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A mechanism requesting prices and quantities may increase the provision of heterogeneous public goods

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Abstract

We study the provision problem of an asymmetrically valued public project using a novel mechanism proposed by Van Essen and Walker (2017). Under this mechanism, each player simultaneously submits a price (either a contribution or a requested compensation) and a desired project quantity. In our context, two non-hosts interact with the project's host, who gets harmed by provision. The minimum submitted quantity is provided if the contributions are sufficient to cover the building costs and the host's requested compensation. We test the efficiency-enhancing effects of communication and find that, although it led to larger provided quantities, the probability of provision is unaffected, and the non-hosts kept most of the efficiency surplus. Moreover, the effect of communication disappears in settings where the host demands a larger compensation in equilibrium. The coding of chat logs reveals that veto threats are rare (1%), although the mechanism allows to do so. Reaching non-binding agreements and the host's engagement with communication are positively correlated with the probability of provision.

Keywords NIMBY · LULU · Public goods provision

JEL Classification C92 · H4 · Q58

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1 Introduction

Unequal benefits from a public project are a threat to its provision because it is much harder to define each party's contribution (Chan et al., 1999; Fisher et al., 1995). In the most extreme case, the project benefits most of the involved parties while it causes damage to the remaining ones that are hosting the project. Think, for instance, about nuclear plants, waste treatment facilities, or prisons. This situation is known as the NIMBY (not in my backyard) or LULU (locally unwanted land use) problem (Popper, 1983; Schively, 2007). Most of the mechanism design literature has focused on auction-like solutions that find and compensate a host (Kleindorfer & Sertel, 1994; Kunreuther & Kleindorfer, 1986; Kunreuther et al., 1987; Minehart & Neeman, 2002; O'Sullivan, 1993). However, this literature is silent on how the compensation depends on collective decisions that divide the surplus from providing larger—though more locally harmful—projects. These joint decisions confront efficiency concerns (by pursuing larger and more socially-desirable projects) and other-regarding considerations (by increasing compensations as projects get larger). We study how the project's asymmetric valuations interplay with communication opportunities when compensations can be directly requested as quantity-dependent prices within a mechanism.

Economic experiments help study behavior when the trade-off between efficiency and equality must be collectively addressed. For instance, the voluntary contribution mechanism (VCM) may involve group members with heterogeneous benefits from a public project and additional institutions (or rules) to alleviate the payoff differences emerging from project provision. However, the evidence suggests that individuals struggle to exploit the *ex post* redistributive institutions that may reduce inequality. In Gangadharan et al. (2017), participants can assign 3 reward points to a group member (at the cost of 1 point) after individual contributions in the VCM are revealed. When groups are allowed to communicate, most of them prioritize equality over efficiency, neglecting the possibility to redistribute through rewards in a further step. Dekel and Fischer (2017) set up a VCM where one group member is harmed by project provision. Punishment is ineffective as an *ex post* redistribution mechanism because prosocial and antisocial sanctions are hard to define given the players' extreme heterogeneity. With communication, rewards are employed to compensate the player harmed by the project, who, in response, increases her contributions.

In this paper, we study a similar conflict as in Dekel and Fischer (2017) using a novel mechanism proposed by Van Essen and Walker (2017). We will call it the PQ mechanism because each group member *simultaneously* submits the maximum price P she is willing to pay per project unit and the maximum project quantity Q she will support. Two reasons justify the exploration of the PQ mechanism in light of the related studies of public good provision with heterogeneous benefits. First, in our case, redistribution considerations respond to *ex ante* information (i.e., the size-dependent benefits or damages from provision) and not to its combination with *ex post* information (i.e., contributions). Second, the bi-dimensional strategy disentangles the players' distributive (P) and efficiency (Q) intentions. Since the mechanism allows the submission of negative values of P, the project's host can request a compensation instead of submitting a contribution. This compensation can be seen as a side payment, known to reduce conflict and promote coordination (Andreoni & Varian, 1999), that is already embedded in the mechanism.

The PQ mechanism operates as follows. A public project directly benefits the non-hosts, who pay for the provision and to compensate a host for the local harm caused by the project. The minimum desired quantity is provided if the sum of contributions per unit (accounting for the host's compensation, a negative contribution) is at least as large as the cost per unit. Hence, the mechanism gives bargaining power to the host in two dimensions. Through P, the host could threaten to request a substantial compensation that makes the non-hosts' contributions insufficient. Through Q, the host could threaten to explicitly block provision by setting her desired project quantity as zero. Although all group members could submit a null contribution, this veto power is, in theory, more likely to be exerted by the host, who is harmed by provision in the absence of compensation. Although these bargaining strategies indicate that the outcome may be a null provision, the PQ mechanism has a multiplicity of equilibria where the unique, efficient equilibrium matches the Lindahl allocation. The Lindahl allocation is a set of personalized prices reflecting fair burden-sharing arrangements that are profit-maximizing under the optimal size (Buchholz & Peters, 2007; Chen, 2002). Since any other outcome where the sum of contributions per unit matches the cost per unit is also an equilibrium, we aim to understand what drives equilibrium selection.

To do so, we introduce communication as our primary treatment variable. Communication not only improves equilibrium selection toward Pareto-dominant outcomes (Cooper et al., 1992), but is also determinant to signal intentions to redistribute (as in Dekel & Fischer, 2017), or to establish whether group intentions are aimed at improving efficiency or equality (as in Gangadharan et al. (2017). Within the PQ mechanism, communication may be determinant in solving two coordination problems: selecting Pareto-improving quantities and agreeing on prices that grant provision. Moreover, the "content analysis" coding method (Cooper & Kagel, 2005) would help us detect relevant elements of communication such as veto threats or sequential agreements on prices and quantities. The latter may signal how groups pursue equality over efficiency (or vice versa), connecting us with Gangadharan et al.'s result where groups failed to anticipate how to use the second stage to pursue both.[1]

We find that communication increased the provided project quantity, though it did not increase the likelihood of project provision. Moreover, most of the efficiency gains were kept by non-hosts. Two explanations for the observed inequality are the seldom use of veto power (and the threats to use it) and the non-hosts' tendency to increase contributions that cover the additional provision cost but not the increase

[1] Lab-in-the-field evidence suggests a similar issue with farmers that, aiming to minimize inequalities in land distribution, failed to achieve more efficient agreements yielding egalitarian payoffs (Gáfaro & Mantilla, 2020).

in the host's damage. Reinforcing this argument, communication did not have any effect when the host was supposed to earn more, in equilibrium, by enforcing larger contributions from the non-hosts.

These findings let us speak to the existing literature in multiple fronts. First, in Kagel et al. (2010), committee members holding veto power get a larger share of the fixed endowment they are deciding how to split. In our study, the host rarely used veto threats or directly vetoed the project. The difference, we argue, is linked to the non-hosts' use of communication to convey provision as a team objective. Second, as in Dekel and Fischer (2017), communication increases the transfers to the minority player harmed by the project. Hence, *ex post* information on the minority's behavior is not necessary to observe compensation. Third, in Gangadharan et al. (2017), groups fail to implement *ex post* redistribution even when efficiency and equality are not opposing objectives. This result holds under our mechanism, in which redistributive and efficiency choices are processed simultaneously through P and Q. Fourth, bargaining over an endogenous surplus reveals tolerance to different sources of inequality. In Baranski (2016), participants support payoff rules that divide the surplus in proportion to individual contributions. This is a "deservingness-based" agreement that is efficiency-enhancing in the long run. We extend the evidence to a "role-based" source of inequality: hosts are willing to accept efficiency-enhancing agreements that allocate most of the surplus to the non-hosts' majority (and the role was randomly assigned).

2 Related literature

2.1 Auctions and the provision of public projects

Public projects with a harmed host (i.e., noxious facilities) were originally tackled with auction-like approaches focused on compensation (Kunreuther et al., 1987; O'Sullivan, 1993). A further generation of mechanisms focused on characterizing voluntary participation and compensation rules (Lescop, 2007; Minehart & Neeman, 2002). Despite the large experimental evidence on auctions (Kagel, 2020), the laboratory tests of auction mechanisms for allocating this type of public projects are scarce. The two exceptions are Kunreuther et al. (1987), who tested their mechanism and showed that learning aids to reach an efficient solution, and Quah and Yong (2008), who conclude that, from an efficiency perspective, the second-price auction performs better than the other four assessed auctions.

Given the PQ mechanism's rule selecting the minimum project size, another related family of mechanisms involves strategy selection based on lowest common denominators (Orzen, 2008). These mechanisms usually have a first stage of pledges, where the minimum submitted contribution defines the least cooperative strategy available in a second stage of binding contributions. In them, efficiency hinges on conditional cooperation from large coalitions (Dannenberg et al., 2014; Orzen, 2008). Gallier et al. (2017) and Kesternich et al. (2018) introduce heterogeneous players into these mechanisms by adding different contribution rules (e.g., aiming at equality of contributions or equality of payoffs).

The experimental evidence is ampler for mechanisms that may achieve a Lindahl allocation, the efficiency benchmark in problems of public goods provision (including the PQ mechanism). Popular mechanisms that, in theory, attain Lindahl allocation were proposed by Walker (1981), Kim (1993), and Chen (2002). The evidence that Walker's mechanism did not converge to the Lindahl allocation (Chen & Tang, 1998; Healy, 2006; Walker, 1981) was followed by a comparative analysis with the Kim and Chen mechanisms, focusing on their out-of-equilibrium properties (Van Essen et al., 2012). The Kim and Chen mechanisms yield a similar consumer surplus (70–95%, both better than Walker's), but the former produced fewer violations of rationality and less costly mistakes. Van Essen and Walker (2019) added the PQ mechanism to this comparative analysis in a setting with slightly asymmetric valuations of the public project. Although the Lindahl allocation was never achieved, the PQ mechanism performed better than the Walker, Kim, and Chen mechanisms, given its enhanced out-of-equilibrium properties.

2.2 Communication in experiments and its relevance for equilibrium selection

Communication is often an efficiency-enhancing institution in cooperation dilemmas (Balliet, 2010; Chaudhuri, 2011; Ledyard, 1995) and bargaining games (Charness, 2012). Farrell and Rabin (1996) and Crawford (1998) describe two reasons explaining why communication works: the (strategic) sharing of private information and the signaling of players' intentions to reduce strategic uncertainty, including equity norms sustaining profit sharing in public goods (Tavoni et al., 2011) and bargaining games (Andreoni & Rao, 2011; Roth, 1995). Brandts et al.'s (2019) points out that free-form communication tends to work better than more structured messages: it increases the revelation of truthful information (Brandts & Cooper, 2018; Lundquist et al., 2009) and allows the use of words leading to non-binding agreements and commitment devices (Bochet et al., 2006; Charness & Dufwenberg, 2006, 2010).

Cooper and Kagel's (2005) shifted the scope of analysis from communication *between* to communication *within* decision units. They explained why a combination of communication and incentives leads to different conclusions with respect to psychology studies, and introduced the "content analysis" coding method for free-form communication (Brandts et al., 2019). Cooper and Kagel (2016) also contributed to the study of communication with asymmetric players. They show that, under an "advisor-advisee" structure, the effect of communication is more limited because the advisors' strategic incentives affect the advisor's quality and advisees' expected truthfulness of information transmission. This result contradicts the effectiveness of one-way communication in solving coordination problems (Cooper et al., 1989), fostering conventions in ultimatum games (Schotter & Sopher, 2007), and increasing contributions in public goods games (Koukoumelis et al., 2012). Baranski and Kagel (2015) explore, through a legislative bargaining game, another setting with a high degree of conflict between player types, as in our case. Coalition proposers within a committee, allowed to privately communicate with voters (who cannot talk to each other), use their power to elicit the lowest acceptable offers from potential coalition partners. Agranov and Tergiman (2019), on the other hand, shows that this power is drastically diminished when committees must approve allocations through unanimity instead of majority rules.

Regarding the use of veto power, Kagel et al.'s (2010) show that it leads to inefficient and inegalitarian allocations. Moreover, Banks et al. (1988) showed that veto power in the Smith Auction (Smith, 1979, 1980), a Lindahl mechanism, reduced overall efficiency. In contrast, Masuda et al. (2014) found a rare use of veto power in their minimal approval game with symmetric players.

After remarking John Kagel and collaborators' contributions to understanding why communication works, we list three reasons why it matters in the study of the PQ mechanism. First, communication may reduce the social distance between the non-hosts and the host and may increase the understanding of why the host demands a compensation. This effect has been shown for ultimatum (Greiner et al., 2014) and public goods games (Isaac & Walker, 1988), and could help groups select larger quantities.

These larger quantities increase conflict between the host and non-hosts, which comes along with coordination problems inherent to the PQ mechanism.[2] Hence, the second reason for introducing communication is equilibrium selection based on efficiency reasons. In the PQ mechanism, when selecting a quantity, participants face a problem equivalent to a coordination game with Pareto-ranked multiple equilibria. In 2×2 games, public communication leads to select the Pareto-dominant Nash equilibrium (Cooper et al., 1992; Grandjean et al., 2017). We thus expect that free-form public communication helps participants agree to submit quantities in the vicinity of the Lindahl allocation, using the additional potential profits as a focal point.

The third benefit of communication is improving the likelihood of budget balancing, another coordination problem. An agreement on quantities cannot assure provision unless the non-hosts' contributions per unit match the sum of the project's cost and the host's compensation per unit. Although equity-driven proposals tend to be focal in bargaining games (Roth, 1985, 1987), they are not necessarily achievable (Bolton et al., 2003; Baranski & Kagel, 2015). Communication may help participants bargain on the total costs, depending on the host's requested compensation, and then coordinate how non-hosts will pay for it. Moreover, communication may facilitate the discussion of quantity-dependent prices. This is not a trivial problem because expecting different provision levels may lead to different proposed prices, even if all players share an equity norm.

[2] We appreciate the suggestion from one Reviewer to think about the implementation challenges of the PQ mechanism in terms of coordination problems.

3 Theoretical background

3.1 The PQ (or van Essen and Walker's) mechanism

A set of n players must decide how many units of a public project they will provide, q, and how they will pay for this project. To do so, each player $i \in \{1, \dots, n\}$ makes a proposal $\zeta_i = (q_i, c_i)$. Here, q_i is the maximum number of project units she is willing to accept, and c_i is the maximum contribution per unit of the public project she is willing to provide. Given a budget e, the proposal ζ_i must be such that $q_i \times c_i \leq e$. The input of the Van Essen andWalker's mechanism is the profile of proposals $\zeta = ((q_1, c_1), \dots, (q_n, c_n))$, yielding:

$$q = \begin{cases} min\{q_1, \dots, q_n\} & \text{if } \sum_{i=1}^{n} c_i \geq \phi \\ 0 & \text{otherwise,} \end{cases} \tag{1}$$

and

$$p_i = \phi/n + c_i - \bar{c}, \quad \text{with} \quad \bar{c} = \sum_{i=1}^{n} c_i/n \tag{2}$$

where ϕ is the cost of providing one unit of the project, and p_i is the tax per unit charged to player i. While intended contributions (and compensations) are part of the mechanism's inputs, its outputs are the effective prices, either taxes ($p_i > 0$) or subsidies ($p_i < 0$). Contributions are identical to compensations only if the budget is balanced. With a budget surplus, $\bar{c}$ exceeds ϕ/n, and the excess contribution is divided by $1/n$ and given back as a rebate. The total contribution of player i, when q units of the public project are provided, will be $T_i = p_i \times q$.

Among the six properties of the PQ mechanism described in Van Essen and Walker (2019),[3] two have particular importance in the provision of highly asymmetric public projects. *Acceptability*, in- and out-of-equilibrium, means that individuals will pay at most their intended contribution (or get at least their requested compensation) with a provision level that will not exceed their desired project size. Combined with *Individual Rationality*, the Lindahl allocation prices would reflect the principle "from each according to his benefit" while selecting the optimal size.

Let us define $v_i(q)$ as player i's valuation of providing q units of the project. For the host, there is a $\tilde{q}$ such that $v_H(q) < 0$. The PQ mechanism allows the host to receive transfers that would prevent her from blocking any project of size $q \geq \tilde{q}$.

[3] (*P1*) budget balancedness; (*P2*) the maximum contribution per unit of the public project is the intended contribution, c_i; (*P3*) any outcome of the vEW mechanism is individually feasible and collectively feasible; (*P4*) if player i submits a proposal $\zeta_i = (q_i, c_i)$ that is acceptable to her, then the outcome of the vEW mechanism will always be acceptable to her. (*P5*) a Nash equilibrium of the vEW mechanism is individually rational, and (*P6*) the Lindahl outcome is an equilibrium outcome.

Table 1 Experimental parameters and efficient (Lindahl) equilibrium outcomes of the vEW mechanism

Label	Type	a_i	q_i	c_i	p_i	q^*	T_i^*	$\pi_i(q^*, T_i^*)$	$\pi_i(0,0)$
City A	NH (non-host)	14	≥ 4	6	6	4	24	46	30
City B	NH (non-host)	14	≥ 4	6	6	4	24	46	30
City C	H (host)	2	4	− 6	− 6	4	− 24	46	30

For player i, q_i corresponds to the requested quantity in the vEW mechanism, c_i to the maximum intended contribution per project unit, p_i to the actual contribution per project unit, q^* and T_i^* to the Lindahl equilibrium quantity and total tax (respectively), and π_i to the payoff

3.2 Game setting to study the provision of a noxious good

Three players face the problem of providing $q \in \{0, \ldots, 10\}$ units of a public project. Two of them are non-hosts (NH), and the other is the host (H). The valuation of providing q units of this project for a Type i player is given by $v_i(q) = a_i q - q^2$ for $i \in \{NH, H\}$. We set the parameters as $a_{NH} = 14$ and $a_H = 2$ to remark the asymmetric valuation of the public project. Whereas the non-hosts benefit from any project provision, the host is harmed if a quantity $q \geq 3$ is provided. Each player receives an endowment of $e = 30$ and faces the same costs function $\Phi(q) = \phi q$, with a project unit cost $\phi = 6$.

Adding the valuation from the three players, the economic surplus is given by

$$S(q) = 2(v_{NH}) + v_H - \Phi(q) = 24q - 3q^2. \tag{3}$$

The maximization of Eq. (3) yields the Pareto optimal provision of public project, $q^* = 4$. At q^*, the optimal tax equalizes each participant's marginal benefit, and corresponds to the Lindahl tax. By setting $\tau_i = a_i - 2q$, we obtain $\tau_{NH} = 6$ and $\tau_H = -6$. To compute each player's payoff, given by $\pi_i = e - T_i + v_i(q)$, we need the total tax (or subsidy), $T_i = p_i q$. In the efficient outcome of this game, the non-hosts will pay $T_{NH} = 6 \times 4 = 24$ for the provision of $q^* = 4$, and the host will receive $(-)T_H = (-)6 \times 4 = (-)24$ as compensation for the provided q^*. Here, the profile of proposals $\zeta = ((q_1, c_1), (q_2, c_2), (q_3, c_3))$ will be $\zeta = ((q_1 \geq 4, 6), (q_2 \geq 4, 6), (4, -6))$. We show in Table 1 that this profile yields identical payoffs for both player types, $\pi_{NH} = 46$ and $\pi_H = 46$.

We thus calibrate a game in which players can eliminate payoff differences in the two extreme cases of null and optimal provision, though the latter requires a sizeable host's compensation. The implementation of this optimal tax remains an empirical question. It would let us study whether individuals' difficulties in jointly pursuing equality and efficiency extend from VCMs with *ex post* redistribution (Dekel & Fischer, 2017; Gangadharan et al., 2017) to the single-stage PQ mechanism.

3.2.1 Other equilibria in the PQ mechanism

According to Theorems 2.1 to 2.3 in Van Essen and Walker (2017), any provided quantity satisfying budget balancedness is an equilibrium. Among the plethora of

Table 2 Benefits of the public project shown to participants in the experiment

Benefits	Burning Towers in the Incinerator (Q)										
	0	1	2	3	4	5	6	7	8	9	10
City A	0	13	24	33	40	45	48	49	48	45	40
City B	0	13	24	33	40	45	48	49	48	45	40
City C	0	1	0	– 3	– 8	– 15	– 24	– 35	– 48	– 63	– 80

equilibria conceivable under this definition, there are two particular families that we want to discuss further. First, the fact that $v_H(q = 2) = 0$ could create some focality for equilibria at $\tilde{q} = 2$ because the project is harmless for the host. It could evoke solutions such as $c_{NH} = \phi/2$ (i.e., each non-host pays half of the building cost) and $c_H = 0$ (because the host will not benefit). Second, equilibria above $q^* = 4$ would be rare to observe. The host's marginal valuation of the facility is $-2q$. Hence, her requested compensation per unit would increase for larger projects, while the endowment would limit the non-hosts' contribution per unit.[4]

4 The experiment

4.1 Experimental setup

We emulated the setting described in Sect. 3.2 in a lab experiment. We framed the instructions as a problem of building a garbage incinerator (see Appendices B.1 and B.2 for instructions in English and Spanish, respectively). Participants within a session were randomly assigned to groups of three and told that each represented a city. Non-hosts were assigned to the labels "City A" and "City B", and the host to the label "City C." Groups and labels remained fixed for the entire experiment. In our framing, the National Government encouraged Cities A, B, and C to build a garbage incinerator that would benefit all three cities but can only be located in City C. The environmental costs increase with the size of the incinerator, and these costs are burdened by City C. Cities A and B have millions of inhabitants and benefit from a large incinerator. By contrast, City C is much smaller, so a small incinerator is preferred. Participants can propose any number of burning towers between 0 and 10 (i.e., $q_i \in \{0, \dots, 10\}$), which determine the "size" of the garbage incinerator. Table 2 lists the incinerator's benefits (or harms) for each City, depending on q. This table was available to all three group members during the whole session.

[4] There are also equilibria with null provision, called "no-trade equilibria" (Van Essen & Walker, 2017). They can be seen as the negative side of the acceptability property: proposals that are too demanding in the case of a host, or too stingy from a non-host, would hardly balance the budget and yield the status quo, which is acceptable by definition. Moreover, any use of veto (by submitting a null quantity) will constitute a no-trade equilibrium.

Each group interacted for ten rounds. Although the mechanism is presented as a one-shot game, repeated interactions improve the understanding of the mechanism and could ease convergence to an outcome, either in- or out-of-equilibrium. A shared history of the game might give room for readjustments in the intended contributions and compensations, increasing the chances of positive and efficient provision. Hence, observing the learning process may be informative for the mechanism's implementation.

Given the game's complexity, the first three rounds were practice rounds. One of the remaining seven rounds was randomly selected for payment. All the participants within a group were paid based on the same selected round. The currency in the experiment was tokens. Participants knew that the tokens earned in the paid round would be multiplied by COP 1000 to compute their earnings.[5] Participants in the role of City C may end up with negative earnings by allowing a $q > q^*$ and submitting a positive contribution. The instructions explained that negative payoffs were rare but possible and could be easily avoided by carefully reading how the mechanism worked.

4.2 Timing of the experiment

(i) *Introduction* Participants read the general instructions of the experiment and signed the informed consent. The instructions described the provision of the garbage incinerator and the mechanism's functioning.

(ii) *Validation* Participants took a validation test to check their understanding of the mechanism: ten questions about mechanism outcomes and participants' contributions, taxes, and payoffs (see Appendix B.3). Participants must correctly complete all questions to proceed. In the case of a mistake, the program explained the correct response, so the participant could correct it.

(iii) *Submission* [Rounds 1–10] Participants submitted their proposal $\zeta_i = (q_i, c_i)$ within a 120 s limit per round. A default proposal $\zeta_i^0 = (0, 0)$ was sent in case that time ran out.

(iv) *Resolution* [Rounds 1–10] Participants received feedback on the mechanism's outputs and their payoff. The computer screen displayed the minimum proposed quantity and the sum of contributions per unit. Individual contributions (or compensations) from the other two group members were not reported.

(v) *Payment* [After Round 10] Participants received a summary of their payoffs in each round. We informed them of their selected round for payment and their final earnings.

[5] At the time of the experiment, USD 1 was equivalent to COP 3,360.

Table 3 Different outcomes of the vEW mechanisms despite minor differences in the proposal profiles

Example 1							Example 2						
City	c_i	q_i	q	p_i	T_i	π_i	City	c_i	q_i	q	p_i	T_i	π_i
A	6	3	0	0	0	30	A	6	3	1	5	5	38
B	3	2	0	0	0	30	B	3	2	1	2	2	41
C	− 6	4	0	0	0	30	C	0	1	1	− 1	− 1	32

Example 3							Example 4						
City	c_i	q_i	q	p_i	T_i	π_i	City	c_i	q_i	q	p_i	T_i	π_i
A	6	3	2	6	12	42	A	6	3	3	6	18	45
B	3	2	2	3	6	48	B	3	3	3	3	9	54
C	− 3	3	2	− 3	− 6	36	C	− 3	3	3	− 3	− 9	36

4.3 Experimental design and hypotheses

We are interested in whether the PQ mechanism, with the aid of communication, can help participants to reach a solution that is efficiency-enhancing and egalitarian. We define two treatments:

- *Baseline*: participants interact for ten rounds under the conditions described in Sect. 4.2.
- (with) *Chat*: during the submission stage, participants have access to a chat box located above the submission box. Participants are instructed to talk about their proposals "in terms of quantities (Q) and contributions (P) or compensations (negative P)."

The chat box was available for two minutes, the maximum duration of each round's submission stage. Although the participants were instructed to talk about proposed quantities and contributions, messages were not restricted to any particular form. Section 7 explores the chat logs.

We argue that communication may enhance the use of the vEW mechanism for three reasons: (i) it may reduce the social distance between player types and improve the understanding of the profit implications of type asymmetry, (ii) it may improve the equilibrium selection toward Pareto-dominant outcomes, and (iii) it may increase the likelihood of budget balancing.

Before listing the specific hypotheses, let us present in Table 3 four examples where the differences in outcomes are considerable despite the minor differences in the proposal profiles. In examples 1 to 3, City A requests $q_A = 3$ and is willing to pay 6 tokens per provided unit, and City B requests $q_B = 2$ and is willing to pay 3 tokens per provided unit. Example 1 shows the paradox that occurs when City C submits the Lindahl equilibrium strategy, which cannot be implemented because, as the non-hosts expect a lower provision, their contributions per unit are insufficient to compensate City C. Example 2 shows that if City C limits the provision to a level where she receives a positive utility, the facility would be smaller than expected by non-hosts. Since they are willing to compensate City C for a larger facility, there will be a budget surplus (of 3 units, yielding a rebate of 1 per provided unit for each player). In example 3, City C accepts a larger facility in exchange for a compensation, yielding better outcomes for Cities A and B than in example 2 (even if City C's compensation increased).

Communication may help moving participants from Examples 1 and 2 to Example 3 through different channels. In Example 1, communication may help solve a budget-balancing problem (channel *iii*) if non-hosts convince City C to decrease the requested quantity by one unit and, in exchange, the requested compensation by three units. In Example 2, cities may use communication to understand better the profit implications of increasing the facility size (channel i): City C can accept a larger facility in exchange for a compensation. Reaching Example 3 increases the players' profits, although they have not fully agreed on their requested quantities. Finally, moving from Example 3 to 4 shows that if City B selects $q_B = 3$, the new outcome is Pareto dominant (channel ii). More generally, each example is Pareto superior to the previous one (though Example 2 is not an equilibrium because it is not budget balanced).

With these examples in mind, we present our hypotheses:

(H1) Communication increases the probability of positive provision (i.e., $q > 0$).

(H2) Communication increases the provided quantity, q.

(H3) Communication increases the non-hosts' contributions and the hosts' compensations.

(H4) Communication increases the hosts' requested quantities.

The first two hypotheses are related to the mechanism's outputs. For some intuition on **H1**, recall moving from Example 1 to 3. The mechanisms behind **H2** reflect the movement from Example 2 to 3, or simply the ability to reach Example 4. The last two hypotheses are related to the mechanism's inputs. To the extent that groups communicate, in **H3**, we expect that hosts request more significant compensations that lead to larger contributions from non-hosts. Finally, **H4** refers to our expectation that the non-hosts' higher requested compensations will accompany their acceptance of larger project sizes.

4.4 Sample and implementation

The experiment was programmed and implemented using oTree (Chen et al., 2016). It was conducted in the Rosario Experimental and Behavioral Economics Lab—REBEL, at Universidad del Rosario in Bogotá (Colombia). We had six sessions in 2019 with 132 participants recruited from REBEL's subjects pool using ORSEE (Greiner, 2015). For each treatment, we had two sessions with 24 participants and

Table 4 Outcomes of the PQ mechanism: provision, taxes, earnings, comparisons to the Lindahl outcome ($q^* = 4, T^*_{NH} = 24, T^*_H = -24, \pi^*(q^*, T^*_i) = 46$), and reasons for failed provision

	Baseline	Chat	Diff.	Obs.
Probability that project is provided	65.6%	68.2%	2.6%	308
Provided units	2.16	3.23	1.07	206
Provision relative to Lindahl (q/q^*)	54.0%	80.8%	26.8%	
Non-hosts' Tax	9.77	16.72	6.94	412
Non-hosts' Tax relative to Lindahl (T_{NH}/T^*_{NH})	40.7%	69.7%	29.0%	
Hosts' Tax (Subsidy)	– 6.59	– 14.07	– 7.47	204
Hosts' Tax (Subsidy) relative to Lindahl (T_H/T^*_H)	27.5%	58.6%	31.1%	
Non-hosts' Earnings	45.3	46.8	1.7	412
Non-hosts' Surplus $(\pi_{NH} - e)/(\pi^* - e)$	95.4%	105.0%	10.6%	
Hosts' Earnings	35.6	38.9	3.3	204
Hosts' Surplus $(\pi_H - e)/(\pi^* - e)$	35.0%	55.6%	20.6%	
Vetoed during decision time	0.9%	0.2%	– 0.6%	924
Vetoed by timeout	0.2%	5.6%	5.4%	924
Choices with timeout	1.1%	33.8%	32.7%	924
Insufficient budget	33.8%	28.6%	– 5.2%	308
Exact contribution (equilibrium)	25.7%	43.8%	18.1%	206

The reported quantities and taxes are conditional on a positive provision of the project ($q > 0$)

one session with 18 participants. Sessions took between 60 and 75 min, and the average payment was COP 38,340 (std. dev. 9147). This payment was equivalent to USD 11.4 at the time of the experiment.

For this experiment, we only recruited undergraduate students from the Economics Department at Universidad del Rosario for two reasons. First, numeracy skills are important in this experiment to prevent underprovision, insufficient contributions, and negative payoffs based on the misunderstanding of the rules.[6] Second, the framing of the experimental setup might be particularly appealing for undergraduate students in Economics and Finance, increasing the attention paid to the instructions.

5 Results

We report first the effect of communication on the mechanism's outputs, followed by an analysis of failed provisions. We then study the treatment differences in the submitted proposals. We excluded the practice rounds (1–3) from the analyses.

[6] There were only two cases with a negative payoff, corresponding to 0.15% of all outcomes: one in the first (practice) round and another in the seventh round. In both cases, the host submitted a positive contribution and a quantity of at least four units. The negative payoff in the seventh round was randomly chosen for payment, and this participant received only the show-up fee.

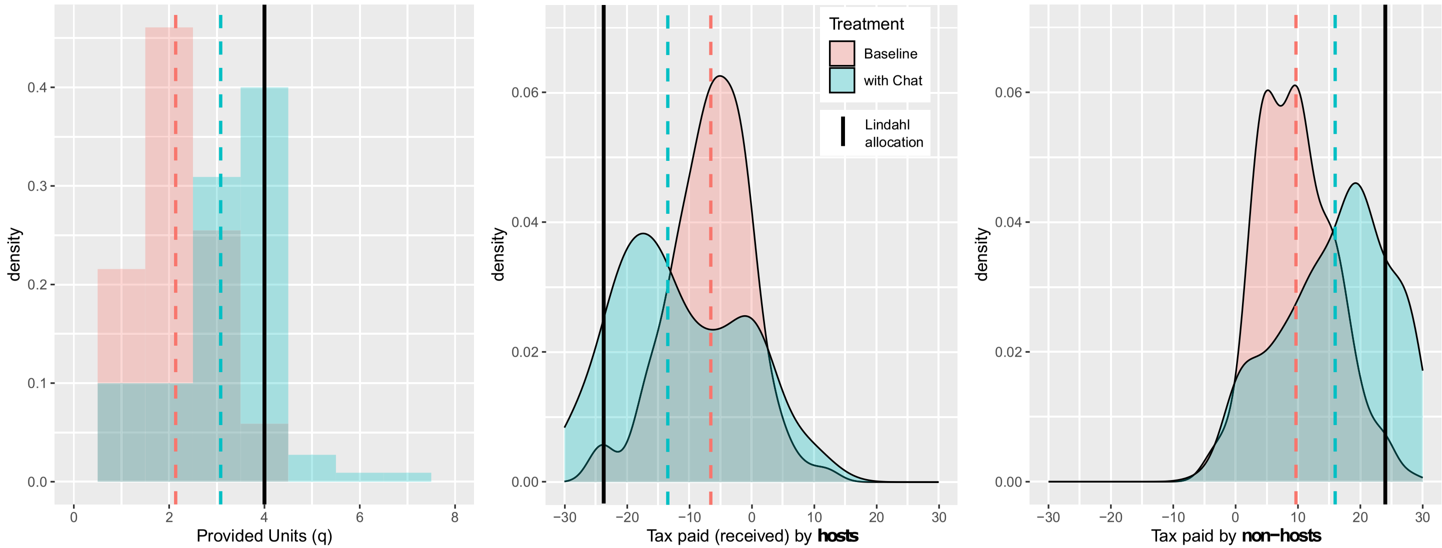

Fig. 1 Outcomes of the mechanism. *Left panel:* produced units of public project. *Central panel:* taxes paid (subsidy received) by the host. *Right panel:* taxes paid by the non-host. Outcomes for the baseline and the communication treatment shown in pink and cerulean, respectively. Colored dashed vertical lines correspond to the treatment average values. The black vertical lines correspond to the Lindahl allocation predictions described in Table 1. (Color figure online)

5.1 Successful provision under the PQ mechanism

Table 4 reports the outcomes of interest from the mechanism. First, the probability provision is 65.6% in the baseline, and communication has little effect in increasing this probability (2.6% points, pp hereafter). Second, conditional on $q > 0$, communication increases the average provided quantity from 2.2 to 3.2. Relative to the efficient provision level $q^* = 4$, it represents an increase of 27pp. The left panel in Fig. 1 reveals that communication shifts the modal provision from $q = 2$ in the baseline (47%) to $q^* = 4$ with communication (42%). One explanation for the salience of $q = 2$ without communication is that $v_H(2) = 0$, reducing the provision problem to a burden-sharing agreement between the non-hosts.

Table 4 also reports the taxes paid (or subsidies received) by player type. For the non-hosts, communication increases the tax from 9.8 to 16.7 tokens. This tax increase of 6.9 tokens covers the additional construction costs (47%[7]) and the additional compensation to the host (53%). Communication increased the average compensation for the host from 6.6 to 14.1 tokens. This shift toward higher taxes and compensations is displayed in the central and right panels in Fig. 1. Despite the increase in the host's compensation, and the slight increase in the non-hosts' average earnings (from 45.3 to 46.8 tokens), Table 4 reveals that, with the current taxes, the host is reaching only 56% of her available surplus with communication (and 35% in the baseline). As compensation did not increase sufficiently, the Lindahl taxes were implemented only in 5 cases (3.2% of all interactions). The rarity of achieving a Lindahl equilibrium goes in line with Van Essen and Walker (2019), who did not observe its play.

Result 1 *In the PQ mechanism, communication improves efficiency at the intensive margin but not at the extensive margin. Since most of the efficiency gains from communication are kept by the non-hosts, the emergence of Lindahl taxes is rare.*

We explore further the taxes paid by non-hosts, and subsidies received by hosts, for $q \in \{1, 2, 3, 4\}$. Figure A.1 in the Appendix reveals that, for $q \in \{3, 4\}$, the host's median (and mean) subsidy per unit is 5, whereas for $q = 1$ and $q = 2$ the median were 1 and 0 tokens, respectively (with a wider variance in the received subsidy). For the non-hosts, there is also an increasing but subtle relationship between higher provision and the tax per unit. Thus, we conclude that groups successfully providing at least three units were aware of the need to increase the host's compensation, even though this compensation remains below the Lindahl's optimal levels. Groups with $q \leq 2$ were pulling downward the host's share of surplus. Hence, groups failing to increase their efficiency with communication were also reaching more unequal agreements.

[7] The mean increase in provision of 1.07 units yields an increase of construction costs of 6.42. Assuming half of this value is paid by each non-host, the resulting 3.21 tokens correspond to 47% of the total tax increase.

Table 5 Random effects regression for outcomes of the mechanism

Variables	Project provision (1)	Quantity (2)	Total tax (3)	Tax per unit (4)	Earnings (5)
Chat	0.0260	1.045***	− 5.935**	− 1.180	5.653**
	(0.0613)	(0.273)	(2.821)	(0.800)	(2.379)
Non-host			16.18***	7.775***	9.172***
			(2.207)	(0.736)	(1.898)
Chat × Non-host			14.92***	1.770	− 2.392
			(4.252)	(1.200)	(3.569)
Constant	0.692***	1.906***	− 7.134***	− 3.183***	35.55***
	(0.0740)	(0.162)	(1.490)	(0.490)	(1.344)
Observations	308	206	618	618	618
Groups (or subjects) in cluster	44	44	132	132	132

All regressions include round fixed effects. Clustered standard errors at the group level are shown in parentheses. Models 3 to 5, reporting individual outcomes, include group fixed effects. Model (1) corresponds to a linear probability model

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

We validate Result 1 with an OLS regression analysis using random effects and clustering the standard errors. We explore two group outcomes: whether the facility was provided (a linear probability model) and the facility size (given $q > 0$). This regression includes the treatment variable and round fixed effects:

$$y_{gr} = \beta_0 + \beta_1 Chat_g + \boldsymbol{\delta_r} + \epsilon_{gr} \quad (4)$$

We also explore three individual outputs from the mechanism: total tax, tax per unit, and participant's earnings. Here, our observation unit becomes the participant i, in group g, interacting in round r. The model is given by:

$$y_{igr} = \beta_0 + \beta_1 Chat_g + \beta_2 NonHost_i + \beta_3 Chat_g \times NonHost_{ig} + \boldsymbol{\delta_r} + \boldsymbol{\delta_g} + \epsilon_{igr} \quad (5)$$

We added the variable $NonHost_i$ to capture the differences between types, its interaction with the treatment variable, and $\boldsymbol{\delta_g}$ to capture group fixed effects.

Table 5 reports the regression results. We validate that communication does not improve the probability of provision but, conditional on $q > 0$, the provided quantity increases by 1.05 units. The earnings are significantly higher for the non-hosts despite the increase in taxes with communication (and the absence of ann efficiency-equality trade-off in the Lindahl equilibrium). Column 4 provides an explanation: the tax per unit did not increase sufficiently with communication to differ statistically from zero. The most likely reason is the heterogeneity between groups below and above $q = 2$, as discussed earlier. These results provide support for **H2**, yielding Pareto-superior outcomes with communication. Nonetheless, we do not find support for **H1**.

Table 6 Random effects regression for proposed contributions and quantities

	Proposed contributions		Proposed quantities	
	(1)	(2)	(3)	(4)
Chat	− 1.448**	− 2.288***	0.617*	0.719**
	(0.723)	(0.656)	(0.324)	(0.286)
Non-host	7.750***	7.750***	1.211***	1.211***
	(0.616)	(0.630)	(0.374)	(0.383)
Chat × Non-host	1.718*	1.718*	− 1.006**	− 1.006**
	(0.961)	(0.984)	(0.419)	(0.429)
Constant	− 3.152***	− 3.186***	2.848***	2.998***
	(0.522)	(0.548)	(0.306)	(0.325)
Group Fixed Effects	✗	✓	✗	✓
Observations	924	924	924	924
Number of ID	132	132	132	132

All regressions include round fixed effects. Standard errors clustered at the group level are shown in parentheses

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

We now focus on the bottom of Table 4, listing the frequency of the potential channels leading to a failed provision. Note that the use of veto (i.e., selecting $q_i = 0$ during the decision time) is very rare, with less than 1% of the frequency and no differences between treatments. By contrast, the timeout submissions (i.e., the values automatically submitted when the two minutes ran out) became common with communication (34%, compared to 1% in the baseline). Nearly one-sixth of them corresponded to $q_i = 0$.[8] Half of the timeout submissions led to a failed provision. Hence, one reason why communication did not increase the provision probability was the difficulty in reaching agreements within the time limit.

When communication was successful, it helped groups to define their contributions better: the proportion of agreements in equilibrium, where the sum of contributions is exactly the provision cost ($\phi = 6$), increased from 26 to 44%. Moreover, the frequency of outcomes with an insufficient budget decreased from 34 to 29%. The frequency of equilibrium play in the baseline is close to the reported levels for standard public goods games under the PQ mechanism (26% according to Van Essen & Walker, 2019). Figure A.2 in the Appendix displays how close each interaction was to the target contribution, ϕ. Without communication, the higher frequency of failed contributions occurs when $q = 2$. With communication, failed contributions only appear for $q \geq 3$, where compensation agreements are harder to achieve.

[8] Unfortunately, among the timeout submissions, we cannot distinguish between voluntary and non-voluntary use of veto: participants may select $q_i = 0$ and wait until time ran out if they disagree with their group mates, though it is also possible (as suggested by some chat records) that participants engage in the discussion about what to submit and forgot the time limit.

Result 2 *Failed provisions are seldom explained by the direct use of veto power. Instead, they result from insufficient contributions* (*notably without communication*) *and running out of time to reach agreements* (*with communication*).

5.2 Proposed contributions and quantities

In this subsection, we focus on the mechanism's inputs rather than on its outputs. We show that communication caused a between-type divergence in the submitted prices (i.e., contributions and compensations) while creating a convergence in the submitted quantities.

The divergence in prices is driven by hosts. Their average requested compensation increased from 2.9 to 4.4 tokens with communication. By contrast, non-hosts slightly increased their contribution, from 4.8 to 5.1. How these slight differences led to more equilibrium outcomes and larger provision levels? Non-hosts reduced their requested quantities from 3.9 to 3.5, whereas hosts increased their quantity requests from 2.7 to 3.3. Since the minimum requested quantity dictates the project size, the host's increase in q_i appears to be the main driver of the efficiency gain. The distributions of requested contributions/compensations and quantities are reported in Appendix A (see Figs. A.4 and A.5). We employ Eq. (5) to validate these findings. Table 6 reports the estimated coefficients. Regarding proposed contributions, the negative coefficient for the *Chat* variable (making the compensation more negative) and the positive coefficient for its interaction with the non-host dummy (making the contribution larger) confirms the divergence in prices. By contrast, the requested quantities converge. Communication increases the host's accepted quantity while reducing the non-hosts' average quantity request. The former drives efficiency and the latter improves coordination by facilitating the discussion of quantity-dependent prices. The significance of these results is robust to clustering at the individual rather than at the group level (see Table A.1).

We validate **H3** with the increase of requested contributions and compensations, and **H4** with the increase in the host's requested size. A finding beyond our initial hypotheses is that non-hosts reduced their requested quantities. In theory, since the mechanism selects the minimum quantity, this reduction is unnecessary to reach more efficient outcomes. Nevertheless, it is n intuitive result: agreeing on quantities eases the coordination in prices, and the non-hosts' reduced requested quantities can also be used to justify a smaller increase in the proposed contributions.

We further explore the convergence of the provided quantity across time, which we will call stability. To measure this stability, we took each group as an observation, yielding 44 in total, and counted backward the number of rounds with the same output quantity. We allow at most one deviation from the focal quantity, increasing the tolerance to small mistakes (though the results are similar if we do not allow such errors). We find that stability is higher without (95%) than with communication (59%), a statistically significant difference (p-value of a Fisher exact test is 0.009).[9] This

[9] When mistakes are not allowed, the convergence is reached 72 and 41% of the time, respectively. Fisher exact test's p-value is 0.067.

Table 7 Parameterization and treatment predictions with payoff inequality in the Lindahl equilibrium

Scenario	Host valuation	Non-host valuation	q^*	T_H^*/q^*	T_{NH}^*/q^*	π_H^*	π_{NH}^*
High Tax ($\pi_H^* > \pi_{NH}^*$)	$v_H = -q^2$	$v_{NH} = 11 - q^2/2$	4	− 8	7	46	38
Egalitarian	$v_H = 2 - q^2$	$v_{NH} = 14 - q^2$	4	− 6	6	46	46
Low Tax ($\pi_H^* < \pi_{NH}^*$)	$v_H = -q^2/2$	$v_{NH} = 13 - q^2$	4	− 4	5	38	46

counter-intuitive result is partly explained by the differences in the stable quantities: 2.14 without and 3.23 with communication. Hence, communication may delay stability among groups more likely to search for more efficient outcomes through experimentation. Figure A.3, in the Appendix, confirms that communication helps groups reach stability at higher provision levels. The rightmost part of this figure shows that the difference in stable provision levels with and without communication is accentuated by groups that converged early to a provided quantity.

Result 3 *Communication delays stability but leads to larger quantities and provision probabilities once strategies become stable. This is consistent with communication facilitating the experimentation of larger quantities and the associated transfer increase*.

Stability explains between-treatment differences in efficiency. Nonetheless, there are also considerable differences in efficiency among groups allowed to communicate: their average probability of provision ranges from 29 to 100 percent (median 57%), and their average provided quantity (including zeros when provision failed) ranges from 0.4 to 5 units, with median 3. Taking the group as our unit of analysis, the correlation between the likelihood of provision and the quantity provided is 0.43 (p-value 0.048). Hence, the between-groups variance in efficiency is partly explained because groups that achieve provision more often are also more likely to provide larger projects. We also find a positive correlation (0.39, p-value 0.077) between the quantity provided and the frequency of equilibrium play. This result suggests that more efficient groups were more likely to set their joint contribution exactly at 6 units, eliminating the incentives to submit contributions below their announced proposals. A third factor explaining the differences in efficiency between groups emerges from the negative correlation between the quantity provided and having at least one group member who committed a total contribution (i.e., P times Q) above her endowment (− 0.547, p-value 0.008). This mistake occurred in 10% of the interactions, and it was typically preceded by an effort to raise the provided quantity and the subsequent host's request for a larger compensation per unit. We thus argue that unsuccessful attempts to increase provision, by demanding too much or contributing too little, also drove the differences in efficiency.

6 Introducing inequality in equilibrium

The confluence of equality and efficiency of the Lindahl equilibrium leaves unexplored other scenarios where conflict between hosts and non-hosts entails larger benefits for one over the other. This section presents the results with two new game parameterizations to study whether payoff inequality would limit the effect of communication in the PQ mechanism.[10] Our first scenario yields a higher payoff for the host under the Lindahl allocation, though it requires a higher tax per unit (7 for non-hosts, −8 for the host). We call it the *High Tax* scenario. Conversely, our second scenario yields a higher payoff for the non-hosts under the Lindahl allocation and requires a lower tax per unit (5 for non-hosts, −4 for the host). We call it the *Low Tax* scenario. Table 7 displays the differences between the three scenarios, where *Egalitarian* refers to the original setting. Note that the Lindahl quantity q^* is identical between treatments, and one player type preserves the earnings of 46 units in each unequal scenario. Moreover, the host's valuation is negative for any positive provision level. Hence, communication may also be less effective because participants cannot agree on any q that is harmless for the host.

In 2022, we conducted eight sessions with 117 participants recruited from REBEL's subjects pool. We maintained the recruitment rule from the original sessions, allowing only undergraduate students from the Economics Department. The average payment was COP 36,930 (std. dev. 8541). We had two sessions per treatment and four treatments in total: *High Tax* (N = 27), *High Tax+Chat* (N = 33), *Low Tax* (N = 24), and *Low Tax+Chat* (N = 33).

Communication does not improve the likelihood or size of provision in the *High Tax* scenario but it increases the provided quantities in the *Low Tax* scenario (see Table A.2 in the Appendix). A more detailed regression analysis, reported in Tables A.3 to A.5, yields the following results. First, we validate that the probability of provision does not increase with communication in any scenario. However, conditional on a positive provision, communication increases the provided quantity as we move from the *High Tax* (− 0.15) to the *Low Tax* treatment (+ 1.55). Second, most of the gains from a higher provision are still kept by non-hosts in the *Low Tax* scenario (in the *High Tax* scenario there is no efficiency surplus from communication to allocate). In fact, the non-hosts' average tax per unit is about 5 units in all scenarios, with and without communication, despite that the theoretically predicted tax was 8, 6, and 4 in the *High Tax*, *Egalitarian*, and *Low Tax* treatment, respectively.

Result 4 *Inequality cancels the effects of communication when the host is expected to earn more through higher Lindahl taxes. By contrast, if inequality favors the majority of non-hosts through lower Lindahl taxes, communication remains efficiency-enhancing.*

[10] We thank the Editors of this special issue for pointing this out.

Table 8 Chat outcomes of the PQ mechanism across treatments

	High Tax	Egalitarian	Low Tax	*p*-values[a]	Interrater agreement[b]
Initial discussion				(0.597)	0.901
Price and quantity	0.584	0.546	0.558		
Quantity first	0.234	0.247	0.325		
Price first	0.117	0.104	0.065		
Null	0.065	0.104	0.052		
Veto threat	0.000	0.022	0.014	(0.691)	0.806
Reached agreement	0.473	0.597	0.603	(0.176)	0.890
Host wrote first	0.311	0.374	0.192	(0.021)	0.848
Total chat entries	5.72	12.32	13.00	(< 0.001), (< 0.001), (0.229)	
Host's share of entries	0.298	0.303	0.274	(0.854), (0.465), (0.287)	

[a] *p*-value of a Fisher's exact test reported for the first four outcomes. For total chat entries and the host's share of chat entries, we report the *p*-values from between-treatment pairwise comparisons using *t*-tests

[b]The coding was performed independently by one of the authors and two research assistants. Discrepancies were solved *ex post* between the three coders. See more details in Appendix C

Recall that in the new treatments any positive provision harms the host (i.e., $v_N(q) < 0 \, \forall \, q > 0$). This paramterization primarily affects the outcomes without communication, via submitted prices. Table A.5 reveals that, without communication, the hosts raised the requested compensation in the *High Tax* and *Low Tax* scenarios with respect to the *Egalitarian* condition. With communication, there are no differences in submitted prices but rather in the requested quantities. Compared to the *Egalitarian* treatment, the *High Tax* scenario reduced the host's requested quantity, whereas the *Low Tax* scenario increased it. In light of this evidence, **H2**, **H3**, and **H4** hold when the expected inequality in the Lindahl equilibrium favors the majority of non-hosts.

7 Analysis of chat logs

In the spirit of Cooper and Kagel's (2005) "content analysis" method, we describe and analyze the information of chat logs to gain further insights into how players interact within the mechanism. Table 8 reports, for each treatment, six chat outcomes of interest for the PQ mechanism. The unit of analysis is the group × round, which we will refer to as a (group) interaction. The reported statistical tests let us check for differences between treatments in the use of communication.

Recall that we instructed participants to talk about their proposals "in terms of quantities (Q) and contributions (P) or compensations (negative P)." Hence, we coded the dimension that groups started discussing in each interaction: Q, P, or both. We find that 56% of interactions start the interaction with a discussion of the two dimensions (without differences between treatments). Moreover, Fig. A.6 in the Appendix suggests some learning: if we divide interactions into practice rounds

Table 9 Random effects regression for how communication affects the PQ mechanism's outcomes

	Prob. of provision		Provided quantity	
	(1)		(2)	
Initial discussion: price and quantity	0.063	(0.071)	− 0.323*	(0.173)
Initial discussion: price first	0.034	(0.114)	− 0.394**	(0.178)
Initial discussion: null	− 0.152	(0.397)	− 1.116***	(0.291)
Non-binding agreement	0.226***	(0.074)	0.351***	(0.106)
Host's share of lines	0.296**	(0.126)	0.059	(0.548)
Constant	0.446***	(0.117)	3.345***	(0.255)
Observations	286		177	

Non-significant regressors omitted from output: whether the host started the discussion and the total number of lines per interaction. Both regressions include round fixed effects. Clustered standard errors at the group level (43 groups) are shown in parentheses. Model (1) is a linear probability model

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

(1–3), an early stage (4–7), and a late stage (8–10), more groups start discussing P and Q simultaneously, and fewer discuss only Q. Suggestions to repeat their previous play, which is by definition a joint discussion of P and Q, only accounts for 5.5% of the total interactions (about one-tenth of the reported discussions of P and Q). On the other hand, 26 and 10% of groups start discussing quantities and prices, respectively. The initial timing of Q and P in this discussion matters because it may signal the group's prioritization of efficiency over equality, which translates into differences in provision levels (although not in the probability of provision), as suggested in Fig. A.7.

Table 8 reveals that the rare use of veto (i.e., $q_i = 0$) is accompanied by almost no threats to use it. Most of the observed veto threats came from the same group of participants, and the non-hosts did not chat when the host started the interaction with this threat. On a different note, we find that the share of groups reaching a non-binding agreement (47–60%) is slightly lower than the probability of provision previously reported for each treatment with communication (52–64%). Differences between treatments are not statistically significant for these two chat outcomes. Note also that in the *High Tax* condition, the fewer agreements are accompanied by fewer messages (or chat entries) per interaction, about half with respect to the other two treatments (p-values below 0.001). This result is consistent with the null effects of communication in this treatment. On the other hand, note that the host is less likely to begin the interaction in the *Low Tax* condition (p-value 0.021). However, the total share of messages from the host in each interaction does not differ between treatments.

Result 5 *The exceptional use of veto is grounded in the low frequency* (1%) *of veto threats*.

Table 9 shows that the dimensions initially discussed, P and Q, P, or none (Q is the excluded category), does not predict the probability of provision, but all three categories have a negative and statistically significant coefficient. Hence, interactions where the quantity was discussed first yield, on average, larger and more efficient provisions. As one would expect, groups reaching a non-binding agreement are more likely to provide the project (23 pp) and do so with larger quantities (0.35 units). Among the variables capturing the asymmetry between players, the only predictor correlated with a higher provision is the host's share of lines during the interaction. Table A.6 reveals similar qualitative results when the *High* and *Low Tax* treatment variables are included and interacted with the categories of the initial discussion. It also reveals that, in the *High Tax* condition, not having a discussion or starting with a discussion of the price is correlated with a dramatic decrease in the probability of provision.

Result 6 *The probability of provision is positively correlated with reaching a non-binding agreement and the host's involvement in the discussion* (*measured by her share of chat entries*). *The provided quantity is positively correlated with reaching a non-binding agreement and with discussing quantities rather than prices first*.

8 Concluding remarks

We tested Van Essen and Walker's PQ mechanism in the context of highly asymmetric benefits from the public project. Communication increased the provided quantity in exchange for a larger host's compensation and improved the group's ability to meet the budget constraint. By contrast, communication did not increase the likelihood of provision. One explanation for this null result is that communication delayed the stability of an agreed quantity. However, once groups reached this stable quantity, they were more efficient and had a higher likelihood of provision.

Despite the efficiency-enhancing effect of communication, most of the surplus was kept by non-hosts. The first explanation is that veto threats and vetoed projects were extremely rare (one percent). This result contrasts with how committee members holding veto power obtain larger payoff shares (Kagel et al., 2010). Moreover, suppose we interpret the mechanism's quantity output as a unanimity rule for selecting the project size (i.e., no participant would prefer a lower quantity). In that case, our results also contrast with previous findings on how the unanimity rule promotes egalitarian payoffs in the presence of communication (Agranov & Tergiman, 2019).

The second explanation is that misunderstanding the PQ mechanism fosters narratives that favor unequal profit sharing: non-hosts agreed to reduce their requested quantities in exchange for lower contributions. Although their reduction had no consequences for the mechanism's output quantity and only eased the coordination of a size-dependent transfer, it appeared to be part of a bargaining strategy that increased payoff inequality. The narrative of non-hosts, of contributing more and then claiming a larger surplus share, is compatible with Baranski's (2016) findings, where voting outcomes reveal that allocations proportional to contributions are an acceptable source of payoff inequality in a bargaining game where the efficiency surplus is endogenous. This unequal profit sharing may also result from our "public project" framing: the host's utility may increase from helping in the collective effort to provide the facility, even if it comes at an individual cost of being under-compensated. Similar framing effects in bargaining processes are reported in Arkes et al. (2017), who find that a labor/management framing reduced acceptable offers in an ultimatum game.

Having a majority who directly benefits from provision, and a minority that indirectly benefits through redistribution, favors decisions that look like the efficiency-over-equality outcomes reported in Gangadharan et al. (2017). The failure to jointly pursue efficiency and equality is not exclusive from the *ex post* redistribution structure in Gangadharan et al., but it also occurs within our mechanism, where redistribution intentions must be committed simultaneously with the efficiency aims. As in Dekel and Fischer (2017), communication is helpful to compensate participants harmed by the project, though not to its maximum level. We show that redistribution does not need to occur *ex post* (as if it was purely based on reciprocity), but can also emerge through the intended compensation in our mechanism.

We created two alternative scenarios with an efficiency-equality trade-off where (i) lower taxes favor the majority or (ii) higher taxes favor the minority. Communication preserved its efficiency-enhancing role when inequality favored the majority. By contrast, when the equilibrium payoff favored the host, the participant in this role could not enforce higher compensations, interactions were shorter (i.e., fewer chat entries), and provision probabilities and quantities also fell.

Could the PQ mechanism yield more egalitarian outcomes? One alternative would be to have two hosts and a single non-host to check whether a majority asking for compensation is compatible with the efficiency-enhancing effects of communication. A second alternative would be a multi-stage variation of the PQ mechanism, à la Bagnoli and Lipman (1989), with sequential rounds of contributions. After each round, the provision increases by one unit if the round's contributions are sufficient. With this exogenous and marginal increase in the quantities, the strategy of "accepting" a lower quantity in exchange for a lower contribution will not be available to the non-hosts, which may lead participants to focus on agreements that reduce payoffs' inequalities.

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