Collective Choice in Dynamic Public Good Provision: Real versus Formal Authority

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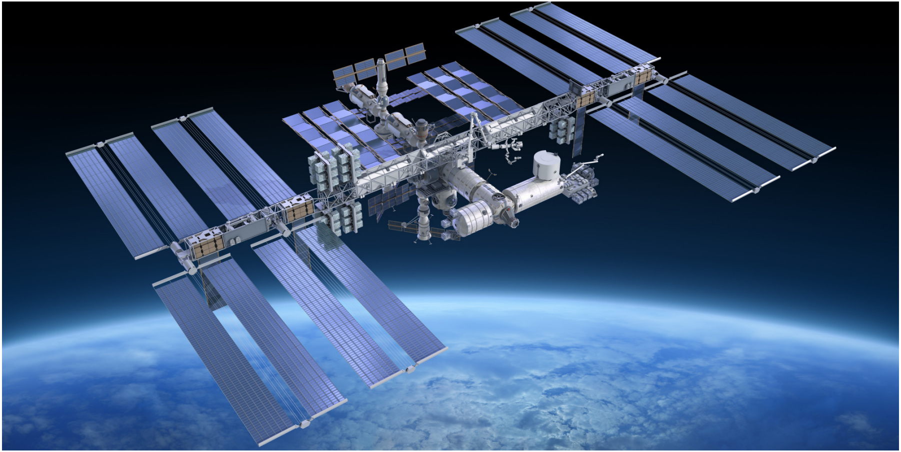
Introduction

- Economic agents must often collectively decide a project goal.
- Examples:
  - Countries collaborating on large projects
  - States / municipalities jointly undertaking infrastructure development
  - Business ventures (alliances, statups, R&D projects, NPD)
- Central trade-off:
  - More ambitious project yields greater (expected) reward on completion,
  - but requires more time and effort to be completed.

The International Space Station



- Collaboration between the US, Russia, the EU, Japan and Canada.
- Cost: $\sim$ \$150 Billion

Other Examples

- Asian Highway network
    - Collaboration among 32 Asian countries, the UN, and others
    - 87,000 miles of road network
    - Cost: $>$ \$25 Billion
- Gordie Howe International Bridge
    - Joint project by the Michigan Department of Transportation and the Ministry of Transportation of Ontario in Canada.
    - Started in 2015
    - Cost: $>$ \$2.1 Billion
- International Thermonuclear Experimental Reactor (ITER) [France]
- Joint European Torus (JET) [UK]

Asymmetry & Control

- If parties have identical preferences, then there is no conflict.
  ... but disagreement is common.
- Often asymmetries are the reason for disagreements.
  - Big versus small stakes.
  - High versus low opportunity (effort) costs.
- Asymmetries naturally imply uneven distribution of power (control).

Two Questions

1. How does collective choice institution affect choice of project scope?
2. Role of the formal collective choice institution in determining control?

Framework in a Nutshell

- Model of dynamic public good provision (Marx & Matthews, 2000)
- Main Features:
  - Progress is gradual and depends on (2) agents' costly efforts.
  - Project generates a payoff upon completion.
  - Ea. agent receives a pre-specified share of the project's payoff.
- The scope (or size) of the project is endogenous.
  - *Trade-off*: A project that requires more effort, generates bigger payoff.
  - Agents differ in their effort costs and stakes in the project.
  - The project scope is decided given a formal collective choice institution (*i.e.*, dictatorship or unanimity).

Formal versus Real Authority

- Notions are similar to Aghion and Tirole (1997).
- Formal authority is conferred by the collective choice institution.
  - Dictatorship: agent that is dictator has formal authority.
  - Unanimity: neither agent has formal authority.
- Real authority is derived from agents' endowed attributes.
  - In our model: cost of effort and stake in the project.

Another Consideration: Commitment

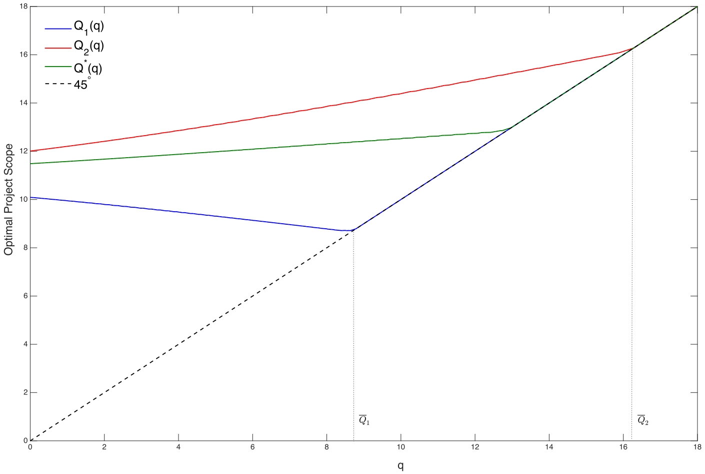
- Can agents commit to a decision about the project scope?
  1. Are there strong institutions that can enforce a contract?
  2. Can the project objectives be accurately described ex-ante?
- If yes, then there is commitment power.
- Commitment versus no commitment
  - Part of the exogenous economic environment.
  - We consider both cases.

Other Applications

- Entrepreneurial ventures (startups)
- Joint Research and Development projects
- New Product Development projects
  - Go for a blockbuster or a smaller (and quicker) payoff?
- Academics collaborating on a research project
  - Aim a top general-interest journal or a specific-field journal?

Preview of Results: Endogenous Preferences

- The agents have *time-inconsistent* preferences over the project scope.



Preview of Results: Collective Choice

1. With commitment, formal and real authority are equivalent.
2. W/o commitment, formal and real authority are not equivalent.
   - The efficient agent always retains real authority.
3. Only unanimity maximizes welfare both w/ and w/o commitment.
   - Unanimity dominates dictatorship in this sense.
   - W/o commitment, inefficient agent as dictator $\equiv$ unanimity.
4. Extensions / Robustness:
   - Transfers and endogenous project stakes improve welfare, and unanimity is robustly welfare maximizing.
   - Results are robust to the inclusion of uncertainty.

Related Literature

- Real vs. formal authority
  - Weber (1958), Aghion and Tirole (1997), Acemoglu and Robinson (2006), Callander (2008), Hirsch and Shotts (2015), Akerlof (2015)
- Collective choice with heterogeneous agents
  - *Static models:* Romer and Rosenthal (1979)
  - *Dynamic models:* Baron (1996), Battaglini and Coate (2008), Strulovici (2010), Bowen, Chen and Eraslan (2014)
- Dynamic provision of public goods
  - Levhari and Mirman (1980), Admati and Perry (1991), Fershtman and Nitzan (1991), Marx and Matthews (2000), Battaglini, Nunnari and Palfrey (2014), Georgiadis (2015), Bonatti and Rantakari (2015)

Roadmap

1. Model
2. Exogenous Project Scope
    - Characterization of Markov Perfect equilibrium
    - Agents' and Social Planner's Preferences over Project Scope
3. Endogenous Project Scope: Real versus Formal Authority
    - Dictatorship
    - Unanimity
    - Welfare
4. Extensions: Transfers, Endogenous shares, Uncertainty

Model Setup

- Time $t \in [0, \infty)$ is continuous.
- Two risk-neutral agents, discount time at rate $r > 0$. Agent i
  - exerts effort $a_{i,t}$ at cost $c_i(a) = \frac{\gamma_i}{2} a^2$; and
  - receives share α_i of the project's payoff upon completion.
- Project starts at $q_0 = 0$, its *state* evolves according to

$$dq_t = \left(\sum_{i=1}^{n} a_{i,t} \right) dt \,,$$

  and if it is completed at state $q_\tau = Q$, then it generates payoff $= Q$.
- Assume agents play Markov strategies (*i.e.*, they depend only on q_t).
- Sort agents such that $\frac{\gamma_1}{\alpha_1} \leq \frac{\gamma_2}{\alpha_2} \Rightarrow$ agent 1 is *more efficient*.

Building Blocks: Agents' Payoff Functions

- Agent i's discounted payoff at t:

$$J_{i,t} = e^{-r(\tau - t)}\alpha_i Q - \int_t^\tau e^{-r(s-t)}\frac{\gamma_i}{2}a_{i,s}^2 ds$$

- Can write recursively as

$$rJ_i(q) = \max_{a_i}\left\{-\frac{\gamma_i}{2}a_i^2 + (a_i + a_j)J_i'(q)\right\}$$

subject to the boundary condition $J_i(Q) = \alpha_i Q$.

- First order condition:

$$\gamma_i a_i = \max\left\{0,\ J_i'(q)\right\}$$

- In a MPE, each agent's payoff function satisfies

$$rJ_i(q) = \frac{\left[J_i'(q)\right]^2}{2\gamma_i} + \frac{1}{\gamma_j}J_i'(q)J_j'(q)$$

subject to $J_i(Q) = \alpha_i Q$ for all i.

Markov Perfect Equilibrium: Characterization

Proposition 1. MPE Characterization

For any Q, there exists a unique well-behaved MPE. Two cases:

1. MPE is project-completing, $J_i(q) > 0$, $J_i'(q) > 0$, and $a_i'(q) > 0$.
2. MPE is not project-completing, and $J_i(0) = a_i(0) = 0$.

- $J_i'(q) > 0$: ea. agent is better off, the closer project is to completion.
- $a_i'(q) > 0$: ea. agent increases his effort as project progresses.
  - Agents discount time and are rewarded upon completion.
  - Thus they have stronger incentives, the closer project is to completion.
  - *An implication:* Efforts are strategic complements across time.

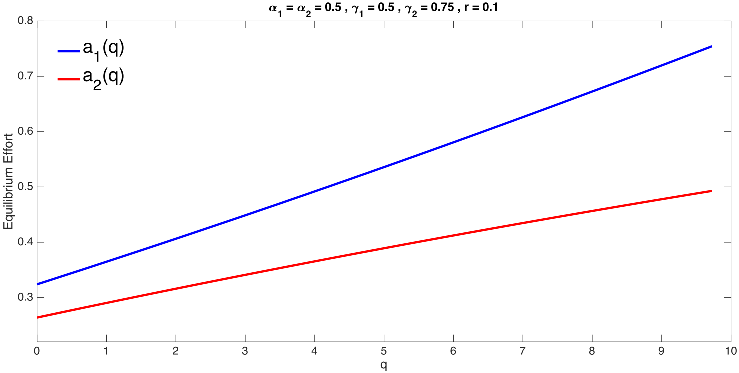
Equilibrium Properties

Proposition 2. MPE Properties

1. Suppose that $\frac{\gamma_1}{\alpha_1} < \frac{\gamma_2}{\alpha_2}$ and a project-completing MPE exists. Then:
   (a) $a_1(q) \geq a_2(q)$ and $a_1'(q) \geq a_2'(q)$ for all $q \geq 0$.
   (b) $\frac{J_1(q)}{\alpha_1} \leq \frac{J_2(q)}{\alpha_2}$ for all $q \geq 0$.
2. If instead $\frac{\gamma_1}{\alpha_1} = \frac{\gamma_2}{\alpha_2}$ and a project-completing MPE exists, then $a_1(q) = a_2(q)$ and $\frac{J_1(q)}{\alpha_1} = \frac{J_2(q)}{\alpha_2}$ for all $q \geq 0$.

- *Part 1 (a):* Efficient agent always exerts higher effort and raises his effort at a faster rate than the inefficient agent.
- *Part 1 (b):* Efficient agent obtains a lower discounted payoff (normalized by his project stake) than the inefficient agent.

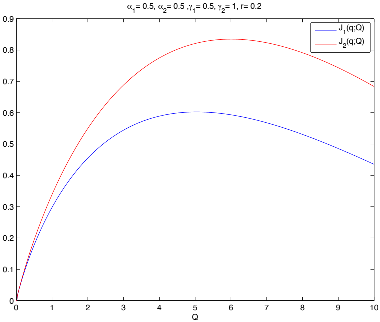
Properties of the Markov Perfect Equilibrium



- More efficient agent exerts higher effort: $a_1(q) \geq a_2(q) > 0$.
- More efficient agent raises effort at faster rate: $a_1'(q) \geq a_2'(q) > 0$.
- Efficient agent obtains higher payoff (norm'd by stake): $\frac{J_1(q)}{\alpha_1} \leq \frac{J_2(q)}{\alpha_2}$.

Preferences over Project Scope

- *Notation:* $J_i(q;Q)$ = agent i's payoff function given project scope Q.



- Definitions:
  - $Q_i(q) = \arg\max_{Q \geq q} \{J_i(q;Q)\}$
  - $\bar{Q}_i = \arg\min_q \{Q_i(q) = q\}$; *i.e.*, $\bar{Q}_i$ is the smallest Q such that agent i finds it optimal to stop immediately.

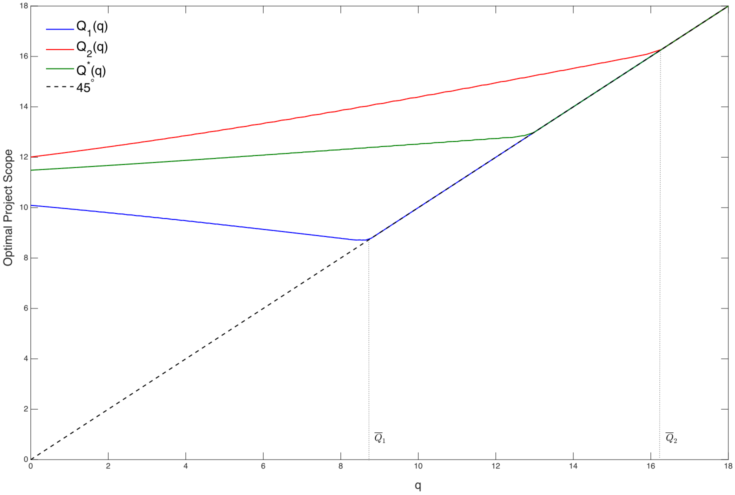
Preferences over Project Scope

Proposition 3. Agent i's Ideal Project Scope

1. If $\frac{\gamma_1}{\alpha_1} < \frac{\gamma_2}{\alpha_2}$ and $J_i(q;Q)$ is strictly concave in Q for $Q \in \left[q, \bar{Q}_i\right]$, then:
   (a) $Q_1(q) < Q_2(q)$ for all $q < \bar{Q}_2$; and
   (b) $Q_1'(q) < 0$ for all $q < \bar{Q}_1$ and $Q_2'(q) > 0$ for all q.
   (c) $Q_i(q) = \bar{Q}_i$ for all $q \geq \bar{Q}_i$.
2. If $\frac{\gamma_1}{\alpha_1} = \frac{\gamma_2}{\alpha_2}$, then $Q_i(q) = \frac{3}{2r}\frac{\alpha_i}{\gamma_i}$ for all q.

- *Part 1 (a):* Eff. agent prefers smaller project scope than ineff. agent.
- *Part 1 (b):* The efficient agent wants to shrink the project as it progresses, whereas the inefficient agent wants to expand it.

Preferences over Project Scope - Illustrated



Intuition (for the Asymmetric Case)

- Each agent trades off
  - bigger payoff associated with larger project scope, and
  - cost associated with additional effort and longer wait until completion.
- *Part 1:* $Q_1(q) < Q_2(q)$ for all q
  - Agent 1 incurs greater effort cost (normalized by share) than agent 2.
  - Thus, agent 1 prefers a smaller project scope than agent 2.
- *Part 2:* $Q_1'(q) < 0 < Q_2'(q)$ for all q
  - Because $a_1'(q) \geq a_2'(q)$ for all q, as the project progresses, agent 1 exerts an ever larger share of remaining effort.
  - So he prefers an ever smaller project scope, *i.e.*, $Q_1'(q) < 0$.
  - By the converse argument, $Q_2'(q) > 0$.

An Intermediate Result

- Assume that $\frac{\gamma_1}{\alpha_1} < \frac{\gamma_2}{\alpha_2}$.

Lemma 1: Optimal Project Scope when working alone

- If agent i works alone, then his optimal project scope

$$\hat{Q}_i = \frac{\alpha_i}{2r\gamma_i},$$

  and it is independent of q.

- Moreover, $\hat{Q}_2 < \hat{Q}_1 < Q_1(q) < Q_2(q)$ for all q.

- *Takeaways:* If an agent works alone, then
  1. his preferred project scope is smaller than if both agents work together ;
  2. his preferences are *time-consistent* ; and
  3. the less efficient agent now prefers the smaller project scope.

Social Planner's Project Scope

- Consider a social planner who
  - cannot dictate the agents' effort levels , but
  - she can choose the project scope.
- In other words, she solves

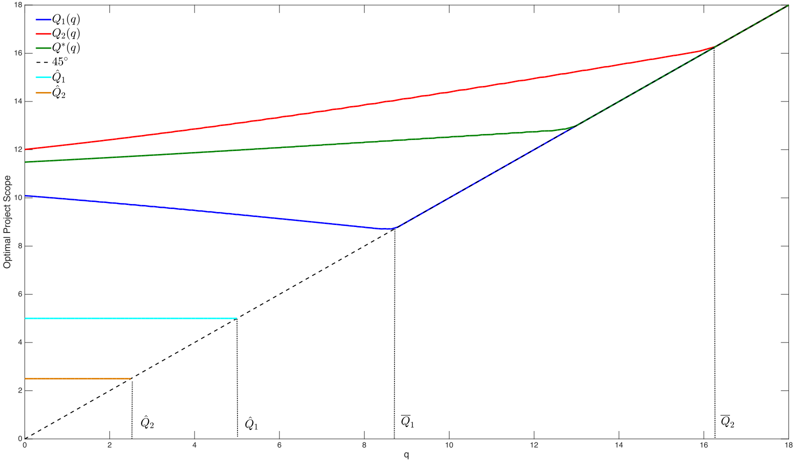
$$Q^*(q) = \arg\max_{Q \geq q} \{J_1(q; Q) + J_2(q; Q)\}$$

Lemma 2: Social Planner's Ideal Project Scope

- The social planner's optimal project scope $Q^*(q) \in [Q_1(q), Q_2(q)]$.

- Planner's optimal project scope lies in between the agents' optimal project scopes.

Summary



$Q_1(q)$
$Q_2(q)$
$Q^*(q)$
45°
$\hat{Q}_1$
$\hat{Q}_2$
Optimal Project Scope
q
$\hat{Q}_2$
$\hat{Q}_1$
$\overline{Q}_1$
$\overline{Q}_2$
0
2
4
6
8
10
12
14
16
18

Collective Choice of Project Scope

- Project scope Q selected by collective choice.
- Institutions:
  (a) Dictatorship
  (b) Unanimity
- Time-inconsistency $\Rightarrow$ *when* the project scope is chosen matters.
- Two cases:
  1. Agents can commit to a particular project scope at the outset.
  2. Agents cannot commit (to not renegotiate), so at every moment, they can either complete the project immediately, or continue.
- If multiple equilibria, focus on the one that maximizes total surplus.

Formal and Real Authority

Definition: Formal Authority

- Dictatorship: agent that is dictator has formal authority.
- Unanimity: neither agent has formal authority.

Definition: Real Authority

- Suppose the project scope Q is decided when the state is q.
- Agent i has real authority if $Q = Q_i(q)$; *i.e.*, if Q is agent i's ideal at the moment the project scope is decided.

Dictatorship

- Agent i is the dictator.
- Markov strategy for agent i given state q is $\{a_i(q), \theta_i(q)\}$.
  - $\theta_i(q)$ is agent i's choice of project scope (if no decision, then $= -1$).
  - If no decision, then agents choose strategies based on beliefs about Q.
- With commitment: $\theta_i(q) \in \{-1\} \cup (0, \infty)$.
  - After agent i has committed to some Q, $\theta_i(q)$ becomes obsolete.
- Without commitment: $\theta_i(q) \in \{-1, q\}$, *i.e.*, continue or stop now.

Dictatorship with Commitment

Proposition 4: Dictatorship with Commitment

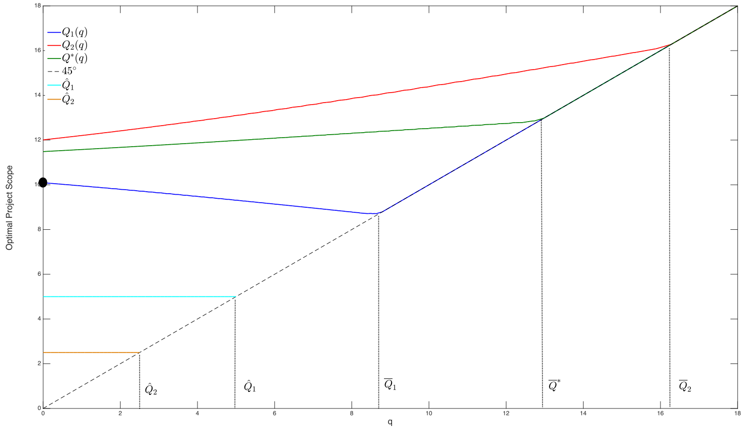
- Unique MPE in which agent i commits to $Q_i(0)$ at the outset.
- Agent i has real and formal authority.

- Because ea. agent's preferences are time-inconsistent, he strictly prefers to commit at the outset rather than wait and commit later.
- As a result, he will commit to his preferred project scope $Q_i(0)$.

Dictatorship with Commitment - Illustrated

Proposition 4: Agent 1 is dictator, with commitment

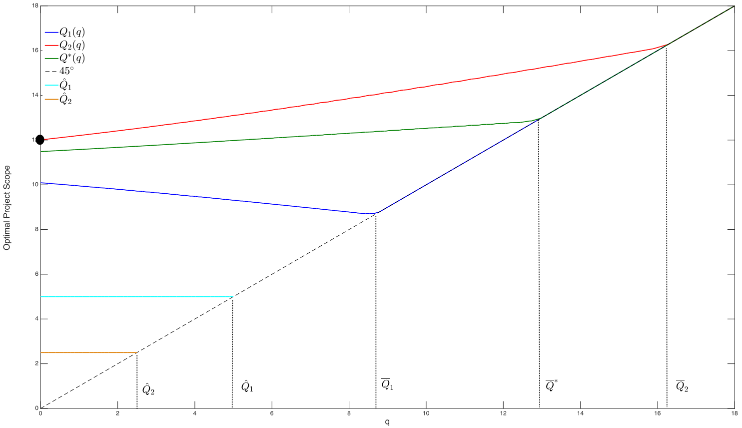
- Unique MPE in which agent 1 commits to $Q_1(0)$ at the outset.



Dictatorship with Commitment - Illustrated

Proposition 4: Agent 2 is dictator, with commitment

- Unique MPE in which agent 2 commits to $Q_2(0)$ at the outset.



Dictatorship without Commitment

- *Assumption:* Focus on the surplus-maximizing equilibrium.

Proposition 5: Dictatorship without Commitment

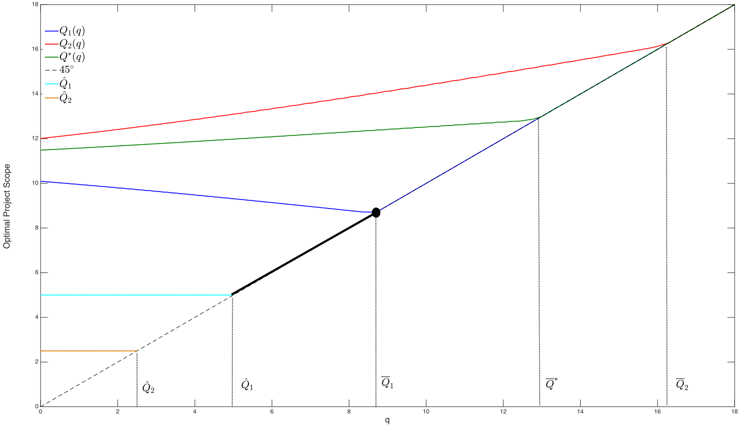
1. If agent 1 is dictator, then project is completed at $Q = \bar{Q}_1$.
2. If agent 2 is dictator, then project is completed at $Q = Q^*(0)$.

- Suppose agent i is dictator and fix any $Q \in \left[\hat{Q}_i,\ \bar{Q}_i\right]$.
- Strategies: agent i exerts effort $a_i(q; Q)\,\mathbf{1}_{\{q<Q\}}$.
- Easy to verify that each strategy is a best-response to the other.
- Ex-ante total surplus increases in Q iff $Q \leq Q_1^*(0)$. Thus:
    - $\bar{Q}_1 \leq Q_1^*(0)$, so if agent 1 is dictator, then $Q = \bar{Q}_1$.
    - $Q^*(0) \in \left(\hat{Q}_2,\ \bar{Q}_2\right]$, so if agent 2 is dictator, then $Q = Q^*(0)$.
- In both cases, agent 1 has real authority.

Dictatorship without Commitment - Illustrated

Proposition 5: Agent 1 is dictator, without Commitment

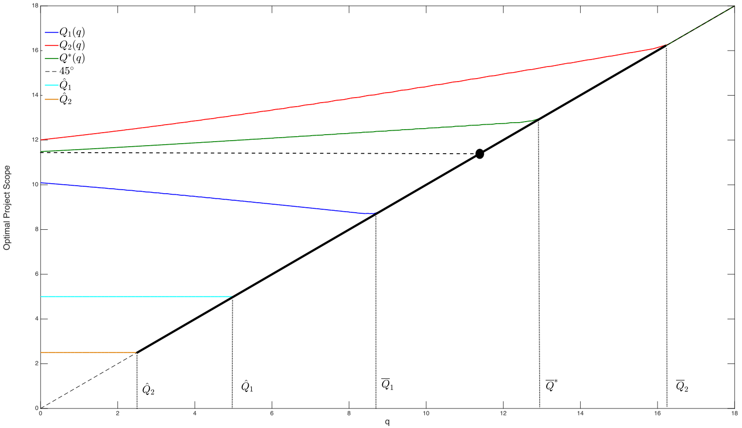
There exists an equilibrium in which project is completed at $Q = \bar{Q}_1$.



Dictatorship without Commitment - Illustrated

Proposition 5: Agent 2 is dictator, without Commitment

There exists an equilibrium in which project is completed at $Q = Q^*(0)$.



Unanimity

- Agent $i \in \{1, 2\}$ is the default agenda-setter.
- Markov strategy for agent i given state q is $\{a_i(q), \theta_i(q)\}$.
  - $\theta_i(q)$ is agent i's proposal. If no proposal, then $\theta_i(q) = -1$.
- Markov strategy for agent $j \neq i$ given state q is $\{a_j(q), Y_j(q)\}$,

$$Y_j(q) = \begin{cases} 1 & \text{accept agent } i\text{'s proposal} \\ 0 & \text{reject} \end{cases}$$

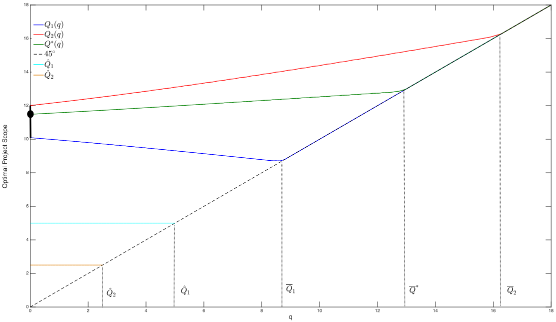
- Agenda-setter can make proposal at any time of his choosing.
- W/ commitment: $\theta_i(q) \in \{-1\} \cup (0, \infty)$
- W/o commitment: $\theta_i(q) \in \{-1, q\}$; *i.e.*, continue or stop now.

Unanimity with Commitment

Proposition 6: Unanimity with Commitment

There is an equilibrium in which agents commit to $Q^*(0)$ at the outset.

- Any $Q \in [Q_1(0), Q_2(0)]$ can be sustained as an equilibrium.
- By assumption, restrict attention to total surplus-maximizing eq'm.

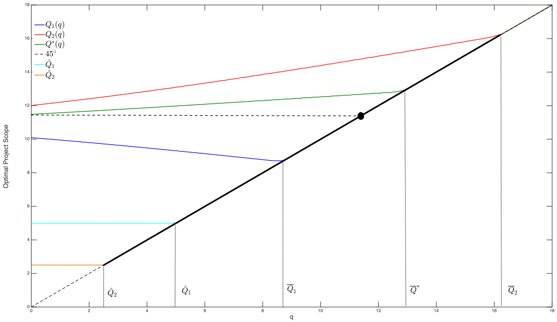


Unanimity without Commitment

Proposition 7: Unanimity without Commitment

There is an equilibrium in which the project is completed at $Q = Q^*(0)$.

- Construction is similar to the case when agent 2 is dictator.
- Agent 1 has real authority.



Real versus Formal Authority

Definition: Real Authority

- We say agent i has real authority if he controls the project scope, *i.e.*, if the equilibrium project scope Q is decided at q and $Q = Q_i(q)$.

Corollary 1:

- With commitment, real and formal authority are equivalent.
- Without commitment:
  - If agent 1 is dictator, then he has formal and real authority.
  - If agent 2 is dictator, then he has formal authority, but not real authority. Instead, agent 1 has real authority.

- Can help explain why large countries have disproportionate influence when the formal collective choice institution is unanimity.

Welfare

- What institutions can implement $Q^*(0)$?

Corollary 2: Planner's Optimal Project Scope in Equilibrium

1. W/ commitment, $Q^*(0)$ can be implemented only w/ unanimity.
2. W/o commitment, $Q^*(0)$ can be implemented if agent 2 is the dictator and w/ unanimity.

- Only unanimity makes it possible to implement the planner's optimal project scope both with and without commitment.
- When one party is strong and the other weak, better to give formal authority to the latter (*American Capitalism*, Galbraith (1952)).

Transfers contingent on Project Scope

- Suppose agent i is dictator (commitment case).
- Can offer transfer in exchange for committing to project scope Q.
- Solves

$$\begin{aligned} \max_{Q \geq 0,\, T \in \mathbb{R}} \quad & J_i\left(0;\ Q\right) - T \\ \text{s.t.} \quad & J_j\left(0;\ Q\right) + T \geq J_j\left(0;\ Q_i\left(0\right)\right) \end{aligned}$$

  - Constraint binds, so:

$$\max_{Q \geq 0} \left\{ J_1\left(0;\ Q\right) + J_2\left(0;\ Q\right) - J_j\left(0;\ Q_i\left(0\right)\right) \right\}$$

- With transfers, dictator commits to surplus-maximizing project scope.
- Without commitment? Challenging!

Transfers and Re-allocation of Project Shares

- Assume $\alpha_1 + \alpha_2 = 1$ and ex-ante allocation $\{\bar{\alpha}_1, \bar{\alpha}_2\}$.
- Suppose agent i is dictator (commitment case).
- Can offer transfer in exchange for re-allocating shares to $\{\alpha_1, \alpha_2\}$.
- Solves

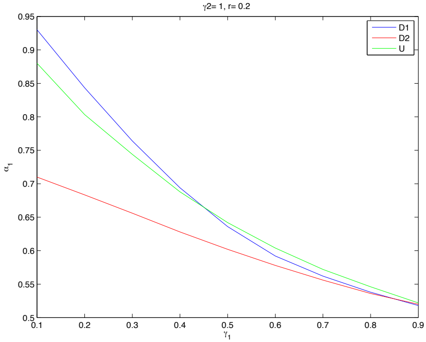
$$\begin{aligned} \max_{\alpha,\, T} \quad & J_i\left(0;\ Q_i\left(0;\alpha\right),\alpha\right) - T \\ \text{s.t.} \quad & J_j\left(0;\ Q_i\left(0;\alpha\right),\alpha\right) + T \geq J_j\left(0;\ Q_i\left(0;\bar{\alpha}\right),\bar{\alpha}\right) \end{aligned}$$

  - Constraint binds, so:

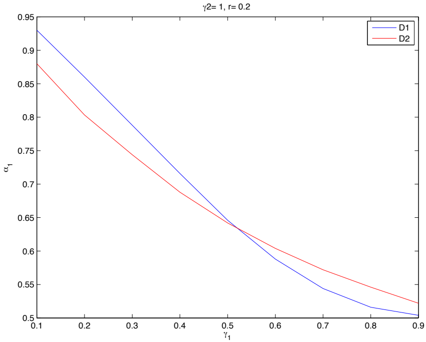
$$\max_{\alpha} \left\{ J_1\left(0;\ Q_i\left(0;\alpha\right),\alpha\right) + J_2\left(0;\ Q_i\left(0;\alpha\right),\alpha\right) - J_j\left(0;\ Q_i\left(0;\bar{\alpha}\right),\bar{\alpha}\right) \right\}$$

- New allocation maximizes total surplus conditional on $Q = Q_i\left(0;\alpha\right)$.
- Result also holds under unanimity and without commitment.

Optimal Project Share



(a) Commitment Case



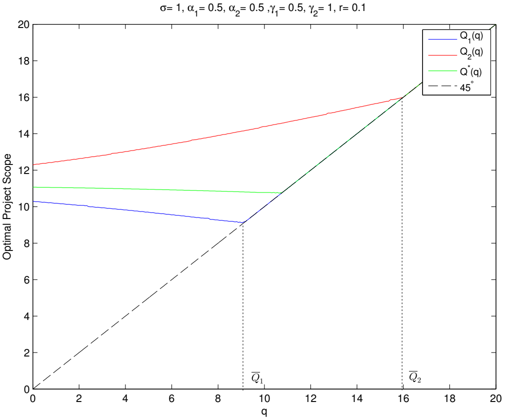
(b) No Commitment Case

- More efficient agent possesses majority of the shares.
- Allocation to agent 1 decreases as he becomes less efficient.
- If agents are symmetric (*i.e.*, $\gamma_1 = \gamma_2$), then $\alpha_1^* = \alpha_2^* = 0.5$.

Uncertainty

- Suppose project progresses stochastically:

$$dq_t = \left(\sum_{i=1}^{n} a_{i,t} \right) dt + \sigma dZ_t$$



Summary: An efficiency theory of real authority

- Model of dynamic public good provision with heterogeneous agents.
    - Efficient agent prefers smaller project scope than inefficient agent.
    - Preferences are time-inconsistent.
- Study how project scope depends on collective choice institution.
    - With commitment: formal authority $=$ real authority.
    - Without commitment: formal authority $\neq$ real authority.
    - Only unanimity can implement the social planner's optimal project scope both with and without commitment.
- Extensions:
    - Transfers and endogenous project shares can enhance efficiency
    - Results are robust to incorporating uncertainty.