Time Consistent Fiscal Policy and Heterogeneous Agents

VERY PRELIMINARY

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Abstract

This paper characterizes the time consistency properties of the set of constrained Pareto efficient (or second best) fiscal policies, in a two-class, stochastic economy similar to Judd (1985). I show that a subset of the constrained Pareto efficient policies are time consistent when the policymaker's preferences are given by the precise Pareto weight distribution indexing the choice among second best policies. Moreover, for any second best policy featuring a zero capital tax, there exist policymaker's preferences, given by an utilitarian social welfare function, such that the policy is time consistent. Special cases are the non-stochastic limit of any constrained Pareto efficient policies, and any second best policy under constant intertemporal elasticity of substitution preferences. I also show that equity considerations are relevant for the characterization of Markov equilibria in an economy without complete markets.

1 Introduction

In the representative agent model of fiscal policy, the constrained Pareto policy is usually not time consistent. Hence it cannot be implemented in equilibrium without any commitment device. There is abundant literature exploring conditions such that optimal fiscal policy can be rendered time consistent. Lucas and Stokey (1983) show how one can restructure debt

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holdings such that the optimal fiscal policy is time consistent, although asset taxation is ruled out. Chari and Kehoe (1990) note that history dependent equilibria can make the optimal fiscal policy sustainable in equilibrium.

In this paper, I explore the time consistency properties of set of constrained Pareto policies in the context of heterogeneous agents. The economy proposed here is similar to Judd (1985). In his classic contribution, Judd (1985) characterizes the asymptotic properties of the set of constrained Pareto policies in an infinite horizon, stochastic economy. Heterogeneity is captured by two types of households, capitalist and workers, with very different factor endowments. In this environment, it is shown that a positive capital tax is never a constrained Pareto policy.[1] This lead most of the analysis of optimal fiscal policy to ignore equity considerations.[2]

However, equity considerations are essential to determine the welfare properties of time consistent policies. The main result is that a subset of the constrained Pareto efficient policies are time consistent when policy deviations are evaluated using the precise Pareto weight distribution indexing the policy among the constrained Pareto set. One can think of the Pareto weight distribution used as the policymaker's preferences over aggregate welfare distributions. Moreover, for any second best policy featuring a zero capital tax, as the asymptotic policy for any constrained Pareto efficient policy or any second best policy under constant intertemporal elasticity substitution household preferences, there exist policymaker's preferences such that the policy is time consistent.

Intuitively, the key insight is that no deviation from a zero capital tax policy is Pareto superior. Hence, there exist equity considerations such that the efficiency gains are offset. While an unexpected increase in capital increases efficiency by reducing overall distortion, the tax rise is mainly paid by capitalist households, who are strictly worse off. If the policymaker values capitalist household welfare relatively more than worker household welfare, the efficiency gains may be forgone to avoid undesired redistribution. Note how the zero capital tax result fits the discussion: if capitalist households would be paying a positive ex-ante capital tax on next period returns, they would also prefer to have a tax increase on present period returns. Then no Paretian policymaker would render such policy as time consistent.

Several noteworthy implications arise. First, the strict Pareto ranking between an economy with and without commitment in a representative agent framework is not a robust property. Equity considerations are an essential parameter for the characterization and welfare properties of time consistent fiscal policy.[3] Second, benevolent policymakers can be ranked according to policy efficiency. This implications unveils interesting possibilities for

[1] The same result is mentioned in Chamley (1986).

[2] A notable exception is Bassetto (1999), who characterizes the optimal fiscal policy with heterogeneous agents and shows that the optimal policy response to fiscal shocks *does* depend on the relative welfare weights. An interesting line of research deals with the redistributive consequences of certain policy experiments: see, for example, Domeij and Heathcote (2000) and Garcia-Mila, Marcet and Ventura (2001).

[3] This parameter is obviously omitted in single agent models like Klein and Rios-Rull (2002) or Fernandez-Villaverde and Tsyvinski (2002).

political economy analysis.

There has been previous literature relating redistribution and the credibility of public debt. Dixit and Londregan (2000) present an explicit political model and show that if political power and government bond holdings are positively correlated, then government debt repayment is credible. They illustrate the argument with an example where human capital formation is the alternative use for wealth. In a recent paper, Sleet and Yeltekin (2002) argue that if debt market participants possess sufficient political influence, they would block debt default, increasing the set of sustainable debt policies. By analyzing full-fledged fiscal policy in an infinite horizon model, I identify an intriguing possibility: when society's redistributive objectives are too regressive, the time inconsistency problem reappears and it would be beneficial to *curtail* the political power of asset holders.

Bassetto (1999) and Albanesi (2002) also deal with the time inconsistency problem in fiscal policy with heterogeneous agents. They show that by manipulating the distribution and maturity structure of government assets, the optimal policy can be made time consistent. These results relate to the work of Lucas and Stokey (1983) and Persson and Svensson (1986). However, it is necessary to rule out direct asset taxation. Another important distinction is the instrument necessary to implement the optimal fiscal policy. In Bassetto (1999) and Albanesi (2002), the government must be able to influence the distribution of public debt across households. In this paper, it is the policymaker's redistributive goals what renders the optimal fiscal policy time consistent.

The remainder of the paper is organized as follows: the next section describes the economy and the private sector competitive equilibrium. Section 3 deals with the concept of policy equilibrium with commitment and Section 4 analyzes its time consistent properties. Section 5 performs some numerical exercises to explore Markov equilibria in a non-complete market environment. Conclusions are in Section 6.

2 The Economy and Private Sector Competitive Equilibrium

Let $\{s_t\}_{t=0}^{\infty}$ be an exogenous first order Markov process with finite possible realizations $s \in S$ and transitions probabilities given by Π. The economy's initial conditions are given by (k_0, b_0, s_0). Let $s^t = \{s_0, s_1, ..., s_t\}$ denote the history up to date $t \geq 0$. The set of possible histories at date j continuation of some history s^t, $j \geq t$, is $S^j(s^t)$. However, if there is no confusion possible, I will omit the dependence on s^t. Let $m = \{m(s^t) \,|\forall s^t \in S^t, t \geq 0\}$ denote be a complete history contingent plan for variable $m \in \{c_1, c_2, n...\}$.

The economy is populated by a representative firm, a policymaker and two types of households. A measure ψ of households are type $i = 1$, labelled **capitalist households**. They own all of the capital stock $k(s^t)$ and private government debt holdings $b(s^t)$ in the economy after any history. They have no time endowment. At every node s^t, capitalist households have access to a complete array of one period state contingent bonds, with the only limitations given by the usual Non-Ponzi scheme conditions.

Households of type $i = 2$ are **worker households**. They have one unit of time at every node s^t to split between labor supply $n(s^t)$ and leisure $1 - n(s^t)$. They do not have access to any savings means, neither physical capital nor bonds. I normalize the measure of worker households to one.

Both types of agents view the fiscal plan τ,

$$\tau = \left\{ \tau^k\left(s^t\right), \tau^n\left(s^t\right), b^g\left(s^{t+1}\right) | \forall s^t \in S^t, t \geq 0 \right\}$$

and prices p,

$$p = \left\{ r^k\left(s^t\right), w\left(s^t\right), \left\{ q\left(s^t, s'\right) \right\}_{s' \in S} | \forall s^t \in S^t, t \geq 0 \right\}$$

as given.

As all households within each type are identical and I will consider only symmetric equilibria, it is convenient to consider an economy populated with just two representative households, a capitalist and a worker.

Capitalist household's preferences over consumption plan c_1 after history s^t are given by

$$U_1\left(c_1, s^t\right) = \sum_{j=t}^{\infty} \sum_{s^j} \beta^{j-t} \pi\left(s^j | s_t\right) u_1\left(c_1\left(s^j\right)\right)$$

with $0 < \beta < 1$, u a standard utility function, i.e., differentiable, strictly increasing and concave, and the usual Inada conditions hold.

The **capitalist household problem** at node s^t consists of choosing allocation plans c_1, k and b given fiscal plan τ and prices p,

$$\max U_1\left(c_1, s^t\right) \tag{\textit{Cap.}-HH}$$

subject to

$$c\left(s^j\right) + \sum_{s_{j+1}} q\left(s^j, s_{j+1}\right) b\left(s^{j+1}\right) + k\left(s^j\right) \leq a\left(s^j\right)$$
$$a\left(s^j\right) = \left(\left(1 - \tau^k\left(s^j\right)\right) r^k\left(s^j\right) + 1 - \delta\right) k\left(s^{j-1}\right) + b\left(s^j\right)$$

and

$$\begin{aligned} 0 &\leq c_1\left(s^j\right), k\left(s^j\right) \\ -B &\leq b\left(s^j\right) \end{aligned}$$

for all $s^j \in S^j, j \geq t$, and $k\left(s^{t-1}\right), b\left(s^t\right), s_t$ given.

Worker household's preferences over c_2 and n after history s^t are given by

$$U_2\left(c_2, n, s^t\right) = \sum_{j=t}^{\infty} \sum_{s^j} \beta^{j-t} \pi\left(s^j | s_t\right) u_2\left(c_2\left(s^j\right), n\left(s^j\right)\right)$$

with u being an utility function with all the standard properties as detailed previously.

The **worker household problem** after history s^t is to set c_2 and n, given fiscal plan τ and prices p,

$$\max U_2\left(c_2, n, s^t\right) \tag{\textit{Wor.}-HH}$$

subject to

$$c_2\left(s^j\right) \leq \left(1-\tau^n\left(s^j\right)\right) w\left(s^j\right) n\left(s^j\right)$$

and

$$\begin{aligned} 0 &\leq c_2\left(s^j\right) \\ 0 &\leq n\left(s^j\right) \leq 1 \end{aligned}$$

for all $s^j \in S^j, j \geq t$, s_t given.

The **representative firm** combines labor and capital inputs to produce final good y according to a standard constant returns to scale production function F. At every node s^t, it maximizes profits taking factor prices $w\left(s^t\right)$ and $r^k\left(s^t\right)$ as given,

$$\max y\left(s^t\right) - r^k\left(s^t\right) k\left(s^t\right) - w\left(s^t\right) n\left(s^t\right) \tag{\textit{Firm}}$$

subject to

$$y\left(s^t\right) \leq F\left(k\left(s^t\right), n\left(s^t\right)\right)$$

The **government budget constraint** needs to hold at every node s^t,

$$g\left(s_t\right) + b^g\left(s^t\right) - \sum_{s^{t+1}} q\left(s^t, s^{t+1}\right) b^g\left(s^{t+1}\right) \leq \tau^n\left(s^t\right) w\left(s^t\right) n\left(s^t\right) + \tau^k\left(s^t\right) r^k\left(s^t\right) k\left(s^{t-1}\right) \tag{\textit{G.B.C.}}$$

The government expenditure $g\left(s_t\right)$ is an exogenous process governed by s_t. Note that $b^g > 0$ is an obligation of the government.

Finally, the aggregate **resource constraint** needs to hold at every s^t:

$$c_1\left(s^t\right) + c_2\left(s^t\right) + g\left(s_t\right) + k\left(s^t\right) \leq y\left(s^t\right) + (1-\delta) k\left(s^{t-1}\right) \tag{\textit{R.C.}}$$

By the Walras' law bond markets clear: $b\left(s^t\right) = b^g\left(s^t\right)$ for all $s^t \in S^t, t \geq 0$.

All is set to describe the competitive equilibrium given a fiscal policy τ.[4] I define the competitive equilibrium at any node s^t to accommodate posterior definitions.

Definition 1 *A **private sector competitive equilibrium** at node s^t is a set of allocation plans $x = \{c_1, k, c_2, n\}$, prices p and a fiscal plan τ such that:*

1. *Allocations x solve both household problems (Cap.-HH) and (Wor.-HH) at node s^t given p and τ.*

[4] The reader is referred to Appendix A for the list of necessary and sufficient conditions characterizing the competitive equilibrium.

2. *Allocations x solve the firm problem (Firm) for $\forall s^j \in S^j$, $j \geq t$.*

3. *The government budget constraint (G.B.C.) is satisfied for $\forall s^j \in S^j$, $j \geq t$.*

4. *The resource constraint (R.C.) holds for $\forall s^j \in S^j$, $j \geq t$.*

Let $X(s^t)$ be the set of allocations such that there exists τ and p for which $\{x, p, \tau\}$ is a private sector competitive equilibrium at node s^t. A fiscal policy plan τ is said to be feasible at node s^t if there exists p and x such that $\{x, p, \tau\}$ constitutes a private sector competitive equilibrium at node s^t.

Because of the heterogeneity of households, I work with the set of Pareto efficient policies rather than *the* optimal fiscal policy. Each point in the Pareto efficient set can be indexed with a Pareto weight distribution. Then, one can interpret the Pareto weights as a parameter of an utilitarian social welfare function representing the preferences of a policymaker who chooses the precise policy among the Pareto efficient set. Because policy equilibrium concepts treat the policymaker as a player, I will work with Pareto efficient sets by considering the complete set of Paretian policymaker types.

In more precise terms, a policymaker of type λ will value competitive equilibrium allocations $x \in X(s^t)$ according to a preference relationship over welfare distributions given by an utilitarian social welfare function (SWF). This utilitarian SWF is indexed by the Pareto weight $\lambda > 0$ assigned to the representative capitalist household. Hence, preferences over $x \in X(s^t)$ are given by the **λ-welfare function**,

$$W^{\lambda}\left(x, s^t\right) = \lambda U_1\left(c_1, s^t\right) + U_2\left(c_2, n, s^t\right)$$

Note that for all policymaker types $\lambda > 0$, this is a Paretian SWF, i.e., for any $x, x' \in X(s^t)$, if x is Pareto superior to x', then $W^{\lambda}(x, s^t) > W^{\lambda}(x', s^t)$. Shortcut $W_0^{\lambda}(x)$ will be used for $W^{\lambda}(x, s_0)$.

I assume that society's preferences over welfare distributions are given by a symmetric utilitarian SWF.[5] Hence, the policymaker that exactly reflects society's distributional value judgements is of type ψ, the measure of capitalists households, and its SWF is W^{ψ}.

3 Policy Equilibrium with Commitment

As all the objects involving a policy decision in this paper, my definition of policy equilibrium with commitment requires to be indexed by the policymaker type. A λ-Ramsey equilibrium is the best private sector equilibrium according to the λ-welfare function.[6] The resulting

[5] Note that I need to distinguish between *a* social welfare function and *the* social welfare function. Symmetry is the distinctive feature of the latter.

[6] If for any fiscal plan τ there are multiple private sector equilibria with distinct welfare properties, only the competitive equilibrium with higher λ-welfare is a λ-Ramsey equilibrium. This is implied by the second point of the definition.

policy will be referred to as the λ-Ramsey policy. The standard Ramsey equilibrium where social welfare is maximized is given by the λ-Ramsey equilibrium with $\lambda = \psi$.

Definition 2 *A λ-**Ramsey Equilibrium** is $\{x, p, \tau\}$ such that:*

1. *Triplet $\{x, p, \tau\}$ constitutes a private sector competitive equilibrium at node s_0.*
2. *There is no $\{x', p', \tau'\}$ such that*

$$W_0^\lambda(x') > W_0^\lambda(x)$$

and $\{x', p', \tau'\}$ constitutes a competitive equilibrium at node s_0.

One can construct the constrained Pareto efficient set by spanning the λ-Ramsey equilibria for all policymakers types $\lambda > 0$.

In order to characterize the λ-Ramsey policy, I will use the so called primal approach. Using the necessary and sufficient conditions for the private sector competitive equilibrium, it is possible to solve for prices and taxes given allocations, and conversely. Using this relationship, the policy problem can be thought as choosing a feasible allocation plan subject to some implementability constraints. Obviously, it is necessary to establish the identity between the set of feasible allocations that satisfy the implementability constraints and the set of private sector competitive equilibrium allocations. There is excellent work detailing and illustrating the applications of the primal approach: see Chari, Christiano and Kehoe (1994) and Chari and Kehoe (1998) and further references. The following proposition extends the standard result to the two-class economy presented here.

Proposition 1 *Let D be the set of allocations x that satisfy:*

1. *For some $\tau^k(s_0)$,*

$$\sum_{t=0}^{\infty}\sum_{s^t}\beta^t\pi\left(s^t|s_0\right)u_1^c\left(s^t\right)c_1\left(s^t\right) = A(s_0) \qquad (\textit{Cap.-IC})$$

where

$$A(s_0) = u_1^c(s_0)\left[\left(\left(1-\tau^k(s_0)\right)F^k(k_0, n(s_0)) + 1 - \delta\right)k_0 + b_0\right]$$

2. *For all $s^t \in S^t, t \geq 0$,*

$$u_2^c\left(s^t\right)c_2\left(s^t\right) + u_2^n\left(s^t\right)n\left(s^t\right) = 0 \qquad (\textit{Wor.-IC})$$

3. *For all $s^t \in S^t, t \geq 0$, (R.C.) holds.*

Then

$$X(s_0) = D$$

Proof. In the Appendix B. ■

Now all is set to state the λ-Ramsey problem in primal approach, which consists in finding the λ-welfare superior private sector competitive equilibrium allocations.[7]

Definition 3 *The λ-**Ramsey problem** (in primal approach) is to set x and $\tau^k(s_0)$ to maximize*

$$W_0^\lambda(x)$$

subject to (Cap.-IC), and (R.C.) and (Wor.-IC) for all $s^t \in S^t$, $t \geq 0$, b_0, k_0, s_0 as given.

Additionally, some constraint may be imposed on the value of initial assets,

$$A(s_0) = \alpha(x_0)$$

The Ramsey problem without any restriction on the value of initial assets $A(s_0)$ is often a trivial problem, because it becomes feasible to implement a zero distortion policy by taxing the initial asset value and financing government expenditure out of accumulated public savings. The constraint imposed on the initial value of assets, $A(s_0)$, is more general than the standard restriction upon the initial capital tax $\tau^k(s_0)$ and it deserves some discussion. First, note that the usual arbitrary restriction $\tau^k(s_0) = \bar{\tau}^k$ can be incorporated as special case, by setting

$$\alpha(x_0) = u_1^c(c_1(s_0))\left[\left(F^k(k_0, n(s_0))\left(1-\bar{\tau}^k\right) + 1 - \delta\right)k_0 + b_0\right]$$

If the face value of the assets for agent 1 must be left intact then it is necessary to impose a constraint of the form

$$A(s_0) = \alpha \tag{1}$$

with no restriction on the value of α but feasibility.[8]

Simply restricting the capital tax is not enough to achieve (1) since there are other fiscal schemes to tax the value of the initial assets. This constraint seems a necessary condition if one wants the initial state of the economy to be compatible with rational expectations set at some date s_{-1}. For the remaining of the paper I will assume that (1) always constraints the λ-Ramsey policy.

To conclude this section, I introduce a slightly modified version of the λ-Ramsey problem in primal approach which is extensively used to prove the time consistency properties of λ-Ramsey policies. Specifically, the implementability constraint associated with the capitalist

[7] The Appendix C contains a brief discussion of the necessary first order conditions associated with the λ-Ramsey problem.

[8] In order to ensure that the choice set is non-empty, $\alpha(x_0)$ must be chosen carefully. Specifically,

$$\alpha(x_0) \geq \underline{\alpha} > 0$$

it is a necessary condition. The lower bound should be stricly positive to ensure that the constraint defines a closed set.

household problem, (*Cap.-IC*), is dropped. Hence, it is an unconstrained version of the λ-Ramsey problem for which it is not possible to conclude that the resulting allocations will be part of any private sector competitive equilibrium.

Definition 4 *The* ***unconstrained λ-Ramsey problem*** *at node s^t is to set x to maximize*

$$W^{\lambda}\left(x,s^{t}\right)$$

subject to (R.C.) and (Wor.-IC) for all $s^j \in S^j$, $j \geq t$, $k\left(s^{t-1}\right)$ given.

The reader may guess that the unconstrained λ-Ramsey policy problem at node s_0 corresponds to the relevant fiscal policy problem when lump sum taxes (and transfers) are available only for the capitalist agent. To see this, note that in the unconstrained λ-Ramsey problem, the policymaker can dictate the full consumption path by the capitalist household. Appendix C contains further details about the unconstrained λ-Ramsey problem.

4 Time Consistent Fiscal Policy

It is well known that the optimal fiscal policy is usually time inconsistent in the representative agent framework. At any date $t \geq 1$, society finds the continuation of the Ramsey fiscal plan suboptimal because of the eventual inelasticity of the capital supply: it would be welfare superior to increase capital taxation, a lump sum, in order to reduce overall distortion by decreasing labor taxation.

This section shows that not all constrained Pareto efficient policies are time inconsistent. It highlights the role of equity considerations as given by the Pareto weight distribution which characterizes the policymaker's preferences. As briefly discussed above, reducing distortion is linked with a redistributive pattern from capitalist to worker households. Depending on the policymaker's evaluation of different welfare distributions, the efficiency gains may be forgone and the policy rendered time consistent.

Conditions are shown such that a constrained Pareto efficient policy, or a feature of it, can be made time consistent by proper choice of the policymaker's preferences, again given by a Pareto weight distribution. A special case involving a constant intertemporal elasticity of substitution is used to link the time consistency properties to redistributive goals.

4.1 The Severity of the Time Inconsistency Problem

A policy will be time consistent if at any node the policymaker does not find any strictly welfare superior fiscal policy. Once again, the statement needs to be qualified for each policymaker type λ to index how welfare changes are aggregated. Thus, the concept of time consistency needs to refer both policy and policymaker.

Definition 5 *Let $\{x, p, \tau\}$ constitute a private sector competitive equilibrium. Feasible fiscal plan τ is λ-**time consistent** if for all $s^t \in S^t, t \geq 0$, there is no $\{x', p', \tau'\}$ such that*

$$W^{\lambda}\left(x', s^t\right) > W^{\lambda}\left(x, s^t\right)$$

and $\{x', p', \tau'\}$ constitutes a private sector competitive equilibrium at node s^t with

$$\begin{aligned} k'\left(s^{t-1}\right) &= k\left(s^{t-1}\right) \\ b'\left(s^t\right) &= b\left(s^t\right) \end{aligned}$$

Note this is a strong time consistency requirement. At node s^t, policymaker λ can set any fiscal plan τ' *as if she had full commitment.* No fiscal policy given by Markovian or history dependent policies would satisfy this requirement in the representative agent framework if any tax after $t = 0$ is positive.

The next proposition formalizes the first main result of the paper: there exists at least one constrained Pareto efficient policy which is time consistent if the deviations are evaluated according to the precise Pareto weight distribution indexing the second best policy choice. In the terminology introduced above, there is a policymaker type λ' such that the λ'-Ramsey policy (the policy choice among the constrained Pareto efficient set) is λ'-time consistent (so no deviation at any time is λ'-welfare superior). This may or may not be the society's preferences, pinned down by the population parameter ψ by the assumption of symmetry.

Proposition 2 *There exists $\lambda' > 0$ such that the λ'-Ramsey policy is λ'-time consistent.*

Proof. In the Appendix D. ■

Loosely speaking, I am stating the existence of a policymaker type λ' such that lump sum taxes upon the capitalist agent are a redundant instrument.

The policymaker λ' must be willing to assume the distortion associated with labor taxation, which involves a certain loss of efficiency, to satisfy some redistributive objectives. This is the classic efficiency-redistribution trade-off. Considering different policymaker types, i.e. moving along the constrained Pareto utility frontier, pins down where this trade off renders the capitalist's lump sum taxes redundant. As reducing overall distortion necessarily involves increasing the capital tax, transfers from capitalists to workers must be valued negatively on the margin by the policymaker to offset the positive net welfare gains due to the efficiency gains.

The reader is referred to the Appendix D for the rigorous proof of Proposition 2. Here I provide only a sketch of the argument. It can be shown that for a certain λ-welfare function, the solutions to the λ-Ramsey problem and the unconstrained λ-Ramsey problem coincide. The proof is built upon the fact that the solution to the unconstrained λ-Ramsey problem at date 0 solves the unconstrained problem at any node s^t. In other words, which involve a conscious abuse of the definitions, the unconstrained λ-Ramsey allocation plan is time consistent. Hence, the λ-Ramsey policy will be time consistent too.

4.2 Solving the Time Inconsistency Problem

In the previous subsection, I have established the extent to which the time inconsistency problem depends on the policymaker type. However, society's preferences may be such that the Ramsey policy is time inconsistent. In this subsection I explore under which conditions there is any policymaker λ^* for whom the Ramsey policy is λ^*-time consistent. Then society could implement the Ramsey policy even if no commitment technology is available by delegating fiscal policy to policymaker λ^*. I show that under certain conditions, for any λ-Ramsey policy there is a policymaker λ^* such that the λ-Ramsey policy is λ^*-time consistent.

As common in the literature on optimal fiscal policy, the most general analytical results concern the non-stochastic steady state Ramsey policy.[9] I show that any λ-Ramsey policy can be made time consistent in the non-stochastic steady state by appointing a policymaker λ^*. Proposition 3 is silent on how to implement any transitional policy or policy responses to fiscal shocks.

Proposition 3 *Assume there exists a non-stochastic steady state $(x^\infty, p^\infty, \tau^\infty)_\lambda$ associated with the λ-Ramsey equilibrium for any $\lambda > 0$. Then for all $\lambda > 0$, there exists a policymaker λ^* such that τ_λ^∞ is λ^*-time consistent.*

Proof. In the Appendix D. ■

The result applies to the Ramsey policy simply by setting $\lambda = \psi$.

If more structure is imposed on the form of the capitalist utility function, it is possible to establish that the Ramsey policy will be λ^*-time consistent along the transition path and for stochastic environments. Assume that the preferences of the capitalist household are given by a constant intertemporal elasticity of substitution (C.E.) utility function,

$$u_1(c_1) = \frac{c_1^{1-\sigma} - 1}{1-\sigma}$$

with $\sigma \geq 0$, with $u_1(c_1) = \log(c_1)$ when $\sigma = 1$. This is a commonly used class of utility functions.[10]

Proposition 4 *Assume $u_1(c_1)$ is a C.E. utility function. Then for all $\lambda > 0$, there exists λ^* such that the λ-Ramsey policy is λ^*-time consistent from date $t \geq 1$ onwards.*

[9] The non-stochastic steady state $(x^\infty, p^\infty, \tau^\infty)_\lambda$ is defined as the asymptotic allocations, prices and fiscal policy associated with the λ-Ramsey equilibrium in a deterministic version of the model such that

$$g(s_t) = \sum_{s \in S} \pi^*(s)\, g(s)$$

where π^* is the ergodic distribution associated with Π. Perhaps, as Klein and Rios-Rull (2002) point out, "long term" would be a more appropiate nomenclature.

[10] And it has a tradition for results in the optimal fiscal policy literature. See Chari and Kehoe (1998).

Moreover, if the λ-Ramsey policy is restricted to satisfy a constraint of the type (1) at $t = 0$, then the λ-Ramsey policy is λ^*-time consistent.

Proof. In the Appendix D. ■

Again, the result applies for the Ramsey policy simply by setting $\lambda = \psi$.

The technical discussion of the proof of Propositions 3 and 4 mirrors the arguments outlined in the previous subsection. By manipulating the necessary first order conditions associated with the λ-Ramsey allocation plan x_λ at all or some nodes s^t, it can be shown that for some policymaker type λ^*, x_λ solves the unconstrained λ^*-Ramsey plan as well. Of course, one must carefully check for the global optimality properties: but this is considerably easier in the unconstrained version than in the Ramsey problem in primal approach. Therefore it can be concluded that x_λ is λ^*-time consistent: The solution to the unconstrained version solves the unconstrained version at all continuation nodes.

As Propositions 3 and 4 suggest, a zero capital tax is a necessary condition.[11] It is easy to see that if next period returns to capital are taxed, then an increase on today's capital tax is strictly preferred by both households. Hence, any benevolent policymaker would pursue such a revision of the policy. Once the capital tax is zero, there is no ex-post policy change which is Pareto superior.

It is worth to emphasize that these strong results are only possible because fiscal policy is not the appropriate vehicle for redistribution. The most famous example is Judd (1985) assertion that the asymptotic optimal fiscal policy is characterized by a zero capital tax and no redistribution, even when capitalists are not weighted at all in the social welfare function. If the efficient fiscal policy would implement redistribution, a policymaker with a larger weight for the capitalist household would be a mixed blessing for the worker households: it will grant efficiency in absence of commitment but it would forgone any redistribution policy. The propositions stated provide conditions such that no redistribution is implemented at all. In a more general setting, as long as the optimal fiscal policy is driven mainly by efficiency rather than redistribution, there would be positive worker household welfare gains associated with a policymaker with a larger welfare weight on capitalist household.

4.3 Progressive and Regressive Redistributive Goals

I have shown how social preferences determine the severity of the time inconsistency problem, and how society can get around the lack of commitment by appointing a policymaker with different redistributive objectives. But, what can be said about the precise social preferences that exacerbate or ease the time inconsistency problem? Is there any key characteristic that identifies the relationship between redistributive objectives and the ability to perform sound fiscal policy?

[11] Actually, the proof of Proposition 4 shows that Chari and Kehoe (1998)'s Proposition 7 extends for the two class economy presented here for any policymaker type λ.

The answer is yes. Typically, the unexpected fiscal policy revision reducing distortion involves easing labor taxes. Only if the policymaker's welfare function decreases with transfers from capitalist to worker households, the net welfare gains from reducing distortion can be offset, and no incentives to reoptimize fiscal policy will be left. In other words, the policymaker's redistributive goals must not be progressive.

The model is explicit only about relative factor income heterogeneity, but I will argue that wealth heterogeneity is the underlying process. Rodriguez, Diaz-Gimenez, Quadrini and Rios-Rull (2002) present evidence for the United States. They report labor earnings, defined to include 85.7 percent of business and farm income, and wealth distribution. One finding is that the earnings-poor are surprisingly wealthy: "*a household who owned the average wealth of the households in the bottom earnings quintal would be in the very top of the fourth quintal of the wealth distribution.*"[12] It is also reported that high income is a good proxy of high share of capital income. Also, see Garcia-Mila et al. (2001) for additional facts used in their calibration. Thus, the different set of weights for capitalist and worker households can effectively be related to the more traditional view of redistributive goals across the wealth distribution.

The first result in this subsection considers a set of Pareto weights which conform to the market distribution under the optimal fiscal policy. This set of welfare weights corresponds to a policymaker type λ' which is not willing to engage in marginal intra-household redistribution. Then I show that the λ'-Ramsey policy is λ'-time inconsistent, and the policymaker λ^* such that the λ'-Ramsey policy is time consistent satisfies $\lambda^* > \lambda'$. I conclude that solving the time inconsistency problem necessarily requires regressive redistributive goals.

Proposition 5 *Let λ' be a policymaker type such that*

$$\lambda' u_1^c \left(c_1^\infty\right) = u_2^c \left(c_2^\infty, n^\infty\right)$$

where x_λ^∞ corresponds to the non-stochastic steady state associated with the λ'-Ramsey policy. Then there exists λ^* such that the τ_λ^∞ is λ^*-time consistent and

$$\lambda' \leq \lambda^*$$

with equality if and only if all taxes τ^∞ are zero.

Proof. In the Appendix D. ■

Note that if the economy is tax free, there is no time inconsistency problem in general.

Again, by imposing more structure on the capitalist preferences, it is possible to pursue further characterization of the λ-welfare function that renders the social optimal fiscal policy time consistent.

[12] Rodriguez et al. (2002), page 6.

Corollary 6 *Assume $u_1(c_1)$ is a C.E. utility function. Then the Ramsey policy is λ^*-time consistent, where λ^* is given by*

$$\lambda^* = \psi + \phi_1 (1 - \sigma)$$

where ϕ_1 is the Lagrange multiplier associated with (Cap.-IC) in the Ramsey problem in primal approach.

Proof. See Proof of Proposition 4 in the Appendix D. ■

The reader can guess that the "rule" for finding the appropriate policymaker λ^* for any λ-Ramsey policy is

$$\lambda^* = \lambda + \phi_1 (1 - \sigma)$$

so the Ramsey equilibrium is just the case $\lambda = \psi$.

The interesting possibility that arises with the last corollary is that society would need to appoint a policymaker with less regressive redistributive goals. Note that both the Lagrange multiplier ϕ_1, an endogenous object, and the inverse of the intertemporal elasticity of substitution σ, a parameter, could imply that $\lambda^* < \psi$. In other words, society would be too regressive.[13]

This possibility seems to be at odds with the overall intuition, but it is not. From the date 0 perspective, transferring resources from workers to capitalists involve two distortions: first, distortionary labor taxation is necessary to raise revenues; second, lump sum transfers are not available, only subsidies. But subsidies are distortionary as well. Once the investment decisions have been set, the latter distortion disappears, and the ex-post taxation problem calls for additional transfers to the capitalist household.

To clarify the discussion, assume first that $\sigma < 1$. Simple algebra shows that if $\phi_1 < 0$, then $\lambda^* < \psi$. The idea of a negative Lagrange multiplier may seem unorthodox. Mathematically, it is correct as the implementability constraint (*Cap.-IC*) needs to hold with strict equality. But the Lagrange multiplier has been said to measure "*the utility costs of raising government revenues through distorting taxes.*"[14] Thus, does a negative Lagrange multiplier implies a welfare gain from distortion?

To clarify this point, consider the marginal benefit of a lump sum tax upon the capitalist at date 0, evaluated at the Ramsey policy:

$$\phi_1 u_1^c (s_0)$$

Hence, when the Lagrangian multiplier is negative, it corresponds the case where society would find beneficial to do a *positive* lump sum transfer to the capitalists. This possibility fits on the previously outlined discussion: if society is very eager to transfer resources to the

[13] I asserted the existence of this possibility by solving numerically for the social optimal fiscal policy for large values of ψ, and then checking for time consistency. However, no analitycal results were found.

[14] Ljungqvist and Sargent (2000), page 323.

capitalists, the need to use a capital subsidy is a distortion as well. If lump sum transfers were available, overall society would be strictly better. Lump sum taxes to the capitalist household, if available, would be left unused.

Let me introduce the case $\sigma > 1$ by stating a possible critique: one could think that since the Ramsey fiscal policy involves a zero capital tax, then simply by ruling out capital subsidies, this particular, atypical time inconsistency problem would be solved. But this is not true since it is possible to tax the inelastic supply of capital and still improve capitalist's welfare at the expense of the worker's. A necessary condition is a high bond price elasticity, i.e., a low intertemporal elasticity of substitution. Then the hike on interest rates can lead to a large enough increase of the capitalist rents than more than compensate the lump sum tax. Precisely, when $\phi_1 > 0$, it is sufficient that $\sigma > 1$ to have $\lambda^* < \psi$.[15]

This possibility is specially relevant for the literature linking the credibility of public debt repayment with redistributive objectives.[16] I include here a simple example without aggregate savings where capitalists are just "rentiers," following Bassetto (1999). The technology is linear in labor and the fiscal instruments available are labor taxes and a tax on the return to government bonds at date 0, which is equivalent to consider the possibility of intermediate default. The environment is deterministic.

Example 7 (Rentiers and Debt Repayment) *The rentiers (previous capitalists) date* 0 *budget constraint is given by*

$$\sum_{t=0}^{\infty} q_t c_{1t} \leq \left(1 - \tau_0^b\right) b_0$$

with $b_0 > 0$*. Let* c_1 *be a consumption sequence associated with some private sector competitive equilibrium for some arbitrary value of* $\tau_0^b < 1$*. Bond prices are*

$$q_t = \beta^t \left(\frac{c_{1t}}{c_{10}}\right)^{-\sigma}$$

where I have used a C.E. utility function for the rentier. Now I will show how a fiscal plan involving a marginal increase on τ_0^b *can implement strictly higher welfare for the rentiers.*

Consider a sequence $\tilde{c}_1$, $\tilde{c}_{1d} = c_{1d}(1+\varepsilon)$ *for* $d \geq 1$, $\tilde{c}_{1t} = c_{1t}$ *for* $t \neq d$, *with an arbitrarily small* $\varepsilon > 0$*. This sequence is strictly welfare superior for the rentier. Evaluated at equilibrium prices* $\tilde{q}_t$ *and* q_t, *it is also "cheaper", since* $\tilde{q}_d < q_d$*. Note that*

$$D = q_d c_{1d} - \tilde{q}_{1d} \tilde{c}_{1d} = q_d c_{1d} \left(1 - (1+\varepsilon)^{1-\sigma}\right)$$

Thus if $\sigma > 1$, D *is positive, meaning that* $\tilde{c}_1$ *will satisfy the budget constraint even if the policymaker raises some taxes on debt returns at date* 0*.*

[15] Obviously the inverse argument applies if $\sigma < 1$ and $\phi_1 < 0$.

[16] To the best of my knowledge, this possibility has not been considered in the literature. Note in the context of debt repayment, ruling out asset subsidies is natural.

But the fall on the bond price brings stress to the government budget constraint. It actually would be violated, as the present value of the surplus run at date d falls

$$(\tilde{q}_d - q_d)(\tau_d^n n_d - g_d) < 0$$

which it is more than the additional income from the date 0 *taxation,* $q_d c_{1d}\left(1-(1+\varepsilon)^{1-\sigma}\right)$. *Therefore the surplus at date d must be increased by* $(1+\varepsilon)$ *as well. Another way to see this: using the aggregate resource constraint*

$$c_1 + c_2 + g = n$$

the government's surplus is exactly equal to the capitalist consumption. Therefore the surplus needs to hike . Note that this leaves the workers strictly worse off and the rentiers strictly better off.

5 Policy Equilibrium without Commitment

In the previous section, it was possible to establish whether the optimal fiscal policy was or was not time consistent. However, analytical results do not convey any information about the welfare properties of economies where the optimal fiscal policy is not time consistent. There are a variety of economies where it is not possible to implement the optimal fiscal policy. Is it still possible to capture a significant part of the social welfare gains from commitment?

To answer this question, I will introduce a suitable definition for a policy equilibrium without commitment. I have chosen to explore an incomplete market economy for its predominance in the analysis of time consistent fiscal policy. I present some numerical exercises with parameter choices set to replicate some stylized facts about the U.S. economy and fiscal policy.

The literature on fiscal policy has used several policy equilibrium concepts in absence of commitment. A celebrated line of research has focused on Nash perfect equilibria to explore how reputation can substitute for commitment.[17] I choose to abstract from reputation mechanisms to emphasize the independent role of equity considerations on the determination of the time inconsistency problem. I conjecture that both mechanisms are complementary.

The equilibrium concept used in this paper is Markov Perfect equilibria.[18] In short, this equilibrium concept requires policies to be Markovian, i.e., policies are restricted to be a

[17] See the seminal work of Chari and Kehoe (1990). Recent research has applied the use of the techniques in Abreu, Pearce and Stacchetti (1990) to characterize some empirical features of the post WWII U.S. fiscal policy. See Phelan and Stacchetti (2000), Fernandez-Villaverde and Tsyvinski (2002) and Sleet and Yeltekin (2003), among others. One drawback is that these papers focus on the best sustainable policy equilibrium without an equilibrium selection theory.

[18] See Krusell and Rios-Rull (1999) and Klein and Rios-Rull (2002) for two leading examples of the use of Markov Perfect equilibria in the positive analysis of fiscal policy. For a theoretical treatment, see Maskin and Tirole (2001).

smooth function of the fundamentals of the economy. Definitions of Markovian policy and λ-Markov equilibrium are provided in the Appendix E.

The only difference with respect to the economy presented in the previous section is that I will drop the complete markets assumption. In particular, I will impose a balanced government budget constraint at every period, effectively ruling out debt as fiscal instrument.[19] In a non-stochastic environment, all results stand. But if government expenditure follows a stochastic process, implementing the optimal fiscal policy would require a different policymaker type for each realization of the fiscal shock. Intuitively, the inability to smooth distortion across states implies that the net welfare gains from reducing distortion are larger in some states than in others. Hence, the policymaker's welfare losses from equity considerations must be specific of each state. Still, the resulting fiscal policy may be close to the optimal fiscal policy minus its stabilization component.

For the numerical exercise, I consider the following stochastic process for government expenditures. Let $S = \{1, 2, 3\}$, with

$$\begin{aligned} g(1) &= 0.98 g(2) \\ g(3) &= 1.02 g(2) \end{aligned}$$

and Markov transition matrix

$$\Pi = \begin{bmatrix} 0.6 & 0.4 & 0 \\ 0.2 & 0.6 & 0.2 \\ 0 & 0.4 & 0.6 \end{bmatrix}$$

with initial state equal $s_0 = 2$, so $g(2)$ is equal to the mean associated with the ergodic distribution π^*, and thus $E(g(s^t) | s_0) = g(2)$ for any $s^t \in S^t$, $t \geq 0$. Matrix Π may seem an arbitrary choice, but it stresses how the theory performs in stochastic environments with incomplete markets.

Computation of Markov equilibria is sometimes difficult. One common problem is that a non-stochastic steady state may be hard to characterize. In this framework, one can get around the problem easily using the policymaker type as a degree of freedom. The target is to calibrate a steady state capital tax rate of 35%, approximately the value given for United States in the 90's. With parameters set to match several stylized features of U.S. economy and a government expenditure to output set to 0.23, which effectively accounts debt service as exogenous government consumption, one can solve for all allocations in the non-stochastic steady state given by the target fiscal policy of $\tau^k = .35$.[20] Then one can evaluate each household first order welfare effect associated with a marginal change in policy and solve for the policymaker type λ^{US} such that the aggregate first order welfare is zero. The sufficiency of the first order condition must be checked numerically, but it did not fail in any numerical simulation performed.

[19] In the context of optimal fiscal policy with commitment, a balanced budget constraint has been analyzed by Stockman (2001).

[20] Details as well as sources used for the parametrization choices are in the Appendix F.

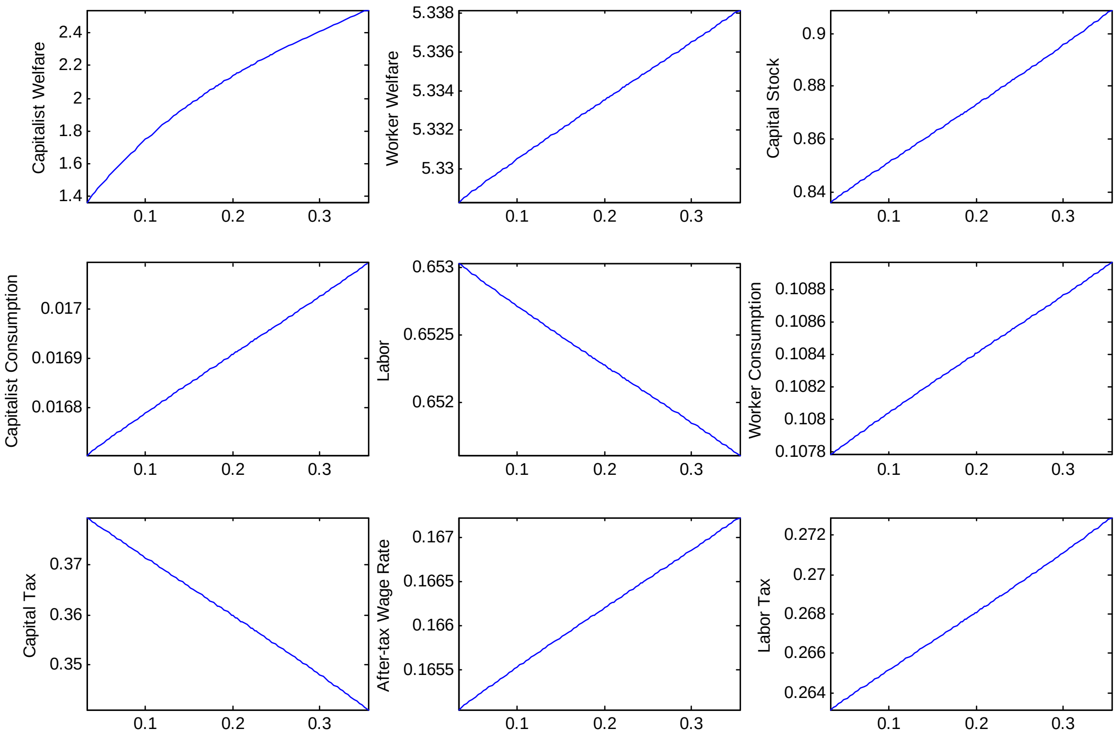

Figure 1: Welfare, Allocations and Taxes for different λ-Markov Equilibria.

Policymaker Type	ψ	$\lambda^{U.S.}$	λ'
c_1	0.96	0.9766	0.983
c_2	0.986	0.991	0.994
n	1.002	1.0015	1.001
k^∞	0.838	0.885	0.895

Table 1: **Allocations for different λ-Markov equilibria**

Figure 1 plots welfare, allocations and taxes as function of the policymaker type λ in the stochastic environment. All variables are evaluated at the steady state associated with the respective λ-Markov equilibrium.[21] The fraction of capitalists households is $\psi = .03$, and the policymaker type that matches U.S. data on the after-tax return to capital is $\lambda^{U.S.} = .2772$. The large difference between the population fraction and the policymaker type is an artifact of the difficulty of matching U.S. income inequality with just two type of households.

From Figure 1 it is clear that a policymaker with higher welfare weight associated with the capitalist household is strictly welfare superior for both capitalist and worker households. Results are driven by a lower capital tax and corresponding higher steady state capital stock. It is interesting to mention that the worker household welfare gains from are considerable. Note that the labor tax increases, but the after-tax wage rate does as well, because a larger capital stock can be sustained in steady state. Worker consumption goes up despite the decrease on labor supply.

Table 1 summarizes results for three λ-Markov equilibria: $\lambda = \psi$, the population parameter; $\lambda = \lambda^{U.S.}$, the policymaker type used to calibrate the capital tax to the U.S. value, and $\lambda = \lambda'$, roughly $\frac{3}{2}\lambda^{U.S.}$. This latter value approximately achieved the maximum social welfare measured by ψ. Allocations are expressed as fraction of the non-stochastic steady state under Ramsey policy.

It can be seen that the welfare gains are considerable. Note that there are additional welfare gains associated with appointing policymaker λ'. This is not unexpected given that the observed U.S. fiscal policy is pretty different from the implied Ramsey policy. The model also abstracts from other policy dimensions with potential redistributive effects which could imply a social cost of appointing a policymaker with regressive redistributive goals.[22] With these additional policy considerations, maybe policymaker type λ^{US} achieves the social welfare maximum, or better, it achieves the median voter welfare maximum. As the model stands now, it is difficult to perform more accurate calibration exercises.

The incomplete markets introduce a flip side on the gains from appointing a more capitalist friendly policymaker. See how the volatility of taxes and consumption behaves across different λ-Markov equilibria in Figure 2. It plots the standard deviations of the percentage differences of each variable with respect the steady state value. Note the different behavior

[21] To be precise, I look at a particular node s^T with $s_t = s_2$ for $t \leq T$, with T arbitrarily large.

[22] An obvious candidate is the determination and composition of government spending.

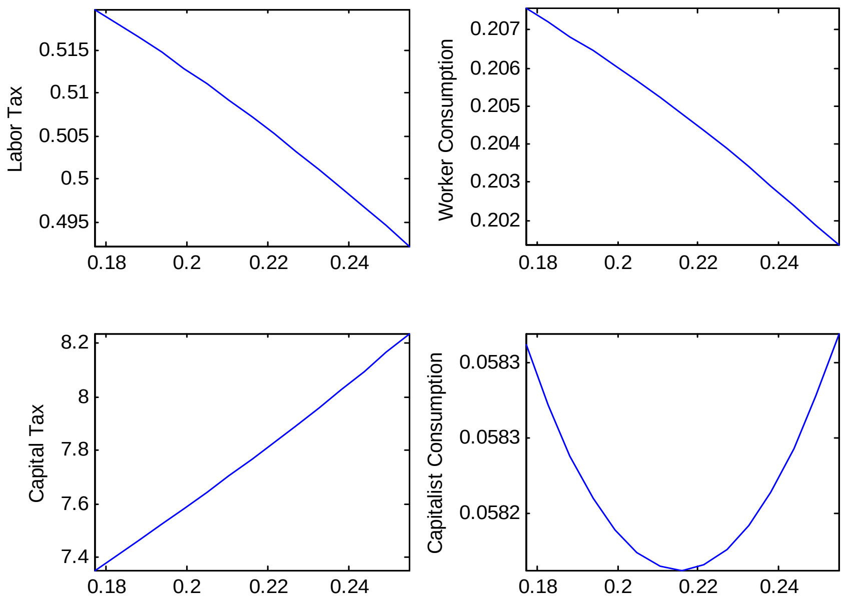

Figure 2: Standard Deviations of Percentage Differences from Steady State values for different λ-Markov Equilibria.

for labor and capital taxes. The volatility of labor taxes decreases as the capital tax absorbs a larger share of the fiscal shock. Worker consumption volatility decreases but capitalist consumption volatility is almost constant.

This is a consequence of the time inconsistency problem. When a fiscal shock hits the economy, the welfare cost of distortion is higher and it is optimal to raise capital taxes to finance the government expenditure. A higher Pareto weight associated with the capitalist household effectively implements a lower capital tax mean and a higher labor tax mean. But when government consumption is high, distortion is even higher because of the lower capital taxes - hence, the sharper correction on capital taxes.

Finally, Figure 3 performs a very simple sensitivity exercise with respect to the government spending to output ratio. The relationship between the policymaker type and the various allocations simply shifts in an almost parallel fashion. Note that in order to achieve a certain low capital tax, the more government spending, the more the policymaker needs to weigh the capitalist household's welfare. Again, it is the larger welfare cost associated with distortion that needs more skew redistributive objectives: recall that the optimal capital tax mean is almost invariant to different values of government spending.

Summarizing, the theory seems able to provide a substitute for commitment even under a balanced budget constraint, which strains the inability to smooth distortion or adjust the

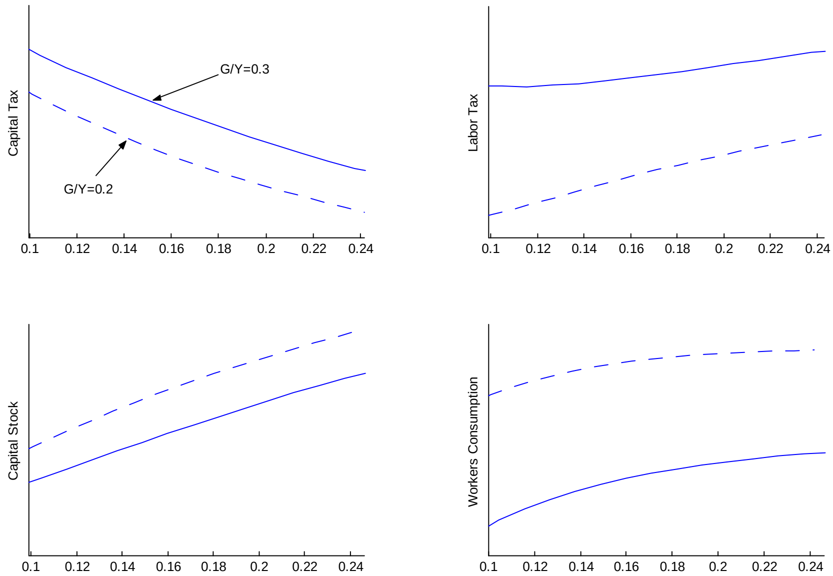

Figure 3: Selected Variables for different λ-Markov Equilibria for different Government Expenditure to Output Ratio.

policymaker type as function of the state. Mainly, the inability to smooth fiscal shocks translates in sharper movements of the capital tax. However, maybe because the capitalists are likely to be accumulating a buffer stock, this volatility does not seem to translate in welfare losses for the workers. The results seems very robust across different government expenditures levels, as well as some other sensitivity analysis not reported here.

6 Conclusions

Agent heterogeneity has proved not to be a trivial extension as the optimal fiscal policy model could have suggested. The welfare properties of the time consistent policies are very different once policymaker's equity considerations are introduced. At a theoretical level, the possibility of rendering the optimal fiscal policy as time consistent by appointing a different but still Paretian policymaker has implications for the role of public choice mechanisms. At a computational level, the results are relevant for the calibration of Markov equilibria.

There are several worthy research lines to be explored. First, the robustness exercise concerning incomplete markets can be extended to allow for non-contingent debt, although it is very demanding computational wise. Second, the household heterogeneity considered in this paper is very simple. In particular, it would be interesting to consider the role of government transfers to population specific groups like elders. Finally, one may want to explore the role of additional economic shocks, as technological shocks. Idiosyncratic shocks will be specially interesting as they would break the agent type immobility present in this paper.

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A Competitive Equilibrium Conditions

In this section of the Appendix I completely characterize a private sector competitive equilibrium $\{x, p, \tau\}$ and provide a lemma on the sequential nature of the equilibrium concept.

The following first order conditions for all $s^t \in S^t, t \geq 0$ are necessary and sufficient to characterize the solution of the capitalist household problem (*Cap.*-HH).[23]

$$\begin{aligned} q\left(s^t, s^{t+1}\right) u_1^c\left(s^t\right) &= \beta \pi\left(s_{t+1}|s_t\right) u_1^c\left(s^{t+1}\right) \\ u_1^c\left(s^t\right) &= \beta \sum_{s_{t+1}} \pi\left(s_{t+1}|s_t\right) u_1^c\left(s^{t+1}\right)\left[\left(1-\tau^k\left(s^{t+1}\right)\right) r^k\left(s^{t+1}\right)+1-\delta\right] \end{aligned}$$

This implies the following arbitrage condition between bond prices and capital rental rate,

$$1 = \sum_{s_{t+1}} q\left(s^t, s^{t+1}\right)\left[\left(1-\tau^k\left(s^{t+1}\right)\right) r^k\left(s^{t+1}\right)+1-\delta\right] \tag{2}$$

Using (2), the sequence of budget constraints can be collapsed in an intertemporal budget constraint.[24]

$$\sum_{t=0}^{\infty} \sum_{s^t} q_0\left(s^t\right) c\left(s^t\right) \leq A\left(s_0\right) \tag{3}$$

with bond prices rewritten

$$q_0\left(s^t\right) q\left(s^t, s^{t+1}\right) = q_0\left(s^{t+1}\right)$$

Previously derived first order conditions imply then

$$q_0\left(s^t\right) = \beta^t \pi\left(s^t|s_0\right) \frac{u_1^c\left(s^t\right)}{u^c\left(s_0\right)} \tag{4}$$

[23] Some interiority conditions are required. It is sufficient to assume standard Inada conditions on the utility function and $k_0 > 0$.

[24] This derivation requires to consider the transversality condition associated with (*Cap.*-HH).

Note that since $u_1^c > 0$, the budget constraint can be evaluated with strict equality.

The following first order conditions $\forall s^t \in S^t, t \geq 0$ are necessary and sufficient to characterize the solution to the worker household problem (*Wor.*-HH)

$$-\frac{u_2^n\left(s^t\right)}{u_2^c\left(s^t\right)} = \left(1-\tau^n\left(s^t\right)\right) w\left(s^t\right) \tag{5}$$

Note since the worker household does not have access to savings, the sequence of budget constraints

$$c_2\left(s^t\right) \leq \left(1-\tau^n\left(s^t\right)\right) w\left(s^t\right) n\left(s^t\right) \tag{6}$$

can not be collapsed into a date 0 intertemporal budget constraint. Since $u_2^c > 0$, the same comment as before applies, and the budget constraint is known to be strictly binding.

The representative firm problem is completely standard: at every s^t,

$$\begin{aligned} F^k\left(s^t\right) &= r^k\left(s^t\right) \\ F^n(s^t) &= w\left(s^t\right) \end{aligned} \tag{7}$$

Finally, the sequence of government budget constraints (**??**) can be collapsed in a date 0 intertemporal budget constraint,

$$\sum_{t=0}^{\infty}\sum_{s^t} q_0\left(s^t\right)\left(\tau^n\left(s^t\right) w\left(s^t\right) n\left(s^t\right) + \tau^k\left(s^t\right) r^k\left(s^t\right) k\left(s^t\right) - g\left(s_t\right)\right) \geq b_0^g \tag{8}$$

It is possible to show that the resource constraint ($R.C.$) must be binding since u_1^c and u_2^c are strictly positive. Then it is straightforward to show that (8) must be binding with strict equality as well.

Remark 1 *A private sector competitive equilibrium at node s^t given feasible fiscal policy τ is completely characterized by*

1. *Equations (2),(4), (5), (6) with strict equality, (7) and resource constraint (R.C.) for all $s^j \in S^j, j \geq t$.*

2. *Equations (3) and (8) with strict equality.*

The private sector competitive equilibrium is defined for any node s^t. The following lemma states a standard result linking equilibria at nodes that are continuation of each other.

Lemma 8 *If triplet $\{x, \tau, p\}$ constitutes a private sector competitive equilibrium at node s^t, then they constitute a private sector competitive equilibrium at any continuation node $s^j \in S^j\left(s^t\right)$, $j > t$.*

Proof. Conditions 2 to 4 of the definition of a competitive equilibrium will obviously be satisfied from any date $j > t$ onwards. Assume there exists some date $j > t$, for any history, such that x does not solve one (or both) of the two representative household problems. This will imply that there exists x' such that at least one household achieves strictly more utility than under x. Set plan x'' such that $x''_d\left(s^d\right) = x_d\left(s^d\right)$ for $d < j$, and $x''_d\left(s^d\right) = x'_d\left(s^d\right)$ for $d \geq t$. It is straightforward to show that x'' satisfies the budget constraints at all $d \geq t$ given p and τ. It delivers strictly more utility, therefore it would contradict the optimality of x at date t. ■

B Proof of the Proposition 1

Once the competitive equilibrium has been completely characterized, I proceed to the proof of the equivalency proposition.

Proof of Proposition 1. First, I will show that a competitive equilibrium plan implies (*Cap.-IC*) and (*Wor.-IC*) for all s^t, since it is obvious that the resource constraint will hold. Substitute the first order condition with respect to bonds (4) into (3), and since $u_1^c\left(s_0\right) > 0$, the implementability constraint (*Cap.-IC*) follows. In a similar fashion, use (5) into (6) to show that (*Wor.-IC*) holds. Details about the strict sign are given in description of the competitive equilibrium.

The second part involves showing that for any allocation plan satisfying (*Cap.-IC*) and (*Wor.-IC*) and (*R.C.*) for all s^t, there exists prices p and a fiscal plan τ such that they constitute a competitive equilibrium. For this, let $\{c_1, c_2, n, k\}$ satisfy the implementability constraints. I propose the following candidates for prices

$$q_0\left(s^t\right) = \beta^t \pi\left(s^t | s_0\right) \frac{u_1^c\left(s^t\right)}{u_1^c\left(s_0\right)}$$

and

$$\begin{aligned} F^k\left(s^t\right) &= r^k\left(s^t\right) \\ F^n(s^t) &= w\left(s^t\right) \end{aligned}$$

By construction, (4) and (7) are satisfied. The capitalist household budget constraint (3) only needs some algebra. Following the identical procedure, let $\tau^n\left(s^t\right)$ solve

$$-\frac{u_2^n\left(s^t\right)}{u_2^c\left(s^t\right)} = \left(1 - \tau^n\left(s^t\right)\right) w\left(s^t\right)$$

This $\tau^n\left(s^t\right)$ will exist given the interiority conditions on c_2 and n. Again, by construction, (5) is satisfied and so it is (6). To retrieve the capital tax, just solve the arbitrage condition (2).[25] The only missing equation to complete a competitive equilibrium is (8).

[25] It is well known that there is an undeterminacy on the precise capital taxes. See the proof in Chari and Kehoe (1998). In the present case, this undeterminacy is not relevant.

Proceed as follows. Add equation (3) to a weighted sum of (6) at every s^t by $q_0(s^t)$. Using the resource constraint with strict sign and the fact that

$$y\left(s^t\right) = w\left(s^t\right) n\left(s^t\right) + r^k\left(s^t\right) k\left(s^{t-1}\right)$$

it can be derived that

$$\sum_{t=0}^{\infty} \sum_{s^t} q_0\left(s^t\right) \left(\tau^n\left(s^t\right) w\left(s^t\right) n\left(s^t\right) - g\left(s_t\right) + \left(r^k\left(s^t\right) + 1 - \delta\right) k\left(s^{t-1}\right)\right) = A_0$$

Finally, using the arbitrage condition

$$q_0\left(s^t\right) = \sum_{s^{t+1}} q_0\left(s^{t+1}\right) \left(\left(1 - \tau^k\left(s^{t+1}\right)\right) r^k\left(s^{t+1}\right) + 1 - \delta\right)$$

the resulting expression is the government budget constraint at date 0 with strict equality.
■

C The λ-Ramsey Problem (in Primal Approach)

In this section I discuss the solution to the λ-Ramsey Policy problem, in its primal approach. I will assume that first period allocations x_0 and initial capital tax $\tau^k(s_0)$ are restricted by

$$A\left(s_0\right) = \bar{\alpha}$$

where $\bar{\alpha} > 0$. This is a slightly different condition that the usual arbitrary condition on $\tau^k(s_0)$.

The necessity of the first order conditions of the λ-Ramsey fiscal policy imply that the allocations associated with the optimal fiscal policy must hold the following set of equations for all $s^t \in S^t, t \geq 1$,

$$\begin{aligned}
\lambda u_1^c\left(s^t\right) + \phi_1 V_1^c\left(s^t\right) &= \theta\left(s^t\right) \\
u_2^c\left(s^t\right) + \phi_2\left(s^t\right) V_2^c\left(s^t\right) &= \theta\left(s^t\right) \\
u_2^n\left(s^t\right) + \phi_2\left(s^t\right) V_2^n\left(s^t\right) &= -\theta\left(s^t\right) F^n\left(s^t\right) \\
\sum_{s^{t+1}} \beta\pi\left(s^{t+1}|s_t\right) \theta\left(s^{t+1}\right) \left(F^k\left(s^{t+1}\right) + 1 - \delta\right) &= \theta\left(s^t\right)
\end{aligned} \tag{9}$$

and at $t = 0$

$$\begin{aligned}
\lambda u_1^c\left(s_0\right) + \phi_1 V_1^c\left(s_0\right) &= \theta\left(s_0\right) + \left(\phi_1 - \gamma\right) A_0^c \\
u_2^c\left(s_0\right) + \phi_2\left(s_0\right) V_2^c\left(s_0\right) &= \theta\left(s_0\right) \\
u_2^n\left(s_0\right) + \phi_2\left(s_0\right) V_2^n\left(s_0\right) &= -\theta\left(s_0\right) F^n\left(s_0\right) + \left(\phi_1 - \gamma\right) A_0^n
\end{aligned} \tag{10}$$

where

$$\begin{aligned} V_1\left(s^t\right) &= u_1^c\left(s^t\right) c_1\left(s^t\right) \\ V_2\left(s^t\right) &= u_2^c\left(s^t\right) c_2\left(s^t\right) + u_2^n\left(s^t\right) n\left(s^t\right) \end{aligned}$$

Lagrange multipliers are associated with each constraint: ϕ_1 associated with (*Cap.-IC*), $\phi_2\left(s^t\right)$ with (*Wor.-IC*) at s^t, $\theta\left(s^t\right)$ with (*R.C.*) at s^t and finally γ associated with the constraint $A\left(s_0\right) = \bar{\alpha}$. Allocations also satisfy the resource constraint (*R.C.*) with strict equality.

For later reference, note that the necessity first order conditions of the unconstrained λ-Ramsey fiscal policy are given by

$$\begin{aligned} \lambda u_1^c\left(s^t\right) &= \theta\left(s^t\right) \\ u_2^c\left(s^t\right) + \phi_2\left(s^t\right) V_2^c\left(s^t\right) &= \theta\left(s^t\right) \\ u_2^n\left(s^t\right) + \phi_2\left(s^t\right) V_2^n\left(s^t\right) &= -\theta\left(s^t\right) F^n\left(s^t\right) \\ \sum_{s^{t+1}} \beta\pi\left(s^{t+1}|s_t\right) \theta\left(s^{t+1}\right)\left(F^k\left(s^{t+1}\right) + 1 - \delta\right) &= \theta\left(s^t\right) \end{aligned} \tag{11}$$

for all $s^t \in S^t$, $t \geq 0$, Lagrange multipliers follow the previous notation.

D Proof of the Time Consistency Propositions

In this Appendix section, I proof propositions 2 to 4. I start, however, with a simple lemma with respect to the solution of the unconstrained λ-Ramsey policy problem and a proposition about it is relationship to the λ-Ramsey policy.

Lemma 9 *Let x be the solution to the unconstrained λ-Ramsey policy problem at some node $s^t \in S^t, t \geq 0$. Then for all $s^j \in S^j$, $j \geq t$, x solves the unconstrained λ-Ramsey policy problem at node s^j.*

Proof. Trivial since the set of continuation allocation plans from any node s^j on satisfying the constraints is dependent on $k\left(s^{t-1}\right)$ alone. ■

Proposition 10 *Let x^* be the solution to the unconstrained λ-Ramsey policy problem. If x^* satisfies (Cap.-IC), then x^* is the solution to the λ-Ramsey policy problem and it is λ-time consistent.*

Proof. It is obvious that if (*Cap.-IC*) is satisfied, then x^* must solve the λ-Ramsey policy problem. At any node s^t, consider

$$\sum_{j=t}^{\infty} \sum_{s^j} \beta^j \pi\left(s^j|s_t\right) u_1^c\left(s^j\right) c_1\left(s^j\right) = A\left(s^j\right) \tag{12}$$

If x^* satisfies (*Cap.-IC*), then (12) is satisfied for all $s^t \in S^t$, $t \geq 0$. By lemma 9, the continuation of x^* solves the unconstrained continuation problem. Therefore x^* solve the constrained continuation problem as well. ■

Loosely speaking, the solution to the unconstrained λ-Ramsey policy problem is time consistent. Now I can proceed to the first proof.

D.1 Severity

Proof of Proposition 2. Consider the unconstrained λ-Ramsey policy x_λ^* and let υ_1 be the set of $U_1(c_1, s_0)$ achieved in the unconstrained λ-Ramsey policy problem for some $0 < \lambda < \infty$. Evaluate the following derivative

$$\frac{dU_1\left(\gamma c_{1\lambda}^*, s_0\right)}{d\gamma}$$

at $\gamma = 1$ and $c_{1\lambda}^*$ corresponding to λ-Ramsey policy x_λ^*. For any $D < \infty$, there exists $\lambda > 0$ such that

$$\frac{dU_1\left(\gamma c_\lambda^*, s_0\right)}{d\gamma} > D$$

as $\lambda \to 0$, $c_{1\lambda}^* \to \vec{0}$, and Inada conditions apply.[26], $U_1\left(c_\lambda^*, s_0\right) \in \upsilon_1$. Note that $c_\lambda^* = \vec{0}$ is actually feasible for the unconstrained λ-Ramsey policy. Let $\bar{U}_1 = \sup \upsilon_1$, with $\bar{\lambda} = \inf_\lambda \left\{U_1\left(c_{1\lambda}^*, s_0\right) = \bar{U}_1\right\}$. Because the resource constraint (*R.C.*) imposes an upper bound on the set of feasible c_1, $\bar{U}_1$ is well defined and $\bar{\lambda} < \infty$. Let G be

$$\frac{dU_1\left(\gamma c_{\bar{\lambda}}^*, s_0\right)}{d\gamma} = G$$

then for any $d \in (G, \infty)$, there exists λ such that $\frac{dU_1\left(\gamma c_\lambda^*, s_0\right)}{d\gamma} = d$, since the continuity of υ_1 is straightforward.

Now, let $\alpha > G$. Then there exists a λ' such that the unconstrained λ'-Ramsey policy satisfies (*Cap.-IC*) as

$$\frac{dU_1\left(\gamma c_1, s_0\right)}{d\gamma} = \sum_{t=0}^{\infty} \sum_{s^t} \beta^t \pi\left(s^t | s_0\right) u_1^c\left(s^t\right) c_1\left(s^t\right)$$

therefore there exists λ' such that the implementability constraint

$$\sum_{t=0}^{\infty} \sum_{s^t} \beta^t \pi\left(s^t | s_0\right) u_1^c\left(s^t\right) c_1\left(s^t\right) = \alpha$$

can be satisfied. Note that $A(s_0)$ given any x_0 can be set to any arbitrary number by appropriate choice of $\tau^k(s_0)$. So Proposition 10 applies. ■

[26] The zero sequence $\vec{0}$ is defined as zero at every node $s^t \in S^t, t \geq 0$.

D.2 Delegation

Proof of Proposition 3. Non stochastic steady state allocations x^{∞} associated with the λ-Ramsey policy will satisfy

$$\lambda u_1^c\left(c_1^{\infty}\right)+\phi_1 V_1^c\left(c_1^{\infty}\right)=\theta^{\infty}$$

and the rest of necessary first order conditions given by (9), constraints (*R.C.*) and (*Wor.-IC*). Let λ^* be given by

$$\lambda^*=\frac{\theta^{\infty}}{u_1^c\left(c_1^{\infty}\right)}$$

It is straightforward that $0<\lambda^*<\infty$. By construction, it satisfies the first order conditions (11) of the unconstrained λ^*-Ramsey policy problem defined at k^{∞} with deterministic path for $g=\sum_{s\in S}\pi^*(s)\,g(s)$. However, this is not sufficient to show optimality. But given c_1^{∞}, x^{∞} already satisfied global optimality conditions for all other allocations. Since (*R.C.*) is a compact set with respect to c_1 and $U_1(c_1)$ is strictly concave, the first order condition with respect to c_1 is sufficient as well. Therefore x^{∞} solves the non stochastic version of the unconstrained λ^*-Ramsey policy problem, and Proposition 10 applies. ■

Proof of Proposition 4. For the C.E.S. class of utility functions

$$V_1^c\left(s^t\right)=u_1^c\left(s^t\right)(1-\sigma)$$

Consider λ^* given by

$$\lambda^*=\lambda+\phi_1(1-\sigma)$$

Since $\infty>\theta\left(s^t\right)>0$ for all s^t, $0<\lambda^*<\infty$. Let x be the allocations associated with the λ-Ramsey policy. Then x solves first order conditions (11) associated with the unconstrained λ^*-Ramsey problem at all nodes $s^1\in S^1$. This can be seen by simple algebra from (9).

Hence, x is a critical point: to show global optimality, note that, conditional on c_1, plan x attains a global maximum for the λ-Ramsey policy problem. Moreover, c_1 is only constrained by the resource constraint (*R.C.*) which defines a compact set, and $U_1\left(c_1,s^1\right)$ is strictly concave in c_1. Therefore, x solves the unconstrained λ^*-Ramsey problem at all $s^1\in S^1$, and Proposition 10 applies.

For the second part, note that if the constraint

$$A\left(s_0\right)=\alpha$$

is imposed, then $\gamma=\phi_1$, and first order conditions at $t=0$ (10) are isomorphic to (9) and all the previous argument applies as well at node s_0. ■

D.3 Policymaker Types

Proof of Proposition 5. The existence of λ^* is just a corollary from 3, as the result is not dependent on any value of λ. Comparing necessary first order conditions (9) and (11), if $\phi_1 V_1^c > 0$, then $\lambda^* > \lambda'$, and $\lambda^* = \lambda'$ if and only if $\phi_1 V_1^c = 0$. Using $\lambda' u_1^c (c_1^\infty) = u_2^c (c_2^\infty, n)$, one can show that

$$\phi_1 V_1^c = \phi_2 V_2^c$$

everything evaluated in the non-stochastic steady state allocations associated with the λ'-Ramsey policy. Assume that $\phi_1 V_1^c < 0$. Then

$$\begin{aligned} \lambda' u_1^c &> \theta \\ u_2^c &> \theta \end{aligned}$$

where θ is the Lagrangian multiplier associated with the resource constraint $(R.C.)$ for the λ'-Ramsey problem. But this would imply that raising an additional unit of resources and transferring it back to both agents would be λ-welfare increasing. Therefore, $\phi_1 V_1^c \geq 0$. With strict equality, then the economy is in the first best as

$$\begin{aligned} \lambda' u_1^c &= \theta \\ u_2^c &= \theta \end{aligned}$$

and therefore all taxes are 0. ■

E Markov Equilibrium

In this section, I define the Markov equilibrium concept used in the paper. For a theoretical discussion of Markov Perfect Equilibrium, see Maskin and Tirole (2001). The key characteristic is that strategies must be function only of payoff relevant variables, the "fundamentals" of the economy. First I start with a definition of a Markovian policy (strategy in the game theoretical language of Maskin and Tirole (2001)), which leads to a λ-Markov policy concept.

For equilibrium computation, as some exercises considered involve a non-stationary process for government expenditure, I do not use a recursive Markov equilibrium approach as in Klein and Rios-Rull (2002) and Krusell, Martin and Rios-Rull (2003). Instead, I will use the limiting equilibrium generated by a sequence of finite T equilibria. The details are in the second section.

E.1 Markovian Policies and λ-Markov Equilibrium

Now it is necessary to extend the state of the economy to record the history of actions. Let $h_t = (s_t, \tau_t)$, $h^t = (h_0, h_1, ..., h_t)$, with $h^{-1} = \varnothing$. Let H^t be the set of possible histories up to date t. Now an allocation plan needs to incorporate all possible histories, e.g., $c_1 = \{c_1(h^t) | \forall h^t \in H^t, t \geq 0\}$, similarly for all other allocations.

Bonds are still one period contingent assets on exogenous state s_t and therefore they are priced according to $q(h^t, s_{t+1})$. The fiscal plan now is

$$\tau = \left\{ \tau^k \left(\tilde{h}^t \right), \tau^n \left(\tilde{h}^t \right), \left\{ b^g \left(\tilde{h}^t, s' \right) \right\}_{s' \in S} | \forall \tilde{h}^t \in H^{t-1} \times S, t \geq 0 \right\}$$

where $\tilde{h}^t = (h^{t-1}, s_t)$. The extension of the private sector competitive equilibrium definition is straightforward, as well as the λ-welfare function.

Let H_t^p be a partition of H^t, and denote by $H_t^p(h^t)$ the partition including h^t.

Definition 6 *Let $\{H_t^p\}_{t=0}^{\infty}$ be a collection of partitions such that for all $h_1^t, h_2^t \in H^t$, $\forall t \geq 0$, if*

$$\left(k\left(h_1^{t-1}\right), b^g\left(h_1^t\right), s_t\right) = \left(k\left(h_2^{t-1}\right), b^g\left(h_2^t\right), s_t\right)$$

*then $h_1^t \in H_t^p(h_2^t)$. Then **policy τ is Markovian** if*

$$\tau\left(\tilde{h}_1^t\right) = \tau\left(\tilde{h}_2^t\right)$$

for $\forall \tilde{h}_1^t, \tilde{h}_2^t \subset H^t$, $\tilde{h}_1^t \subset H_t^p\left(\tilde{h}_2^t\right)$, $t \geq 0$.

Now I proceed to define the λ-Markov equilibrium. Aside of the requirement that allocations, prices and fiscal policy constitute a private sector competitive equilibrium, the fiscal policy must be Markovian in the sense given above and optimality must be satisfied at every node h^t, effectively imposing subgame perfection.

Definition 7 *A **λ-Markov equilibrium** is $\{x, p, \tau\}$ such that:*

1. *Triplet $\{x, p, \tau\}$ constitutes a private sector competitive equilibrium at node h_0.*
2. *The policy τ is Markovian.*
3. *For all nodes h^t, there is no one period fiscal plan τ_t' such that*

$$W^\lambda\left(x', \left(\tilde{h}^t, \tau_t'\right)\right) > W^\lambda\left(x, h^t\right)$$

with $\{x'.p', \tau'\}$ being a private sector equilibrium, $\tau' = \tau$ for all nodes but h^t.

F Computation

For all numerical examples in the text, I have used the following specific forms:

$$\begin{aligned} u_1(c_1) &= \frac{c_1^{1-\sigma_1}}{1-\sigma_1} \\ u_2(c_2, n) &= \frac{c_2^{1-\sigma_2}}{1-\sigma_2} + \varphi_0 \frac{(1-n)^{1-\varphi}}{1-\varphi} \\ F(k, n) &= Ak^\alpha n^{1-\alpha} \end{aligned}$$

Table 2 summarizes the parameter choices invariant across numerical exercises.

These values are well into the usual range of the literature on fiscal policy, see Chari et al. (1994), Chari and Kehoe (1998) and Stockman (2001). Following Cooley and Prescott (1995), they imply that capital is slightly above 3 times total output, the real annual interest rate is 2% in the steady state and capital rents are 1/3 of total output.[27]

The remaining parameters $\{\varphi_0, \varphi, A, \psi\}$ as well as $\{g(s)\}_{s\in S}$, Π and b_0 are set to match some features of U.S. fiscal policy in the non-stochastic steady state for each particular model considered. If not noted otherwise, the government consumption to output ratio is set to be 0.23, roughly the average for federal government expenditure net of debt service the period 1983-2003, and similarly the steady state debt to output ratio is set to 0.43.[28] The measure of capitalists households ψ is set such that the ratio $\frac{c_1}{c_2}$ is 400.[29] I calibrate the policymaker type λ to match an effective capital income tax of $\tau^k = 0.35$, above the values given in Chari, Christiano and Kehoe (1995), but slightly below the estimates in Mendoza, Razin and Tesar (1994) and Mulligan (2003), and almost the same estimate used in Lucas (1990). Finally, the leisure parameter preferences $\{\varphi_0, \varphi\}$ are set to match a labor tax around .24.[30]

Table 3 states the remaining parameter values for the different models considered.

[27] Their estimate is slightly higher, $\alpha = .4$, but they include government capital stock. The depreciation rate δ and intertemporal discount rate are identical to Cooley and Prescott (1995) the second decimal.

[28] Source: NIPA tables at the Bureau of Economic Analysis and Office (2003).

[29] Which is blatant underestimation given that Rodriguez et al. (2002) report that top income is more than 3000 times the average income. They also report high correlation between income and the share of capital income.

[30] Mendoza et al. (1994) report values around $\tau^n = .27$, and Chari et al. (1995) use $\tau^n = .24$.

Model	*Parameter and Values*	
Technology	$\alpha = 0.3100$	$\delta = 0.05$
Preferences	$\beta = 0.9804$	$\sigma_1 = 1.5$
	$\sigma_2 = 1.5$	

Table 2: **Constant Parameters**

Parameter	Balanced Budget	U.S., 1790	U.S., 1990
φ_0	2	2	2
φ	0.8	0.6	0.94
A	0.3014	0.3183	0.3007
ψ	0.0324	0.033	0.0295

Table 3: **Remaining Parameters**