



Optimal fiscal policy under finite planning horizons

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Abstract

We propose a novel framework that revisits the seminal Chamley-Judd zero capital taxation result in light of bounded rationality stemming from a finite policy planning horizon and structural frictions in fiscal institutions. We show a mechanism that generates positive optimal capital taxation in the long run. Our numerical results indicate that the current tax system in the United States could be near-optimal in a constrained environment where policymakers exhibit limited policy planning horizons and imperfect altruism toward household welfare under subsequent governments.

Keywords Fiscal policy · Optimal taxation · Institution · Bounded rationality

JEL Classification E02 · E62 · E71 · H21

1 Introduction

One of the most influential results in the dynamic public finance literature is that the capital income tax rate should be zero in the long run (e.g., Chamley, 1986; Judd, 1985, 1999) or ex-ante zero in a stochastic environment (e.g., Chari et al., 1994; Stockman, 2001). It is widely acknowledged, however, that contemporary tax systems do not conform to this theory. What causes this discrepancy between optimal policy theory and actual policy design? Among the many possible factors that could lead to positive optimal capital tax rates, this paper focuses on institutional constraints in the policymaking process. Specifically, we investigate the following structural frictions observed in most democratic societies: (i) finite policy planning horizons; (ii) rigid tax rate adjustments; and (iii) imperfect government altruism.

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These frictions induce benevolent social planners to behave virtually in a bounded-rational manner, which distinguishes our approach from the conventional optimal taxation framework.

We are primarily concerned with policy limitations stemming from limited policy planning horizons. In contrast to the standard Ramsey planner, who formulates complete state-contingent intertemporal plans for an infinite future, we consider an environment in which policymakers have limited policy authority due to finite government incumbency. In our environment, each government has a truncated policy planning horizon, and policy coordination across governments is infeasible. In addition, our model allows an incumbent government to value household welfare under subsequent governments less than the welfare provided during the current regime, which we refer to as imperfect altruism. On the other hand, we formalize the practical difficulties associated with tax reforms by introducing tax rate adjustment costs. This is motivated by the fact that taxes, particularly the capital tax on property rights, seldom change unless exceptional circumstances (e.g., a fiscal crisis) arise since tax reforms necessitate arduous political agreements that are difficult to achieve, often take too long, and possibly incur considerable social costs. Institutional constraints, unlike other factors such as information asymmetry or household heterogeneity, have received little attention in the optimal taxation literature, despite their apparent relevance in real-world policymaking. Our proposed framework enables us to look into the role of institutional constraints in policy formulation, potentially bridging the gap between optimal taxation theory and its practical application.

Given the aforementioned institutional constraints, the optimal capital tax rate can be far above zero in the long run due to the following intuitive reasons: Policymakers pursue a time path of capital tax rates close to a time-invariant one because of tax adjustment costs. When determining a specific tax schedule within a regime, planners have to strike a balance between (i) the short-run welfare benefit of confiscatory capital taxation in the early periods of a regime due to its implied lump-sum nature and (ii) the subsequent medium-run welfare losses within the regime resulting from rigid tax adjustments over time. When government incumbency is short, the optimal tax scheme is characterized by high capital income taxes and low labor income taxes because each planner with limited tenure seeks to take advantage of the lump-sum nature of capital taxation in the short run. As the planning horizon increases, planners constrained by tax adjustment costs prefer to keep the capital tax rate low to mitigate the medium-run distortion arising from positive capital income taxation in the latter periods of the regime. As a result, the government optimally chooses a relatively low capital tax rate in the initial period and maintains this level during its incumbency while raising labor income tax rates to meet budgetary pressures.

While a plausible length of government incumbency combined with rigid tax adjustments results in positive optimal capital taxation in the long run, the implied capital tax rates fall short of the rates currently observed. We find that policymakers' imperfect altruism toward future household welfare is important in accounting for optimal capital tax rates far above zero. Due to limited altruism, planners undervalue the long-run benefits of capital accumulation, incentivizing them to deplete accumulated capital to boost short-term welfare. This raises capital income tax

rates in all periods. Our numerical results suggest that the current tax system in the United States may be near-optimal in an environment with the structural frictions we put forward. In particular, none of the institutional constraints alone can produce an optimal tax scheme consistent with current tax policies. Rather, a comprehensive understanding of the interactions among various institutional constraints is required to account for the formation of modern tax schemes.

As an extension, we investigate an environment where fiscal policy implementation involves time lags. Klein and Ríos-Rull (2003) and Clymo and Lanteri (2020) address a similar situation. Given our baseline calibration, where the intertemporal elasticity of substitution (IES) is less than unity, this new restriction tends to lower optimal capital tax rates because each government seeks to increase welfare within its own regime by committing to a low capital tax rate during the early periods of the next regime. Nonetheless, if planners exhibit imperfect altruism, the optimal capital tax rate could be much higher than zero.

The current study can be compared to the literature on loose commitment technology. Debortoli and Nunes (2010, 2013) and Debortoli et al. (2014) investigate an environment in which the social planner is subject to a stochastically occurring chance to re-optimize previously committed policies. While sharing the idea that a social planner has limited control over future policy, our model has the following distinctive features: First, we develop a novel framework that explicitly incorporates finite policy planning horizons, as opposed to an exogenous stochastic chance of policy re-optimization, into the dynamic optimal taxation problem. Second, we propose a new mechanism that leads to optimal capital income tax rates being positive in the long run. Finally, rather than tackling the time inconsistency issue in the dynamic optimal taxation problem, we focus on the role of institutional constraints in the formation of tax systems in modern democratic societies.

1.1 Related literature-positive optimal capital taxation

There have been myriad endeavors challenging the classical result of zero optimal capital taxation by incorporating new elements into the conventional framework: information friction (e.g., Golosov et al., 2003; Kocherlakota, 2005; Golosov et al., 2006; Farhi & Werning, 2012), household life cycles and/or the (in)flexibility of tax scheme (e.g., Erosa & Gervais, 2002; Banks & Diamond, 2010; Abel, 2007), an incomplete market and wealth heterogeneity (e.g., Aiyagari 1995; Ferriere et al., 2021; Boar & Midrigan, 2022), heterogeneous tastes (e.g., Piketty & Saez, 2013; Golosov et al., 2013; Saez & Stantcheva, 2018), a comprehensive framework incorporating many of the aforementioned features (e.g., Conesa et al., 2009), etc. Straub and Werning (2020) demonstrate that the optimal capital tax rate, even in the Chamley and Judd models, can be far above zero under certain conditions. Whereas, using a similar model but with a richer set of taxes, Chari et al. (2020) show that a zero capital tax rate can be optimal if the government can use a variety of tax instruments. In a nutshell, despite a large body of work, optimal capital taxation remains an open question. The current study contributes to the literature by investigating how institutional constraints affect policymakers' decisions. In contrast to previous

studies that also highlighted policy-related frictions such as information asymmetry or inflexible tax schemes, we focus on institutional constraints in fiscal policy formation, which have long been overlooked.

Straub and Werning (2020) examine the conventional zero capital taxation result in the Chamley-Judd models under general conditions. They demonstrate that the steady state without capital taxation is a special case of the Chamley model, and that in the Chamley model with additively time-separable utility, capital taxes are binding at their upper bound indefinitely if initial government debt is high enough and the IES is less than unity. We develop a comparable Chamley-type model in which households have time-additive utility, the IES is below one, and each government with finite incumbency inherits a non-excessive amount of government debt. Even in this stylized environment, where Chamley (1986) and Straub and Werning (2020) show that the conventional zero optimal capital taxation result would hold, the institutional frictions result in positive and empirically plausible optimal capital tax rates.

2 A simple model of optimal taxation under finite planning horizons

We intend to keep the model simple and focus on formalizing the institutional frictions of interest in a tractable way within an otherwise standard Chamley-type economy (Chamley 1986). Time is discrete and indexed by $t = 0, 1, 2, \dots$. The economy is deterministic and is comprised of homogenous households, a representative firm, and successive governments. The private sector (households and firms) lives forever and is infinitely farsighted. In contrast, governments change on a regular basis, resulting in a succession of social planners with policy authority for a limited period. In other words, each social planner has finite planning horizons due to limited government incumbency, whereas other private agents make complete intertemporal allocative decisions over infinite time periods.

2.1 A representative household

A representative household lives infinitely and maximizes lifetime welfare. The utility function is additively separable (i) between consumption and labor¹ and (ii) over time periods. The lifetime welfare can be written as follows:

$$\sum_{t=0}^{\infty} \beta^t (U(C_t) - V(N_t))$$

¹ Under a utility function separable between consumption and labor, the conventional Chamley-type model produces a stronger result: the optimal capital tax should be zero in every period except for the first one. For this reason, the earlier literature tends to assume a non-separable utility function. In contrast, despite the separable utility function, the optimal capital tax rate in this paper can be significantly higher than zero, depending on the severity of the structural constraints.

where C_t and N_t denote consumption and hours worked in period t , and β is a subjective discount rate. The utility function satisfies the standard regularity conditions: $U'(C) > 0$, $U''(C) < 0$, $V'(N) > 0$, $V''(N) \geq 0$, etc. Households invest in productive capital or government bonds. The household budget constraint is as follows:

$$C_t + B_{t+1} + K_{t+1} \leq (1 - \tau_t^N)w_tN_t + (1 - \delta + (1 - \tau_t^K)r_t)K_t + (1 + r_t^B)B_t \quad (1)$$

where w_t stands for the wage, r_t for the capital return, and r_t^B indicates the real interest rate for government bonds. K_t and B_t indicate capital and government bonds, respectively. Lastly, τ_t^N and τ_t^K represent the labor and capital income tax, respectively. Households take all prices (factor returns and taxes) as given. The optimal conditions are standard:

$$V_{N,t} = U_{C,t}(1 - \tau_t^N)w_t \quad (2)$$

$$U_{C,t} = \beta(1 - \delta + (1 - \tau_{t+1}^K)r_{t+1})U_{C,t+1} \quad (3)$$

$$U_{C,t} = \beta(1 + r_{t+1}^B)U_{C,t+1} \quad (4)$$

The standard non-arbitrage condition determines the equilibrium bond price; $r_t^B = (1 - \tau_t^K)r_t - \delta$.² Hence, Eqs. (3) and (4) are isomorphic in equilibrium.

2.2 Firms

Firms are symmetric and compete in a competitive market. A representative firm maximizes profits in each period:

$$\Pi_t = \max_{K_t, N_t} F(K_t, N_t) - w_tN_t - r_tK_t$$

where $F(K_t, N_t)$ represents a neoclassical constant returns to scale (CRS) production function. The firm's optimal conditions are standard.

$$w_t = F_{N,t} \quad (5)$$

$$r_t = F_{K,t} \quad (6)$$

2.3 The government

The government budget constraint is written as follows:

² Taxes on bond returns can also be allowed, but this raises an indeterminacy issue. The non-arbitrage condition requires the net-of-tax returns on capital and government bonds to be equalized in equilibrium, allowing us to pin down the equilibrium net-of-tax bond return. However, the tax rate on bond returns and the gross rate of return on bonds cannot be separately determined.

$$\tau_t^K r_t K_t + \tau_t^N w_t N_t + B_{t+1} \geq G + (1 + r_t^B) B_t \quad (7)$$

G represents exogenous government spending, which is assumed to be constant over time and wasteful. We suppose that the capital and labor tax rates should be non-negative, namely that a planner cannot provide a subsidy to one production factor by heavily taxing another. In equilibrium, the government's and the household's budget constraints together lead to the resource constraint due to Walras's law:

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

where $Y_t = F(K_t, N_t)$ denotes the aggregate output.

We introduce the following frictions to capture the constraints that a government faces when designing fiscal policy: First, it is generally acknowledged that tax reform requires an arduous procedure. Given the modern parliamentary system, tax reform necessitates a political agreement, which is generally difficult to reach and incurs considerable social costs. Based on this motivation, we assume that adjusting tax rates is associated with quadratic adjustment costs (c_t^i), similar to Rotemberg (1982), measured in the welfare unit:

$$c_t^i = \frac{\Phi}{2} (\tau_t^i - \tau_{t-1}^i)^2 \quad \text{where } \Phi \geq 0$$

for $i \in \{K, N\}$. The non-negative scale parameter Φ encapsulates the extent of difficulty policymakers confront when adjusting tax rates from the one determined earlier. Adjusting tax rates over time is completely flexible when $\Phi = 0$, while it becomes more rigid as the cost parameter increases. For generality, we impose policy adjustment costs for both taxes in a symmetric manner.

Second, we suppose that each government has power only for T periods, during which a central planner has exclusive authority over fiscal policy. At period $T + 1$, a new government takes over the economy for another T period, and the economy continues. In addition, we assume that policy coordination across governments is infeasible: an incumbent government cannot directly affect the decisions of its subsequent government, and vice versa. As a result, even if each social planner with a limited policy planning horizon is rational and seeks to maximize household welfare, their actions end up being *as if* bounded-rational and lead to a suboptimal outcome. Later, we relax this assumption and look into an environment in which an incumbent planner can partially determine capital tax rates implemented during the next regime. Finally, even with limited government incumbency, a well-defined dynamic model requires planners to take into account the continuation value of household welfare under future governments. To this end, we introduce a welfare-relevant measure that an incumbent planner uses to assess household welfare after her term. We will elaborate on this in the subsequent section.

We impose a relaxed form of balanced budget constraint that prevents each government from leaving a pile of debts to its successor. In particular, each government that will leave office at period T is subject to a debt limit given by:

$$B_T \leq \bar{B} \tag{9}$$

The within-regime balanced-budget constraint is less restrictive than the conventional balanced-budget constraint that applies each period sequentially. To be specific, our balanced budget constraint allows implementing flexible budget management in sub-periods of a regime with a budget deficit or surplus, as long as the constraint (9) holds. Because policymakers do not incur additional government debt under the within-regime budget constraint, the initial debt level that each government inherits is kept stable. Fiscal rules for a debt-to-GDP ratio ceiling may be an example of prohibiting excessive debt accumulation within a government over time. For simplicity, we will set $\bar{B} = 0$ from now on.³ It should be noted that the constraint has to be binding in equilibrium. Otherwise, it indicates that an incumbent government builds up a positive surplus, but it is always possible in this case to improve the welfare of the current regime by marginally reducing tax rates and saving less. The within-regime balanced budget constraint is necessary for our optimal taxation problem. In the absence of a debt limit, the optimal fiscal policy for each planner with finite planning horizons would heavily rely on debt financing, eventually leading to the economy falling into a Ponzi scheme. In addition, given the within-regime balanced budget constraint, a stationary allocation under finite planning horizons is comparable to the long-run equilibrium in standard dynamic problems, where the government eventually liquidates any debts or assets due to the transversality condition.

It is well known that capital taxation in the initial period mimics non-distortionary lump-sum taxation. As a result, unless government debt or spending is excessively high, optimal fiscal policy in the classical framework is trivial: run large budget surpluses using confiscatory capital taxation during the initial periods and then impose zero tax on capital and labor income afterward.⁴ In an economy where a planner has a T -period planning horizon starting from period t , we can similarly define an implied upper bound for the initial capital tax rate:

$$\bar{\tau}_t^K = \frac{1}{r_t K_t} \left(\sum_{s=0}^{T-1} \frac{G}{\prod_{j=0}^s (1 + r_{t+j}^B)} \right) \quad \text{where} \quad r_t^B = 0 \tag{10}$$

The upper bound indicates the initial capital income tax rate in each government required to fund all public spending without imposing any additional taxes. Given initial capital and government debt, the discounted sum of government spending within a regime should be below the peak of the Laffer curve; otherwise, the tax burden exceeds what each government can afford. We assume that government spending is sustainable in the sense that each government, in principle, can fund its within-regime spending entirely through initial capital taxation. Finally, we assume that a planner takes this endogenous maximal initial capital tax rate as given.

³ The zero-debt restriction does not affect our main results but simplifies the problem.

⁴ To preclude this possibility, the literature typically imposes an ad hoc upper bound on the initial capital tax rate.

2.4 A Ramsey problem

A benevolent planner with a T -period planning horizon commands allocation to maximize household welfare during her regime. A government decides on fiscal policy as soon as it takes power, and its decisions are fully committed within the regime. Formally, a social planner with a T -period planning horizon who seizes power from period t to $t + T - 1$ solves the following problem:

$$W(\tau_{t-1}^N, \tau_{t-1}^K, K_t, B_t) \equiv \max_{\{\mathbf{X}_{t+s}\}_{s=0}^{T-1}} \sum_{s=0}^{T-1} \beta^s \left[U(C_{t+s}) - V(N_{t+s}) - \frac{\Phi}{2} \left((\tau_{t+s}^K - \tau_{t+s-1}^K)^2 + (\tau_{t+s}^N - \tau_{t+s-1}^N)^2 \right) \right] + \eta \beta^T Z(\tau_{t+T-1}^N, \tau_{t+T-1}^K, K_{t+T}, B_{t+T}) \quad (11)$$

subject to the optimal conditions in the private sector (Eqs. (2) to (6)), the government periodic budget constraint (7), the *within-regime* balanced-budget condition (9), the resource constraint (8), the non-negative restrictions on the tax rates, and the endogenous upper bound for initial capital taxation (10). The subscript s indicates the sub-period within the regime, and $\{\mathbf{X}_{t+s}\}_{s=0}^{T-1}$ denotes the set of control variables where $\mathbf{X}_i = \{C_i, N_i, K_{i+1}, B_{i+1}, \tau_i^K, \tau_i^N\}$. Each government solves the optimization problem sequentially with an interval of T periods and takes the allocation and policies commanded by previous and succeeding governments as given.

Only during its term does the government determine allocations and tax rates. As a result, when determining the optimal allocation for the final period of each regime, a planner with a finite planning horizon takes the future allocations and policies commanded by succeeding planners as given. This reflects the lack of policy coordination across governments. The absence of policy coordination distinguishes our proposed framework from the loose commitment literature that also tackles a planner's limited authority over future policy (e.g., Debortoli & Nunes, 2010). The loose commitment literature addresses an environment where the social planner internalizes the possibility of future policy re-optimization when making current policy decisions. In contrast, our environment presumes that the policy decisions made by future policymakers who have not yet been elected have no direct impact on the decisions of an incumbent social planner who will leave the stage permanently at the end of her term.

The parameter $\eta \in [0, 1]$ measures an incumbent government's altruistic motive toward household welfare under subsequent governments, which can also be interpreted as the degree of myopia of each social planner. A few remarks are in order. First, uncertainty about re-election could provide a micro-foundation for imperfect altruism. In this case, the altruistic motive parameter can be interpreted as a probability of re-election for an incumbent government. Second, imperfect altruism is related to hyperbolic discounting in the literature (e.g., Strotz, 1955; Angeletos et al., 2001; Laibson, 1997; Gabaix, 2020). To be specific, we consider an environment where households discount welfare exponentially, and so do policymakers within their own regimes. Nonetheless, each policymaker with a limited tenure may evaluate household welfare during her own regime more highly than welfare under

subsequent governments. As a result, the Ramsey problem could exhibit a variation of hyperbolic discounting by social planners.

The function $Z(\tau_{t+T-1}^N, \tau_{t+T-1}^K, K_{t+T}, B_{t+T})$ represents the coarse value function used by a planner to assess household welfare after her term.⁵ Woodford (2019) addresses a similar truncated planning horizon problem in which households look ahead only a finite distance into the future due to limited cognitive abilities. Departing from the standard assumption that rational agents formulate complete state-contingent intertemporal plans over an infinite future, Woodford (2019) proposes an environment in which infinitely lived households make a finite-horizon allocative decision while truncating their planning for a distant future using a welfare-relevant metric, i.e., the coarse value function, that measures future welfare in a bounded rational manner. Because households in his model have limited cognitive capacity, the coarse value function does not necessarily correspond to the value function established by the recursive structure of household welfare under rational expectations.⁶ In contrast, we do not take cognitive limitations into account, but limited government incumbency, along with a lack of policy coordination across governments, leads social planners to make virtually bounded rational decisions. For simplicity, we assume that an incumbent planner employs her value function $W(\cdot)$ to assess household welfare under subsequent governments $Z(\cdot)$:

$$Z(\tau_{t+T-1}^N, \tau_{t+T-1}^K, K_{t+T}, B_{t+T}) = W(\tau_{t+T-1}^N, \tau_{t+T-1}^K, K_{t+T}, B_{t+T}) \quad (12)$$

Substituting $W(\cdot)$ for $Z(\cdot)$ in the Ramsey problem (11) results in a problem structure similar to those in the bequest literature based on overlapping-generations models. Barro (1974) and other studies (e.g., Weil, 1987; Thibault, 2000; Michel et al., 2006) propose a comparable recursive definition of altruism that incorporates imperfect altruism into agents' intertemporal decisions in a parsimonious manner. The distinction is that we consider policymakers with limited government incumbency, contrary to the bequest literature based on households with finite lifespans. Finally, despite $\eta = 1$, our finite planning horizon problem does not nest into a standard infinite horizon problem because policy coordination across governments is not allowed. On the other hand, given that we do not allow debt rollover and redistribution through a lump-sum subsidy, a planner's only concern is to fund public spending while minimizing the resulting tax distortions. As a result, even if a planner with a finite planning horizon does not value household welfare under subsequent governments at all ($\eta = 0$), the model economy rules out the possibility that a social planner fully depletes all resources within her regime and causes economic collapse.

⁵ The term 'coarse' is borrowed from the terminology in Woodford (2019).

⁶ In Woodford (2019), households with limited cognitive capacity update their coarse value function through a real-time learning process from past experience. Similarly, one can introduce an alternative form of the coarse value function to our model, which adds another source of bounded rationality to our Ramsey problem. We believe this could be an interesting extension for future work.

2.4.1 The stationary equilibrium

The current study focuses on the optimal tax scheme in a stationary equilibrium. In our case, the standard definition of a steady state for a stationary equilibrium is not applicable because, depending on the severity of the structural frictions, the economy under finite planning horizons can generate endogenous fluctuations without time-varying factors. Alternatively, we define a periodically stable allocation as one in which the economy repeatedly follows the same dynamic allocation path within a regime. This corresponds to the Nash equilibrium across symmetric policymakers with limited tenure. The periodically stable allocation represents a stationary allocation in our dynamic environment, where a planner with a limited policy planning horizon comes to power in succession. Formally, a periodically stable allocation is defined as follows:

Definition 2.1 (A periodically stable equilibrium allocation) Let T be a positive integer. If planners have a T -period planning horizon, the equilibrium allocation is periodically stable if it satisfies:

$$x_t = x_{t+T} \quad \forall \quad t \in \mathbf{Z}^+$$

for an endogenous variable $x_t \in \{C_t, N_t, K_t, B_t, \tau_t^K, \tau_t^N, w_t, r_t, r_t^B\}$

Because exogenous government spending is assumed to be constant and governments are symmetric, a periodically stable allocation, if it exists, applies in the long run. Now, we define the stationary Ramsey optimal allocation, which is the main theme of this paper.

Definition 2.2 (A stationary Ramsey optimal allocation under a T -period planning horizon) A stationary Ramsey optimal allocation under a T -period planning horizon solves the problem (11) and is periodically stable.

When the planning horizon is infinite, a periodically stable allocation corresponds to a conventional steady-state equilibrium in which endogenous variables are time-invariant. In contrast, as previously mentioned, the optimal allocation under finite planning horizons may be time-dependent despite constant government spending and the absence of stochastic disturbances. This is because a social planner's interest in her regime may vary over time depending on the state variables inherited from the previous regime and the extent of institutional restrictions.

Before delving into the general properties of a stationary Ramsey equilibrium with finite policy planning horizons, it is useful to look into two extreme cases to recall some well-known properties of optimal fiscal policy.

Proposition 2.1 *In a stationary Ramsey optimal allocation under one period of the planning horizon, planners fully finance government spending via capital taxation.,*

i.e., $\tau_t^K = \bar{\tau}_t^K$, and the stationary optimal allocations of C_t , N_t , K_{t+1} , and τ_t^N are determined independently of the values of $0 < \eta \leq 1$ and $0 \leq \Phi$.

Proof) See Appendix.

A benevolent planner aims to maximize household welfare by minimizing tax distortions. When the planning horizon is one period, this can be accomplished by means of non-distortionary taxation, i.e., capital taxation on accumulated capital. A planner's only concern is to tax capital as much as is required to fund public spending, and the degree of altruism has no bearing on this decision. One may notice that the one-period planning horizon situation is comparable to the optimal taxation problem under discretion, namely the optimal policy decision when policy commitment is infeasible. Another extreme case, an infinite-period policy planning horizon with perfect commitment technology, is discussed below.

Proposition 2.2 *The planner finances government spending entirely through labor taxation and keeps the capital tax rate at zero in a steady-state Ramsey allocation over an infinite-period planning horizon.*

Proof) See Appendix.

The proposition simply restates the Chamley-Judd result in a different setting: A benevolent planner does not impose a capital tax in the long run because positive capital taxation generates intertemporal distortions that accumulate exponentially over time.⁷

2.4.2 The optimal allocation under a T-period planning horizon

The problem is solved in the appendix. To solve for the optimal allocation in a given regime, it is necessary to pin down the equilibrium allocations in previous and subsequent regimes; thus, the problem is, in principle, intractable. To address this issue, we concentrate on the stationary Ramsey allocation that satisfies the periodically stable property. Since allocations are stable on a periodic basis, allocations over sub-periods in previous and subsequent regimes can be replaced by their counterparts in the corresponding sub-period in the current regime.

2.4.2.1 First-order conditions: Chamley vs. Ours It is useful to compare our economy to the Chamley economy to see how institutional frictions alter the traditional optimal taxation problem. We present below the Ramsey planner's first-order condition (FOC) with respect to capital for the standard Chamley model (Eq. (13)) and our finite policy planning horizons model (Eq. (14)). Specifically, Eq. (14) indicates the

⁷ When considering an interior steady state under the infinite planning horizon, all structural frictions in our model become irrelevant. As a result, the standard result applies to our infinite-period planning horizon economy. As Straub and Werning (2020) stress, however, convergence to the zero capital taxation steady state is not trivial. Our Proposition 2.2 requires an initial condition compatible with a locally stable interior steady state, i.e., sufficiently low initial government debt, which we implicitly assume here. For a thorough discussion of the convergence property in Chamley-Judd type models, see (Straub and Werning, 2020).

FOC at the last period of a regime; $T - 1$ and T denote the last and first sub-period of an incumbent and a subsequent regime, respectively.

$$\begin{aligned} \lambda_{T-1}^{RC} = & \beta \left[\lambda_T^{RC} (1 - \delta + F_{K,T}) + \lambda_T^{GBC} \left(\tau_T^K (F_{KK,T} K_T + F_{K,T}) \right. \right. \\ & + \left. \tau_T^N F_{NK,T} N_T \right) + \lambda_T^{LS} (1 - \tau_T^N) F_{NK,T} U_{C,T} \\ & \left. + \lambda_{T-1}^{EE} (1 - \tau_T^K) F_{KK,T} U_{C,T} \right] \end{aligned} \tag{13}$$

$$\begin{aligned} \lambda_{T-1}^{RC} = & \eta \beta \left[\lambda_T^{RC} (1 - \delta + F_{K,T}) + \lambda_T^{GBC} \left(\tau_T^K (F_{KK,T} K_T + F_{K,T}) \right. \right. \\ & + \left. \tau_T^N F_{NK,T} N_T \right) + \lambda_T^{LS} (1 - \tau_T^N) F_{NK,T} U_{C,T} \left. \right] \\ & + \beta \lambda_{T-1}^{EE} (1 - \tau_T^K) F_{KK,T} U_{C,T} \end{aligned} \tag{14}$$

where the Lagrange multiplier λ_t^j represents the shadow cost associated with each constraint. The superscripts *RC*, *GBC*, *LS*, and *EE* indicate ‘Resource constraint’, ‘Government budget constraint’, ‘Labor supply condition’, and ‘Household Euler equation’, respectively.

A few remarks are in order. First, we observe that the equations differ due to the imperfect altruism represented by η , indicating that a current planner may discount household welfare in future regimes more highly. Now, for the sake of exposition, suppose $\eta = 1$. Using FOCs with respect to capital and labor taxes, the CRS feature of production technology, and the within-regime balanced-budget constraint for a frictional case, we can simplify the equations, respectively, as follows:

$$\lambda_{T-1}^{RC} = \beta \left(\lambda_T^{RC} (1 - \delta + F_{K,T}) + \lambda_T^{GBC} \tau_T^K F_{K,T} \right) \tag{15}$$

$$\lambda_{T-1}^{RC} = \beta \left(\lambda_T^{RC} (1 - \delta + F_{K,T}) + \lambda_T^{GBC} \tau_T^K F_{K,T} + \Phi \mathbf{T}_T \right) \tag{16}$$

$\Phi \mathbf{T}_T$ ⁸ in Eq. (16) represents the welfare costs associated with both capital and labor tax adjustments, which are irrelevant in the Chamley setting (Eq. (15)). For expositional convenience, consider the first case where policy adjustment costs are sufficiently high, so each planner accordingly prefers a stable tax path within a regime (i.e., $\mathbf{T}_T \approx 0$). Then, Eq. (16) can be written as follows:

$$\lambda_{T-1}^{RC} \approx \beta \left(\lambda_T^{RC} (1 - \delta + F_{K,T}) + \lambda_T^{GBC} \tau_T^K F_{K,T} \right) \tag{17}$$

If a policymaker’s planning horizon is longer than one period, endogenous variables may not remain constant in a stationary equilibrium. However, stable tax paths within a regime under sufficiently high policy adjustment costs imply stable

⁸ $\mathbf{T}_T = \frac{F_{NK,T}}{F_{N,T}} (1 - \tau_T^N) (\beta \Delta \tau_{T+1}^N - \Delta \tau_T^N) + \frac{F_{KK,T}}{F_{K,T}} (1 - \tau_T^K) (\beta \Delta \tau_{T+1}^K - \Delta \tau_T^K)$ where $\Delta \tau_t^i \equiv \tau_t - \tau_{t-1}$ for $i \in \{N, K\}$.

allocations of other variables, including the shadow costs. Then, provided that taxes follow stable paths, Eq. (17) becomes similar to the steady-state version of Eq. (15), implying that capital tax rates would be close to zero during the later periods of each regime. That is, the analytical investigation predicts that the capital income tax path within a regime appears to be not only stable but also low when policy adjustment costs are sufficiently high and imperfect altruism is not considered ($\eta = 1$). We will revisit this issue in the numerical analysis section.

Finally, we turn to the second case where there is no policy adjustment cost, i.e., $\Phi = 0$. In this case, we need to look at the FOC with respect to the capital tax rate at the first period of each regime, which is written as follows:

$$\lambda_0^{GBC} F_{K,0} K_0 = \lambda_0^{IUB} \quad (18)$$

where the time subscript 0 denotes the initial period of each regime, and λ_0^{IUB} is the Lagrange multiplier attached to the implied upper bound for the initial capital tax rate. The equation suggests that a government should finance all its spending through initial capital taxation without levying distortionary taxes on capital and labor during a regime. It should be noted that this equation applies to the first period of all regimes in our periodically stable optimal allocation. Thus, given a stationary allocation, fiscal policy appears to periodically impose high capital taxation. This contrasts with the conventional literature that suggests initial heavy capital taxation followed by a prolonged period of zero tax rates.⁹

2.4.2.2 Within- and Inter-regime policy trade-offs The previous analysis sketches how our optimal tax scheme differs from the conventional one. To gain a sense of a specific optimal tax structure under varying degrees of structural friction, we discuss the policy trade-offs that each planner faces.

To begin, we can consider a within-regime policy trade-off related to capital taxation. Expropriatory capital taxation on initial capital is, in principle, the most efficient way of financing public spending. However, confiscatory initial capital taxation may lead to inefficiently high capital tax rates in the latter phases of the regime because policy adjustment costs impede flexible tax adjustments over time. This could generate sizable medium-run welfare costs by discouraging capital accumulation within a regime. Therefore, a planner should strike a balance between (i) the short-run welfare benefit of non-distortionary capital taxation in the early periods and (ii) the medium-run welfare losses caused by rigid tax rate adjustments over time. When the planning horizon is short, the welfare benefit of expropriatory initial capital taxation may outweigh the welfare cost arising from positive capital tax rates during the remaining regime periods. As the planning horizon increases, the welfare cost due to positive capital tax rates in the later periods of a regime increases exponentially, giving a planner subject to policy adjustment costs a stronger incentive to keep tax rates low throughout the regime, including the initial period.

⁹ If there is an ad hoc upper bound to the initial capital tax rate (e.g., 100 %), positive capital and labor tax rates may occur in subsequent sub-periods of a regime, provided that the government is subject to excessive public spending. This case resembles the situation highlighted by Straub and Werning (2020). Since we focus on an interior solution, this scenario is not explicitly considered in the current study.

Table 1 Calibration summary

Parameters	Value	Remark
α	0.35	Capital income share
β	0.96	Subjective discount rate
δ	0.1	Annual capital depreciation rate
σ	1.5	Relative risk aversion
ν	0.25	Frisch elasticity
G	0.098	Government spending
Ψ	3.07	Labor disutility scale factor
Φ	100	Tax rate adjustment cost
η	1	(Absence of) Myopic behavior

On the other hand, each planner also has to deal with an inter-regime fiscal policy trade-off. The tax rates set by an incumbent planner affect not only the allocation during its own regime but also indirectly limit the range of tax rates chosen by the next planner under policy adjustment costs. Depending on the extent of myopia, an incumbent planner partially internalizes the impact of their fiscal policy on the welfare of subsequent regimes.

The following section numerically examines the various interactions among the structural frictions and discusses some stylized properties of optimal taxation in our constrained environment.

3 Quantitative analysis

3.1 Calibration

The finite planning horizons we examine range from one to four periods, where the model period indicates one year. The baseline calibration builds on the zero-debt steady state Ramsey equilibrium with an infinite-period planning horizon. Our baseline calibration is summarized in Table 1. First, the household's felicity function is specified as follows:

$$U(C_t) - V(N_t) = \frac{C_t^{1-\sigma} - 1}{1-\sigma} - \Psi \frac{N_t^{1+\frac{1}{\nu}}}{1 + \frac{1}{\nu}}$$

The production function follows the Cobb–Douglas technology:

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

The calibration largely refers to standard parameter values common in the business cycle literature (e.g., Kydland & Prescott, 1982). The share of (gross) capital income is set at 0.35, i.e., $\alpha = 0.35$. The subjective discount rate (β) is set at 0.96, corresponding to a 4 percent annual real interest rate. We suppose that capital depreciates

10 percent per year, $\delta = 0.1$, consistent with the standard estimate of 2.5 percent capital depreciation per quarter. We set the relative risk aversion (σ) to 1.5, which is in the middle of empirical estimates in the literature (Mankiw et al., 1985; Attanasio & Weber, 1993). The Frisch elasticity (ν) is set to 0.25 (Altonji, 1986; Peterman, 2016). G is internally computed so that government spending accounts for 18 percent of total output in the benchmark economy. The labor disutility scale parameter (Ψ) is internally calculated so that the steady-state labor supply in the baseline economy equals one-third of time endowment. Our external parameters and steady-state targets are consistent with the previous optimal fiscal policy literature (Chari et al., 1994; Stockman, 2001; Klein & Ríos-Rull, 2003).

Unlike the other parameters, there is little econometric evidence on the extent of policy adjustment costs and the degree of myopia. To provide some empirical support for setting these parameters, we utilize their different quantitative roles: the policy adjustment cost determines the capital tax trajectory within the regime, while the degree of imperfect altruism affects the overall capital tax rates. We calibrate the parameters so that the model-generated optimal tax scheme can reflect certain empirical features of observed tax rates. Technically, our calibration strategy is consistent with the inverse-optimum welfare weight method proposed by Bourguignon and Spadaro (2012).

To begin, considering that (i) the model is deterministic without stochastic disturbances, (ii) symmetric governments continue, and (iii) we typically observe stable tax systems with rare reform, our baseline calibration sets sufficiently high policy adjustment costs to produce a stable tax rate path within a regime across all planning horizons considered. Specifically, $\Phi = 100$ suffices to generate a stable tax path within a regime.¹⁰ Any further increase in this parameter beyond the baseline level has a negligible effect on our numerical results. Meanwhile, Sect. 3.2.2 below depicts the stylized dynamics at an intermediate value of policy adjustment costs, i.e., when more flexible tax changes within a regime are allowed for. On the other hand, the baseline economy begins by shutting off the imperfect altruism channel, i.e., $\eta = 1$, to clarify the effects of other institutional frictions. We will later explore a different level of imperfect altruism under which an optimal tax scheme matches the tax rates observed.

To assess the welfare costs of institutional frictions, we use the consumption-compensating variation conditional on the stationary equilibrium. The details are presented in the appendix. Because a finite planning horizon is essentially structural friction, the welfare of the Ramsey allocation without a planning horizon constraint should be no less than that under finite planning horizons.

¹⁰ This level of policy adjustment cost indicates that a one percentage point increase in tax rates results in welfare costs roughly equivalent to a 25 percent temporary decline in current consumption in partial equilibrium in an economy with an infinite-period planning horizon, which can be found by computing x such that $x = \frac{\bar{C} - C_{ss}}{C_{ss}} \times 100$ where C_{ss} denotes the steady-state consumption in an economy with an infinite-period planning horizon and \bar{C} satisfies $U(\bar{C}) = U(C_{ss}) - \frac{\Phi}{2}(0.01)^2$.

Table 2 The stationary Ramsey optimal allocations under the various planning horizons

Planning horizons	1 period	2 periods	3 periods	4 periods	Infinite
Output	0.33	0.37	0.48	0.52	0.55
Consumption	0.20	0.23	0.29	0.31	0.31
Capital	0.27	0.41	0.94	1.19	1.36
Labor	0.37	0.35	0.34	0.34	0.33
Capital tax rate	0.68	0.56	0.23	0.09	0
Labor tax rate	0	0.11	0.19	0.24	0.28
Welfare cost (CV)	-0.40	-0.29	-0.08	-0.02	0

The table shows the stationary Ramsey optimal allocations for finite planning horizons and the steady-state Ramsey equilibrium for an infinite planning horizon. In the case of finite planning horizons, the numbers in the table represent the average value within the regime. The welfare cost expresses the consumption compensating variation relative to a steady-state economy with an infinite planning horizon, conditional on the stationary Ramsey allocation

3.2 A stationary Ramsey optimal allocation

3.2.1 Planning horizons

Table 2 summarizes the equilibrium allocations under different policy planning horizons, as well as the welfare loss caused by truncated policy planning horizons. As the planning horizon lengthens, the stationary Ramsey allocation under finite planning horizons converges to the steady-state allocation of the economy with an infinite-period planning horizon. The Ramsey allocation under an infinite-period planning horizon indicates a zero capital income tax rate in the steady state (see the last column of Table 2). This is consistent with Proposition 2.2. On the other hand, the economy associated with one period of the planning horizon indicates that planners finance government spending entirely through capital taxation (see the first column of Table 2). Because planners rely solely on capital taxation, fiscal policy in an economy under one period of the planning horizon leads to a large decline in accumulated capital, resulting in significant output and welfare losses. The consumption compensating variation implies that household consumption in an economy where a social planner holds infinite periods of the planning horizon should be reduced by 40 percent uniformly across all periods to make households indifferent to living in an economy where planners only have one period of the planning horizon.

Because of its lump-sum nature, benevolent social planners are more inclined to rely on initial capital taxation to finance their spending. However, the policy adjustment cost prevents planners from adjusting capital tax rates flexibly in subsequent periods. As a result, when determining the capital tax path within the regime, a planner must consider this implicit medium-term welfare cost of heavy initial capital taxation. If policymakers have short policy planning horizons, the short-term welfare benefit of confiscatory initial capital taxation may outweigh the medium-term welfare cost. Under extended planning horizons, the opposite holds. As a result, the capital tax rate tends to fall as the planning horizon lengthens, while the labor tax rate rises to accommodate budgetary pressures. Although such a fiscal policy combination may

be optimal from the perspective of each government, the relatively higher dependence on capital taxation under finite planning horizons renders the Ramsey optimal allocation *de facto* suboptimal. For example, when the government has a four-year planning horizon that corresponds to the current term of office for the United States government, the output is about 5 percent lower compared to the counterfactual economy with infinite periods of the planning horizon. Consumption in an economy with infinite planning horizons should be reduced by 2 percent for all periods to make households indifferent to living in an economy with a four-period planning horizon.

There are two important remarks. First, policymakers with finite planning horizons longer than one period endogenously choose the initial capital tax rate well below its implied upper bound. In other words, as long as tax reforms are sufficiently demanding, confiscatory capital taxation in the early stages of a regime is avoided. Second, as the planning horizon increases, the stationary allocation converges to the standard Chamley-Judd case. Given the baseline calibration, we observe that the allocation under a six-period planning horizon closely approximates the zero capital taxation steady-state, in line with our analytical predictions. That is, while limited planning horizons combined with rigid policy adjustments can result in optimal capital tax rates greater than zero in a stationary equilibrium, the implied capital income tax rates under the plausible range of government tenure are far lower than the rates currently in place. To close the gap between the optimal tax rates and their practical implementations, we need to take into account the imperfect altruism of incumbent social planners, which we will discuss in the following section.¹¹

3.2.2 Rigid policy adjustments and imperfect altruism

We consider two counterfactual economies with a four-period planning horizon: (i) an economy with low tax adjustment costs ($\Phi = 1$)¹² and a perfect altruistic motive ($\eta = 1$); and (ii) an economy with the baseline tax adjustment cost ($\Phi = 100$) and partially myopic behavior ($\eta = 0.85$). As shown later, the alternative extent of altruistic motive, i.e., $\eta = 0.85$, is calibrated to illustrate some empirical relevance of the model economy.¹³ Table 3 reports the stationary Ramsey optimal allocations within the regime, and Fig. 1 displays the within-regime dynamics of selected variables.

3.2.2.1 Tax rate adjustment costs When a planner faces low adjustment costs in adjusting tax rates, we observe a pattern of relatively higher capital tax rates in

¹¹ As mentioned earlier, increasing the policy adjustment cost beyond the baseline level has little effect on our numerical results. Given that policy should be perfectly time-consistent when adjustment costs are infinite, it implies that the optimal allocation under the baseline calibration of the policy adjustment cost, at least numerically, approximates a time-consistent solution.

¹² $\Phi = 1$ is close to the lower bound that ensures numerical accuracy. For intermediate values of adjustment cost ($1 \leq \Phi < 100$), we observe the general pattern of a time-varying front-loaded capital tax path within a regime.

¹³ As previously stated, one may interpret the degree of myopia as a probability of re-election. According to the past voting results from the U.S. presidential elections, around two-thirds of presidents have been re-elected since 1951, when the 22nd Amendment of the U.S. Constitution established a two-term limit on the presidency. The sample proportion of re-election (≈ 0.65) is roughly consistent with our calibration ($\eta = 0.85$).

Table 3 The stationary Ramsey optimal allocations of the baseline and counterfactual economies conditional on a four-period planning horizon

Allocation	Output				Labor				Capital			
	1	2	3	4	1	2	3	4	1	2	3	4
Sub-period	0.52	0.52	0.52	0.52	0.34	0.34	0.34	0.34	1.19	1.19	1.19	1.19
Baseline ($\Phi = 100, \eta = 1$)	0.54	0.54	0.54	0.54	0.34	0.34	0.34	0.34	1.29	1.29	1.29	1.29
Flexible pol. adj. ($\Phi = 1, \eta = 1$)	0.48	0.48	0.48	0.48	0.34	0.34	0.34	0.34	0.91	0.91	0.91	0.91
Myopia ($\Phi = 100, \eta = 0.85$)	Fiscal policy											
	Capital tax rate				Labor tax rate				Bond			
Sub-period	0.09	0.09	0.09	0.09	0.24	0.24	0.24	0.24	0.00	0.00	0.00	0.00
Baseline ($\Phi = 100, \eta = 1$)	0.14	0.11	0.03	0.00	0.17	0.18	0.17	0.16	-0.02	-0.03	-0.02	0.00
Flexible pol. adj. ($\Phi = 1, \eta = 1$)	0.24	0.24	0.24	0.24	0.19	0.19	0.19	0.19	0.00	0.00	0.00	0.00
Myopia ($\Phi = 100, \eta = 0.85$)												

the early periods of the regime, followed by gradual downward adjustments. This policy path is comparable to the standard case of an infinite planning horizon, in which the planner accumulates positive assets in the early periods through confiscatory capital taxation in order to keep tax rates low in the later periods. Similarly, each planner with a finite planning horizon accumulates positive public assets at the outset by employing partially confiscatory capital taxation. We maintain that capital taxation is partially confiscatory because the tax revenue from capital taxation is not high enough to prevent policymakers from relying on labor taxes during the regime. We observe that labor tax rates remain stable and sufficiently high throughout the regime. Putting it another way, despite low policy adjustment costs, the government does not tax initial capital as heavily as the conventional theory implies. This is because, despite low adjustment costs, a sharp increase in initial capital tax rates and the subsequent downward adjustment incur nontrivial convex welfare costs. Therefore, policymakers use a front-loaded capital tax path to solely minimize distortions caused by capital taxation within the regime while continuing to rely on labor taxation to meet budget constraints. Lower adjustment costs imply lessened policy friction, thereby improving welfare.

3.2.2.2 Imperfect altruism We will now discuss the effects of imperfect altruism. First, we can observe that the myopic behavior of an incumbent planner results in a considerable output decline. When planners have lower levels of altruism, they place less importance on household welfare under future governments. This means that a myopic planner discounts the benefits of capital accumulation more highly as the social discount rate increases (i.e., $\eta \times \beta$ declines). We call this effect *the social discount rate channel*. The social discount rate is effective intermittently, depending on the length of the government's incumbency. Planners with limited altruism have a stronger incentive to rely on capital taxation to increase short-term welfare during their regimes, which drives up capital tax rates in every period. Table 3 shows that optimal fiscal policy under imperfect altruism indicates higher capital tax rates and lower labor income tax rates. In addition, due to the significant policy adjustment costs, the tax rates are kept stable throughout the regime, resulting in considerable output and welfare losses in the long run.

The economy under myopic behavior indicates that the optimal capital and labor income tax rates are 24 percent and 19 percent, respectively, which are roughly consistent with the current tax scheme in the United States. This result implies that the tax system in the United States may reflect the imperfect altruism of incumbent policymakers with truncated planning horizons, which results in nontrivial welfare losses. For instance, when planners exhibit imperfect altruism, the capital income tax rate increases by 15 percentage points, which results in a 25 percent output decline compared to the baseline economy with the same planning horizon length.

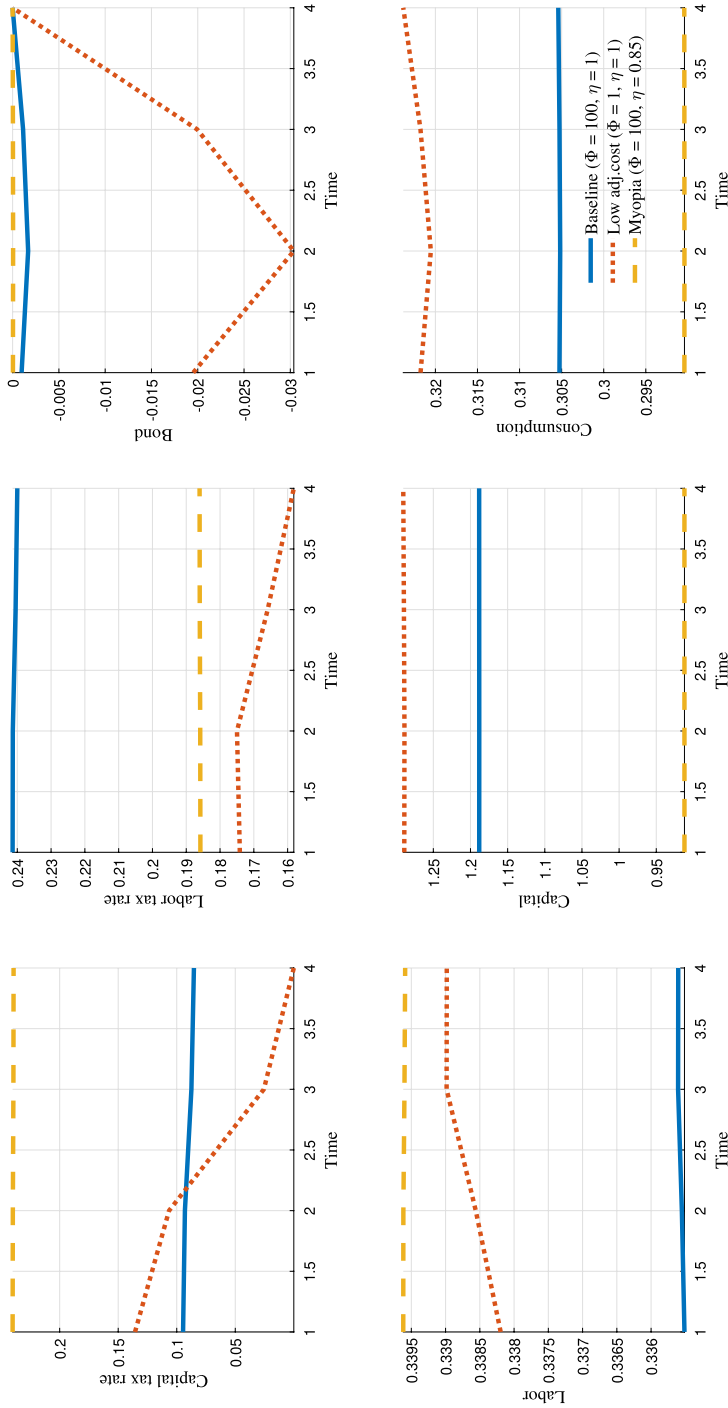


Fig. 1 The *within regime* dynamics of fiscal policy and allocations under a four-period planning horizon

3.3 Fiscal policy implementation lags

3.3.1 Motivation

It is well recognized that there is a significant time lag between policy announcements and implementation. In practice, a government tends to make future policy decisions while taking current or near-future policies as given. Clymo and Lanteri (2020) refer to this situation as a limited time commitment (LTC). Given this motivation, we relax our assumption that each government cannot directly affect the policies of the other. We explore optimal fiscal policy when policy implementation requires a unit period lag, and thus each government in its final period of the regime can directly decide the capital tax rate in the first period of the following government. Klein and Ríos-Rull (2003) and Clymo and Lanteri (2020) use a similar model setup to investigate optimal fiscal policy under limited commitment technology.

We focus on two types of planning horizons: one and four periods. When the implementation lag is unity, a social planner with a unit-period planning horizon determines the capital tax rate that will be imposed during the next regime, subject to the current capital tax rate determined by the previous government.¹⁴ Similarly, if the planning horizon is four periods, the current government determines the capital tax rate for the first period of the subsequent regime.

Because the government budget should be balanced in each regime, at least one tax instrument should be free from implementation lag in our LTC setting. Thus, we assume that each government can determine labor tax rates enforced during its own regime without policy implementation lag. In addition, to make our LTC environment comparable to that in Klein and Ríos-Rull (2003), we assume that labor taxation is exempt from policy adjustment costs.

3.3.2 Intuition

The timing difference gives rise to nontrivial differences in optimal policy. We begin with a single period of the planning horizon. Without LTC, the strategy for optimal taxation within the regime was trivial from the perspective of each government: imposing the implied upper bound of the capital tax rate to reduce tax distortions. When the government chooses the capital tax rate that will be enforced in the next regime, the underlying mechanism of optimal capital taxation becomes more subtle. Recall that the primary objective of an incumbent policymaker is to maximize household welfare in her own regime, although she may also value household welfare in the future, depending on the extent of myopia. The following are the

¹⁴ The one-year planning horizon combined with a unit period of implementation lag may appear impractical because tax policies mostly influence policies implemented in the subsequent regime. However, we deal with this case due to a couple of benefits. First, given that the model already contains an array of structural frictions, the simplified LTC environment is a tractable starting point for illustrating the role of LTC in an optimal fiscal policy decision. Second, the model environment under unit lag is comparable to the existing LTC literature, allowing us to interpret our results in comparison with earlier research, such as Klein and Ríos-Rull (2003).

Table 4 The stationary Ramsey allocations under a unit-period planning horizon with and without LTC

		Output	Consumption	Capital	Labor	Capital tax rate	Labor tax rate
Without LTC	Baseline ($\eta = 1,$ $\sigma = 1.5$)	0.33	0.20	0.27	0.37	0.68	0
With LTC	$\eta = 1$ $\sigma = 1.5$	0.51	0.30	1.15	0.34	0.11	0.23
	$\eta = 1$ $\sigma = 0.5$	0.11	0.00	0.06	0.15	0.78	0.98
	$\eta = 0.75$ $\sigma = 1.5$	0.31	0.19	0.23	0.36	0.71	0.11

first-order conditions with respect to the capital tax rate under a one-period planning horizon, conditional on the periodically stable allocation:

$$\begin{aligned}\lambda^{GBC} F_K K &= \lambda^{UB} && \text{without LTC} \\ \lambda^{EE} F_K U_C &= \eta \lambda^{GBC} F_K K && \text{with LTC}\end{aligned}$$

The first equation is the optimality condition in our baseline case without LTC, where λ^{GBC} denotes the Lagrange multiplier attached to the government budget constraint, and λ^{UB} represents the Lagrange multiplier applied to the implied upper bound of the capital income tax rate. On the other hand, the second equation denotes the optimality condition under LTC if the equilibrium capital tax rate takes an interior value, and λ^{EE} denotes the Lagrange multiplier attached to the household's Euler equation. By comparing the two equations, we can notice that the right-hand side of the second equation represents the welfare gain from taxing accumulated capital, discounted by the myopic behavior parameter. The left-hand side captures the welfare cost of capital taxation imposed tomorrow, which works through household consumption-saving decisions. Because capital taxation is essentially lump-sum within a unit regime, the government has an incentive to impose high capital taxation for the sake of the next government, if it has sufficient altruism. However, any anticipated increase in the capital tax rate stimulates higher savings and more labor supply today because the income effect is relatively stronger than the substitution effect under our baseline calibration of the intertemporal elasticity of substitution (IES), i.e., $1/\sigma = 1/1.5$. This clearly reduces the welfare of the current regime. In addition, there is a general equilibrium effect. As in Klein and Ríos-Rull (2003), when a government inherits a capital tax rate, its choice of the future capital tax rate will result in an indirect distortionary adjustment in labor income tax rates because it affects the rate of return on leisure today and the revenue from capital taxation tomorrow not only via the capital tax rate but also through the accumulated level of capital.

3.3.3 Finite planning horizons under LTC

Table 4 compares the allocations with and without LTC. First, we can observe that the optimal capital income tax rate is much lower with LTC than without LTC under the baseline parameterization due to the income effect channel. The primary goal of each government with a unit-period planning horizon is to maximize welfare during its own term. When the IES is greater than one ($\sigma < 1$), the substitution effect dominates, and thus the government has an incentive to announce a high capital tax rate for tomorrow since an anticipated increase in the capital income tax rate stimulates current consumption and leisure. As this type of tax policy persists due to the absence of policy coordination across governments, capital accumulation substantially declines. To achieve budget balance, policymakers should gradually raise the labor income tax rate, which severely distorts labor supply, while the tax revenue shortfall pushes the capital tax rate even higher. In the long run, total output falls to one-third of the baseline case without LTC, and consumption converges to zero. The opposite happens when the income effect is stronger, i.e., $\sigma > 1$.

The capital tax rate is much higher when planners have an imperfect altruistic motive. At first glance, this may seem counterintuitive because each government has less incentive to impose a high capital tax rate on the next regime, as discussed before. However, the social discount rate channel kicks in when the altruistic motive is weak, which pushes up capital tax rates in every period. In equilibrium, the social discount rate channel dominates, and the capital tax rate is higher than in the baseline case, despite having an IES less than unity and an imperfect incentive to levy a higher capital tax for the subsequent regime.

3.3.4 Rigid policy adjustments and imperfect altruism under LTC

Table 5 displays optimal allocations under LTC when the policy planning horizon is four periods. When $\eta = 1$ and $\Phi = 100$, we observe that the capital tax rate is nearly zero, and the long-run economy resembles the standard Chamley-Judd case. Each government has an incentive to levy a low level of capital tax due to the income effect, which explains the decline in capital tax rates. On the other hand, when policy adjustment costs are sufficiently high, a planner pursues a time-invariant capital tax path around the initial capital tax rate determined by the former government. In the long run, the capital tax rate approaches its lower bound in all sub-periods of the regime, and a government fully relies on labor income taxation to fund public spending. Our result is consistent with Clymo and Lanteri (2020), who demonstrate that optimal allocation under LTC could be analogous to the optimal allocation implied by full commitment technology, given that the government is subject to the balanced-budget constraint.

Table 5 The stationary Ramsey optimal allocations under the unit period implementation lag conditional on a four-period planning horizon

Allocation	Output				Labor				Capital			
	1	2	3	4	1	2	3	4	1	2	3	4
Sub-period	1	2	3	4	1	2	3	4	1	2	3	4
Case 1 ($\eta = 1, \Phi = 100$)	0.55	0.55	0.55	0.55	0.33	0.33	0.33	0.34	1.38	1.38	1.38	1.38
Case 2 ($\eta = 0.75, \Phi = 100$)	0.45	0.45	0.44	0.44	0.35	0.35	0.34	0.33	0.72	0.73	0.73	0.73
Case 3 ($\eta = 0.75, \Phi = 0.01$)	0.45	0.45	0.45	0.44	0.35	0.35	0.34	0.34	0.72	0.73	0.73	0.73
Fiscal policy	Capital tax rate				Labor tax rate				Bond			
Sub-period	1	2	3	4	1	2	3	4	1	2	3	4
Case 1 ($\eta = 1, \Phi = 100$)	0.00	0.00	0.00	0.00	0.28	0.28	0.27	0.26	0.00	-0.01	0.00	0.00
Case 2 ($\eta = 0.75, \Phi = 100$)	0.35	0.35	0.35	0.35	0.07	0.13	0.18	0.24	0.02	0.03	0.02	0.00
Case 3 ($\eta = 0.75, \Phi = 0.01$)	0.47	0.51	0.18	0.22	0.06	0.15	0.18	0.21	0.01	-0.02	0.00	0.00

The mechanisms are similar when the altruistic motive is weak: the social discount rate channel leads to higher capital tax rates. Still, an interesting policy implication can be found when a government has imperfect altruism and faces low adjustment costs.¹⁵ A myopic government with low adjustment costs seeks to reduce within-regime capital tax distortions by pursuing front-loaded capital taxation. On the other hand, we can observe that the government implements a back-loaded labor income tax path.¹⁶ This is because, by imposing relatively higher labor income taxation in the later periods, the government can stimulate households' savings and labor supply in the earlier periods of the regime, which alleviates the cumulative distortion generated by positive capital tax rates in the later periods of the regime.

Finally, the case of flexible tax adjustments shows that the capital tax rate for the last period is higher than the capital tax rate for the third period. Recall that a government takes the first period of capital tax rates ($= 0.47$) as a state variable and will impose the same capital income tax rate for the first period in the next regime. Because gradual tax rate adjustments are less costly than drastic changes due to the convex policy adjustment cost, each planner conducts a gradual increase in the capital tax rate to the desired level. The effects of incentives to implement front-loaded capital taxation and to spread wasteful tax adjustment costs over time lead to a U-shaped optimal capital tax trajectory (from sub-periods 2–4 and the first period of the next regime).

4 Conclusion

The seminal theory of capital taxation lacks practical applicability in actual policy implementation because the conventional framework is based on the strong assumption that the social planner has unlimited power and formulates complete state-contingent intertemporal plans for an infinite future, whereas policymakers' authority in the real world is typically limited and subject to a variety of institutional constraints. To address these limitations, we introduce the following institutional restrictions into the otherwise standard Ramsey problem: (i) a finite planning horizon; (ii) tax rate adjustment costs; and (iii) imperfect altruism. Using a tractable model, we show that when planners have a finite planning horizon while tax rate adjustment is rigid, the optimal capital tax rate is positive in a stationary equilibrium. Numerical findings suggest that the current tax system in the United States may be a near-optimal tax scheme in an environment associated with structural restrictions.

Although the current study presents a simple framework to illustrate our new modeling elements succinctly, we believe the novelty of this paper lies in its theoretical approach. We propose a framework that accounts for policymakers' de facto bounded rational decisions due to institutional constraints, which can dramatically

¹⁵ When LTC is included, sufficient numerical accuracy can be attained even with minimal policy adjustment costs. We present the case of $\Phi = 0.01$, which approximates the lower bound for numerical accuracy of this parameter. The results under intermediate levels of adjustment costs are similar to the representative case presented here.

¹⁶ Recall that we assume neither policy adjustment cost nor policy implementation lag for labor taxation.

alter the policy implications implied by the conventional framework. Incorporating institutional friction prevalent in the actual policymaking process into the optimal policy framework can provide novel policy implications that the existing literature could not uncover. Our framework can be applied to other pressing policy issues, such as environmental regulations, where policy planning horizons play an important role.

Appendix

The Ramsey problem of planners with finite planning horizons

For the sake of simplicity, we designate the starting period of the regime as 0 throughout the model descriptions and proofs provided in the appendix and solve the within-regime problem ranging from period 0 to $T - 1$. With a slight abuse of notation, we use the time subscript t instead of s to denote the sub-period within the regime.

Formally, we can describe the optimization problem of the planner as follows:

$$\begin{aligned}
 W(\tau_{-1}^N, \tau_{-1}^K, K_0, B_0) = & \sum_{t=0}^{T-1} \beta^t \left[U(C_t) - V(N_t) - \frac{\Phi}{2} (\tau_t^K - \tau_{t-1}^K)^2 - \frac{\Phi}{2} (\tau_t^N - \tau_{t-1}^N)^2 \right. \\
 & + \lambda_{1,t} \left((1 - \delta)K_t + F(K_t, N_t) - C_t - K_{t+1} - G_t \right) \\
 & + \lambda_{2,t} \left(\tau_t^K F_{K,t} K_t + \tau_t^N F_{N,t} N_t + B_{t+1} - G - (1 - \delta + (1 - \tau_t^K) F_{K,t}) B_t \right) \\
 & + \lambda_{3,t} \left((1 - \tau_t^N) F_{N,t} U_{C,t} - V_{N,t} \right) + \lambda_{4,t} \left(\beta(1 - \delta + (1 - \tau_{t+1}^K) F_{K,t+1}) U_{C,t+1} - U_{C,t} \right) \\
 & \left. + \lambda_{5,t} \tau_t^N + \lambda_{6,t} \tau_t^K \right] + \lambda_{7,0} (\bar{\tau}_0^K - \tau_0^K) + \eta \beta^T W(\tau_{T-1}^N, \tau_{T-1}^K, K_T, B_T)
 \end{aligned}$$

subject to the within-regime balanced budget restriction, i.e., $B_T = B_0 = 0$.

The first-order conditions with respect to consumption and labor for $0 \leq t \leq T - 1$ are:

$$\begin{aligned}
 [C_t] \quad & : \quad U_{C,t} = \lambda_{1,t} - \lambda_{3,t} (1 - \tau_t^N) F_{N,t} U_{CC,t} + \lambda_{4,t} U_{CC,t} - \lambda_{4,t-1} (1 - \delta + (1 - \tau_t^K) F_{K,t}) U_{CC,t} \\
 [N_t] \quad & : \quad V_{N,t} = \lambda_{1,t} F_{N,t} + \lambda_{2,t} \left(\tau_t^K F_{KN,t} K_t + \tau_t^N (F_{NN,t} N_t + F_{N,t}) - (1 - \tau_t^K) F_{KN,t} B_t \right) \\
 & \quad + \lambda_{3,t} \left((1 - \tau_t^N) F_{NN,t} U_{C,t} - V_{NN,t} \right) + \lambda_{4,t-1} (1 - \tau_t^K) F_{KN,t} U_{C,t}
 \end{aligned}$$

For the sub-periods $0 \leq t \leq T - 2$, the first-order conditions with respect to $\tau_t^K, \tau_t^N, K_{t+1}$ and B_{t+1} satisfy

$$\begin{aligned}
 [\tau_t^K] &: \lambda_{2,t} F_{K,t}(K_t + B_t) \geq \Phi(\tau_t^K - \tau_{t-1}^K) - \beta \Phi(\tau_{t+1}^K - \tau_t^K) + \lambda_{4,t-1} F_{K,t} U_{C,t} + \mathbf{1}(t = 0) \lambda_{7,0} \\
 [\tau_t^N] &: \lambda_{2,t} F_{N,t} N_t \geq \lambda_{3,t} F_{N,t} U_{C,t} + \Phi(\tau_t^N - \tau_{t-1}^N) - \beta \Phi(\tau_{t+1}^N - \tau_t^N) \\
 [K_{t+1}] &: \lambda_{1,t} = \beta \lambda_{1,t+1} (1 - \delta + F_{K,t+1}) \\
 &\quad + \beta \lambda_{2,t+1} \left(\tau_{t+1}^K (F_{KK,t+1} K_{t+1} + F_{K,t+1}) + \tau_t^N F_{KN,t+1} N_{t+1} - (1 - \tau_{t+1}^K) F_{KK,t+1} B_{t+1} \right) \\
 &\quad + \beta \lambda_{3,t+1} (1 - \tau_{t+1}^N) F_{NK,t+1} U_{C,t+1} + \beta \lambda_{4,t} (1 - \tau_{t+1}^K) F_{KK,t+1} U_{C,t+1} \\
 [B_{t+1}] &: \lambda_{2,t} = \beta \lambda_{2,t+1} (1 - \delta + (1 - \tau_{t+1}^K) F_{K,t+1})
 \end{aligned}$$

where $\lambda_{4,-1} = 0$. For the first two equations, the equality holds if the tax rate is strictly positive. The indicator function $\mathbf{1}(t = 0)$ takes 1 if the sub-period $t = 0$ and zero otherwise. For the last sub-period $t = T - 1$, we have the following first order conditions:

$$\begin{aligned}
 [K_T] &: \lambda_{1,T-1} = \eta \beta \frac{\partial W'}{\partial K_T} + \beta \lambda_{4,T-1} (1 - \tau_T^K) F_{KK,T} U_{C,T} \\
 [\tau_{T-1}^K] &: \lambda_{2,T-1} F_{K,T-1} (K_{T-1} + B_{T-1}) \geq \Phi(\tau_{T-1}^K - \tau_{T-2}^K) + \lambda_{4,T-2} F_{K,T-1} U_{C,T-1} - \eta \beta \frac{\partial W'}{\partial \tau_{T-1}^K} \\
 [\tau_{T-1}^N] &: \lambda_{2,T-1} F_{N,T-1} N_{T-1} \geq \lambda_{3,T-1} F_{N,T-1} U_{C,T-1} + \Phi(\tau_{T-1}^N - \tau_{T-2}^N) - \eta \beta \frac{\partial W'}{\partial \tau_{T-1}^N}
 \end{aligned}$$

The equality holds if and only if the tax rate is strictly positive in each case. Using the periodically stable allocation property and the envelope condition, we can find:

$$\begin{aligned}
 [\tau_{-1}^K] &: \frac{\partial W'}{\partial \tau_{T-1}^K} = \frac{\partial W}{\partial \tau_{-1}^K} = \Phi(\tau_0^K - \tau_{-1}^K) \\
 [\tau_{-1}^N] &: \frac{\partial W'}{\partial \tau_{T-1}^N} = \frac{\partial W}{\partial \tau_{-1}^N} = \Phi(\tau_0^N - \tau_{-1}^N) \\
 [K_0] &: \frac{\partial W'}{\partial K_T} = \frac{\partial W}{\partial K_0} = \lambda_{1,0} (1 - \delta + F_{K_0}) + \lambda_{2,0} \left(\tau_0^K (F_{KK,0} K_0 + F_{K,0}) + \tau_0^N F_{NK,0} N_0 - (1 - \tau_0^K) F_{KK,0} B \right) \\
 &\quad + \lambda_{3,0} (1 - \tau_0^N) F_{NK,0} U_{C,0}
 \end{aligned}$$

Using these, the optimal conditions with respect to K_T , τ_{T-1}^K , and τ_{T-1}^N are written as:

$$\begin{aligned}
 \lambda_{1,T-1} &= \eta \beta \left(\lambda_{1,T} (1 - \delta + F_{K,T}) + \lambda_{2,T} \left(\tau_T^K (F_{KK,T} K_T + F_{K,T}) \right. \right. \\
 &\quad \left. \left. + \tau_T^N F_{NK,T} N_T \right) + \lambda_{3,T} (1 - \tau_T^N) F_{NK,T} U_{C,T} \right) \\
 &\quad + \beta \lambda_{4,T-1} (1 - \tau_T^K) F_{KK,T} U_{C,T}
 \end{aligned} \tag{19}$$

$$\begin{aligned}
 &\tau_{T-1}^K \lambda_{2,T-1} F_{K,T-1} (K_{T-1} + B_{T-1}) \\
 &= \tau_{T-1}^K \left(\Phi(\tau_{T-1}^K - \tau_{T-2}^K) + \lambda_{4,T-2} F_{K,T-1} U_{C,T-1} - \eta \beta \Phi(\tau_T^K - \tau_{T-1}^K) \right)
 \end{aligned} \tag{20}$$

$$\tau_{T-1}^N \lambda_{2,T-1} F_{N,T-1} N_{T-1} = \tau_{T-1}^N \left(\lambda_{3,T-1} F_{N,T-1} U_{C,T-1} + \Phi(\tau_{T-1}^N - \tau_{t-2}^N) - \eta\beta\Phi(\tau_T^N - \tau_{T-1}^N) \right) \tag{21}$$

Solution algorithm To find a stationary Ramsey optimal allocation under a T -period planning horizon, we need to solve $T \times 10 - 1$ nonlinear equations simultaneously. We use the MATLAB optimization toolbox to solve the problem. The following is a sketch of our algorithm. We interchangeably use the MATLAB nonlinear system solvers 'fsolve' and 'lsqnonlin'. The latter solver allows solution ranges (The upper and lower bound of each variable) to be assigned, whereas the former does not. We begin by assigning a reasonable initial numerical search point based on the stationary equilibrium under the other planning horizons. The nonlinear system of equations is then solved using "lsqnonlin", which finds the (possibly local) solution with the smallest error. Following that, we use "fsolve" to find the global solution, with the solution from the previous step serving as an initial search point. Finally, we re-run "lsqnonlin" to find the final solution that meets the desired solution ranges, using the solution suggested by "fsolve" as the initial starting point of the numerical search. We intend to refine the solution using this three-step approach, which reduces the reliance of numerical search on an arbitrary choice of the initial search point. Finally, we examine whether the solution meets our $10e^{-10}$ tolerance level and other reasonable requirements (e.g., the welfare must increase as the policy planning horizon lengthens or fall as the policy adjustment cost goes up). To be fair, our nonlinear problem could have multiple solutions. If multiple equilibria are found, we select the allocation that produces the greatest welfare among the candidate solutions.

Proof of proposition 2.1

Because of the within-regime balanced-budget condition, $B_t = 0$ for all t . The Ramsey problem with a one-period planning horizon is written as follows:

$$\begin{aligned} W(\tau_{-1}^N, \tau_{-1}^K, K_0) = & \max_{\{C_0, N_0, K_1, \tau_0^K, \tau_0^N\}} U(C_0) - V(N_0) \\ & - \frac{\Phi}{2} \left((\tau_0^K - \tau_{-1}^K)^2 + (\tau_0^N - \tau_{-1}^N)^2 \right) + \eta\beta W(\tau_0^N, \tau_0^K, K_1) \\ & + \lambda_{1,0} \left((1 - \delta)K_0 + F(K_0, N_0) - C_0 - K_1 - G \right) \\ & + \lambda_{2,0} \left(\tau_0^K F_{K,0} K_0 + \tau_0^N F_{N,0} N_0 - G \right) \\ & + \lambda_{3,0} \left((1 - \tau_0^N) F_{N,0} U_{C,0} - V_{N,0} \right) \\ & + \lambda_{4,0} \left(\beta(1 - \delta + (1 - \tau_1^K) F_{K,1}) U_{C,1} - U_{C,0} \right) \end{aligned}$$

along with the restrictions on the feasible range of tax rates, $0 \leq \tau_0^N$ and $0 \leq \tau_0^K$, and the implied upper bound on the capital tax rate $\tau_0^K \leq \bar{\tau}^K = \frac{G}{F_{K,0} K_0}$.

We start with the corner solution case. First, without loss of generality, we can rule out the case where the planner relies solely on labor taxation to finance public spending while imposing a zero capital tax rate because capital taxation is non-distortionary in the first sub-period. On the other hand, if $\tau_0^N = 0$, the capital tax rate should, by definition, reach its upper bound, i.e., $\tau_0^K = \bar{\tau}^K$, and the result is trivial.

Now, assume τ_0^N is strictly positive. Then, by definition, $\tau_0^K \in (0, \bar{\tau}^K)$. The first order condition with respect to τ_0^K gives:

$$\lambda_{2,0} F_{K,0} K_0 + \eta\beta \frac{\partial W(\tau_0^N, \tau_0^K, K_1)}{\partial \tau_0^K} = \Phi(\tau_0^K - \tau_{-1}^K)$$

Since $\tau_0^N > 0$, the equality should hold. The envelope condition gives

$$\frac{\partial W(\tau_{-1}^N, \tau_{-1}^K, K_0)}{\partial \tau_{-1}^K} = \Phi(\tau_0^K - \tau_{-1}^K)$$

Using this, we can find

$$\lambda_{2,0} F_{K,0} K_0 = \Phi(\tau_0^K - \tau_{-1}^K) - \eta\beta \Phi(\tau_1^K - \tau_0^K)$$

In a stationary equilibrium where $\tau_t^K = \tau_{t-1}^K$ for all t , the equation indicates:

$$\lambda_{2,0} F_{K,0} K_0 = 0$$

The Lagrange multiplier $\lambda_{2,0}$ denotes the shadow welfare cost of fiscal redistribution from households to government, which should be strictly positive as long as the labor tax rate is positive because labor taxes are distortionary. This yields a contradiction.

The result implies that the optimal capital tax rate reaches its maximum in a stationary Ramsey optimal allocation over one period of the planning horizon, while the optimal labor tax rate should be zero. Conditional on $\tau_0^K = \bar{\tau}^K$, we have four constraints (household's FOCs, government budget constraint, and the resource constraint) to solve for four endogenous variables C_0, N_0, K_1, τ_0^N . Since these equations do not include η and Φ , it implies that those variables are determined independently of the levels of η and Φ . □

Proof of proposition 2.2

Suppose the optimal capital tax rate in the steady-state Ramsey allocation is strictly positive. The planner's problem can be described as:

$$\begin{aligned}
 W(\tau_{-1}^N, \tau_{-1}^K, K_0, B_0) = & \max_{\{C_t, N_t, K_{t+1}, B_{t+1}, \tau_t^K, \tau_t^N\}} \sum_{t=0}^{\infty} \beta^t \left[U(C_t) - V(N_t) - \frac{\Phi}{2} \left((\tau_t^K - \tau_{t-1}^K)^2 + (\tau_t^N - \tau_{t-1}^N)^2 \right) \right. \\
 & + \lambda_{1,t} \left((1 - \delta)K_t + F(K_t, N_t) - C_t - K_{t+1} - G \right) \\
 & + \lambda_{2,t} \left(\tau_t^K F_{K,t} K_t + \tau_t^N F_{N,t} N_t + B_{t+1} - G_t - (1 - \delta + (1 - \tau_t^K) F_{K,t}) B_t \right) \\
 & \left. + \lambda_{3,t} \left((1 - \tau_t^N) F_{N,t} U_{C,t} - V_{N,t} \right) + \lambda_{4,t} \left(\beta(1 - \delta + (1 - \tau_{t+1}^K) F_{K,t+1}) U_{C,t+1} - U_{C,t} \right) \right]
 \end{aligned}$$

along with the transversality conditions $\lim_{t \rightarrow \infty} B_t = 0$, and the non-negativity restrictions on the tax rates. The first-order conditions are as follows:

$$[K_{t+1}] \quad \lambda_{1,t} = \beta \lambda_{1,t+1} (1 - \delta + F_{K,t+1}) \tag{22}$$

$$\begin{aligned}
 & + \beta \lambda_{2,t+1} \left(\tau_{t+1}^K (F_{KK,t+1} K_{t+1} + F_{K,t+1}) + \tau_t^N F_{KN,t+1} N_{t+1} - (1 - \tau_{t+1}^K) F_{KK,t+1} B_{t+1} \right) \\
 & + \beta \lambda_{3,t+1} (1 - \tau_{t+1}^N) F_{NK,t+1} U_{C,t+1} + \beta \lambda_{4,t} (1 - \tau_{t+1}^K) F_{KK,t+1} U_{C,t+1} \\
 [B_{t+1}] \quad \lambda_{2,t} = & \beta \lambda_{2,t+1} (1 - \delta + (1 - \tau_{t+1}^K) F_{K,t+1}) \tag{23}
 \end{aligned}$$

$$\lambda_{2,t} F_{K,t} (K_t + B_t) = \Phi (\tau_t^K - \tau_{t-1}^K) - \beta \Phi (\tau_{t+1}^K - \tau_t^K) + \lambda_{4,t-1} F_{K,t} U_{C,t} \tag{24}$$

$$\lambda_{2,t} F_{N,t} N_t = \lambda_{3,t} F_{N,t} U_{C,t} + \Phi (\tau_t^N - \tau_{t-1}^N) - \beta \Phi (\tau_{t+1}^N - \tau_t^N) \tag{25}$$

$$U_{C,t} = \lambda_{1,t} - \lambda_{3,t} (1 - \tau_t^N) F_{N,t} U_{CC,t} + \lambda_{4,t} U_{CC,t} - \lambda_{4,t-1} (1 - \delta + (1 - \tau_t^K) F_{K,t}) U_{CC,t} \tag{26}$$

$$\begin{aligned}
 [N_t] \quad V_{N,t} = & \lambda_{1,t} F_{N,t} + \lambda_{2,t} \left(\tau_t^K F_{KN,t} K_t + \tau_t^N (F_{NN,t} N_t + F_{N,t}) - (1 - \tau_t^K) F_{KN,t} B_t \right) \\
 & + \lambda_{3,t} \left((1 - \tau_t^N) F_{NN,t} U_{C,t} - V_{NN,t} \right) + \lambda_{4,t-1} (1 - \tau_t^K) F_{KN,t} U_{C,t} \tag{27}
 \end{aligned}$$

We focus on steady-state equilibrium, where variables are time-invariant. Without loss of generality, we can suppress the time subscript. From Eq. (A.6), we have

$$\lambda_2 F_K (K + B) = \lambda_4 F_K U_C \tag{28}$$

Eq. (23) and the household’s Euler equation give

$$\lambda_2 = U_C \tag{29}$$

Hence, Eq. (28) indicates

$$\lambda_4 = K + B \tag{30}$$

Eq. (25) suggests

$$\lambda_3 = N \tag{31}$$

Using Eqs. (29) to (31), Eq. (22) can be rewritten as follows:

$$\begin{aligned}
 (1 - \beta(1 - \delta + F_K))\lambda_1 &= \beta \left(\lambda_{2,t+1} \left(\tau_{t+1}^K (F_{KK,t+1}K_{t+1} + F_{K,t+1}) + \tau_t^N F_{KN,t+1}N_{t+1} - (1 - \tau_{t+1}^K)F_{KK,t+1}B_{t+1} \right) \right. \\
 &\quad \left. + \lambda_{3,t+1}(1 - \tau_{t+1}^N)F_{NK,t+1}U_{C,t+1} + \lambda_{4,t}(1 - \tau_{t+1}^K)F_{KK,t+1}U_{C,t+1} \right) \\
 \implies -\beta\tau^K F_K \lambda_1 &= \beta U_C \tau^K F_K
 \end{aligned}$$

If we assume $\tau^K > 0$, the equation leads to

$$\lambda_1 = -U_C$$

λ_1 denotes the Lagrange multiplier associated with the resource constraint. Because it captures the shadow welfare cost when the resource constraint is marginally tightened, this multiplier cannot be negative. Thus, the above equation is a contradiction. □

The Ramsey problem of planners under limited time commitment

The capital tax rate for the first period of each regime is included as a state variable under LTC. The Ramsey problem is discussed below. Recall that we assumed that labor taxation is exempt from LTC and policy adjustment costs.

$$\begin{aligned}
 W(\tau_{-1}^K, \tau_0^K, K_0, B_0) &= \sum_{t=0}^{T-1} \beta^t \left[U(C_t) - V(N_t) - \frac{\Phi}{2} (\tau_t^K - \tau_{t-1}^K)^2 \right. \\
 &\quad + \lambda_{1,t} \left((1 - \delta)K_t + F(K_t, N_t) - C_t - K_{t+1} - G_t \right) \\
 &\quad + \lambda_{2,t} \left(\tau_t^K F_{K,t}K_t + \tau_t^N F_{N,t}N_t + B_{t+1} - G - (1 - \delta + (1 - \tau_t^K)F_{K,t})B_t \right) \\
 &\quad + \lambda_{3,t} \left((1 - \tau_t^N)F_{N,t}U_{C,t} - V_{N,t} \right) + \lambda_{4,t} \left(\beta(1 - \delta + (1 - \tau_{t+1}^K)F_{K,t+1})U_{C,t+1} - U_{C,t} \right) \\
 &\quad \left. + \lambda_{5,t}\tau_t^N + \lambda_{6,t}\tau_t^K \right] + \eta\beta^T W(\tau_{T-1}^K, \tau_T^K, K_T, B_T)
 \end{aligned}$$

Although a social planner can choose the capital tax rate for the first period of the next regime, it should be noted that a government cannot directly affect other future allocations under the following regime but takes them as given. The first-order conditions are mostly kept the same, but the optimality conditions with respect to the tax rates are different. We will focus on the case where the optimal tax rates have an interior solution, which is true since the LTC effectively rules out the use of confiscatory capital taxation at the beginning of each regime.

Due to the assumption of LTC, a social planner having power over periods $0 \leq t \leq T - 1$ determines τ_t^K for periods $1 \leq t \leq T$. The first-order conditions for labor tax rates and capital tax rates over sub-periods $1 \leq t \leq T - 2$ are as follows:

$$\begin{aligned}
 [\tau_t^N] &: \lambda_{2,t}F_{N,t}N_t = \lambda_{3,t}F_{N,t}U_{C,t} \\
 [\tau_t^K] &: \lambda_{2,t}F_{K,t}(K_t + B_t) = \Phi(\tau_t^K - \tau_{t-1}^K) - \beta\Phi(\tau_{t+1}^K - \tau_t^K) + \lambda_{4,t-1}F_{K,t}U_{C,t}
 \end{aligned}$$

Using the envelope theorem, the first-order conditions for τ_{T-1}^K and τ_T^K can be written as follows:

$$\begin{aligned} [\tau_{T-1}^K] &: \lambda_{2,T-1} F_{K,T-1} (K_{T-1} + B_{T-1}) = \Phi(\tau_{T-1}^K - \tau_{T-2}^K) + \lambda_{4,T-2} F_{K,T-1} U_{C,T-1} - \eta \beta \Phi(\tau_T^K - \tau_{T-1}^K) \\ [\tau_T^K] &: \lambda_{4,T-1} F_{K,T} U_{C,T} = \eta \left(\lambda_{2,T} F_{K,T} (K_T + B_T) - \Phi(\tau_T^K - \tau_{T-1}^K) + \beta \Phi(\tau_{T+1}^K - \tau_T^K) \right) \end{aligned}$$

Welfare measure: Consumption compensating variation

We use the consumption compensating variation conditional on the stationary equilibrium to evaluate welfare implications, similar to Lester et al. (2014). In particular, we denote the household welfare conditional on the stationary Ramsey allocation in which the planner holds T periods of the planning horizon as $W^T(\tau_{-1}^N, \tau_{-1}^K, K_0, B_0) \equiv \sum_{t=0}^{\infty} \beta^t \left(U(C_t^T) - V(N_t^T) \right)$ where C_t^T and N_t^T stand for the periodically stable Ramsey allocations conditional on T periods of the planning horizon, and the initial state variables are set to their stationary Ramsey equilibrium allocations. Likewise, we compute the household lifetime welfare conditional on the steady-state Ramsey equilibrium in an economy where the planner holds the infinite planning horizon, and we denote it as $W^\infty(\tau_{-1}^N, \tau_{-1}^K, K_0, B_0) \equiv \sum_{t=0}^{\infty} \beta^t \left(U(C^\infty) - V(N^\infty) \right)$ where C^∞ and N^∞ are the steady-state consumption and labor, respectively, when the planning horizon is infinite, and the initial state variables are set to their steady-state levels. Then, we define our welfare measure of the conditional consumption compensating variation λ_T of the economy with a T -period planning horizon relative to the infinite planning horizon economy as:

$$W^T = \sum_{t=0}^{\infty} \beta^t \left(U((1 + \lambda_T)C^\infty) - V(N^\infty) \right)$$

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References

- Abel, A. B. (2007). Optimal Capital Income Taxation. NBER Working Paper (w13354).
- Aiyagari, S. R. (1995). Optimal capital income taxation with incomplete markets, borrowing constraints, and constant discounting. *Journal of political Economy*, *103*(6), 1158–1175.
- Altonji, J. G. (1986). Intertemporal substitution in labor supply: Evidence from micro data. *Journal of Political Economy*, *94*(3), S176–S215.
- Angeletos, G. M., Laibson, D., Repetto, A., Tobacman, J., & Weinberg, S. (2001). The hyperbolic consumption model: Calibration, simulation, and empirical evaluation. *Journal of Economic perspectives*, *15*(3), 47–68.
- Attanasio, O. P., & Weber, G. (1993). Consumption growth, the interest rate and aggregation. *The Review of Economic Studies*, *60*(3), 631–649.
- Banks, J., & Diamond, P. (2010). The base for direct taxation. In *Dimensions of tax design: The Mirrlees review* (pp. 548–648). Oxford University Press.
- Barro, R. J. (1974). Are government bonds net wealth? *Journal of political economy*, *82*(6), 1095–1117.
- Boar, C., & Midrigan, V. (2022). Should we tax capital income or wealth? *The American Economic Review: Insights*, *5*(2), 259–274.
- Bourguignon, F., & Spadaro, A. (2012). Tax-benefit revealed social preferences. *The Journal of Economic Inequality*, *10*, 75–108.
- Chamley, C. (1986). Optimal taxation of capital income in general equilibrium with infinite lives. *Econometrica: Journal of the Econometric Society*, *4*, 607–622.
- Chari, V. V., Christiano, L. J., & Kehoe, P. J. (1994). Optimal fiscal policy in a business cycle model. *Journal of political Economy*, *102*(4), 617–652.
- Chari, V. V., Nicolini, J. P., & Teles, P. (2020). Optimal capital taxation revisited. *Journal of Monetary Economics*, *116*, 147–165.
- Clymo, A., & Lanteri, A. (2020). Fiscal policy with limited-time commitment. *The Economic Journal*, *130*(627), 623–652.
- Conesa, J. C., Kitao, S., & Krueger, D. (2009). Taxing capital? Not a bad idea after all! *American Economic Review*, *99*(1), 25–48.
- Debortoli, D., & Nunes, R. (2010). Fiscal policy under loose commitment. *Journal of Economic Theory*, *145*(3), 1005–1032.
- Debortoli, D., & Nunes, R. (2013). Lack of commitment and the level of debt. *Journal of the European Economic Association*, *11*(5), 1053–1078.
- Debortoli, D., Maih, J., & Nunes, R. (2014). Loose commitment in medium-scale macroeconomic models: Theory and applications. *Macroeconomic Dynamics*, *18*(1), 175–198.
- Erosa, A., & Gervais, M. (2002). Optimal taxation in life-cycle economies. *Journal of Economic Theory*, *105*(2), 338–369.
- Farhi, E., & Werning, I. (2012). Capital taxation: Quantitative explorations of the inverse Euler equation. *Journal of Political Economy*, *120*(3), 398–445.
- Ferriere, A., Grübener, P., Navarro, G., & Vardishvili, O. (2021). Larger transfers financed with more progressive taxes? On the optimal design of taxes and transfers.
- Gabaix, X. (2020). A behavioral New Keynesian model. *American Economic Review*, *110*(8), 2271–2327.
- Golosov, M., Kocherlakota, N., & Tsyvinski, A. (2003). Optimal indirect and capital taxation. *The Review of Economic Studies*, *70*(3), 569–587.
- Golosov, M., Troshkin, M., Tsyvinski, A., & Weinzierl, M. (2013). Preference heterogeneity and optimal capital income taxation. *Journal of Public Economics*, *97*, 160–175.
- Golosov, M., Tsyvinski, A., Werning, I., Diamond, P., & Judd, K. L. (2006). New dynamic public finance: A user's guide [with comments and discussion]. *NBER Macroeconomics Annual*, *21*, 317–387.
- Judd, K. L. (1985). Redistributive taxation in a simple perfect foresight model. *Journal of public Economics*, *28*(1), 59–83.
- Judd, K. L. (1999). Optimal taxation and spending in general competitive growth models. *Journal of Public Economics*, *71*(1), 1–26.

- Klein, P., & Ríos-Rull, J. V. (2003). Time-consistent optimal fiscal policy. *International Economic Review*, 44(4), 1217–1245.
- Kocherlakota, N. R. (2005). Zero expected wealth taxes: A Mirrlees approach to dynamic optimal taxation. *Econometrica*, 73(5), 1587–1621.
- Kydland, F. E., & Prescott, E. C. (1982). Time to build and aggregate fluctuations. *Econometrica: Journal of the Econometric Society*, 50, 1345–1370.
- Laibson, D. (1997). Golden eggs and hyperbolic discounting. *The Quarterly Journal of Economics*, 112(2), 443–478.
- Lester, R., Pries, M., & Sims, E. (2014). Volatility and welfare. *Journal of Economic Dynamics and Control*, 38, 17–36.
- Mankiw, N. G., Rotemberg, J. J., & Summers, L. H. (1985). Intertemporal substitution in macroeconomics. *The Quarterly Journal of Economics*, 100(1), 225–251.
- Michel, P., Thibault, E., & Vidal, J. P. (2006). Intergenerational altruism and neoclassical growth models. *Handbook of the Economics of Giving, Altruism and Reciprocity*, 2, 1055–1106.
- Peterman, W. B. (2016). Reconciling micro and macro estimates of the Frisch labor supply elasticity. *Economic Inquiry*, 54(1), 100–120.
- Piketty, T., & Saez, E. (2013). A theory of optimal inheritance taxation. *Econometrica*, 81(5), 1851–1886.
- Rotemberg, J. J. (1982). Monopolistic price adjustment and aggregate output. *The Review of Economic Studies*, 49(4), 517–531.
- Saez, E., & Stantcheva, S. (2018). A simpler theory of optimal capital taxation. *Journal of Public Economics*, 162, 120–142.
- Stockman, D. R. (2001). Balanced-budget rules: Welfare loss and optimal policies. *Review of Economic Dynamics*, 4(2), 438–459.
- Straub, L., & Werning, I. (2020). Positive long-run capital taxation: Chamley-Judd revisited. *American Economic Review*, 110(1), 86–119.
- Strotz, R. H. (1955). Myopia and inconsistency in dynamic utility maximization. *The Review of Economic Studies*, 23(3), 165–180.
- Thibault, E. (2000). Existence of equilibrium in an OLG model with production and altruistic preferences. *Economic Theory*, 15, 709–715.
- Weil, P. (1987). Love thy children: Reflections on the Barro debt neutrality theorem. *Journal of Monetary Economics*, 19(3), 377–391.
- Woodford, M. (2019). Monetary policy analysis when planning horizons are finite. *NBER Macroeconomics Annual*, 33(1), 1–50.

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