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POLITICO-ECONOMIC EQUILIBRIUM AND ECONOMIC GROWTH

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1. INTRODUCTION

Recent research on the subject of economic growth emphasizes models where growth outcomes vary in a more drastic way with underlying preference and technology parameters than in the standard Solowian growth model. Usually, this has been expressed by letting the long-run growth rate be nontrivially determined. The new theories also imply a dramatic increase in the scope for economic policy to affect the economy. The view taken in this paper is that as the role for policy increases, it becomes all the more important to study how the policies themselves are determined in the economies under study. Put differently, in order to understand the uneven growth records around the world and over time, it is perhaps insufficient to show that differences in policies are likely causes, because this only begs the follow-up question: "Why, then, are the low-growth policies chosen?".

It is likely that the political considerations behind policy determination fundamentally have economic determinants. Aside from pure redistributional issues, almost all policies in practice affect different agents differently. For example, if tax rates on capital income are proportional, then they *de facto* redistribute income from agents with high wealth to agents with low wealth. It is clear that when the tax code is such that taxes on income from physical or human capital have a differential impact within the population, then the characteristics of agent heterogeneity will, via the political process, likely be an important factor for economic growth. This is indeed the perspective taken in this paper and in a series of recent contributions starting with Alesina & Rodrik (1994) and Persson

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& Tabellini (1994). More broadly, in the context of understanding economic growth and development, politico-economic theory is about understanding the process determining policies which affect human and physical capital accumulation, R&D, etc., and a key part of this process involves the economics of tracing out the differential impact of these policies. Although this research program is exclusively positive at this stage, the hope is that politico-economic theory may ultimately also help design institutions and rules that are conducive to "good" growth policies.

In this paper we propose a general recursive framework which allows us to deal with a conceptual problem which is present when economic policy is chosen sequentially, namely, how agents' political preferences are formed. Our equilibrium definition is based on earlier work in Krusell & Ríos-Rull (1992), where we described agents' policy preferences as derived in a fully forward-looking and rational way by tracing out all the current and future political and economic equilibrium effects of changing the policy currently to be chosen. We then use a specific model economy, the externality-based growth model of Romer (1986), to show how changes in the initial wealth distribution give rise to changes in the long-run growth rates in the politico-economic equilibrium. This demonstration makes a sharp point about the importance of policy endogeneity, since changes in the initial wealth distribution can have no effect on the long-run growth rate if the policy is treated as exogenous.

We also relate our way of thinking about dynamic policy determination to some existing literature. First, we point out that there is a connection to the issue of time-consistency of optimal plans: a government/planner who wants to choose an optimal policy plan is in a similar situation to that which our voters are in. The similarity has two parts, one of which being the problem of how at all to think about what will happen in the future in response to a certain current policy choice (provided future policies cannot be committed to today). The other part is that in our economy, as in many others, unrestricted optimal plans are inherently time-inconsistent: even if the politically pivotal agent is the same agent at each point in time, this agent will want to change plans in the future. Our politico-economic equilibria are time-consistent, i.e. they have the property that agents' preferences are formed by thinking about future policies as they would indeed occur.

Second, we use our framework to discuss some existing dynamic models with voting which have been applied to study economic growth. More precisely, we explain how the equilibrium concepts employed in those models relate to ours, and we use our example economy to illustrate the differences quantitatively. We identify three approaches. The first approach is consistent with our notion of politico-economic equilibrium, and it is represented e.g. by Persson & Tabellini (1994), Perotti (1993), Glomm & Ravikumar (1992), Krusell & Ríos-Rull (1993), and Saint-Paul & Verdier (1992). Some of these papers build on models with dynamics which do not require voters to be forward-looking. We show in particular how the setup in Persson & Tabellini (1994) can be mapped into our general framework, and we point to the key assumptions in that model which allow the equilibrium to be computed analytically.

A second approach, which has been used in Alesina & Rodrik (1994) and in Bertola (1993), is to assume that taxes are voted on at time zero only, and that they are required to be constant over time. We argue that it is difficult to justify this assumption. First, if there is commitment, the chosen tax sequence would not involve constant taxes, but instead a very high initial (distortionary) tax and redistributive transfer, with a subsequent reversion to Pareto-efficient taxation. Second, when there is no commitment, the chosen tax policies need to be time-consistent, and we show in our example that although the linear growth environment leads to politico-economic equilibria with constant taxes, the time-consistency requirements implicit in this equilibrium makes these taxes much higher than those calculated by choosing a constant sequence at time zero.[1]

Finally, we compare our politico-economic equilibria to a third approach, one which assumes that voters who contemplate a change in a current policy are myopic in a certain sense: voters are assumed to think that a change in current policy will not affect future policy. We argue that if the median voter is myopic and poorer than average, he will choose a lower tax, and the economy will experience higher growth, than if he would correctly predict future policy changes. This is because an increase in taxes will lead to less income dispersion in the future, which amounts to a net current benefit due to lower future tax distortions. We also show the quantitative amount by which the politico-economic equilibrium tax rates differ from those resulting in models with myopic voters in the context of our example economy.

The literature on policy determination in dynamic models not only has to deal with the difficult issue of how to derive time-consistent policy preferences. It also inherits a problem of the existing political theory: given a population and given preferences in this population over some policy vector, there are few general insights about the properties of a "reasonable" process for aggregating these preferences into a policy outcome.[2] However important, we do not attempt to solve this problem: given a set of agents and a set of (derived) preferences over a policy vector, we simply take as an input into our analysis a constitution in the form of a political aggregator mapping the set of agents and their preferences into a policy outcome. Because we do not restrict the type of aggregator, our general framework is not limited other than by the best

[1] We say much higher as opposed to much lower because we assume that the median voter has below-average wealth.

[2] For example, the median-voter theorem delivers a certain type of aggregation: there exists an agent—who has a median level of some parameter underlying the differences in preferences over policies—whose preferred policy would win in any pairwise vote among policies, and therefore this agent's preferred policy is one reasonable way to aggregate preferences. However, for most populations and preferences, the pairwise voting procedure can give rise to cyclical votes (policy A defeats policy B, which defeats policy C, which in turn defeats policy A), and the median-voter theorem does not hold.

available political theory.

The outline of the paper is as follows. In Section 2 we first formulate a general framework capable of nesting a set of models with agent heterogeneity and with endogenous policy selection. We then apply our definition of politico-economic equilibrium to the endogenous-growth example in Section 2.2. In this context we point out that the median voter does not change over time, so it is relevant to ask what this agent would prefer were he to choose a sequence of taxes already at time zero. We refer to this problem as the Ramsey problem, which we analyze in Section 2.2.3. This analysis is useful for understanding the connection to the time-consistency literature. In Section 3 we then discuss some of the other setups in the recent literature on endogenous policy in dynamic models. Section 4 concludes.

2. THE POLITICO-ECONOMIC MODEL

In Section 2.1 we first describe the politico-economic setup using a neoclassical model of growth. This setup is fairly general, and in particular it encompasses our earlier structures in Krusell & Ríos-Rull (1992) and in Krusell & Ríos-Rull (1993). The first of these papers was concerned with regulatory policy, and it showed how technological innovation and growth may move in cycles in response to technology-related vested interests inherent in the skill distribution. The second paper focused on income taxation in the context of the standard Solowian growth model, and it showed that small redistributions can have large long-run effects due to the endogeneity of taxes. That paper also explored different constitutional environments with regard to the progressivity of taxes and the frequency of the vote. Our present framework is tailored more toward determining tax rates than regulatory policy, but it should be pointed out that any dynamic politico-economic equilibrium model with sequential voting and fully rational agents should be conceptually close to the setup we present here.

The general framework is specialized in Section 2.2 and applied to a particular case with infinitely-lived agents which allows endogenous growth. We use this environment to derive the typical politico-economic implications relating the distribution of wealth, via taxes, to economic growth. We finally make some comments in Section 2.3 on the connection between our analysis and that in the time-consistency literature.

2.1. The Setup

We use a representation of our model which nests two interdependent parts. The first part involves the problem of finding a competitive equilibrium given a law of motion for policies, and the second part involves the political equilibrium problem of making the law of motion for policies consistent with that coming out of the political process. We thus first postulate that the economic agents take as given a law of motion for the policy variables in the form of a policy outcome function Ψ mapping the state variable of the economy into a policy outcome. We take the state variable to be the distribution of asset holdings, A, possibly together with a policy which was determined in the previous period but which goes into effect in the current period and thus has a direct effect on current behavior.[3] For each given such law of motion a recursive competitive equilibrium can then be derived in the form of a law of motion of the state variables of the economy. This step is a standard fixed-point problem: the behavior of the agents has to be consistent with the aggregate behavior they take as given when solving their maximization problems. We describe this part in Section 2.1.1.

In Section 2.1.2 we then employ the equilibrium characterization implicit in Section 2.1.1, namely, how different policies give rise to different equilibrium paths, in order to derive agents' preferences over policies: an agent prefers one set of policies over another set if it gives rise to an equilibrium with higher utility than the alternative. These induced preferences over policies are then aggregated with an abstract aggregator in order to determine the chosen policy. This aggregator can take many different forms, and we discuss a number of possibilities.

The final fixed-point problem is to make sure that the law of motion for policies underlying the determination of the economic equilibria is reproduced by the political selection of policies. In this sense, of course, the two layers of equilibria are typically not independent: economic equilibria depend on the law of motion for the policy variable taken as given by the agents; and policy preferences and policy determination depend on the law of motion for the state variable determined as economic equilibria. We describe the policy determination and the full definition of equilibrium at the end of Section 2.1.2.

To motivate the kind of equilibria we are looking at, let us now describe in some detail how we view agents as thinking in their evaluation of policies. First, it is a crucial aspect of all the present analysis that policy preferences are derived, and not just postulated: the agent thinks through the equilibrium effects of the various policy alternatives, and thus forms a preference relation over the different alternatives.

Second, we view the political system as not being able to commit to future policies, so we are interested in policies that are chosen sequentially. This means that we will need to derive agents' preferences over the policies currently to be chosen, as opposed to over entire sequences of policies. Consequently, agents need to think about the equilibrium consequences of each given policy choice today. We can distinguish two kinds of the competitive equilibria on these grounds: those which will occur as outcomes—and where the policy is always given by the function Ψ—and those which will not occur, but which

[3] The restriction to Markovian equilibria, i.e. the assumption that policies are a function of the current state only is important; if we allow policies to depend on histories of past policy choices, the set of equilibria can typically be expanded in a manner parallel to that described in Chari & Kehoe (1990); see Section 2.3 below.

the agents nevertheless need to think about to form their policy preferences. The latter equilibria will then be "one-period deviations" from the equilibria which will be outcomes: they involve an arbitrary policy today, but take the policies in the future periods to be given by the function Ψ: if a policy change today makes the aggregate state next period equal A', then tomorrow's policy outcome will be $\Psi(A')$. Thus, if Ψ is part of a politico-economic equilibrium, our voters will correctly predict how future policies change in response to a change in policy today.

In the next subsection we describe economic equilibria given a policy outcome function. We describe separately those equilibria which will be outcomes, where the policy is always given by Ψ, and those which will not be outcomes, where the policy is arbitrary today and given by Ψ in all future periods. After that, we move on to the determination of policies.

2.1.1. Economic equilibria for given policy

We assume that the population consists, at any point in time, of a finite number of types of agents. We index the agent type by $ij \in \mathcal{T}$. The type index thus has two parts. One part, i, indicates age. Second, agents of the same age may differ in wealth holdings or labor efficiency, and the wealth/labor efficiency type is indexed by j.[4,5] We think of there being a finite number of types, but a large number of agents of each type. The population measures are denoted μ_{ij} with $\sum_{ij\in\mathcal{T}} \mu_{ij} = 1$. The endowment of time of each agent is 1, and the efficiency of this unit of time of an agent of type ij is denoted ϵ_{ij}.

We assume that the preferences are additively time-separable and equal across agents of the same age, with discount factors β and period utility functions $u_i(c,l)$, where c is consumption and l is leisure. If, say, we are looking at an infinitely-lived agent model, then $u_i(c,l) = u(c,l)$, whereas a two-period-lived overlapping-generations model would have $u_i(c,l) = 0$ for $i \geq 3$. We use $\bar{N}$ to denote the total amount of efficiency units of labor used in production, i.e. $\bar{N} = \sum_{ij\in\mathcal{T}} \mu_{ij}\epsilon_{ij}(1 - l_{ij})$.

Let a be a scalar denoting the current holdings of assets of a given agent, and let A be a vector of economy-wide asset holdings for all types of agents, i.e. A has dimensionality equal to the number of elements in $\mathcal{T}$. We let $\bar{A}$ denote the aggregate amount of assets: $\bar{A} = \sum_{ij\in\mathcal{T}} \mu_{ij} A_{ij}$.

Production on the firm level in our economy takes place according to a production function f which takes as inputs capital and labor, and which in addition as in Romer

[4]Agents of the same type will always make the same choices in the equilibria we consider here, and therefore they do not change types. Furthermore, all agents of a given age with labor endowment of type j will have the same wealth level in the economies we consider, so it is sufficient to use the index j.

[5]In the context of an overlapping-generations economy, young agents enter the economy without asset holdings.

(1986) is influenced by an externality from the aggregate amount of capital. Thus, if k and n are the capital and labor inputs on the firm level, the firm-level output is $f(k, n, \bar{k})$, with $\bar{k}$ denoting the aggregate capital stock, and we assume that f is concave and homogeneous of degree one in its two first arguments. Note that since in our economy $\bar{k}$ has to equal $\bar{A}$, aggregate production in this economy is $f(\bar{A}, \bar{N}, \bar{A})$. Output can divided up one-for-one into consumption or additions to the stock of capital, and capital depreciates with a constant geometric rate of depreciation δ.

Our policy vector is denoted by π, and in the present economy we let it consist of the tax rates on labor and/or capital income, τ_k and τ_l, respectively. Because the general-equilibrium political-economy models typically have a trade-off between efficiency and redistribution in the mind of every agent who compares policies, we take the policy to be chosen in the current period to be π', i.e. next period's taxes. We restrict π to the set Π, and this set is an important part of the fiscal constitution: it specifies what values are feasible for the policy vector. In general, Π could contain any set of current and future taxes which can be committed to.

Throughout we will focus on recursive equilibria where the state variables of the economy consist of A and last period's policy decision, π. Note that π has separate economic significance, since both the transfers and the net-of-tax income which agents receive are relevant in order to determine the relative wealth levels in the population.

We assume in this section that the policy vector follows the law of motion

$$\pi' = \Psi(A, \pi).$$

We refer to Ψ as the policy outcome function: it describes, when the current distribution of asset holdings across types is given by A and last period's policy choice is given by π, what the current policy choice will be. In this subsection, we will take the policy outcome function as given, and equilibria are defined given this function. We now describe each of the equilibria we need to consider in turn.

A. Equilibria which will be outcomes

We state the consumer's problem given the policy outcome function Ψ. Any function with Ψ as an explicit argument is an equilibrium function which depends on the Ψ at hand. An agent of type ij thus solves

$$v_{ij}(A, a, \pi; \Psi) = \max_{c, a', l} \{u_i(c, l) + \beta v_{i+1,j}(A', a', \pi'; \Psi)\}$$

subject to

$$c + a' = ar(1 - \tau_k) + a + w\epsilon_{ij}(1 - l)(1 - \tau_l) + tr_i,$$

$$A' = H(A, \pi; \Psi),$$

$$\bar{N} = N(A, \pi; \Psi),$$

$$r = r(A, \bar{N}),$$
$$w = w(A, \bar{N}),$$
$$tr_i = \nu_i tr(A, \bar{N}, \pi),$$
$$\pi' = \Psi(A, \pi),$$

where π is taken to equal (τ_k, τ_l). The function H describes the law of motion for A, and $\bar{N}$ is aggregate labor input. Rental rates and wages are denoted r and w, respectively, and tr_i denotes the transfer to an agent of age i.

We denote the solution to this problem with the functions

$$a' = h_{ij}(A, a, \pi; \Psi),$$

and

$$l = l_{ij}(A, a, \pi; \Psi).$$

The pricing functions are standard; they satisfy

$$r(A, \bar{N}) = f_1(\bar{A}, \bar{N}, \bar{A}) - \delta$$
$$w(A, \bar{N}) = f_2(\bar{A}, \bar{N}, \bar{A}),$$

and the tr function is feasible, i.e. such that

$$tr(A, \bar{N}, \pi) = \tau_k \bar{A}(r - \delta) + \tau_l \bar{N} w.$$

The fraction of the total tax bill transferred to each age group is denoted ν_i, with $\sum_{ij \in \mathcal{I}} \mu_{ij} \nu_i = 1$. We regard the ν vector as a second part of our fiscal constitution, i.e. this vector is given and not voted upon. The fiscal aspects of a constitution can therefore be summarized by (i) Π, i.e. what policy vectors are feasible to be chosen in the political process; and (ii) the ν vector, i.e. where the transfers go.

For a given fiscal constitution, we are now ready to define equilibrium outcomes resulting from a law of motion for policies given by Ψ.

Definition: *For a given fiscal constitution (Π, ν), a recursive equilibrium given the policy function Ψ is a set of individual functions v_{ij}, h_{ij}, and l_{ij} solving the agent's problem; a set of aggregate functions H, N that are consistent with those of the individuals when evaluated at economy-wide values, i.e.*

$$H_{1j}(A, \pi; \Psi) = 0 \quad \forall j, A, \pi,$$

$$H_{i+1,j}(A, \pi; \Psi) = h_{ij}(A, A_{ij}, \pi; \Psi) \quad \forall j, A, \pi, i \geq 1,$$

and

$$N(A, \pi; \Psi) = \sum_{ij \in \mathcal{I}} \mu_{ij} \epsilon_{ij} \left(1 - l_{ij}(A, A_{ij}, \pi; \Psi)\right) \quad \forall A, \pi;$$

and a set of pricing and transfer functions r, w, and tr as defined above.

B. Equilibria which will not be outcomes

We now study those equilibria which agents need to think about in order to evaluate alternative values of the policies, i.e. values that do not satisfy $\pi' = \Psi(A, \pi)$. The goal in here is thus to define equilibria when the current policy vector π' takes on any value and when policies in the future are given by those generated as outcomes through the function Ψ.

The agent's problem therefore becomes

$$\tilde{v}_{ij}(A, a, \pi, \pi'; \Psi) = \max_{c, a', l} \{u_i(c, l) + \beta v_{i+1,j}(A', a', \pi'; \Psi)\}$$

subject to

$$\begin{aligned} c + a' &= ar(1 - \tau_k) + a + w\epsilon_{ij}(1 - l)(1 - \tau_l) + tr_i, \\ A' &= \tilde{H}(A, \pi, \pi'; \Psi), \\ \bar{N} &= \tilde{N}(A, \pi, \pi'; \Psi), \\ r &= r(A, \bar{N}), \\ w &= w(A, \bar{N}), \\ tr_i &= \nu_i tr(A, \bar{N}, \pi), \end{aligned}$$

where tildes are used to distinguish the equilibrium functions from those associated with policy vectors consistent with Ψ. Note that the tilde functions include the current policy vector π' as an explicit argument.

It is important to note that the end-of-period indirect utility of wealth in the agent's problem is given by $v_{i+1,j}$, i.e. by that indirect utility which is an actual outcome for the state vector (A', a', π'). The equilibria in this section can hence be viewed as one-period-deviations from the recursive equilibria that describe actual outcomes and that were described in the previous section.

We denote the agent's decision rules with the functions

$$a' = \tilde{h}_{ij}(A, a, \pi, \pi'; \Psi)$$

and

$$l = \tilde{l}_{ij}(A, a, \pi, \pi'; \Psi),$$

and the pricing functions are defined as above.

We can now state

Definition:

For a given fiscal constitution (Π, ν), an equilibrium where the current policy vector is given by π' and all future periods' policy vectors given by Ψ is a set of functions

v_{ij}, h_{ij}, l_{ij}, H, N, r, w, and tr satisfying Definition 2.1.1 together with the individual functions $\tilde{v}_{ij}$, $\tilde{h}_{ij}$, and $\tilde{l}_{ij}$ solving the agent's problem; and aggregate functions $\tilde{H}$ and $\tilde{N}$ consistent with the corresponding individual functions when evaluated at economy-wide values, i.e.

$$\tilde{H}_{1j}(A, \pi, \pi'; \Psi) = 0 \quad \forall j, A, \pi, \pi'$$

$$\tilde{H}_{i+1,j}(A, \pi, \pi'; \Psi) = \tilde{h}_{ij}(A, A_{ij}, \pi, \pi'; \Psi) \quad \forall j, A, \pi, \pi', i \geq 1$$

and

$$\tilde{N}(A, \pi, \pi'; \Psi) = \sum_{ij \in \mathcal{T}} \mu_{ij} \epsilon_{ij} \left(1 - \tilde{l}_{ij}(A, A_{ij}, \pi, \pi'; \Psi)\right) \quad \forall A, \pi, \pi'.$$

We are now ready to describe how policies are chosen.

2.1.2. Determination of policies

Given the economic equilibria as characterized by Definition 2.1.1, it is now straightforward to proceed to the formation of policy preferences. The key object we use is the indirect utility function $\tilde{v}_{ij}$: its dependence on π' is what allows us to trace out any given agent's derived utility over π'. In particular, when the aggregate state is (A, π), the preferred policy of an agent of type ij with asset holdings A_{ij} is

$$\psi_{ij}(A, A_{ij}, \pi; \Psi) \equiv \arg\max_{\pi' \in \Pi} \tilde{v}_{ij}(A, A_{ij}, \pi, \pi'; \Psi),$$

where we assume for simplicity that there are no ties.

Turning to the political aspects of the constitution, we assume that the political outcome π' is generated in a political process which we do not model in any detail, and which we simply denote by an aggregator function $\mathcal{A}$; this function aggregates, at each given economy-wide state, the induced policy preferences into an outcome:

$$\pi' = \mathcal{A}(A, \tilde{v}),$$

where we use $\tilde{v}$ for the vector of derived policy preferences over the variable π'; it is implicit that the preferences of an agent of type j are evaluated at (A, A_{ij}, π), and that π is restricted to belong to Π. The aggregator $\mathcal{A}$ thus takes the wealth distribution and individual preferences into a chosen policy. The reason why the aggregator may depend separately on A is that one may want to consider "political power" as being income- or wealth-weighted. As discussed briefly in the introduction, finding an aggregator which does not give rise to cycles in pairwise voting contests or which is not unattractive in other ways is difficult in general. When there is only one policy parameter to vote over, and when the derived preferences are single-peaked in this policy parameter, the median-voter theorem applies, but this is a restrictive set of circumstances. Since we do not restrict the form of $\mathcal{A}$, our analysis stretches as far as does the best available political theory. Furthermore, particular applications may also reveal that the median voter is a reasonable aggregator even though single-peakedness is violated globally: single-peakedness is not a necessary condition for ruling out cycles in pairwise voting constests. Given that our approach is computational in nature, it is always possible to determine this numerically.

We are now ready to define our politico-economic equilibrium:

Definition: *Given a fiscal constitution* (Π, ν) *and a political constitution* $\mathcal{A}$*, a politico-economic equilibrium is a function* Ψ*, together with a set of functions* v_{ij}*,* h_{ij}*,* l_{ij}*,* H*,* N*,* r*,* w*,* tr_{ij}*,* $\tilde{v}_{ij}$*,* $\tilde{h}_{ij}$*,* $\tilde{l}_{ij}$*,* $\tilde{H}$ *satisfying Definition 2.1.1 and such that at each aggregate state* (A, π) *the policy outcome reproduces the function* Ψ*:*

$$\Psi(A, \pi) = \mathcal{A}(A, \tilde{v}).$$

This final fixed point condition is nontrivial in that the policy determination itself depends on the policy outcome function (via the dependence of $\tilde{v}$ on Ψ), which in turn requires the study of a whole class of dynamic equilibria. Our description of the equilibrium notion is now completed, and we proceed to look at an application.

2.2. Politics and Growth: A Simple Example

In this section we make use of our definition of politico-economic equilibrium to compute tax and growth outcomes for a simple, but nontrivial, economy: the externality-based growth model of Romer (1986) with income taxes determined by the median voter. This economy is simple in the sense that if taxes are constant over time, then the economy's output, consumption, and total and individual holdings of capital will all grow at a constant rate independently of the initial level and distribution of capital. A first question is: will this hold true when taxes are endogenous? It should be clear from the previous section that this question is not easy to answer: even though taxes may end up being constant in a politico-economic equilibrium, to support such an outcome it is necessary to analyze how the voters compare it to each possible alternative, i.e. the voter needs to think through all the implied alternative paths for taxes and prices.

We will use numerical techniques to show that, indeed, taxes as well as growth rates in this economy are constant along a politico-economic equilibrium path, independently of initial conditions. In Section 2.2.3 we then compare this outcome to what we label the Ramsey problem. The Ramsey problem asks what taxes would be chosen if the median voter could choose an entire sequence of taxes at time zero. Given our findings, namely, that the Ramsey solution consists of a plan which is not time-consistent, Section 2.3 is devoted to a brief discussion of the connection between our analysis and the results in the literature on time-consistency.

2.2.1. The capital-externality model with infinitely-lived agents

Turning first to the description of the example economy, assume that agents are infinitely-lived, which allows us to drop the subscript i, that agents have constant relative risk aversion utility for consumption, and that leisure does not generate utility: $u_i(c,l) = u(c) = \frac{c^{1-\sigma}-1}{1-\sigma}$, with $\sigma > 0$. Moreover, there are only two types of agents, so $\mathcal{T} = \{1,2\}$ and $A = (A_1, A_2)$. We assume that the agents do not differ in labor productivity, i.e. $\epsilon_1 = \epsilon_2$, and for simplicity we set $\mu_1 = \mu_2$.[6]

The production function is of a simple form:

$$f(k,n,\bar{k}) = k^{\alpha} n^{1-\alpha} \bar{k}^{1-\alpha},$$

and it allows sustained growth, since its aggregate form is linear in aggregate capital. It is well-known that, in the absence of taxes, the competitive equilibrium growth rate in this type of economy is $(\alpha \bar{N}^{1-\alpha} + 1 - \delta)^{1/\sigma} \beta^{1/\sigma}$, and that the optimal growth rate is higher: $(\bar{N}^{1-\alpha} + 1 - \delta)^{1/\sigma} \beta^{1/\sigma}$.

Our policy vector is very simple; let $\Pi \equiv \{(\tau'_k, \tau'_l) \in \mathbf{R}^2_+ : \tau'_k = \tau'_l\}$. In other words, each period agents vote on a common tax rate on capital and labor income for the following period. This way, the tax distorts savings behavior; the tradeoff in forming preferences over policies will then be between the net transfer and the costs of distortion.[7] Note that in this case, Ψ needs to depend on τ, since what matters is not A alone, but initial income net of taxes and transfers.

With only two types of agents, it is reasonable to use as a political aggregator the agent with median wealth level, which in this case means the most numerous type. We thus define agents of type 2 to be median voters: $\mathcal{A}(A, \tilde{v}) \equiv \arg\max_{\tau'} \tilde{v}(A, A_2, \tau, \tau'; \Psi)$.

Before we go on to the characterization of equilibria, let us point out as a background that the version of our economy in which taxes are exogenous has the property that the distribution of wealth does not influence, nor is it influenced by, the capital accumulation path.[8] Any effect on either capital accumulation or the evolution of the wealth distribution is hence solely a result of the endogeneity of policy.

2.2.2. Model solution

Even though the dynamics are comparatively simple in this endogenous-growth setup, the equilibrium is fully forward-looking, and equilibria can only be solved for explicitly for special cases of the policy outcome function Ψ. It is possible to show that when

[6] The assumption of equally-sized groups was made entirely for notational purposes, and it plays no role in the arguments below.

[7] If the policy choice concerned the current tax rate, the policy preference would be degenerate, given that income taxes are non-distortionary ex post when leisure is not valued.

[8] See Krusell & Ríos-Rull (1993) for an exposition.

there is initial wealth equality, or when the median wealth level equals the average wealth level, then the politico-economic equilibrium is characterized by tax rates that offset the effect of the externality at all dates, leading to a Pareto optimum: since there is no net gain in redistribution for the median voter, taxes are set to minimize distortions.[9]

For unequal wealth distributions, we can approximate the key equilibrium function $\Psi(A,\tau)$. We thus postulate a guess, Ψ^0, and solve for the economic equilibria associated to this guess: $H(A,\tau;\Psi^0)$, $\tilde{H}(A,\tau,\tau';\Psi^0)$, $v(A,a,\tau;\Psi^0)$, and $\tilde{v}(A,a,\tau,\tau';\Psi^0)$. Finally, $\arg\max_{\tau'} \tilde{v}(A,A_2,\tau,\tau';\Psi^0)$ can be evaluated for each (A,τ); if it coincides with Ψ^0, then a politico-economic equilibrium has been found. If not, then a new guess Ψ^1 is constructed on the basis of the initial guess and the preferences of the median voter given the initial guess, and the process is repeated until convergence.[10]

The results are as follows: political-equilibrium tax rates are constant, independently of the initial wealth distribution. Hence, and this is no surprise, growth is constant from time zero on. Figures 1 and 2 describe the findings. In these figures we include the level at which the tax rate and the growth rate would be along a Pareto-efficient capital accumulation path (this path involves a negative income tax, i.e. a subsidy to correct for the externality).

We see in the figures that as the relative wealth of the median voter increases (with wealth calculated to include labor income and transfers and denoted B_i for an agent of type i), the chosen tax rate decreases, and the growth rate increases. When the relative wealth is 1, the growth path is Pareto efficient. In Section 3 we will come back to the example in the context of looking at some other approaches to defining equilibria.

2.2.3. The Ramsey problem

Given that the identity of the median voter in our example does not change over time, one might ask why he does not allow himself to plan over a longer horizon; rather than passively taking the future policies to be given by the function Ψ, it might pay off to optimize without this constraint. For this reason, it is informative to analyze what this voter would choose were there full commitment to future tax rates at time zero. This being reminiscent of an optimal-taxation problem with the type 2 agent playing the role of the planner, we thus define a Ramsey problem as follows:

$$\max_{\{c_{1t},c_{2t},A_{1,t+1},A_{2,t+1},\tau_{t+1}\}_{t=0,1,\dots}} \sum_{t=0}^{\infty} \beta^t \frac{c_{2t}^{1-\sigma}-1}{1-\sigma}$$

subject to

$$c_{1t}+c_{2t}+A_{1,t+1}+A_{2,t+1}=(\bar{N}^{1-\alpha}+1-\delta)(A_{1t}+A_{2t}), \quad t=0,1\dots,$$

[9] For a formal proof of this claim, see Krusell & Ríos-Rull (1993).

[10] For a more detailed description of our computational procedure, see Krusell & Ríos-Rull (1993).

$$c_{i,t+1} = c_{it}\left[(\alpha\bar{N}^{1-\alpha}-\delta)(1-\tau_{t+1})+1\right]^{1/\sigma}\beta^{1/\sigma}, \quad i=1,2;\ t=0,1,\ldots,$$

$$c_{it}+A_{i,t+1} = (1+(\alpha\bar{N}^{1-\alpha}-\delta)(1-\tau_t))A_{it}+$$

$$(1-\alpha)\bar{N}^{1-\alpha}\frac{A_{1t}+A_{2t}}{2}+\tau_t(\alpha\bar{N}^{1-\alpha}-\delta)\frac{A_{1t}+A_{2t}}{2}, \quad i=1,2;\ t=0,1,\ldots,$$

and

$$\lim_{t\to\infty}\beta^t A_{it}/R_t = 0, \quad i=1,2,$$

where $R_t \equiv \Pi_{s=1}^{t}(1+(\alpha\bar{N}^{1-\alpha}-\delta)(1-\tau_s))$, i.e. R_t is the accumulated real interest rate between time 0 and time t. The set of constraints is simply a listing of all the equilibrium conditions in the 2-agent economy, where for clarity we include the aggregate feasibility constraint even though it is implied by the individuals' budgets. The importance of the initial values A_{10} and A_{20} is clear here: they will have a fundamental effect on the path of taxes, and hence on equilibrium growth rates. The Ramsey problem thus maximizes the median voter's time-zero utility by choosing a tax sequence, while taking into account equilibrium behavior given each tax sequence. It is possible to prove the following:

Proposition 1. *The solution to the Ramsey problem has the following property: taxes are set so that there are no distortions after time 1:*

$$1-\tau_t = \frac{\bar{N}^{1-\alpha}-\delta}{\alpha\bar{N}^{1-\alpha}-\delta}, \quad t=2,3,\ldots.$$

The proof of the proposition, which is contained in the Appendix, is straightforward: the tax formula follows from manipulation of the first-order conditions to the Ramsey problem. Later we completely characterize the Ramsey solution for our example and compare its properties with those of the politico-economic equilibria.

This simple solution implements a Pareto optimal solution with optimal capital accumulation and growth rates after time 1, with all the redistribution taking place using the (distortionary) income tax at time 1: any dollar of redistribution is better implemented by taxing income at time 1 than at later dates. This result is related to the literature of optimal taxation (see e.g. Chamley (1986)). Thus we have shown formally the time inconsistency of this optimal plan: since the tax imposed at time 1 will not equalize income (unless $A_{10}=A_{20}$ to start with, there will still be inequality at time 1), the median would change his mind were he to reoptimize one period later.

2.3. Politico-Economic Equilibrium and Time-Consistency

Following the papers by Kydland & Prescott (1977) and Calvo (1978), there is by now a large literature on time-consistency of optimal plans in dynamic economies.[11] When future policies cannot be committed to by the current policy maker, it is necessary to specify what the policy maker believes will happen for different choices of current policy—otherwise the policy maker does not have a well-defined problem. The early papers on time-consistency pointed out that if the current policy maker makes a plan as if he could commit to future policies, then in many environments there is a time-consistency problem: future policy makers, whether consisting of the future selves of the current policy makers or different agents, will want to change the original plan. Now observe that there is a close parallel in our political-economy models. First, although a given (small) voter does not have any influence on policy, his preferences over policies need to be derived, and beliefs about how future policies are set are a crucial input in this derivation. Thus, the policy maker is replaced by the policy preferences $\tilde{v}$ and the political aggregator $\mathcal{A}$. Second, as we indeed saw in Section 2.2.3, the future self of the median voter or the politically pivotal agent will typically want to change plans if these plans are based on an unrestricted choice of future policies.

The solution to the problem of time-consistency involves making sure that beliefs about how future policies are set are consistent with the outcomes. The literature on time-consistency thus suggests that the policy maker needs to take the policy rules, or strategies, of future policy makers into account when choosing current policy, and there is therefore a fixed-point problem in ensuring that these perceived strategies are consistent with the optimal behavior of future policy makers. This solution was in fact already proposed in Kydland & Prescott (1977), where they computed the time-consistent equilibria in several linear-quadratic examples where beliefs about future policies were based on a policy rule mapping the state of the economy into a policy outcome. They followed two different procedures to compute the time-consistent policies. One was to postulate finite-period economies and then proceed by backward induction. The other was very similar to our procedure of iterating on the policy determination function Ψ, with computation of the equilibrium laws of motion H at every iteration.

Another paper which deals with the time-consistency problem in an infinite-horizon economy using explicit recursive language to derive time-consistent policy is Cohen & Michel (1988). There, a linear-quadratic economy was shown to lead to the characterization of time-consistent policy in the form of a linear rule. However, in that paper there is no nontrivial determination of equilibrium prices or quantities; the private agents all act independently of each other. Perhaps the closest relative to our concept of equilibrium is the Markovian equilibrium defined in Chari & Kehoe (1993), but there are few attempts other than the original Kydland & Prescott (1977) analysis to characterize

[11] For a survey of this literature, see Persson & Tabellini (1990).

Markovian equilibria analytically or numerically.

In the political-economy model, our notion of politico-economic equilibrium ensures time-consistency. The agents in the current population form preferences over the policy π' taking the future policies to be given by the function Ψ, whose argument is the economy-wide state variable. When these preferences are aggregated at each value of the economy-wide state, equilibrium dictates that the function Ψ be reproduced. This restriction on beliefs created by the lack of a commitment technology clearly constitutes a restriction on the constraint set of the pivotal voter. In particular, for a given distribution of wealth, the median voter will enjoy lower utility in a politico-economic equilibrium than in the Ramsey solution. This can be seen in Figure 5, where the utility of the median voter can be compared to the utility resulting in the Ramsey allocation.

Some of the proposed solutions to the time-consistency problem use reputational arguments to support allocations that are seemingly time-inconsistent. This approach, which draws heavily on the theory of dynamic games (see e.g. Basar & Olsder (1982)), more formally points out that policy rules can be history-dependent, and that this history dependence allows a much larger set of allocations to be supported as equilibria.[12] In our economy, this would correspond to including as arguments to Ψ the history of policy decisions $(\pi, \pi_{-1}, \pi_{-2}, \dots)$. Because policies in our economy are chosen via an abstract aggregator and not necessarily identifiable with a person or a party, it is harder to think of reputation as playing an important role in our context, and we found the restriction to Markovian equilibria a natural one to make. As in the models of dynamic games, however, it should also be true here that expectations about the future behavior, and hence current and future behavior themselves, are indeterminate once one allows histories to play an independent role.

3. OTHER APPROACHES: A METHODOLOGICAL SURVEY

We now relate our setup to some existing models aimed at explaining growth from the point of view of political economy. Since our focus is methodological, and since many of the existing studies are quite similar in method, our discussion only covers a limited set of contributions. The literature to date has adopted several kinds of short-cuts to overcome the analytical difficulties inherent in models with sequential voting. We will now take the perspective of the model formulation of the previous section to describe these short-cuts.

We divide the approaches that have been adopted into three groups. The first group of papers study politico-economic equilibria in environments which have been constructed so as to avoid the difficulties involved in the derivation of preferences over policies. Specifically, these environments have the property that forward-looking is

[12] For a recent treatment, see Chari & Kehoe (1990).

either trivial or not necessary for the median voter. The second approach considers voting not to be sequential, but to instead occur at time zero only. In addition, this group of papers assumes that the tax rate which is the object of the voting is restricted to be constant over time. Finally, a third approach features models with full economic dynamics but with the assumption that agents are not fully forward-looking in forming their policy preferences; in particular, this approach assumes that agents base these policy preferences on taking all future policies as given and unaffected by the current policy outcome. We describe each approach in turn.

3.1. Politico-Economic Equilibria with Limited Dynamics

The first approach to studying dynamic models with voting restricts the economic and political setups so that equilibria are easy to calculate. This group of papers includes Persson & Tabellini (1994), Saint-Paul & Verdier (1992), Glomm & Ravikumar (1992), Perotti (1993), Saint-Paul & Verdier (1991), and Fernandez & Rogerson (1994). We will most closely follow Persson & Tabellini (1994), which studies taxes on capital income. Saint-Paul & Verdier (1992) analyzes regulation of the access to foreign capital markets in small open economies, while the remaining references study human capital accumulation and policies concerning the funding of public education.

The key simplification necessary to make equilibria possible to calculate is to make sure that $\mathcal{A}(A, \tilde{v})$ does not depend on Ψ. In other words, if the political preferences $\tilde{v}$ underlying the political aggregator do not depend on how policies are chosen in the future, the fixed point problem in Definition 2.1.2 is simplified substantially: the Ψ function can be derived as a function of A directly. We will use a version of our general setup—one which is very similar to the setup in Persson & Tabellini (1994)—to illuminate this point.

Consider a population structure with two-period-lived overlapping generations: $\mathcal{T} = \{11, 21, 12, 22, \ldots, 1J, 2J\}$, where J is the number of different types within a generation. Assume for simplicity that old agents cannot work ($\epsilon_{2j} = 0$), whereas a young agent of type j has available ϵ_{1j} efficiency units of labor. Because young agents are born without capital, our distribution of capital can be summarized with the holdings of the old agents: $(A_1, A_2, \ldots, A_J)$. The production technology is assumed to be the same as in our example economy in Section 2.2, i.e. $k^{\alpha} n^{1-\alpha} \bar{k}^{1-\alpha}$.

The constitution looks as follows: the policy decided in the current period is next period's tax rate on capital, $\tau_k' \equiv \tau'$, and taxes on labor income are constitutionally set at zero: $\Pi \equiv \{(\tau_k', \tau_l') \in \mathbf{R}_+^2 : \tau_l' = 0\}$. Tax proceeds are distributed equally among the old agents, so

$$\nu_1 = 0 \text{ and } \nu_2 = 2,$$

and only young agents are allowed to vote.

The key question is: do voters need to forecast the outcomes of future votes in forming their preferences over τ'? The overlapping-generations framework is helpful in this respect, cutting off some ties to the future: each voter only votes once, and since he is not altruistic, he at least does not care in a direct way about the next vote. However, the current voter may care about future votes indirectly: expectations about future policies may affect prices today and tomorrow, and these prices directly affect the agent's economic situation. Some additional assumptions are therefore needed to ensure that prices are not affected by expectations about the future.[13]

The relevant prices for the agent are the rental rate r and the wage rate w. Because of perfect competition, these are given by marginal productivities, which in turn are pinned down by the supplies of capital and labor. The current period's capital stock is predetermined, and next period's capital stock is determined by the current generation. Hence, if the current generation does not care about the outcomes of future votes, next period's capital stock can be predicted without knowing the future votes. A similar argument could be used for this period's labor input. However, if next period's labor supply is elastic, there is a link to the future: next period's young do care directly about the outcome of future votes (they decide the next outcome), and their labor supply will in general depend on this vote. The final assumption needed is therefore that

$$u_1(c, l) = u(c).$$

We assume for notational simplicity that old agents have the same utility function: $u_2(c, 1) = u(c)$.

With the total supply of labor now given exogenously by the number $\bar{N}$, we have

$$tr_2(A, \tau) = \tau \bar{A}(\alpha \bar{N}^{1-\alpha} - \delta),$$

and, the agent's problem reads

$$\tilde{v}_{1j}(A, 0, \tau') = \max_{c, a'} \{u(c) + \beta v_{2j}(A', a', \tau')\} \text{ s.t.}$$

$$c + a' = \epsilon_{1j}(1 - \alpha)\bar{A}\bar{N}^{-\alpha}$$
$$A' = \tilde{H}(A, \tau')$$

and

$$v_{2j}(A, a, \tau) = u\left(a\left[(\alpha \bar{N}^{1-\alpha} - \delta)(1 - \tau) + 1\right] + \tau \bar{A}(\alpha \bar{N}^{1-\alpha} - \delta)\right).$$

[13] Some papers in the literature (e.g. Glomm & Ravikumar (1992) and Fernandez & Rogerson (1994)) consider explicit connections across generations: this allows income inequality to be inherited. One way to implement this is to assume that agents do not care about their children per se, but about the size of the bequests they give. If in addition only old agents vote in this type of environment, we get a similar effect as in the Persson-Tabellini world: the voter does not care in a direct way about the future.

which simplifies to

$$\tilde{v}_{1j}(A,\tau') = \max_c \{u(c)+$$

$$\beta u\Bigg((\epsilon_{1j}(1-\alpha)\bar{A}\bar{N}^{-\alpha} - c)\left[(\alpha \bar{N}^{1-\alpha} - \delta)(1-\tau') + 1\right] +$$

$$\tau(\alpha \bar{N}^{1-\alpha} - \delta) \sum_{j=1}^{J} \mu_j \tilde{H}_{1j}(A,\tau')\Bigg)\}.$$

Each agent j thus solves for his optimal consumption levels and the level of capital accumulation taking as given the law of motion for aggregate capital.

The agent's problem is straightforward to solve, and since we are now dealing with an economy which does not interact with the future, it is also straightforward to find the equilibrium law of motion $\tilde{H}$. In particular, it is possible to solve for A' as a function of A and τ'. With A' written as a function of A and τ' and substituted into the agent's problem, we have an explicit form for $\tilde{v}_{1j}(A, A_j, \tau')$.[14] If this function is single-peaked in τ' for each j, the median voter theorem can be used:

$$\mathcal{A}(A,\tilde{v}) = \psi_{1m}(A, A_m) = \arg\max_{\tau'} \tilde{v}_{1m}(A, A_m, \tau'),$$

with m denoting the type with median preferred tax rate. In this case, the type with median preferred tax rate will also be the agent with median income/wealth.[15]

To summarize, the assumptions made ensure that the fixed point problem for finding Ψ is trivial. With specific assumptions on the utility function u, it is then straightforward to derive Ψ, from which follows a growth path which depends fundamentally on the distribution of time endowments.

3.2. Voting at Time Zero Only

The approach of studying policy determination only at time zero was used in Alesina & Rodrik (1994) and in Bertola (1993). There, it was also imposed in addition that the policy variable be constant over time. The issue in Alesina & Rodrik (1994) was to determine the level of a constant proportional tax on capital income in the setting of a population of infinitely-lived agents with different amounts of wealth. In Bertola (1993), the focus was instead on the mix of capital and labor income taxation. In either case, the two main assumptions—that taxes be restricted to constant paths and that the vote occurs only at time zero—are critical.

[14] In this problem, only the mean of A matters; however, the distribution of the L_j's will of course matter to the capital accumulation path.

[15] For details, see Persson & Tabellini (1994) and Grandmont (1978).

First, it is typical in these economies, where agents live forever and have monotone decision rules for capital accumulation, that the agent with median wealth (i) will determine the policy outcome; and (ii) will remain median in wealth rank over time. Given that the median agent does not change over time, then, it is natural to determine a whole sequence of taxes according to the liking of this agent. However, we argued before, that such a policy would not be time consistent: if the median agent finds a particular sequence optimal at time zero, then the continuation of this sequence will not be optimal if the agent were to reoptimize at a later date.

It also turns out that the dynamic voting equilibrium as defined in Section 2.1.2 above indeed involves a constant tax policy for the type of economy studied in, say, Alesina & Rodrik (1994). The second point to be made is that this policy is not the same as the one derived with voting over constant sequences at time zero: it typically involves higher taxes, i.e. more distortion and more redistribution. This is illustrated in Figures 3 though 7, where we compare numerically calculated allocations and taxes for different equilibrium concepts applied in a given economic environment. Figures 3 and 4 compare the tax rates and growth rates. It is clear from these figures that the politico-economic equilibrium gives rise to higher tax rates and lower growth than the model where taxes are chosen at time zero (provided the median agent has below-mean wealth). The intuitive reason for this is that the sequential voting equilibria have a time-consistency property which makes them more restrictive and therefore lower the equilibrium welfare of the median voter.[16] From Figure 5 it is clear that the Ramsey solution, as it should, gives higher utility to the median voter than do the politico-economic and the voting-at-time-zero-only equilibria. It is also shown in Figure 6 that actually the non-median voter may be worse off in the Ramsey solution than in the other equilibria. The combination of utilities that result from different initial wealth pairs are displayed in Figure 7. Over the range studied, Figure 7 shows that some equilibrium concepts (those of the Ramsey solution and the politico-economic equilibrium) may give perverse outcomes in the sense that an initial lump-sum redistribution from the non-median to the median voter would increase both agents' utility. This can occur since the increase in the distortion implied by taking wealth away from the median voter may hurt the non-median voter more than the increase in relative wealth benefits him.

In summary, we have shown that the voting equilibria described in Alesina & Rodrik (1994) and in Bertola (1993) cannot be supported either with unrestricted commitment to future tax rates at time zero (this will lead to nonconstant paths of taxes) or with sequential voting (this will lead to higher tax rates).

[16] The environments where voting over constant tax sequences have been studied are linear growth models. This implies that the policy outcomes are time-consistent in another, and in our view less interesting, sense: if at each point in time there is a restriction to constant sequences, then the median voter will choose the same sequence in each period.

3.3. Restricting the Voter's Ability to Predict

The strong assumptions that are necessary in order to restrict the need for forward-looking of the voter bring us to the third approach, which is more drastic: it is to simply say that agents do not make rational forecasts when evaluating the effects of a change in the current policy. The first example of this approach that we know of—a paper by Hansen, Epple, & Roberds (1985), described in Sargent (1987)—is not an explicit voting model. This paper instead assumes that there is an administration at each point in time with some objective function, and this administration decides on current taxes, taking the sequence of future taxes as given. This problem may be complicated in that the future equilibrium paths need to be predicted for each current policy, but it does not require the administration to figure out what will happen to future policies. Hence, the fixed point problem is greatly simplified, since it can be set in terms of a sequence of values for policies rather than in terms of a policy outcome function. More recent examples of this type of approach can be found in Cukierman & Meltzer (1989), Boldrin (1993), and Huffman (1993).

Figures 3 through 7 also compare the properties of equilibria resulting from the myopic-voter approach with politico-economic equilibria. It can be seen that the allocations and taxes do not coincide; this is because the myopic median agent misses the effect on future taxes when contemplating a tax change today. We see that the myopic-voting assumption leads to a higher growth rate than does the politico-economic equilibrium. This can be understood as follows. When there is a tax increase, the resulting decrease in wealth dispersion will lead to lesser needs to tax for redistributional reasons in the future and hence lower future taxes. On net, these decreases in future taxes are beneficial to the median voter (the distortions of taxing in the future outweigh the redistributional benefits). Hence, myopic voters will predict this tax increase to be less beneficial than it really is, and they will therefore choose lower taxes than will voters who make correct predictions.

4. Concluding Remarks

Recent models of politico-economic equilibrium focus on how conflicts of interest within the population influence the determination of growth-related economic policies. This paper has discussed some of the methodological issues that are important in this literature. We have argued in favor of an approach to studying sequential policy determination which relies on an explicit derivation of preferences over policy choices. This derivation is based on assuming that the agents think rationally through all the current and future effects on prices and policies—and hence on present discounted utility—of the policy choice currently under consideration. We have two final remarks.

First, whereas politico-economic equilibria typically are quite hard to characterize analytically, the methods currently available for numerical computation are powerful enough for solving nontrivial versions of the models we have discussed in this paper. For example, it is feasible to compute dynamic politico-economic equilibria in the context of the infinitely-lived agent growth model with five classes of agents, which allows confrontation with quintile-based income distribution data.

Second, we want to point to one important shortcoming of the literature on politico-economic equilibrium. All of the papers we have made reference to have had to take a stand on the set of policies that are subjected to the policy determination process. Put in terms of our setup, the fiscal as well as political constitutions are regarded as exogenous. For example, one can ask in the context of positive capital taxation models why consumption taxes are not implemented instead: typically, theory says that consumption taxes are less distortionary. In short, one should ask, whenever politico-economic equilibrium models predict outcomes which are not Pareto optimal, what prevents Pareto improvements from occurring. A full specification of the technology available for taxing and transferring is in principle necessary, and one would expect politico-economic equilibrium outcomes to be Pareto optimal given the constraints imposed by this technology. One issue is whether, say, consumption can be monitored at low cost. Another issue concerns compensating transfers, which according to many theories should occur but which are far from common in practice. Thinking about the feasibility and desirability of different policy instruments on a more detailed level seems necessary in order to make progress in addressing these questions.

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Appendix

Proof of Proposition 1:

Define g_{t+1} to be the growth rate in consumption between t and $t+1$, and let $D \equiv \bar{N}^{1-\alpha}+1-\delta$. Some manipulations now imply that the constraint set (excluding transversality conditions) can be rewritten as

$$c_{i,t+1} = c_{it}g_{t+1}, \quad i=1,2$$
$$c_{1t} + A_{1,t+1} = D\frac{A_{1t}+A_{2t}}{2} + \frac{g_t^\sigma}{\beta}\frac{A_{1t}-A_{2t}}{2}$$
$$c_{2t} + A_{2,t+1} = D\frac{A_{1t}+A_{2t}}{2} + \frac{g_t^\sigma}{\beta}\frac{A_{2t}-A_{1t}}{2}.$$

The first two constraints imply that the ratio between c_{1t} and c_{2t} is constant over time. Denote this constant ratio x and substitute $c_{1t} = xc_{2t}$ into the constraints. This allows us to eliminate the sequence of constraints $c_{1,t+1} = c_{1t}g_{t+1}$ and to write the maximization over x and $\{c_{2t}, A_{1,t+1}, A_{2,t+1}, g_{t+1}\}_{t=0,1,2,...}$.

The Lagrangian now reads

$$L = \sum_{t=0}^{\infty}\beta^t\left[\frac{c_{2t}^{1-\sigma}-1}{1-\sigma} - \gamma_{1t}\left[xc_{2t} + A_{1,t+1} - D\frac{A_{1t}+A_{2t}}{2} - \frac{g_t^\sigma}{\beta}\frac{A_{1t}-A_{2t}}{2}\right]\right.$$
$$-\gamma_{2t}\left[c_{2t} + A_{2,t+1} - D\frac{A_{1t}+A_{2t}}{2} - \frac{g_t^\sigma}{\beta}\frac{A_{2t}-A_{1t}}{2}\right]$$
$$\left. - \lambda_t\left[c_{2,t+1} - c_{2t}g_{t+1}\right]\right]$$

and the first-order necessary conditions are, for x,

$$\sum_{t=0}^{\infty}\beta^t\gamma_{1t}c_{2t} = 0; \tag{4.1}$$

for c_{20},

$$c_{20}^{-\sigma} - \gamma_{10}x - \gamma_{20} + \lambda_0 g_1 = 0; \tag{4.2}$$

for c_{2t}, $t = 1,2,\ldots$,

$$c_{2t}^{-\sigma} - \gamma_{1t}x - \gamma_{2t} + \lambda_t g_{t+1} - \frac{\lambda_{t-1}}{\beta}; \tag{4.3}$$

and for the remaining variables, for $t = 0,1,2,\ldots$,

$$-\gamma_{1t} + \frac{1}{2}\gamma_{1,t+1}\beta D + \frac{1}{2}\gamma_{1,t+1}g_{t+1}^\sigma + \frac{1}{2}\gamma_{2,t+1}\beta D - \frac{1}{2}\gamma_{2,t+1}g_{t+1}^\sigma = 0 \tag{4.4}$$

$$-\gamma_{2t} + \frac{1}{2}\gamma_{2,t+1}\beta D + \frac{1}{2}\gamma_{2,t+1}g_{t+1}^\sigma + \frac{1}{2}\gamma_{1,t+1}\beta D - \frac{1}{2}\gamma_{1,t+1}g_{t+1}^\sigma = 0 \tag{4.5}$$

$$\gamma_{1,t+1}\sigma g_{t+1}^{\sigma-1}\frac{A_{1,t+1}-A_{2,t+1}}{2} + \gamma_{2,t+1}\sigma g_{t+1}^{\sigma-1}\frac{A_{2,t+1}-A_{1,t+1}}{2} + \lambda_t c_{2t} = 0 \tag{4.6}$$

$$xc_{2t} + A_{1,t+1} - D\frac{A_{1t} + A_{2t}}{2} - \frac{g_t^\sigma}{\beta}\frac{A_{1t} - A_{2t}}{2} = 0 \tag{4.7}$$

$$c_{2t} + A_{2,t+1} - D\frac{A_{1t} + A_{2t}}{2} - \frac{g_t^\sigma}{\beta}\frac{A_{2t} - A_{1t}}{2} = 0 \tag{4.8}$$

$$c_{2,t+1} - c_{2t}g_{t+1} = 0. \tag{4.9}$$

The transversality conditions read

$$\lim_{t\to\infty} \beta^t \gamma_{it} A_{i,t+1} = 0, \quad i = 1, 2. \tag{4.10}$$

We now manipulate the first-order conditions to obtain the desired result. Multiplying (4.3) by c_{2t} and using (4.9) we obtain

$$c_{2t}^{1-\sigma} - \gamma_{1t}xc_{2t} - \gamma_{2t}c_{2t} + \lambda_t c_{2t}g_{t+1} - \frac{\lambda_{t-1}}{\beta}c_{2t-1}g_t = 0. \tag{4.11}$$

From (4.6) we get

$$-\frac{\lambda_{t-1}}{\beta}c_{2t-1}g_t = (\gamma_{1t} - \gamma_{2t})\sigma\frac{g_t^\sigma}{\beta}\frac{A_{1t} - A_{2t}}{2}$$

$$\lambda_t c_{2t}g_{t+1} = -(\gamma_{1,t+1} - \gamma_{2,t+1})\sigma g_{t+1}^\sigma \left(\frac{A_{1,t+1} - A_{2,t+1}}{2}\right),$$

and substituting the result into (4.11) we arrive at

$$c_{2t}^{1-\sigma} - \gamma_{1t}xc_{2t} - \gamma_{2t}c_{2t} - (\gamma_{1,t+1} - \gamma_{2,t+1})\sigma g_{t+1}^\sigma \frac{A_{1,t+1} - A_{2,t+1}}{2}$$

$$+(\gamma_{1t} - \gamma_{2t})\sigma\frac{g_t^\sigma}{\beta}\frac{A_{1t} - A_{2t}}{2} = 0.$$

Using (4.4) and (4.5), we have

$$(\gamma_{1t} - \gamma_{2t}) = (\gamma_{1,t+1} - \gamma_{2,t+1})g_{t+1}^\sigma. \tag{4.12}$$

Therefore,

$$c_{2t}^{1-\sigma} - \gamma_{1t}xc_{2t} - \gamma_{2t}c_{2t} - \sigma(\gamma_{1t} - \gamma_{2t})\left[\frac{A_{1,t+1} - A_{2,t+1}}{2} - \frac{g_t^\sigma}{\beta}\frac{A_{1t} - A_{2t}}{2}\right] = 0. \tag{4.13}$$

Subtracting (4.8) from (4.7) and dividing by 2 we get

$$\left[\frac{A_{1,t+1} - A_{2,t+1}}{2} - \frac{g_t^\sigma}{\beta}\frac{A_{1t} - A_{2t}}{2}\right] = -\frac{(x-1)c_{2t}}{2}.$$

Substituting this into (4.13) and dividing by c_{2t} gives

$$c_{2t}^{-\sigma} - \gamma_{1t}x - \gamma_{2t} + \sigma(\gamma_{1t} - \gamma_{2t})\frac{(x-1)}{2} = 0. \tag{4.14}$$

Updating (4.14) and using (4.12) to eliminate $\gamma_{1,t+1}$, we obtain

$$c_{2,t+1}^{-\sigma} - (1+x)\gamma_{2,t+1} - x\frac{\gamma_{1t}-\gamma_{2t}}{g_{t+1}^{\sigma}} + \sigma\frac{\gamma_{1t}-\gamma_{2t}}{2g_{t+1}^{\sigma}}(x-1) = 0. \tag{4.15}$$

Equating (4.14) with (4.15) and collecting terms, we get

$$g_{t+1}^{\sigma} = \frac{\gamma_{2t}}{\gamma_{2,t+1}}, \quad t = 1, 2, \ldots.$$

From (4.12) we furthermore have

$$g_{t+1}^{\sigma} = \frac{\gamma_{1t}}{\gamma_{1,t+1}}, \quad t = 1, 2, \ldots.$$

The last two results imply

$$\frac{\gamma_{1t}+\gamma_{2t}}{\gamma_{1,t+1}+\gamma_{2,t+1}} = g_{t+1}^{\sigma},$$

and adding (4.4) and (4.5) we see that

$$\frac{\gamma_{1t}+\gamma_{2t}}{\gamma_{1,t+1}+\gamma_{2,t+1}} = \beta D.$$

From this we conclude that

$$g_{t+1} = (\beta D)^{1/\sigma}, \quad t = 1, 2, \ldots$$

has to be true on a maximizing path. □