relations are listed in Table 3.

B. *Results*

1. *The Static Model.*—For comparison, we start by reporting some results from a static version of the model—a calibrated Meltzer and Richard model. The static version is a one-period model with the same (intratemporal) preference and technology structure as in the dynamic model. Agents differ, as in the dynamic model, in labor efficiency and in incoming wealth. In the static model, the stock of capital is inelastically supplied. The purpose of looking at a static model initially is to see to what extent a calibrated static Meltzer-Richard model is able to match the level of transfers in the data. As in the dynamic model, we let agents vote on a tax rate applied to all income. That is, the agent's budget reads

$$c_i = [w\varepsilon_i(1 - l_i) + a_i r](1 - \tau) + T.$$

An alternative would have been to let agents vote on a tax rate on labor income alone. However, this would ignore an important element of inequality and a source of redistribution. We report some results from a model of this kind, too.

In the static model, our calibration proceeds as follows: we first select taxes and transfers exogenously and solve the model to pin down all its parameters, including the capital stock, so that the static model looks exactly like a snapshot of the dynamic one. We then ask, given these parameters, what tax rate the median voter would choose in a political equilibrium.

Table 4 displays the results, including a number of robustness checks. The basic finding is that politico-economic equilibria in the static model predict much too high equilibrium transfers when the tax is allowed to be chosen by the median voter. In the baseline calibration with sorting according to wealth, the endogenous level of transfers (as a fraction of GNP) is 20.6 percent, that is, roughly three times that in the data, with a tax rate at 51.7 percent; with sorting according to earnings transfers are 28.6 percent and the tax rate 64.9 percent. The large amount of redistribution is a result of two model properties: there is significant inequality—in particular, there is a large difference between the means and the medians of earnings and wealth—and taxation does not appear to be very distortionary.

When the baseline model is altered so that there is no asset inequality at all, transfers go down significantly to 12.5 percent of GNP, which is a little less than double our measure from the data. This case is similar to one where there is no capital income taxation. Still, the model's estimate of transfers is high, even though there is "no capital to steal" for the median voter.

TABLE 5—TRANSFERS AND TAXES (IN PERCENT) FOR THE DYNAMIC MODEL

	Different calibrations					
Age-group	Middle		Young		All	
Sorting criterion	Wealth	Earnings	Wealth	Earnings	Wealth	Earnings
T/Y	6.15	6.61	7.58	2.57	2.45	8.77
τ	31.1	31.5	32.5	27.3	27.4	33.6

The table also shows a few robustness results that are worthwhile commenting on. To disentangle the effects of marginal changes in asset and earnings inequality, consider on the one hand an increase in the richest agent's asset holding, A_R, by 5 percent. It increases transfers and taxes, but not by very much. On the other hand, an increase in the richest agent's labor efficiency, ε_R, by 5 percent has a stronger effect. The fact that marginal changes in asset holdings have a small effect is partly because assets are a smaller part of total income, and partly because changes in wealth lead to counteracting changes in work effort: there is more capital to steal from the rich, but less labor income. This qualitative feature will be present in the dynamic model as well.

Finally, the experiments involving a changed labor-supply elasticity show that a movement toward lower elasticities makes the predictions worse. An elasticity of 0.5, which is somewhere in the middle of the range reported in micro studies, corresponding to a ρ of -3 (recall that the baseline elasticity is 2, with $\rho = 0$), gives estimated transfers of over 50 percent of GDP. If one instead moves further away from the micro-based estimates to an elasticity of 4 ($\rho = 0.5$), predictions improve: transfers are now 11.8 percent of GDP. The intuition for these results is clear: with less elastic labor supply, the median voter wants to tax even more.

2. *The Dynamic Model.*—Let us now turn to our calibrated dynamic economy. We obtain equilibrium values for total tax rates and for transfer-to-GDP ratios as reported in Table 5. In the table, we tabulate the findings for several different ways of calibrating the distributions: we identify the model dynasties with three different age-groups—middle-aged agents, young agents, and all agents—and we consider two ways of sorting households into three groups—by wealth or by earnings.

The table shows that the tax rates and transfer-to-GDP ratios implied by the dynamic Meltzer and Richard economy are of quite reasonable magnitude. For transfers, the different sortings lead to a range of about 3 to 9 percent of GDP, depending on the income/wealth distribution employed. For tax rates, the order of magnitude is around 27 to 33 percent. Our most preferred sorting, that according to wealth and earnings distributions for middle-aged, give transfers between 6 and 7 percent of GDP. Recall that our estimates of the observed U.S. transfers are 6.8 percent for those transfers which are not means-tested, and 10.6 percent if means-tested transfers are included.

Compared to the results from the static version of the model, the dynamic baseline economy gives results which are remarkably close to the data. We now turn to sensitivity analysis.

IV. Which Model Features Affect the Results?

In this section we vary some parameters of interest and examine the effects on the size of government. We have both economic and political parameters to investigate. Let us consider each in turn as perturbations of the baseline economy.

A. *Distributional Properties*

We start by changing the distributional properties of the economy. We do this by changing the wealth and wages of the two large groups by 5 percent (one change at a time).

The table describes the effects of changing the distributional characteristics in a variety of ways. Given that we are dealing with a median-voter model, the qualitative results are that increases in the wealth or earnings of the middle group (other groups) lower (raise) tax rates and transfers. These effects of changing the income and wealth distributions are also underlying the

TABLE 6—TRANSFERS AND TAXES (IN PERCENT): COMPARATIVE STATICS, INCOME, AND WEALTH DISTRIBUTIONS

Model economy	T/Y	τ
Baseline	6.15	31.1
$1.05A_m$, $1.05\varepsilon_m$	4.84	29.0
$1.05A_R$	6.15	31.1
$1.05A_m$	6.14	31.1
$1.05A_P$	6.15	31.1
$1.05\varepsilon_R$	7.71	32.6
$1.05\varepsilon_m$	4.85	29.0
$1.05\varepsilon_P$	6.57	31.5

TABLE 7—TRANSFERS AND TAXES (IN PERCENT): COMPARATIVE STATICS, PREFERENCES, AND TECHNOLOGY

Model economy	T/Y	τ
Baseline	6.15	31.1
$\sigma = 8$	6.84	32.2
5-percent reduction in θ	5.20	30.9
$\rho = -2$	20.4	45.8
$\rho = 0.5$	1.69	25.0
5-percent reduction in β	2.60	33.0
5-percent reduction in δ	6.40	31.1

differences in policy outcomes in Table 5 between different sorting criteria.[23]

Quantitatively, what we take away from Table 6 is that, as in the static model, (i) large changes in tax rates or transfer levels do not result from small to moderate changes in distributional characteristics; and that (ii) marginal changes in the earnings distribution seem to have somewhat larger effects than changes in the asset distribution. Overall, marginal changes in distributions have smaller effects in the dynamic than in the model: the median voter responds less to changes in the tax base since taxation involves an added distortion in the dynamic model.

B. *Changes in the Economic Parameters*

The key economic parameters have the following effects [see Table 7].

Consider first the decrease in the labor-supply elasticity, which we achieve by decreasing ρ to -2 from its benchmark value of 0. The result is a substantial increase in transfers and taxes, to 20 and 46 percent, respectively. As in the static model, when labor is less elastically supplied, it is less costly to tax it, and the median voter increases the amount of redistribution. Similarly, when the elasticity is increased, transfers fall to 1.7 percent and taxes to 25 percent.

An increase in σ from 4 to 8 represents a decrease in the intertemporal elasticity of substitution, and this leads to more taxation. We see from the table that a doubling of σ leads to a little bit more than a 1-percentage-point increase in the income tax rate.

A decrease in θ, the capital share, lessens the importance of capital relative to labor. Capital is distributed in a more skewed fashion—the median is much poorer relative to the mean—and this should account for the resulting drop in the size of government. The size of this effect is quite small, however.[24]

Changes in the remaining parameters, β and δ, affect equilibrium transfers through changes in the capital stock. With capital accumulation, changes in the capital stock affect the size of the tax base and, therefore, the size of the redistribution base. With more capital, total income and total income inequality is larger, so there will be more taxation. The table shows that a decrease in β, which means that agents are less patient and thus save less, leads to a sizeable decrease in the size of government. Similarly, a decrease in δ makes capital depreciate less and the capital stock increases, leading to higher taxation.

C. *Changes in the Definition of Transfers*

We consider two alternative specifications: one in which public-schooling expenditures are considered pure transfers, and one in which we explicitly include means-tested transfers in the analysis as transfers that are made only to the poorest agent type.

Public-schooling expenditures total around 5 percent of GDP. In the experiment, we change g so that g/Y decreases to 14.3 percent. With this lower value of total government consumption,

[23] We performed the same experiments with the baseline based on the earnings ranking. The results are very similar.

[24] The static model shows the same kind of comparative static result as the dynamic model with respect to changes in θ.

we find that the equilibrium value of T/Y goes up (from 6.15 to 11.5 percent) and that the tax rate barely changes (it goes down from 31.1 to 30.9 percent). In other words, the lower value of g makes taxation less distorting: the less revenue needs to be raised with taxes, the less costly is each dollar raised. For this reason, the median agent now sees a reason to increase the tax rate, and transfers in fact go up by about as much as g goes down.[25] In the equilibrium with a lower g, the median voter's first-order condition pins down a tax rate, not a transfer level: the marginal cost of redistribution is given by the tax rate on income, and the marginal benefit does not depend in an important way on the level of g. Thus, the model's predictions are still remarkably close to the data.

When we treat the two kinds of transfers separately, T_1 representing transfers which are the same for all agents and T_2 being a "means-tested" transfer given only to the poorest agent type, we see an increase in the income tax rate by about 1 percentage point. Thus, we set T_2 so that T_2/Y equals 3.8 percent, and we find that T_1/Y equals 4.0 percent. Thus, total transfers equal a little short of 8 percent, to be compared with 10.6 percent in the data (recall that in the data, $T_1/Y = 6.8$ percent). That is, we again find that when total exogenous expenditures/transfers change, the endogenous transfers change in an offsetting direction by a similar amount.

D. *Changes in the Constitutional Parameters*

To recall, our baseline framework is one with a one-year model period with voting every two years on taxes to be implemented one year after the vote. The following table shows the effects of changing the constitutional parameters.

Quantitatively, Table 8 shows that changes in the election frequency and in the implementation lag have small effects on the size of government. Qualitatively, we see that an increase in the time between elections and an increased implementation lag both increase the tax rate. This qualitative result is perhaps somewhat surprising in light of our earlier findings in Krusell and Ríos-Rull (1994), where the same constitutional changes have the opposite effect on taxes. There, the logic behind why an increased implementation lag would lower taxes in the political equilibrium goes as follows. Capital responds more to changes in taxes if the taxes are levied further in the future, since capital is more elastically supplied in the future. As a result, any amount of redistribution via capital taxation is more costly, so the median voter chooses to do less of it.[26] In the present paper, however, taxation also affects labor supply. This complicates the picture and, as is clear from the table, involves a counteracting effect which overturns the qualitative features of the economy with exogenous labor supply.

TABLE 8—TRANSFERS AND TAXES (IN PERCENT): COMPARATIVE STATICS, ELECTION FREQUENCIES, AND IMPLEMENTATION LAGS

Voting frequency and implementation lag	T/Y	τ
Baseline: vote every 2 years, 1-year lag	6.15	31.1
Vote every 2 years, 2-year lag	6.34	31.4
Vote every 4 years, 1-year lag	6.33	31.4
Vote every 4 years, 4-year lag	6.92	32.3
Vote every year, 1-year lag	6.05	30.9

To understand the nature of the counteracting effect, consider a pure labor tax and the experiment of increasing the implementation lag. In each case, any contemplated increase in the tax on labor will lead to both a wealth and a substitution effect. The substitution effect will mean that labor supply in the period of the tax change will go down. The wealth effect will lead to increased labor supply at least prior to the tax increase: leisure is a normal good, and less leisure will be consumed. This increase in labor supply prior to the date at which the tax change is implemented has two consequences, and each of these acts to encourage more taxation.

[25] Although we did not report the experiment in the paper, the same effect is present in the static model.

[26] This logic is similar to why capital should not be taxed in the long run in the standard neoclassical framework (see, e.g., Christophe Chamley, 1986). Also, note that the same kind of argument works for an increase in the time between elections, since in our framework election frequency determines the period over which taxes are constant and committed to. Thus, less frequent elections means that capital is more elastic and responds more to changes in taxes, which leads to lower equilibrium tax rates.

First, since labor income is unevenly distributed, the increases in labor supply, which will occur for all agents, will lead to an increased tax base and a net redistribution to the median voter. The longer the implementation lag is, the longer is the period for which this effect is active, so the stronger is the effect.

Second, given the new income streams, the consumers aim to smooth consumption. This means that the additional labor income prior to the tax increase will in large part be saved and used to prevent a large fall in consumption later on. That is, the capital stock will increase. Moreover, the further in the future the tax change is, that is, the longer is the implementation lag, the longer is the period of time over which labor income will go up and, hence, the larger is the accumulated increase in capital. This counteracts the increased elasticity of capital at longer horizons emphasized in our earlier work.[27]

The arguments use a pure labor tax but are, of course, valid also in the case all income is taxed. It seems clear, however, that the more important labor is as a fraction of total income, and the more unevenly distributed it is, the more important are the counteracting effects. We found, for example, that in an economy where ⅔ of income goes to capital, or in one where labor efficiency is equal for all agents, the counterbalancing effects are much weaker. The net effect of an increased implementation lag in each of these two cases is to decrease the size of government.

V. Conclusions

We have revisited Meltzer and Richard's analysis of the size of government. Among the determinants of how people vote, one issue seems fundamental: how large a government to have, and how much to redistribute from rich to poor. Arguably, this issue is of first-order importance for most voters. For this reason, the median voter seemed a good framework to Meltzer and Richard when they wrote their paper, and we think it still is. The contribution in this paper is to build further on this framework.

With modern tools, it is possible to extend Meltzer and Richard's model to include another important determinant of how the median voter makes the decision of how high to set taxes: the possibility to tax wealth, and the associated distortion to the consumption-savings choice. This distortion has been in focus in the macroeconomic public policy literature, as standard models imply that taxing savings is very costly in terms of welfare. We assume that there is only one tax rate that is voted on, since we think that Meltzer and Richard's approach was essentially sound: the single issue is the size of government, and thus a model with a single tax on all sources of income—labor earnings and capital income in the model—seems to us a very reasonable way to characterize how voters think about the central issue. We show that a static model, calibrated to match the essential features of the data, including the distributions of wealth and earnings, overpredicts the amount of transfers, and the tax rate, that will result in a political equilibrium. At least as far as we can tell, this overprediction is robust to reasonable changes in the basic parameters. The dynamic model, on the other hand, performs much better. In the dynamic model, the distortion on savings brings taxes and transfers down to a level which is very close to the observed amount of transfers.

The results are quite robust. The elasticity of labor supply and intertemporal substitution elasticity matter, but small changes do not cause large changes in results. Regarding the elasticity of labor supply, we find that the elasticity used in the macroeconomic literature gives more realistic tax and transfer outcomes than do the (lower) elasticities estimated in the labor literature. Whether this reflects a merit of the macroeconomic practice and of the present model or a failure of both of them is an open question. Marginal changes in the distribution of earnings seem to play a more important role in relative terms than changes in the distribution of wealth. Constitutional changes in the form of changes in timing—changes in election frequency and policy implementation lags—do not lead to large effects on equilibrium tax and transfer rates.

Given the success the median voter model considered in this paper has in accounting

[27] These arguments work for an increase in the time between elections as well—a long-lasting tax increase leads to a stronger counteracting increase in labor supply.

quantitatively for the level of government in one important economy—postwar United States—it seems important to continue to investigate the model and to put it to further challenging use. First, there are a number of institutional questions that have been subject to debate and that can feasibly be analyzed using a model of the kind we develop here. One such question is how balanced-budget rules affect voting outcomes. Another (very broad) question is how details of the legislative process may affect aggregate outcomes—this would require enriching the median-voter model to include elected representatives. Second, policies have significant variations over time. Adding shocks to the present kind of framework would allow us to address fiscal empirical regularities from a political-economy perspective. Third, there are, as we mention in the introduction, large differences in public policy choices between countries. Could the model presented here account for these differences? We have learned in this paper that significant differences in the distributions of earnings and wealth can be associated with significant differences in policy choices, and that the tax base matters for tax outcomes. Whether the differences in distributions and types of taxation across economies are important enough to be able to account for cross-country policy differences is an open question. Clearly, more institutional differences also need to be incorporated into the model and evaluated. The methodology developed in this paper is quite general and should allow these issues to be studied.

Appendix A: A Formal Definition of Equilibrium

We define equilibrium recursively. First, we define economic equilibrium given that policy follows the function Ψ. Second, we turn to the fixed-point problem for Ψ. As in the theoretical section, we assume here that taxes are voted on every period; for the details of how equilibrium is defined when taxes are voted on every n periods, see Krusell and Ríos-Rull (1994).

Economic Equilibrium

In its dynamic programming version, agent i's problem reads as follows.

$$\text{(A1)}\quad v_i(\mathbf{A}, \tau, a) = \max_{c,l,a'} u(c, l) + \beta v_i(\mathbf{A}', \tau', a') \text{ s.t.}$$

$$a' = a + (ar(K/N) + w(K/N)(1-l)\varepsilon_i) \times (1-\tau) + T - c$$

$$T = \tau(F(K, N) - \delta K)$$

$$\tau' = \Psi(\mathbf{A}, \tau)$$

$$\mathbf{A}' = \mathbf{H}(\mathbf{A}, \tau)$$

$$K = \sum_i \mu_i A_i$$

$$N = G(\mathbf{A}, \tau).$$

Here, we let a denote the agent's own asset holding, whereas capital letters refer to economywide variables. Variables without primes refer to current values, and variables with primes refer to values in the next period. A solution to the dynamic-programming problem gives next period's asset holdings as a function $a' = h_i(\mathbf{A}, \tau, a)$ and leisure as $l = g_i(\mathbf{A}, \tau, a)$.

We define recursive competitive equilibrium in the standard way, given the function Ψ, by a set of functions $\{\mathbf{H}, \mathbf{h}, G, \mathbf{g}\}$ such that

$$H_i(\mathbf{A}, \tau) = h_i(\mathbf{A}, \tau, A_i)$$

and

$$G(\mathbf{A}, \tau) = \sum_i \mu_i(1 - g_i(\mathbf{A}, \tau, A_i))\varepsilon_i$$

for all τ, $\mathbf{A}$, and i. These conditions represent the fixed-point problem of the recursive equilibrium formulation, i.e., they require that the optimal laws of motion of the individual agents reproduce the aggregate laws of motion they perceive when solving their decision problems.[28]

In the above equilibrium, taxes are given by

[28] See, for example, Thomas F. Cooley (1995 Chs. 1–4) for an exposition and details on this concept as well as on its computation and properties.

Ψ at every point in time. In order to define our political equilibrium, we need to also consider economic equilibria where taxes are set slightly differently: one-period deviations in tax policies. Consider therefore τ' to be set arbitrarily but all tax rates at later dates to be given by Ψ. These are the equilibria which the voter needs to think through when contemplating a current vote. We let $\tilde{\mathbf{H}}$ and $\tilde{G}$ denote the law of motion of assets and the total labor-supply function, respectively, for these deviations; these functions have τ' as an argument. Therefore, consider the following problem for a given agent of type i who has wealth a:

$$\text{(A2)}\quad \tilde{v}_i(\mathbf{A}, \tau, \tau', a) = \max_{c,l,a'} u(c, l) + \beta v_i(\mathbf{A}', \tau', a') \text{ s.t.}$$

$$a' = a + (ar(K/N) + w(K/N)(1 - l)\varepsilon_i) \times (1 - \tau) + T - c$$

$$T = \tau(F(K, N) - \delta K)$$

$$\mathbf{A}' = \tilde{\mathbf{H}}(\mathbf{A}, \tau, \tau')$$

$$K = \sum_i \mu_i A_i$$

$$N = \tilde{G}(\mathbf{A}, \tau, \tau').$$

In this problem—where next period's tax rate is given, as opposed to determined by Ψ—it is important to note that next period's value function is given by the solution to (A1). The decision rules for (A2) are given by $a' = \tilde{h}(\mathbf{A}, \tau, \tau', a)$ and $l = \tilde{g}(\mathbf{A}, \tau, \tau', a)$. The equilibrium conditions for the deviation problem are $\tilde{H}_i(\mathbf{A}, \tau, \tau') = \tilde{h}_i(\mathbf{A}, \tau, \tau', A_i)$ and $\tilde{G}(\mathbf{A}, \tau, \tau') = \sum_i \mu_i(1 - \tilde{g}_i(\mathbf{A}, \tau, A_i))\varepsilon_i$ for all τ, τ', $\mathbf{A}$, and i.

Politico-Economic Equilibrium

Turning to the determination of Ψ, suppose that an agent i contemplates the effect of different tax rates for next period τ', given the family of $\tilde{\mathbf{H}}$ equilibria, on his realized utility. By construction, the indirect utility function $\tilde{v}_i$ can be used directly for this purpose. All the relevant effects of the tax rate τ' are incorporated into this function: the effect on next period's transfer and, via its effect on asset accumulation and distribution, on prices, transfers, and taxes in the future. For example, the agent perceives (correctly) that future taxes are given by τ', $\tau'' = \Psi(\tilde{\mathbf{H}}(\mathbf{A}, \tau, \tau'), \tau')$, $\tau''' = \Psi(\mathbf{H}(\tilde{\mathbf{H}}(\mathbf{A}, \tau, \tau'), \tau'), \Psi(\tilde{\mathbf{H}}(\mathbf{A}, \tau, \tau'), \tau'))$, and so on.

The highest utility achievable for an agent of type i then occurs for the tax rate that solves:

$$\text{(A3)}\qquad \max_{\tau'} \tilde{v}_i(\mathbf{A}, \tau, \tau', A_i).$$

We denote the solution to this problem $\psi_i(\mathbf{A}, \tau, A_i)$. This function returns the most preferred value for next period's tax rate of agent i, given that at all later dates the tax policy is given by the function Ψ.[29]

In our numerical computations, we verify that $\tilde{v}_i$ is single-peaked in τ' for all i. Based on this, a median-voter theorem applies, and with the three group distributions we consider, the median agent is always the middle group: this group is large, and has intermediate values both of labor efficiency and asset wealth. We refer to median-agent type with an m.

The fixed-point condition determining Ψ is thus:

$$\text{(A4)}\quad \Psi(\mathbf{A}, \tau) = \psi_m(\mathbf{A}, \tau, A_m) \text{ for all } \mathbf{A}, \tau.$$

Appendix B: Computation

Our procedure involves linear-quadratic approximations to solve for recursive equilibria for given policies (Ψ functions), and the median voter's problem is then solved given these equilibrium functions, again using linear-quadratic approximations. If the choice of the median voter coincides with the original Ψ function, an equilibrium is found; if not, we update and continue until convergence.

We are searching for a $I - 1$-dimensional subspace of steady states. We first choose a grid on the ratio of asset holdings between the different types of agents around the point of perfect equality. For each point on this grid, the search for a steady state involves a search for a

[29] Of course, this need not be a function, but since none of the discussion below depends on (A3) having a unique solution we use the simpler notation.

tax rate. The procedure for computing such a tax rate can be described as follows.

(i) Let $R_i^0(\mathbf{A}, \tau, \tau', a, a')$ be a quadratic function that approximates the utility function in a neighborhood of the steady state (note that the budget constraint has been used here to substitute out consumption). Guess on τ_0 as a value for the tax rate and compute the implied steady-state values of the other variables. This involves computing a value for aggregate capital with the property that the after-tax rate of return is the inverse of the discount rate.
(ii) Fix an initial affine tax policy Ψ^0.
(iii) Given Ψ_0, use standard methods to solve for the equilibrium elements h_i^0, $\mathbf{H}^0$, g_i^0, and G^0 as linear functions and v_i^0 as a quadratic function.
(iv) Solve for the one-period deviation equilibrium elements. Note that this is a simple static problem since we already have obtained functions v_i^0; the key difference is that in this case we do not use Ψ^0 as an update for next period's tax rate, instead leaving the dependence on τ' explicit. The application of a representative-type assumption on $\tilde{h}_i^0$, summing up of the $\tilde{g}_i^0$'s, and matrix inversion then deliver the equilibrium elements $\tilde{\mathbf{H}}^0$ and $\tilde{G}^0$.
(v) Substitute the decision rules and obtained equilibrium functions into the maximand in (A2) to obtain the function $\tilde{v}_i^0$.
(vi) Maximize $\tilde{v}_i^0$ with respect to τ' to obtain a function ψ_i^0 of the distribution of wealth and the own wealth of the agent. Check for the concavity of the function $\tilde{v}_i^0$ with respect to τ', ensuring that the first-order conditions deliver a maximum.
(vii) Use the representative-type condition on the median agent to obtain the function Ψ^1 by letting $\Psi^1(\mathbf{A}, \tau) \equiv \psi_m^0(\mathbf{A}, \tau, A_m)$.
(viii) Compare Ψ^1 to Ψ^0. If these functions are close enough, continue to (ix). If not, redefine Ψ^0 to be a linear combination of its old value and Ψ^1 and go back to step (iii). This updating procedure has been used before and it is necessary in our case for avoiding "overshooting" problems. We found that a very small step (less than 0.01 in the direction of Ψ^1) works best.
(ix) Verify that the policy function Ψ reproduces the conjectured tax rate. In other words, the following condition has to be verified:

$$\text{(B1)} \qquad \tau^0 = \tau^1 \equiv \Psi(\mathbf{A}, \tau^0).$$

If it is not, go back to step (i) and update the guess for τ. We update using $\tau_0 = (\tau_0 + \tau_1)/2$.

In our experiments we use two procedures to characterize the set of steady states. The first consists of performing steps (i) through (ix) described above. The second procedure, which is much simpler and less time-consuming, was already described in the description of the mechanics of the model. It is based on the knowledge that a zero tax and equal distribution constitute a steady state: by using the law of motion for the economy approximated around this point, one can compute the set of steady states by simply finding the set of values for A_1 and A_2 that are reproduced by this law of motion. Clearly this procedure is only strictly valid locally, and it is likely to give lower accuracy further away from the point of perfect equality. Finally, note that this procedure can also be applied to extend locally the set of steady states around any steady-state point found with the first procedure.

Appendix C: A Simple Example

Before we proceed to our quantitative analysis, let us illustrate the dynamics of the system by the use of linearization, similar to that which we describe in Appendix B and that which we use to compute equilibria numerically. For simplicity, let us also assume that leisure is not valued, i.e., that $\alpha = 1$. Consider a case when the type 2 group is only arbitrarily larger than the type 1 group, i.e., $\mu_1 = \mu_2 = 0.5$, and where the preference parameters are the following: the discount rate, β, is set at 0.96^4 (reflecting a four-year period), and we assume a constant relative risk aversion, σ, equal to 2. We assume a Cobb-Douglas production function with a labor share θ of 0.64, and we assume that the depreciation rate equals $1 - \delta = (1 - 0.08)^4 = 0.28$. Further, assume that the holdings of capital of each type are the same, and that the total capital stock equals that of the steady state with an exogenous tax rate of zero, which is approximately equal to 0.70 for this economy.

When we compute the linearized version of Ψ for this economy, we obtain

$$\Psi(A_1, A_2, \tau) = 3.953A_1 - 3.953A_2,$$

which equals 0 as long as the two types have the same capital stock. Furthermore, note that if $A_2 > (<) A_1$, there will be a negative (positive) current tax: if the median is richer (poorer), savings will be subsidized (taxed).

The law of motion of the economy can be described locally by the matrix

$$\mathbf{H} = \begin{pmatrix} 0.50 & 0.27 \\ -0.50 & 1.27 \end{pmatrix}.$$

This matrix applied to any initial deviation $(\Delta A_1, \Delta A_2)'$ from the zero-tax, equal-wealth steady state describes the deviation implied in the next period. It is straightforward to check that this matrix has one eigenvalue equal to one and one positive and less than one. The eigenvalue equal to one indicates the steady-state indeterminacy we expected, and the fact that the remaining eigenvalue is less than one says that the system is nonexplosive.

It is possible to use the **H** matrix to find the set of steady states in the neighborhood of the zero-tax steady state. It is given by the null space of **H**, or, equivalently, it can be calculated by substituting the obtained function Ψ into the rate-of-return equation (1) to yield

$$\frac{1}{0.85} = 1 + (0.64(0.5A_1 + 0.5A_2)^{0.36} - 0.28)(3.953A_1 - 3.953A_2).$$

Linearizing this expression and writing it in deviation form, we obtain

$$\Delta A_2 = 1.85\Delta A_1.$$

When taxes are exogenously set at zero, we know that the set of steady states is given by a line of slope $-\mu_1/\mu_2 = -1$. Here, in contrast, we see that the set of steady states with endogenous taxes slopes upward! The interpretation of this finding is that politics are quantitatively very powerful in this example. More to the point, the example has the property that the cost of distorting savings is low enough that the median voter finds it beneficial to use a high tax rate. This outcome depends, among other things, on the absence of a distortion of the labor-leisure choice.

It is also useful to compare the dynamics of our politico-economic equilibrium to that of the case with exogenous zero taxes. The law of motion in that case can be described by a matrix $\bar{\mathbf{H}}$, which satisfies

$$\tilde{\mathbf{H}} = \begin{pmatrix} 0.89 & -0.11 \\ -0.11 & 0.89 \end{pmatrix}.$$

Clearly, the local dynamics are also very different from when taxes are exogenous. In particular, an initial increase in, say, A_1 by one unit will trigger tax increases when type 2 is the median voter, and the economy will move away from the initial steady state. In the case taxes are exogenous, the dynamics following this initial change in type 1's capital are simple: the economy decumulates capital to get back to a new point on the line with slope -1, a point implying that type 1 is permanently richer than type 2 by one unit. What happens in the endogenous-tax economy in the long run? To find out, one can calculate $\mathbf{H}_\infty$, which when postmultiplied by any vector $(\Delta A_{10}, \Delta A_{20})'$ describes the long-run change, $(\Delta A_{1\infty}, \Delta A_{2\infty})'$, in the two capital stocks, i.e., $\mathbf{H}_\infty = \lim_{t\to\infty} \mathbf{H}^t$. In our example, we obtained

$$\mathbf{H}_\infty = \begin{pmatrix} -1.2 & 1.2 \\ -2.2 & 2.2 \end{pmatrix}.$$

The changes following initial changes in the asset distribution in this example are dramatic. If type 1 (2) is given 1 additional unit at time zero, the long-run response is for both types to decrease (increase) their capital stock by 2.2 units. The dynamic response takes us back to a new point on the positively sloped steady-state line, but we are now far away from the initial equal-capital point. The relative distribution remains intact throughout time: the type given an additional unit will remain richer indefinitely.

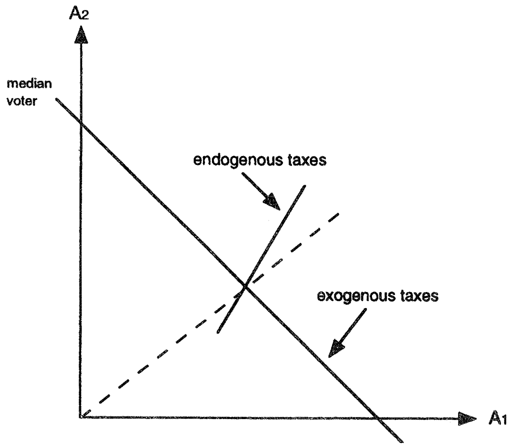

FIGURE C1. ILLUSTRATION OF THE LINEARIZED SET OF POLITICO-ECONOMIC STEADY STATES

We see that at least in this example, the capital accumulation path fundamentally changed with a small change in the initial distribution of capital. Again, the magnitudes in this example are exaggerated due to the absence of a labor-leisure choice. Figure C1 illustrates these experiments.

REFERENCES

Aiyagari, S. Rao. "Uninsured Idiosyncratic Risk and Aggregate Saving." *Quarterly Journal of Economics*, August 1994, *109*(3), pp. 659–84.

Aiyagari, S. Rao and Gertler, Mark. "Asset Returns with Transactions Costs and Uninsured Individual Risk." *Journal of Monetary Economics*, June 1991, *27*(3), pp. 311–31.

Alesina, Alberto and Rodrik, Dani. "Distributive Politics and Economic Growth." *Quarterly Journal of Economics*, May 1994, *109*(2), pp. 465–90.

Auerbach, Alan J and Kotlikoff, Laurence J. *Dynamic fiscal policy*. New York: Cambridge University Press, 1987.

Bertola, Giuseppe. "Factor Shares and Savings in Endogenous Growth." *American Economic Review*, December 1993, *83*(5), pp. 1184–98.

Boyd, John H., III. "The Existence of Steady States in Multisector Capital Accumulation Models with Recursive Preferences." *Journal of Economic Theory*, October 1996, *71*(1), pp. 289–97.

Caselli, Francesco and Ventura, Jaume. "A Representative Consumer Theory of Distribution." Massachusetts Institute of Technology, Working Paper No. 96/11, April 1996.

Chamley, Christophe. "Optimal Taxation of Capital Income in General Equilibrium with Infinite Lives." *Econometrica*, May 1986, *54*(3), pp. 607–22.

Chatterjee, Satyajit. "Transitional Dynamics and the Distribution of Wealth in a Neoclassical Growth Model." *Journal of Public Economics*, May 1994, *54*(1), pp. 97–119.

Cooley, Thomas F. *Frontiers of business cycle research*. Princeton, NJ: Princeton University Press, 1995.

Cubeddu, Luis Manuel. "The Role of Household Composition, Formation and Dissolution in Life Cycle Economies: Theory and Evidence." Ph.D. dissertation, University of Pennsylvania, 1995.

Denzau, Arthur T. and Mackay, Robert J. "Structure-Induced Equilibria and Perfect-Foresight Expectations." *American Journal of Political Science*, November 1981, *25*(4), pp. 762–79.

Díaz-Gimenez, Javier; Prescott, Edward C.; Alvarez, Fernando and Fitzgerald, Terry J. "Banking in Computable General Equilibrium Economies." *Journal of Economic Dynamics and Control*, July 1992, *16*(3–4), pp. 533–59.

Díaz-Gimenez, Javier; Quadrini, Vincenzo and Ríos-Rull, José-Víctor. "Dimensions of Inequality: Facts on the U.S. Distributions of Earnings, Income, and Wealth." *Federal Reserve Bank of Minneapolis Quarterly Review*, Spring 1997, *21*(2), pp. 3–21.

Epple, Dennis N. and Kadane, Joseph B. "Sequential Voting with Endogenous Voter Forecasts." *American Political Science Review*, March 1990, *84*(1), pp. 165–75.

Glomm, Gerhard and Ravikumar, Balasubrahmanian. "Public versus Private Investment in Human Capital: Endogenous Growth and Income Inequality." *Journal of Political Economy*, August 1992, *100*(4), pp. 813–34.

Greenwood, Jeremy; Hercowitz, Zvi and Huffman, Gregory W. "Investment, Capacity Utilization, and the Business Cycle." *American Economic Review*, June 1988, *78*(3), pp. 402–17.

Grossman, Gene M. and Helpman, Elhanan. "Intergenerational Redistribution with Short-Lived Governments." *Economic Journal*, September 1998, *108*(450), pp. 1299–329.

Huggett, Mark. "The Risk-Free Rate in Heterogeneous-Agent Incomplete-Insurance Economies." *Journal of Economic Dynamics and Control*, September–November 1993, *17*(5–6), pp. 953–69.

______. "The One-Sector Growth Model with Idiosyncratic Shocks: Steady States and Dynamics." *Journal of Monetary Economics*, August 1997, *39*(3), pp. 385–403.

İmrohoroğlu, Ayse. "The Cost of Business Cycles with Indivisibilities and Liquidity Constraints." *Journal of Political Economy*, December 1989, *97*(6), pp. 1364–83.

Killingsworth, Mark R. and Heckman, James J. "Female Labor Supply: A Survey," in Orley Ashenfelter and Richard Layard, eds., *Handbook of labor economics*, Vol. 1. Amsterdam: North-Holland, 1986, pp. 103–204.

Knowles, John. "Measuring Lifetime Income Inequality." Working paper, University of Pennsylvania, 1999.

Kotlikoff, Laurence J. and Summers, Lawrence H. "The Role of Intergenerational Transfers in Aggregate Capital Accumulation." *Journal of Political Economy*, August 1981, *89*(4), pp. 706–32.

Krusell, Per; Quadrini, Vincenzo and Ríos-Rull, José-Víctor. "Politico-Economic Equilibrium and Economic Growth." *Journal of Economic Dynamics and Control*, January 1997, *21*(1), pp. 243–72.

Krusell, Per and Ríos-Rull, José-Víctor. "What Constitutions Promote Capital Accumulation? A Political Economy Approach," W. Allen Wallis Institute of Political Economy Working Paper No. 1, 1994.

______. "Vested Interests in a Positive Theory of Stagnation and Growth." *Review of Economic Studies*, April 1996, *63*(2), pp. 301–29.

______. "The Effect of the Wealth Distribution on Aggregate Activity." Notes, University of Rochester, 1997.

McKee, Michael J.; Visser, Jacob C. and Saunders, Peter G. "Marginal Tax Rates on the Use of Labour and Capital in OECD Countries." *OECD Economic Studies*, Autumn 1986, (7), pp. 45–101.

Meltzer, Alan H. and Richard, Scott F. "A Rational Theory of the Size of Government." *Journal of Political Economy*, October 1981, *89*(5), pp. 914–27.

Pencavel, John H. "Labor Supply of Men: A Survey," in Orley Ashenfelter and Richard Layard, eds., *Handbook of labor economics*, Vol. 1. Amsterdam: North-Holland, 1986, pp. 3–102.

Perotti, Roberto. "Political Equilibrium, Income Distribution, and Growth." *Review of Economic Studies*, October 1993, *60*(4), pp. 755–76.

Persson, Torsten and Tabellini, Guido. "Is Inequality Harmful for Growth?" *American Economic Review*, June 1994, *84*(3), pp. 600–21.

Ríos-Rull, José-Víctor. "Life-Cycle Economies and Aggregate Fluctuations." *Review of Economic Studies*, July 1996, *63*(3), pp. 465–89.

Saint-Paul, Gilles and Verdier, Thierry. "Education, Democracy and Growth." *Journal of Development Economics*, December 1993, *42*(2), pp. 399–407.

Sarte, Pierre-Daniel G. "Progressive Taxation and Income Inequality in Dynamic Competitive Equilibrium." *Journal of Public Economics*, October 1997, *66*(1), pp. 145–71.

Stokey, Nancy L. "Shirtsleeves to Shirtsleeves: The Economics of Social Mobility." Nancy L. Schwartz Lecture, Northwestern University, 1996.