Organizational Equilibrium with Capital

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LAEF

November 16, 2019

Question

- Time inconsistency is a pervasive issue
  - taxation, government debt, consumption-saving problem, monetary policy, ...
- Two Benchmarks:
  - Markov equilibrium
  - Sequential equilibrium/sustainable plan

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  - Markov equilibrium
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- Markov equilibrium:
  - Interesting comparative statics
  - Outcome determined by fundamentals
  - ... but can be largely improved upon

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- Markov equilibrium:
  - Interesting comparative statics
  - Outcome determined by fundamentals
  - ... but can be largely improved upon
- Sequential equilibrium:
  - Can often attain very good outcomes (folk theorem)
  - Can also attain very bad outcomes (folk theorem again)
  - Relies on self-punishment as a threat
  - Weak predictions (big set of equilibria)

Our View

- Good institutions and social norms do not evolve overnight
- Collaboration across cohorts of decision makers builds slowly
- It probably also erodes slowly
- Look for equilibrium concept that captures this, and addresses shortcomings of Markov & Best Sequential Eq.

Organizational Equilibrium

- Reconsideration-Proof Equilibrium (Kocherlakota, 1996); Organizational Equilibrium (Prescott-Ríos-Rull, 2005)
- Based on renegotiation-proofness (Farrell and Maskin, 1989)
- Punisher does not suffer from punishing past misdeeds
- Retains meaningful comparative statics
- Improves on Markov Equilibrium

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- Based on renegotiation-proofness (Farrell and Maskin, 1989)
- Punisher does not suffer from punishing past misdeeds
- Retains meaningful comparative statics
- Improves on Markov Equilibrium
- ... but does not deal with state variables (only repeated games, no dynamic games)
- This is where we come in

Equilibrium Properties

- Compare with Markov equilibrium
  - payoff only depends on state variables, like Markov equilibrium
  - action can depend on history, different from Markov equilibrium

- Compare with sequential equilibrium
  - no self-punishment
  - Refinement I: same continuation value on or off equilibrium path
  - Refinement II: no one wants to deviate and wait for a restart of the game

- New issues with state variables
  - how to induce stationary environment
  - Player preferences no longer purely forward-looking (new role for no-delaying condition)

Quantitative Findings

- Apply the equilibrium concept in
  - quasi-geometric discounting growth model
  - government taxation model
- Steady state
  - allocation is close to Ramsey outcome, much better than Markov equilibrium
- Transition
  - allocation starts similar to Markov, converges to similar to Ramsey

Related Literature

- Markov equilibrium and GEE
  - Currie and Levine (1993), Bassetto and Sargent (2005), Klein and Ríos-Rull (2003), Klein, Quadrini and Ríos-Rull (2005), Krusell and Ríos-Rull (2008), Krusell, Kuruscu, and Smith (2010), Song, Storesletten and Zilibotti (2012)
- Sustainable plan
  - Stokey (1988), Chari and Kehoe (1990), Abreu, Pearce and Stacchetti (1990), Phelan and Stacchetti (2001)
- Quasi-geometric discounting growth model
  - Strotz (1956), Phelps and Pollak (1968), Laibson (1997), Krusell and Smith (2003), Chatterjee and Eyigungor (2015), Bernheim, Ray, and Yeltekin (2017), Cao and Werning (2017)
- Refinement of subgame perfect equilibrium
  - Farrell and Maskin (1989), Kocherlakota (1996), Prescott and Ríos-Rull (2005), Nozawa (2014), Ales and Sleet (2015)

Plan

1. An example: a growth model with quasi-geometric discounting
2. General definition and property
3. Application in government taxation problem

Part I: A Growth Model

The Environment

- Preferences: quasi-geometric discounting

$$\Psi_t = u(c_t) + \delta \sum_{\tau=1}^{\infty} \beta^{\tau} u\left(c_{t+\tau}\right)$$

  - period utility function $u(c) = \log c$
  - $\delta = 1$ is the time-consistent case

- Technology

$$f(k_t) = k_t^{\alpha}, \qquad k_{t+1} = f(k_t) - c_t.$$

Benchmark I: Markov Perfect Equilibrium

- Take future $g(k)$ as given

$$\max_{k'} \; u[f(k) - k'] + \delta\beta\Omega(k'; g)$$

cont. value: $\Omega(k; g) = u[f(k) - g(k)] + \beta\Omega[g(k); g]$

- The Generalized Euler Equation (GEE)

$$u_c = \beta u_c' \left[\delta f_k' + (1-\delta)\, g_k'\right]$$

- The equilibrium features a constant saving rate

$$k' = \frac{\delta\alpha\beta}{1 - \alpha\beta + \delta\alpha\beta}\, k^\alpha = s^M\, k^\alpha$$

Benchmark II: Ramsey Allocation with Commitment

- Choose all future allocations at period 0

$$\max_{k_1} \; u[f(k_0) - k_1] + \delta\beta\Omega(k_1)$$

cont. value: $$\Omega(k) = \max_{k'} \; u[f(k) - k'] + \beta\Omega(k')$$

- The sequence of saving rates is given by

$$s_t = \begin{cases} s^M = \frac{\alpha\delta\beta}{1-\alpha\beta+\delta\alpha\beta}, & t = 0 \\ s^R = \alpha\beta, & t > 0 \end{cases}$$

- Steady state capital in Markov equilibrium is lower than Ramsey

$$s^M < s^R$$

Elements of Organization Equilibrium: Proposal

- A proposal is a sequence of saving rates $\{s_0, s_1, s_2, \dots\}$
- Given an initial capital k_0, the proposal induces a sequence of capital

$$k_1 = s_0 k_0^\alpha$$
$$k_2 = s_1 k_1^\alpha = k_0^{\alpha^2} s_1 s_0^\alpha$$
$$\vdots$$
$$k_t = k_0^{\alpha^t} \Pi_{j=0}^{t-1} s_j^{\alpha^{t-j-1}}$$

Proposal and Value Function

- A proposal is a sequence of saving rates $\{s_0, s_1, s_2, \ldots\}$
- The lifetime utility for the agent who makes the proposal is

$$
\begin{aligned}
& U(k_0, s_0, s_1, \ldots) \\
=& \log[(1-s_0)k_0^\alpha] + \delta \sum_{j=1}^{\infty} \beta^j \log\left[(1-s_j)k_j^\alpha\right] \\
=& \frac{\alpha(1-\alpha\beta+\delta\alpha\beta)}{1-\alpha\beta} \log k_0 + \log(1-s_0) + \delta \sum_{j=1}^{\infty} \beta^j \log\left[(1-s_j)\Pi_{\tau=0}^{j-1} s_\tau^{\alpha^{j-\tau}}\right] \\
\equiv& \phi \log k_0 + V(s_0, s_1, \ldots)
\end{aligned}
$$

Separability

- The lifetime utility for agent at period t is

$$\underbrace{U(k_t, s_t, s_{t+1}, \ldots)}_{\text{total payoff}} = \phi \log k_t + \underbrace{V(s_t, s_{t+1}, \ldots)}_{\text{action payoff}}$$

- There is a *Separability* property between capital and saving rates
  - true for the initial proposer and all subsequent followers
  - this property is crucial to our equilibrium concept

.

- What type of proposals can be implemented?

Organizational Equilibrium

Definition

A sequence of saving rates $\{s_\tau\}_{\tau=0}^{\infty}$ is organizationally admissible if

1. $V(s_t, s_{t+1}, s_{t+2}, \ldots)$ is (weakly) increasing in t
2. The first agent has no incentive to delay the proposal.

$$V(s_0, s_1, s_2, \ldots) \geq \max_s V(s, s_0, s_1, s_2, \ldots)$$

Within organizationally admissible sequences, a sequence that attains the maximum of $V(s_0, s_1, s_2, \ldots)$ is an *organizational equilibrium*.

Remarks on Organizational Equilibrium

- OE is outcome of some SPE
  - SPE example: if someone deviates, next agent restarts from s_0
- SPE refinement criterion
  - same continuation value on and off equilibrium path (for V component)
  - no one better off by deviating and counting on others to restart the game
- In equilibrium,

$$U(k_t, s_t, s_{t+1}, \dots) = \phi \log k_t + V(s_t, s_{t+1}, \dots) = \phi \log k_t + V^*$$

  - total payoff only depends on capital, not a trigger with self-punishment
  - agents' action depend on past actions, not a Markov equilibrium

Can the Ramsey Outcome be Implemented?

- Imagine the initial agent with k_0 proposes $\{s^M, s^R, s^R, \ldots\}$, which implies

$$k_1 = s^M k_0^\alpha$$

- By following the proposal, the next agent's payoff is

$$U\left(k_1, s^R, s^R, s^R, \ldots\right) = \phi \log k_1 + V\left(s^R, s^R, s^R, \ldots\right)$$

- By copying the proposal, the next agent's payoff is

$$\begin{aligned} U\left(k_1, s^M, s^R, s^R, \ldots\right) &= \phi \log k_1 + V\left(s^M, s^R, s^R, \ldots\right) \\ &> \phi \log k_1 + V\left(s^R, s^R, s^R, \ldots\right) \end{aligned}$$

- Copying is better than following, Ramsey outcome cannot be implemented

Can a Constant Saving Rate be Implemented?

- Suppose the initial agent proposes $\{s, s, s \ldots\}$

- By following the proposal, the payoff for agent in period t is

$$U(k_t, s, s, \ldots) = \phi \log k_t + V(s, s, \ldots)$$

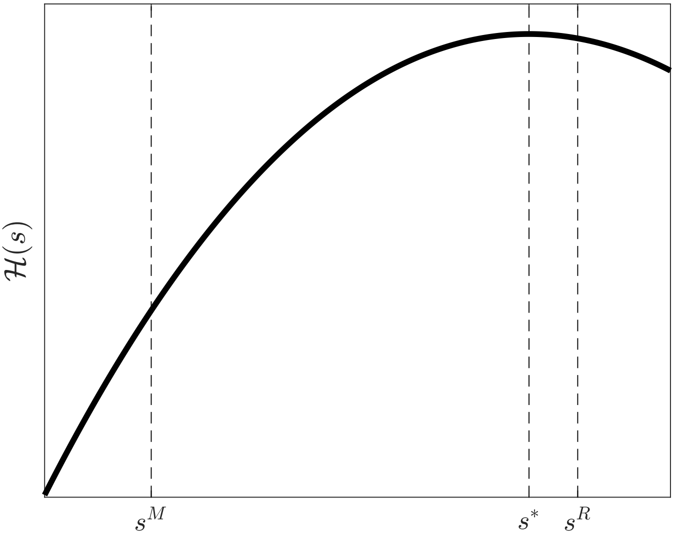
  where

$$V(s, s, \ldots) \equiv \mathcal{H}(s) = \left(1 + \frac{\beta\delta}{1-\beta}\right) \log(1-s) + \frac{\delta\alpha\beta}{(1-\alpha\beta)(1-\beta)} \log(s)$$

- To be followed, the constant saving rate has to be

$$s^* = \operatorname{argmax} \mathcal{H}(s)$$

Optimal Constant Saving Rate



$$s^M < s^* < s^R$$

Can $\{s^*, s^*, \ldots\}$ be Implemented?

- If the initial agent proposes $\{s^*, s^*, \ldots\}$, no one has incentive to copy
- But, she prefers to choose s^M, and wait the next to propose $\{s^*, s^*, \ldots\}$

$$\begin{aligned} U\left(k_0, s^M, s^*, s^*, \ldots\right) &= \phi \log k_0 + V\left(s^M, s^*, s^*, \ldots\right) \\ &> \phi \log k_0 + V\left(s^*, s^*, s^*, \ldots\right) \end{aligned}$$

- Constant s^* proposal cannot be implemented, incentive to delay
- But, something else can be implemented, which converges to s^*

Construct the Organizational Equilibrium

- Look for a sequence of saving rates $\{s_0, s_1, \ldots\}$
- Every generation obtains the same $\overline{V}$

$$V(s_t, s_{t+1}, \ldots) = V(s_{t+1}, s_{t+2}, \ldots) = \overline{V}$$

which induces the following difference equation

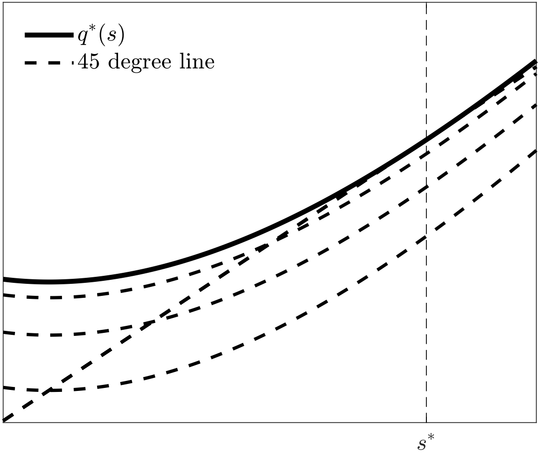
$$\beta(1-\delta)\log(1-s_{t+1}) = \frac{\delta\alpha\beta}{1-\alpha\beta}\log s_t + \log(1-s_t) - (1-\beta)\overline{V}$$

- We call this difference equation as the proposal function

$$s_{t+1} = q(s_t; \overline{V})$$

- The maximal $\overline{V}$ and an initial s_0 are needed to determine $\{s_\tau\}_{\tau=0}^{\infty}$

Determine V^*



- As $\overline{V}$ increases, the proposal function $q(s;\overline{V})$ moves upwards
- The highest $\overline{V} = V^*$ is achieved when $q(s;\overline{V})$ is tangent to the 45 degree line (at s^*)

Determine the Initial Saving Rate s_0

- The first agent should have no incentive to delay the proposal

$$\max_s V(s, s_0, s_1, s_2, \ldots) = V(s^M, s_0, s_1, s_2, \ldots)$$

- s_0 has to be such that

$$V^* = V(s_0, s_1, s_2, \ldots) \geq V(s^M, s_0, s_1, s_2, \ldots)$$
$$\longrightarrow s_0 \leq q^*\left(s^M\right)$$

- We select $s_0 = q^*\left(s^M\right)$, which yields the highest welfare for period $t+1$

Organizational Equilibrium in Quasi-Geometric Discounting Growth Model

Proposition

The organizational equilibrium $\{s_\tau\}_{\tau=0}^{\infty}$ is given recursively by the proposal function q^*

$$s_t = q^*(s_{t-1}) = 1 - \exp\left\{\frac{-(1-\beta)V^* + \frac{\delta\alpha\beta}{1-\alpha\beta}\log s_{t-1} + \log(1-s_{t-1})}{\beta(1-\delta)}\right\}$$

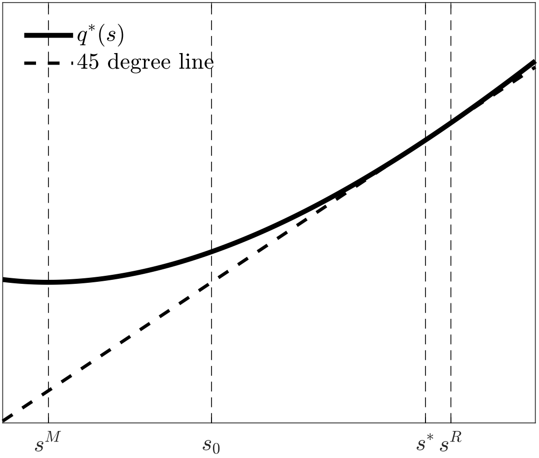
where the initial saving rate s_0, the steady state s^*, and V^* are given by

$$s_0 = q^*\left(s^M\right)$$

$$s^* = \frac{\delta\alpha\beta}{(1-\beta+\delta\beta)(1-\alpha\beta)+\delta\alpha\beta}$$

$$V^* = \frac{1-\beta+\delta\beta}{1-\beta}\log(1-s^*) + \frac{\alpha\delta\beta}{(1-\beta)(1-\alpha\beta)}\log s^*$$

Transition Dynamics



- The equilibrium starts from s_0, and monotonically converges to s^*.

Remarks

1. To solve proposal function, no agent can treat herself specially, $V_t = V_{t+1}$

   Thank you for the idea, I will do it myself

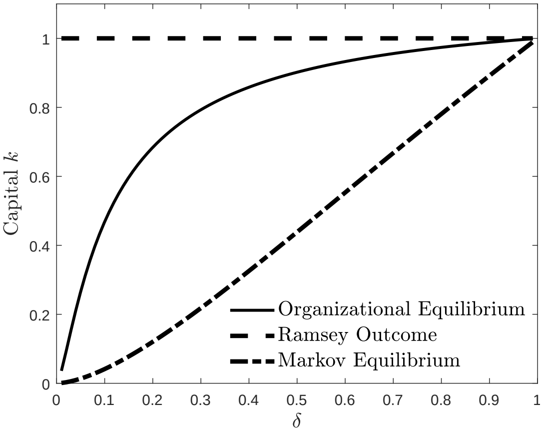
2. To determine the initial saving rate, the agent starts from low saving rate

   Goodwill has to be built gradually

3. We will show how the outcome compared with the Markov and Ramsey

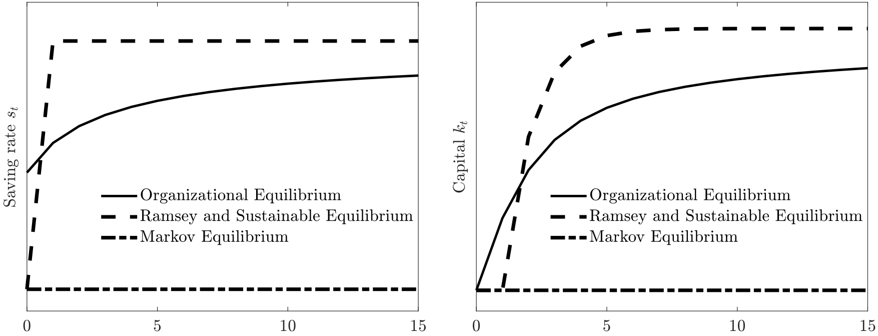
   We do much better than Markov equilibrium

Comparison: Steady State



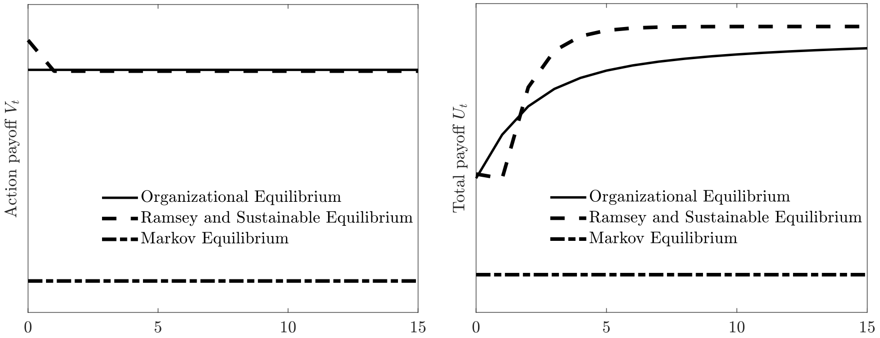
- Organizational equilibrium is much better than the Markov equilibrium

Comparison: Allocation in Transition



- Organizational equilibrium: starts low, converges to being close to Ramsey

Comparison: Payoff in Transition



$$\underbrace{U(k_t, s_t, s_{t+1}, \ldots)}_{\text{total payoff}} = \phi \log k_t + \underbrace{V(s_t, s_{t+1}, \ldots)}_{\text{action payoff}}$$

Part II: Organizational Equilibrium for Weakly Separable Economies

General Definition

- An infinite sequence of decision makers is called to act
  - state $k \in K$
  - action $a \in A$
  - state evolves $k_{t+1} = F(k_t, a_t)$
  - preferences: $U(k_t, a_t, a_{t+1}, a_{t+2}, \ldots)$

Assumption

1. *At any point in time t, the set A is independent of the state k_t*
2. *U is weakly separable in k and in $\{a_s\}_{s=0}^{\infty}$*

$$U(k, a_0, a_1, a_2, \ldots) \equiv v(k, V(a_0, a_1, a_2, \ldots)).$$

   and such that v is strictly increasing in its second argument.

3. *V is weakly separable in a_0 and $\{a_s\}_{s=1}^{\infty}$*

$$V(a_0, a_1, a_2, ...) \equiv \widetilde{V}(a_0, \widehat{V}(a_1, a_2, \ldots)),$$

   with $\widetilde{V}$ strictly increasing in its second argument.

On the Choice of Actions

- Weak separability and state independence of A depend on the specification of the action set
- Example: hyperbolic discounting. If the choice is c, feasible actions depend on k
- So, sometimes a problem may look nonseparable, but may become separable by rescaling actions appropriately

Organizational Equilibrium

Definition

A sequence of actions $\{a_t\}_{t=0}^{\infty}$ is organizationally admissible if

1. $V(a_t, a_{t+1}, a_{t+2}, \ldots)$ is (weakly) increasing in t
2. The first agent has no incentive to delay the proposal.

$$V(a_0, a_1, a_2, \ldots) \geq \max_{a \in A} V(a, a_0, a_1, a_2, \ldots)$$

Within organizationally admissible sequences, the sequence that attains the maximum of $V(a_0, a_1, a_2, \ldots)$ is an *organizational equilibrium*.

Organizational Equilibrium (OE) vs. Subgame-Perfect Equilibrium

1. OE is the equilibrium path of a sub-game perfect equilibrium
2. It can be implemented through various strategies. Examples:
   - restart from the beginning when someone deviates
   - use difference equation to make each player indifferent between deviating and following the equilibrium strategy (over a range)

OE vs. Reconsideration-Proof Equilibrium

- Reconsideration-proof equilibria $\Longrightarrow$ Value for all current and future players independent of past history
- OE: same property only for action payoff:

$$U(k, a_0, a_1, a_2, \ldots) \equiv v(k, V(a_0, a_1, a_2, \ldots)).$$

  Future players affected by different state
- Without state variables, OE is the outcome of a reconsideration-proof equilibrium

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  Future players affected by different state
- Without state variables, OE is the outcome of a reconsideration-proof equilibrium
- Rationale for renegotiation/reconsideration-proofness: reject threats that are Pareto-dominated ex post
- Similar spirit for no-delay condition:
  - If agents coordinate on Pareto-dominant equilibrium (s^*) right away...
  - ... then they should do the same next period (independent of past history)...
  - $\Longrightarrow$ no discipline for first player

Existence and Properties

- Under separability and other weak conditions, OE exists
- Assume that continuation utility is recursive:

$$\widehat{V}(a_1, a_2, ...) = W(a_1, \widehat{V}(a_2, a_3, ...))$$

Then:

- OE admits a recursive structure

$$a_{t+1} = q^*(a_t)$$

- Equilibrium converges to a steady state

A Class of Separable Economies

- Most economies do not satisfy separability condition
- Our strategy: approximate the original economy by separable ones
- First order approximation satisfies the separable property

$$\Psi_t = u(k_t, a_t) + \delta \sum_{\tau=1}^{\infty} \beta^\tau u\left(k_{t+\tau}, a_{t+\tau}\right)$$

subject to

$$u(k_t, a_t) = \Gamma_{10} + \Gamma_{11} h(k_t) + \Gamma_{12} m(a_t)$$
$$h(k_{t+1}) = \Gamma_{20} + \Gamma_{21} h(k_t) + \Gamma_{22} g(a_t)$$

  - $h(k), m(a), g(a)$ can be any monotonic functions

Example

- Original economy

$$\Psi_t = \log(c_t) + \delta \sum_{\tau=1}^{\infty} \beta^\tau \log(c_{t+\tau})$$

$$\text{s.t.} \qquad c_t + i_t = k_t^\alpha$$
$$k_{t+1} = (1-d)k_t + i_t$$

- The approximated economy

$$\Psi_t = \log(c_t) + \delta \sum_{\tau=1}^{\infty} \beta^\tau \log(c_{t+\tau})$$

$$\text{s.t.} \qquad c_t + i_t = k_t^\alpha$$
$$k_{t+1} = \overline{k}\, k_t^{1-d} i_t^d$$

  - Let $c_t = (1-s)k_t^\alpha$, $i_t = sk_t^\alpha$, the economy is separable between k and s

Part III: Government Taxation Problem

A Simple Version

- Preference: $\sum_{t=0}^{\infty} \beta^t [\gamma_c \log c_t + \gamma_g \log g_t]$
- Technology: $f(k_t) = k_t^\alpha, \qquad k_{t+1} = f(k_t) - c_t - g_t.$
- Consumers' budget constraint: $c_t + k_{t+1} = (1 - \tau_t) r_t k_t + \pi_t$
- Prices: $r_t = f_k(k_t), \qquad \pi_t = f(k_t) - r_k k_t$
- Government budget constraint: $g_t = \tau_t r_t k_t$

Difference from Previous Setup

- In the quasi-geometric discounting, only one player per period
- Here, gov't + private sector
- Need to short-circuit competitive equilibrium component

Payoff

- Given an arbitrary $\{\tau_t\}_{t=0}^{\infty}$, Euler equation has to hold in equilibrium

$$u'(c_t) = \beta(1-\tau_{t+1})f'(k_{t+1})u'(c_{t+1})$$

- Induce a sequence of saving rates such that

$$\frac{s_t}{1-s_t-\alpha\tau_t} = \frac{\alpha\beta(1-\tau_{t+1})}{1-s_{t+1}-\alpha\tau_{t+1}}$$

- From saving rate, get allocation
- Total payoff with initial capital k

$$U(k,\tau_0,\tau_1,\tau_2,\ldots) = \frac{\alpha(1+\gamma)}{1-\alpha\beta}\log k + V(\tau_0,\tau_1,\tau_2,\ldots)$$

- Action payoff

$$V(\{\tau_t\}_{t=0}^{\infty}) = \sum_{t=0}^{\infty}\beta^t\left\{\log(1-\alpha\tau_t-s_t)+\gamma\log\alpha\tau_t+\frac{\alpha\beta(1+\gamma)}{1-\alpha\beta}\log s_t\right\}$$

Organizational Equilibrium in Government Taxation Problem

Definition

A sequence of tax rates $\{\tau_t\}_{t=0}^{\infty}$ is organizationally admissible if

- $V(\tau_t, \tau_{t+1}, \tau_{t+2}, \ldots)$ is (weakly) increasing in t

Within organizationally admissible sequences, any sequence that attains the maximum of $V(\tau_0, \tau_1, \tau_2, \ldots)$ is an *organizational equilibrium*.

Organizational Equilibrium in Government Taxation Problem

Definition

A sequence of tax rates $\{\tau_t\}_{t=0}^{\infty}$ is organizationally admissible if

- $V(\tau_t, \tau_{t+1}, \tau_{t+2}, \ldots)$ is (weakly) increasing in t
- The implementability constraint is satisfied

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Organizational Equilibrium in Government Taxation Problem

Definition

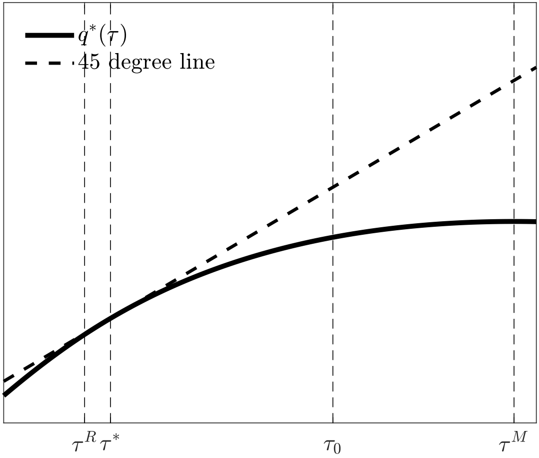
A sequence of tax rates $\{\tau_t\}_{t=0}^{\infty}$ is organizationally admissible if

- $V(\tau_t, \tau_{t+1}, \tau_{t+2}, \ldots)$ is (weakly) increasing in t
- The implementability constraint is satisfied
- Government has no incentive to delay the proposal.

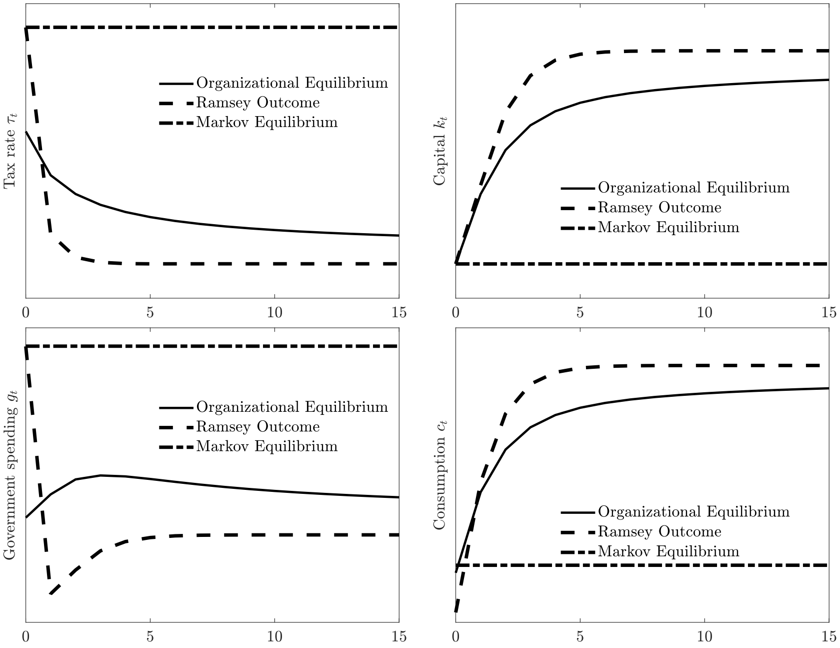
$$V(\tau_0, \tau_1, \tau_2, \ldots) \geq \max_{\tau} V(\tau, \tau_0, \tau_1, \tau_2, \ldots)$$

Within organizationally admissible sequences, any sequence that attains the maximum of $V(\tau_0, \tau_1, \tau_2, \ldots)$ is an *organizational equilibrium*.

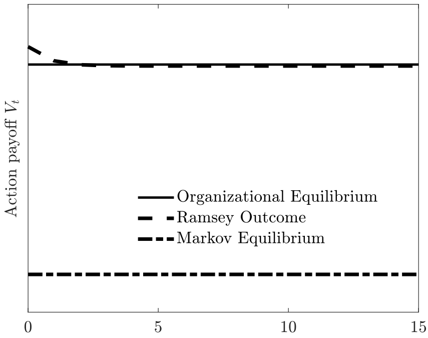
Proposal Function in Organizational Equilibrium

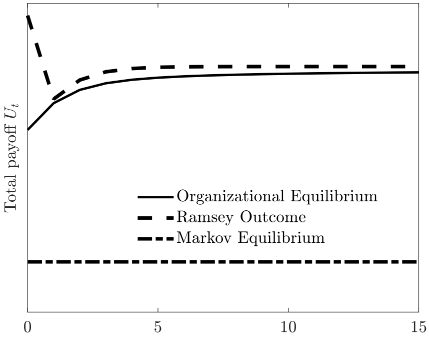


- The equilibrium starts from τ_0, and monotonically converges to τ^*.


Tax rate τ_t
Capital k_t
Government spending g_t
Consumption c_t
Organizational Equilibrium
Ramsey Outcome
Markov Equilibrium
0
5
10
15

Comparison: Payoff in Transition





$$\underbrace{U(k_t, \tau_t, \tau_{t+1}, \ldots)}_{\text{total payoff}} = \frac{\alpha(1+\gamma)}{1-\alpha\beta} \log k_t + \underbrace{V(\tau_t, \tau_{t+1}, \ldots)}_{\text{action payoff}}$$

A Quantitative Version

- Preference

$$\sum_{t=0}^{\infty} \beta^t [\gamma_c \log c_t + \gamma_g \log g_t + \gamma_\ell \log(1 - \ell_t)]$$

A Quantitative Version

- Preference

$$\sum_{t=0}^{\infty} \beta^t [\gamma_c \log c_t + \gamma_g \log g_t + \gamma_\ell \log(1 - \ell_t)]$$

- Consumers' budget constraint

$$c_t + k_{t+1} = k_t + (1 - \tau_t^\ell - \tau_t) w_t \ell_t + (1 - \tau_t^k - \tau_t)(r_t - \delta) k_t$$

A Quantitative Version

- Preference

$$\sum_{t=0}^{\infty} \beta^t [\gamma_c \log c_t + \gamma_g \log g_t + \gamma_\ell \log(1-\ell_t)]$$

- Consumers' budget constraint

$$c_t + k_{t+1} = k_t + (1-\tau_t^\ell - \tau_t) w_t \ell_t + (1-\tau_t^k - \tau_t)(r_t - \delta) k_t$$

- Technology

$$f(k_t) = k_t^\alpha \ell_t^{1-\alpha}, \qquad k_{t+1} = (1-\delta) k_t + i_t$$

A Quantitative Version

- Preference

$$\sum_{t=0}^{\infty} \beta^t [\gamma_c \log c_t + \gamma_g \log g_t + \gamma_\ell \log(1 - \ell_t)]$$

- Consumers' budget constraint

$$c_t + k_{t+1} = k_t + (1 - \tau_t^\ell - \tau_t) w_t \ell_t + (1 - \tau_t^k - \tau_t)(r_t - \delta) k_t$$

- Technology

$$f(k_t) = k_t^\alpha \ell_t^{1-\alpha}, \qquad k_{t+1} = (1 - \delta) k_t + i_t$$

- Government budget constraint

$$g_t = \tau_t^k (r_t - \delta) k_t + \tau_t^\ell w_t \ell_t + \tau_t (w_t \ell_t + (r_t - \delta) k_t)$$

Labor Income Tax

Aggregate statistics	Labor income tax			
	Pareto	Ramsey	Markov	Organization
y	1.000	0.790	0.794	0.792
k/y	2.959	2.959	2.959	2.959
c/y	0.583	0.583	0.600	0.591
g/y	0.180	0.180	0.164	0.172
c/g	3.240	3.240	3.662	3.435
ℓ	0.320	0.253	0.254	0.253
τ		0.281	0.256	0.269

Parameter: $\alpha = 0.36, \beta = 0.96, \delta = 0.08, \gamma_g = 0.09, \gamma_c = 0.27, \gamma_\ell = 0.64$

Capital Income Tax

Aggregate statistics	Capital income tax			
	Pareto	Ramsey	Markov	Organization
y	1.000	0.685	0.570	0.660
k/y	2.959	1.972	1.360	1.824
c/y	0.583	0.722	0.697	0.716
g/y	0.180	0.120	0.195	0.138
c/g	3.240	6.018	3.580	5.188
ℓ	0.320	0.275	0.282	0.277
τ		0.594	0.774	0.645

Parameter: $\alpha = 0.36, \beta = 0.96, \delta = 0.08, \gamma_g = 0.09, \gamma_c = 0.27, \gamma_\ell = 0.64$

Total Income Tax

Aggregate statistics	Total income tax			
	Pareto	Ramsey	Markov	Organization
y	1.000	0.764	0.769	0.767
k/y	2.959	2.676	2.698	2.687
c/y	0.583	0.601	0.612	0.606
g/y	0.180	0.185	0.173	0.179
c/g	3.240	3.240	3.542	3.379
ℓ	0.320	0.259	0.259	0.259
τ		0.236	0.220	0.228

Parameter: $\alpha = 0.36, \beta = 0.96, \delta = 0.08, \gamma_g = 0.09, \gamma_c = 0.27, \gamma_\ell = 0.64$

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- Future agenda:
  - Idea can be used to generalize renegotiation-proofness in games with multiple players Further analysis of approximation options