Sharing the Burden of Negative Externalities

A Tale of Gridlock and Accountability Elusion

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How to allocate the costs of public bads ex post?

Public bads are byproducts of individuals' self-interested actions;

- The budget deficits due to the excessive private spending for locally-targeted projects $\Rightarrow$ insufficient public infrastructure.
- Firms' and countries' profit-maximizing decisions $\Rightarrow$ GHG emissions.

The costs induced by public bads need to be charged in a certain form of allocation of burdens (e.g., taxes), often resulting from political bargaining.

Research Question: How does **posterior bargaining of the costs** affect the voluntary production of public bads?

- How would a voting rule affect?
- How would a size of negative impact to the society affect?

A Simple Model

Let's focus on the environmental pollution context. Public bads = pollution. Contribution to the production of public bads = polluting behavior.

- Three players indexed by $i = \{1, 2, 3\} \equiv N$, two stages.
- 1st stage: Every player is endowed with $E > 0$ units of resource, and player i claims $g_i \in [0, E]$ for his/her own sake.
- The total sum of claims generates public bads, which incurs the costs of $C = \alpha \sum_i g_i$, $\alpha \in (0, 2)$.
- Everyone observes who claimed how much.

Interpret g_i as the activities beneficial to self but harmful to society, such as profitable productions that produce pollution. α describes how good/bad the production technology is for the environment.

Note that if $\alpha \in (0, 1)$, full contributions for the production of public bads maximize utilitarian welfare.

A Simple Model

- 2nd stage: A many-person ultimatum(*) to allocate the costs.
- One of the players is randomly selected with equal probability, and she proposed how to split the costs, $p \in \mathcal{P} = \{(p_1, p_2, p_3) \in [0,1]^3 | \sum_i p_i = 1\}$.
- If $q \in \{2, 3\}$ or more players vote for the proposal, it is approved, and player i accrues the payoff of $g_i - p_i C$.
- Otherwise, player i accrues the payoff of $g_i - \frac{C}{2}$.

  (* Why $C/2$? Simple representation of $\delta > 1$)
- $q = 2$: majority. $q = 3$: unanimity.

(* We could consider a many-person divide-the-penalty game (Kim and Lim, 2024), but the ultimatum is simpler while capturing the essence of legislative bargaining over the division of costs.)

Equilibrium When $q = 3$

Each player's strategy consists of

- the amount of claims (= how much to pollute),
- the proposal when selected as a proposer, and
- the voting decision when not selected as a proposer.

The subgame-perfect equilibrium (SPE) is our solution concept.

Proposition

(In words,) under unanimity, the unique equilibrium is: All players fully claim ($g_i^* = E$), a proposer offers half of the entire costs to the other two players, and nonproposers accept the proposal if the offered cost is less than half of the entire costs.

Notes

- This result holds regardless of the size of $\alpha < 2$.
- When $\alpha > 1$, utilitarian social welfare decreases with pollution.

Equilibrium When $q = 2$

When $q = 2$, there is a **continuum of SPEa**. This is different from political bargaining over public goods (Baranski, 2016).

- We focus on two "extreme" ones.

  (other equilibria are between the two.)
- One equilibrium is practically identical to that when $q = 3$.

Proposition

(In words,) under a majority rule, one equilibrium is: All players fully claim ($g_i^* = E$), a proposer offers half of the entire costs to the other two players, and nonproposers accept the proposal if the offered cost is less than half of the entire costs.

Equilibrium When $q = 2$

A distinctively different SPE may arise when

(1) the proposer assigns the entire costs to **one person** and

(2) when the proposer selects the one who bears the entire costs based on the first-stage observations.

Considering (1) only doesn't change the equilibrium level of pollution, $g_i^* = E\ \forall i$.

Proposition

(In words,) under a majority rule, one equilibrium is: All players fully claim ($g_i^* = E$), a proposer offers the entire costs to random one of the other two players, and nonproposers accept the proposal if the offered cost is less than half of the entire costs as a non-proposer.

Equilibrium When $q = 2$

A distinctively different SPE may arise when

(1) the proposer assigns the entire costs to **one person** and

(2) when the proposer selects the one who bears the entire costs based on the **first-stage observations**.

Considering both (1) and (2) can drastically change the equilibrium prediction, given α is sufficiently large.

Proposition

(In words,) under a majority rule and when $\alpha > \frac{3}{2}$, one equilibrium is: All players claim nothing ($g_i^* = 0$), a proposer offers the entire costs to one whose claim was the largest (randomly select if tied), and nonproposers accept the proposal if the offered cost is less than half of the entire costs.

Interim Summary

Deterring polluting behavior is hard.

Under unanimity, everyone fully pollutes, regardless of the size of α.

Under majority, full pollution can sustain. Pollution can be deterred only when three conditions hold.

- Majority rule
- Allocating the entire costs to the largest polluter.
- The environmental harm of pollution (α) is substantial.

Experimental Design

Treatment	Voting Rule (q)	Cost Multiplier (α)	#Sessions
U08	Unanimity (3)	0.8	2
M08	Majority (2)	0.8	2
U12	Unanimity (3)	1.2	3
M12	Majority (2)	1.2	3
U16	Unanimity (3)	1.6	3
M16	Majority (3)	1.6	3

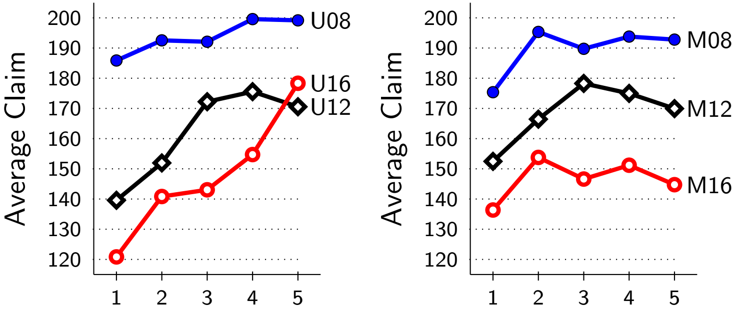
- The subjects are anonymously divided into groups of three.
- Each person can claim up to 200 tokens.
- 1st stage: Claim $g_i \in [0, 200]$. $C = \alpha \sum g_i$ is later known.
- 2nd stage: Submit a proposal. When q or more members vote for the one randomly selected proposal, the costs are distributed accordingly. If not, $C/2$ is charged to all.
- Repeat this for 5 periods. Random rematch

Hypotheses

1. Within each voting rule, the pollution amount decreases as the cost multiplier increases.
2. When the cost multiplier is less than 1.5, pollution under majority and unanimity rule is the same, holding the cost multiplier fixed.
3. Under the majority rule, proposals that assign the largest cost share to the highest polluter are the most frequently observed, and such proposals are more commonly observed than under the unanimity rule.
4. If aligning a large share to the higher polluter is more likely under majority, pollution is lower in M16 than in U16.
5. Within each voting rule, the disagreement rate is unaffected by the cost multiplier.

Result 1

The pollution amount decreases as the cost multiplier increases.



(a) Unanimity treatments (b) Majority treatments

Figure 1: Average Claim by Period

Result 2

When the cost multiplier is less than 1.5, the average pollution levels are indifferent in voting rules, holding the cost multiplier fixed.

Treatment	Socially Optimal Pollution	Pollution in Equilibrium	Observed Avg. Pollution	Observed Avg. Pollution Level
U08	100%	100%	96.93%	193.86
M08	100%	100%	94.70%	189.40
U12	0%	100%	80.99%	161.98
M12	0%	100%	84.22%	168.44
U16	0%	100%	73.78%	147.56
M16	0%	0% or 100%†	73.27%	146.54

†: Prediction varies by equilibrium. See propositions for details.

Table 1: Theoretical and Observed Average Levels of Pollution

% as a proportion of maximum pollution

Result 3

In Majority, proposals assigning almost all costs to one player are modal, but these are rarely observed in Unanimity. The recipient of the largest cost is typically the highest polluter.

Proposal Type		Three-way split	Two-way split	One-way split	Egalitarian	Proportional
Unanimity	All	0.852	0.123	0.025	0.273	0.313
	Accepted	0.981	0.019	0.000	0.433	0.413
Majority	All	0.433	0.071	0.496	0.075	0.110
	Accepted	0.400	0.034	0.566	0.062	0.103

Table 2: Types of the Submitted and Accepted Proposals

n-way split: n members receive costs more than 5% of the entire costs.

Egalitarian: Similar to (1/3, 1/3, 1/3).

Proportional: Similar to $(g_1/G,\ g_2/G,\ g_3/G)$.

Result 4

Although the largest polluter is likely punished under majority, high polluters often penalize others when proposing, and as such, the relationship between pollution and share of the costs is weak. As a result, the overall pollution in M16 is not significantly different from that in U16.

Table 3: The determinants of Proportion of Costs Offered

	Majority			Unanimity		
	(1)	(2)	(3)	(4)	(5)	(6)
Pollution (relative)	0.48^{***}	0.73^{***}	0.74^{***}	0.42^{***}	0.46^{***}	0.46^{***}
	(0.11)	(0.18)	(0.17)	(0.06)	(0.07)	(0.07)
Share to self (0 or 1)	-0.31^{***}	-0.14^{*}	-0.14^{*}	-0.12^{***}	-0.10^{**}	-0.10^{**}
	(0.03)	(0.06)	(0.06)	(0.01)	(0.03)	(0.03)
Pollution $\times$ Share to self		-0.52^{***}	-0.52^{***}		-0.09	-0.09
		(0.19)	(0.19)		(0.08)	(0.08)
CostMultiplier			0.04			-0.02^{*}
			(0.03)			(0.01)
Num. Obs.	960	960	960	960	960	960
R^2	0.251	0.259	0.260	0.347	0.349	0.351

Result 5

The likelihood of disagreement increases as the cost multiplier increases, within each voting rule.

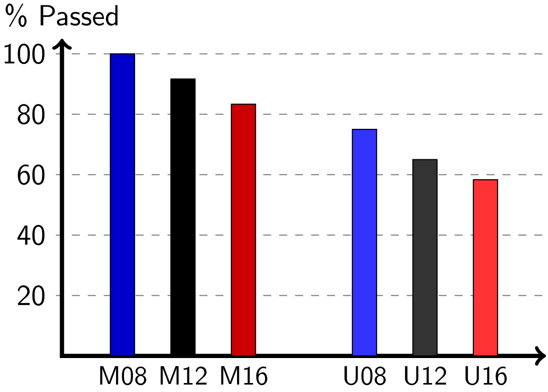


Figure 2: % Proposals Approved by Treatment

Takeaway Messages

- Pollution is (very) hard to deter.
- Theoretically and experimentally, unanimity doesn't help to reduce pollution. ("If you mess up that much, why wouldn't I, who has the same veto power, do that much?")
- A "threat" to allocate the entire costs to one member whose environmental harm was the largest doesn't help to reduce pollution. ("If everyone fully pollutes, it all boils down to a lottery. Why would I reduce pollution?")
- An increase in α reduces pollution to some degree in both voting rules, but it decreases the agreement rate.