

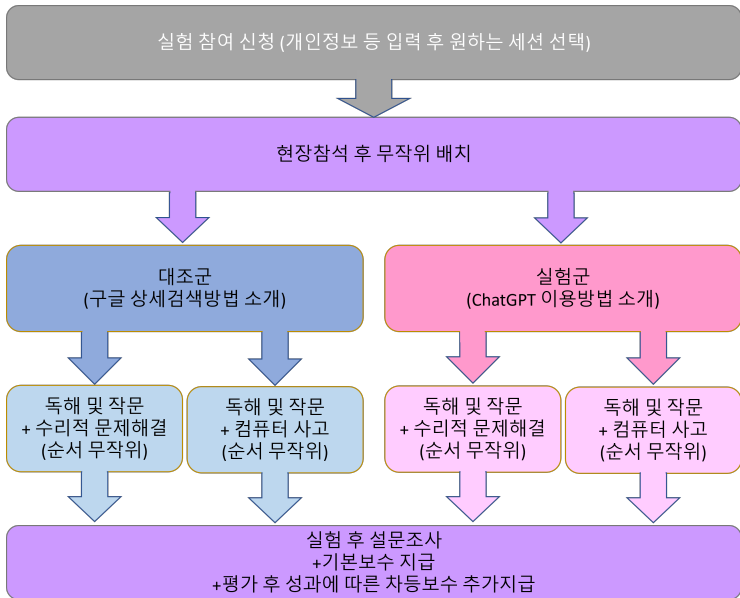
# Sharing the Burden of Endogenous Negative Externalities

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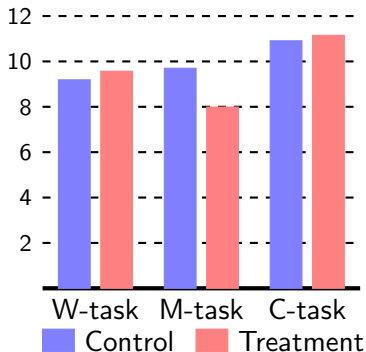
Nov 22, 2023  
SKKU

# Excuses (1/3): ChatGPT and Labor Productivity



# Excuses (1/3): ChatGPT and Labor Productivity

Weak improvement in writing and reading task (W-task).  
Significant drop in mathematical problem-solving task (M-task).



Default (GPT-3.5)

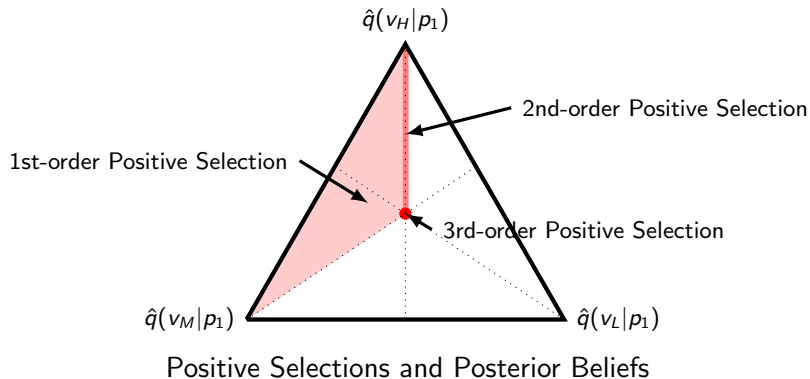
 다음의 수식을 계산해줘: '1212\*34/12'

 주어진 수식 '1212\*34/12'을 계산하면 다음과 같이 됩니다:  

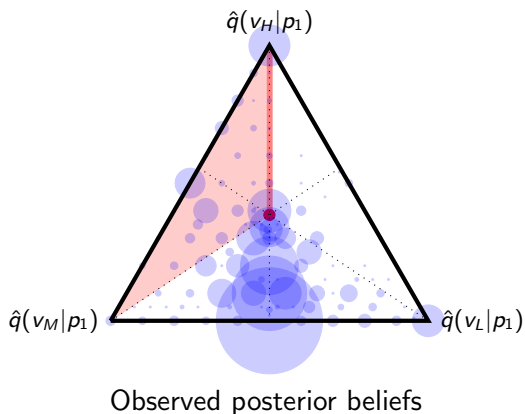
1. 먼저 곱셈을 수행합니다.  
 $1212 * 34 = 41,128$
2. 그 다음 나눗셈을 수행합니다.  
 $41,128 / 12 = 3,427$

따라서 수식 '1212\*34/12'의 결과는 3,427입니다.

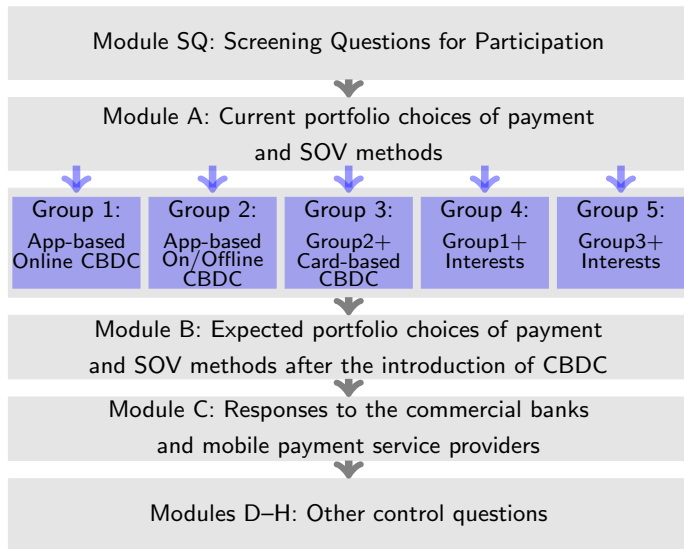
## Excuses (2/3): Higher-order reasoning in positive selection



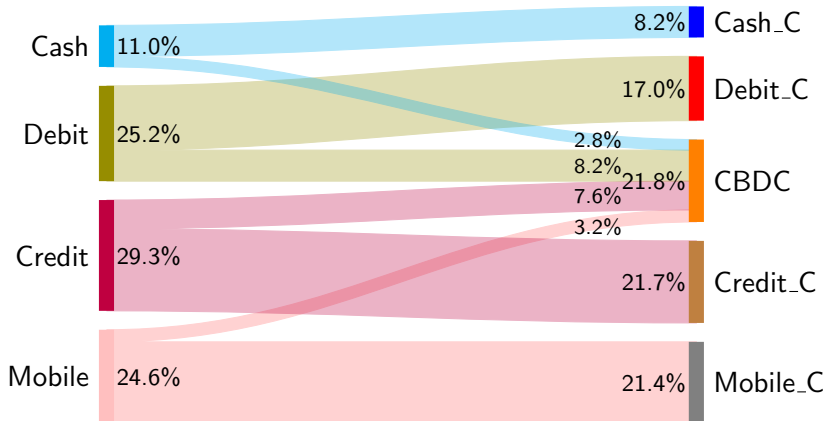
## Excuses (2/3): Higher-order reasoning in positive selection



## Excuses (3/3): Demand for CBDC



## Excuses (3/3): Demand for CBDC



Sankey diagram for payment methods portfolio, All

## Q: Allocating 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, reparations, and sanctions), often resulting from political bargaining.

**Research Question:** How does ex-post 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

(Focusing on the context of pollution)

- ▶ 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. (Player  $i$  “pollutes”  $g_i$ .)
- ▶ The total sum of claims generates public bads, which incurs the costs of  $C = \alpha \sum_i g_i$ ,  $\alpha \in (0, 3)$ . (Players’ polluting behaviors incur  $C$ .)
- ▶ Everyone observes who claimed how much.

$\alpha$  describes how the polluting behavior is bad for the environment.

Note if  $\alpha \in (0, 1)$ , complete pollution maximizes 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,  
 $p \in \mathcal{P} = \{(p_1, p_2, p_3) \in [0, 1]^3 \mid \sum_i p_i = 1\}$ .
  - ▶ 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  $\delta > 1$ . Magnitude of the costs increase upon disagreement.)
- ▶  $q = 2$ : majority.  $q = 3$ : unanimity.

(\* We could consider a many-person divide-the-penalty game (Kim and Lim, 2019), 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,
- ▶ 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

*When  $q = 3$ , the essentially unique SPE is (1) for all  $i$ ,  $g_i^* = E$ , (2) proposer  $i$  offers  $p_i^* = 0$  and  $p_j^* = \frac{1}{2}$  for  $j \neq i$ , and (3) non-proposer  $j$  votes for the proposal if  $p_j^* \leq \frac{1}{2}$ . The proposal is approved, as all players vote for it.*

This result holds regardless of the size of  $\alpha < 3$ .

## Equilibrium When $q = 2$

When  $q = 2$ , there is a **continuum of SPEs**. This is different from bargaining over joint profits (Baranski, 2016).

- ▶ We focus on two “extreme” ones.  
(extreme in the sense that other SPEs are between the two.)
- ▶ One equilibrium is practically identical to that when  $q = 3$ .

### Proposition (Equal Split Allocation)

*When  $q = 2$ , the following strategy profile is a SPE: (1) For all  $i$ ,  $g_i^* = E$ , (2) proposer  $i$  offers  $p_i^* = 0$  and  $p_j^* = \frac{1}{2}$  for  $j \neq i$ , and (3) non-proposer  $j$  votes for the proposal if  $p_j^* \leq \frac{1}{2}$ . The proposal is approved, as all players vote for it.*

## 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 polluting behavior.

Considering (1) only doesn't drastically change the equilibrium prediction. Particularly, public bads are fully produced,  $g_i^* = E \forall i$ .

### Proposition (Random Cost Allocation)

*When  $q = 2$ , the following strategy profile is another SPE: (1) For all  $i$ ,  $g_i^* = E$ , (2) proposer  $i$  **randomly** selects one non-proposer  $k \neq i$  with equal probability and proposes  $p_k^* = 1$  and  $p_{-k}^* = 0$ , and (3) player  $j$  votes for the proposal if  $p_j^* \leq \frac{1}{2}$ . The proposal is approved, as **two** players vote for it.*

## 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 polluting behavior**.

Considering (1) and (2) can drastically change the equilibrium prediction, given  $\alpha$  is sufficiently large.

### Proposition (Allocating to the Largest Polluter)

*When  $q = 2$  and  $\alpha > \frac{3}{2}$ , the following strategy profile is another SPE: (1) For all  $i$ ,  $g_i^* = 0$ , (2) proposer  $i$  picks player  $k \neq i$  whose  $g_k = \max_{j \in N \setminus \{i\}} g_j$ , proposes  $p_k^* = 1$  and  $p_{-k}^* = 0$ , and (3) non-proposer  $j$  votes for the proposal if  $p_j^* \leq \frac{1}{2}$ . In this equilibrium, the proposal is approved as all players vote for it.*

# Interim Summary

## Deterring Pollution is Hard.

When  $q = 3$ , everyone fully pollutes, regardless of the size of  $\alpha$ .

When  $q = 2$ , full pollution may sustain. Complete deterrence of pollution can be achieved only when three conditions hold.

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

## Risk and social preferences?

Perhaps risk aversion and social preference may play a role. When  $q = 2$ , allocating half of the costs to two players

- ▶ is least “risky” (if the players perceive that the bargaining outcomes merely depend on the realization of the proposer selection) and
- ▶ lead to the least skewed allocation, which maximizes Rawlsian social welfare (given the same level of public bads)

than allocating the entire cost to one player. Also, when  $\alpha > 1$ , utilitarian social welfare decreases when public bads are produced. Studies show that people are concerned with overall efficiency (Andreoni and Miller, 2002; Engelmann and Strobel, 2004).



## Experimental Design

Treatment	Voting Rule ( $q$ )	Cost Multiplier( $\alpha$ )	#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

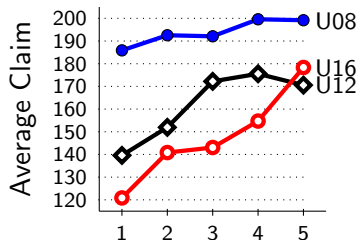
- ▶ The subjects are anonymously divided into groups of three.
- ▶ Each person can claim up to 200 tokens.
- ▶ 1st stage: Claim  $g_i \in [0, 200]$ .  $C = \alpha \sum g_i$  is later known.
- ▶ 2nd stage: Submit a proposal. When  $q$  or more members vote for the one randomly selected proposal, the costs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

# Hypotheses

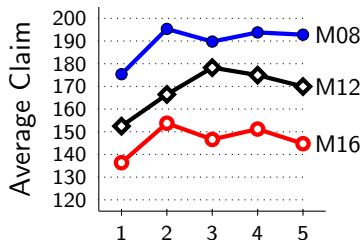
(Call the claimed tokens,  $g$ , as *pollution* from now on.)

1. Holding  $q$  fixed,  $g$  decreases in  $\alpha$ .
2.  $g(M08) = g(U08)$  and  $g(M12) = g(U12)$ .
3. Under M, proposals that assign the largest cost share to the highest polluter are modal and are more commonly observed than under U.
4. If the likelihood of being assigned a large share to the higher polluter is high under M, then  $g(M16) < g(U16)$ .
5. Holding  $q$  fixed,  $\alpha$  and  $C$  don't affect the disagreement rate.

## Results (1/5)



(a) Unanimity treatments



(b) Majority treatments

Figure 1: Average Claim by Period

### Result 1

The amount of pollution is lower when the cost multiplier is higher.

## Results (2/5)

Treatment	Socially Optimal Pollution	Pollution in Equilibrium	Observed Pollution
U08	100%	100%	96.93%
M08	100%	100%	94.70%
U12	0%	100%	80.99%
M12	0%	100%	84.22%
U16	0%	100%	73.78%
M16	0%	0% or 100% <sup>†</sup>	73.27%

% as a proportion of maximum pollution

<sup>†</sup>: Prediction varies by equilibrium.

Table 1: Theoretical and Observed Levels of Pollution

### Result 2

When  $\alpha$  is 0.8 or 1.2, the average level of pollution under M is not significantly different from that under U, holding  $\alpha$  fixed.

## Results (3/5)

Table 2: Types of the Submitted and Accepted Proposals

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	0.007	0.496	0.075	0.110
	Accepted	0.400	0.034	0.566	0.062	0.103

We say a member is included in the distribution of costs if she receives a share that is at least 5% of the total costs. *n-way split*: *n* member is included. A proposal is *egalitarian* if  $\text{diff}(\text{max.share} - \text{min.share}) \leq 5\%$ . A proposal as *proportional* if  $|\text{cost.share} - \text{pollution.share}| \leq 5\%$ .

### Result 3

In M, one-way split proposals are modal, but these are rarely observed in U. The highest polluter typically receives the largest cost (77.8% in M08, 76.7% in M12, and 58.8% in M16).

## Results (4/5)

Table 3: The determinants of Proportion of Costs Offered

	Majority		Unanimity	
	(1)	(2)	(3)	(4)
Pollution (relative)	0.38*** (0.08)	0.56*** (0.09)	0.15*** (0.05)	0.18** (0.07)
Share to self (0 or 1)	-0.16*** (0.02)	0.02 (0.05)	-0.06*** (0.01)	-0.04 (0.04)
Pollution $\times$ Share to self		-0.56*** (0.15)		-0.08 (0.12)
N	1440	1440	1440	1440
R <sup>2</sup>	0.064	0.071	0.062	0.064

The unit of observation is a share of the costs offered by a subject to each member of the group. *Pollution* is the relative size of the claim in the group for a given recipient. *Share to self* is the indicator of whether the offered share is to herself. Standard errors clustered at the individual level of the subject making the offer are in parentheses. \*, \*\*, and \*\*\* indicate statistical significance at the 5% level, 1% level, and 0.1% level, respectively.

### Result 4

Although the largest polluter in M tends to be punished more, high polluters often *penalize others* when proposing, and as such, the relationship between pollution and share of the costs is weak.  $g(M16)$  is not significantly different from  $g(U16)$ .

## Results (5/5)

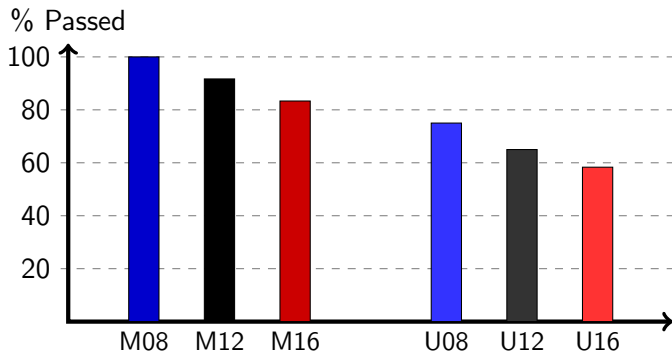


Figure 2: % Proposals Approved by Treatment

### Result 5

The disagreement rate in M is lower than that in U. Holding  $q$  fixed, the disagreement rate increases by  $\alpha$ .

# Summary

- ▶ Public bads production is (very) hard to deter.
- ▶ Theoretically and experimentally, unanimity doesn't help to reduce public bads. (“If you mess up that much, why wouldn't I, who has the same veto power, do that much?”)
- ▶ Under the majority rule, the overall distribution of costs are sharply contrast with the equitable sharing norm, widely observed in bargaining games with joint production.
- ▶ A “threat” to allocate the entire costs to one member whose environmental harm was the largest is well observed under the majority rule, but it doesn't help to reduce public bads.
- ▶ An increase in  $\alpha$  reduces pollution to some degree. Relying on the individual concerns for social efficiency isn't a solution.