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Working Paper

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Jena Economic Research Papers, No. 2012,034

Provided in Cooperation with:
Max Planck Institute of Economics

Suggested Citation: Güth, Werner; Koukoumelis, Anastasios; Levati, M. Vittoria; Ploner, Matteo (2012) : Public projects benefiting some and harming others: Three experimental studies, Jena Economic Research Papers, No. 2012,034, Univ. u.a., Jena

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JENA ECONOMIC RESEARCH PAPERS



2012 – 034

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by

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www.jenecon.de

ISSN 1864-7057

The JENA ECONOMIC RESEARCH PAPERS is a joint publication of the Friedrich Schiller University and the Max Planck Institute of Economics, Jena, Germany. For editorial correspondence please contact markus.pasche@uni-jena.de.

Impressum:

Friedrich Schiller University Jena
Carl-Zeiss-Str. 3
D-07743 Jena
www.uni-jena.de

Max Planck Institute of Economics
Kahlaische Str. 10
D-07745 Jena
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Public projects benefiting some and harming others: three experimental studies

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Abstract

Based on an axiomatically derived provision rule allowing community members to endogenously determine which, if any, public project should be provided, we perform experiments where (i) not all parties benefit from provision, and (ii) the projects' "costs" can be negative. In the tradition of legal mechanism design, the proposed provision rule is widely applicable. Additionally, it relies on intuitive fairness and profitability requirements. Our results indicate that the provision rule is conducive to efficiency, despite its multiplicity of equilibria and underbidding incentives. The only condition is that the cost of the most efficient project is positive.

JEL Classification: C72, C92, D63, H44

Keywords: Public project, Bidding behavior, Procedural fairness

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1 Introduction

Public projects vary in how costly or rewarding they can be. Yet the literature has focused on public goods, that is projects which are valuable for all parties involved. Here we do not confine ourselves to public goods, but consider as well projects whose provision benefits some people and harms others. Relevant examples include the construction of a highway or a football stadium; the pollution and noise associated with their operation could annoy the people that live close-by. We say that such projects cause mixed feelings.

Additionally, while the provision of public goods usually entails positive costs, we allow for public projects whose “costs” are negative, in the sense that they generate revenues or that they replace more expensive projects. The exploitation of a natural resource (drilling for oil, mining, etc.) is the most obvious example of a revenue-generating project. As an example of the second category, people that invest in residential solar panels cut down on energy, but may also benefit from rebate programs and tax credits applicable to renewable energy equipment.

Following the literature on provision point (or threshold) public goods mechanisms (e.g., Bagnoli and Lipman 1989; Bagnoli and McKee 1991; Marks and Croson 1998; Cadsby and Maynes 1999; Cadsby et al. 2008; Spencer et al. 2009), we assume that the size and the cost of the projects are predetermined. There are several competing projects on offer, but the involved parties have no saying in either their quantity or their quality; they can only decide which project, if any, should be provided.

In the literature, each group member typically decides how much of his endowment to spend on a public good. We allow instead the group members

to bid for each available public project.¹ The bids that they report express the maximal amounts that they are willing to pay for implementing these projects.

Our axiomatic approach draws on legal or constitutional mechanisms that, in game theoretic terminology, define a game form but not a proper game. To give an example of a game form, think of the acquisition of goods or services by a public authority. The laws that regulate the procurement process apply to a wide range of contracts. The definition of the proper game necessitates additional information. For example, the procuring authority could be required to issue public tenders if the contract is worth over a certain value.

Why do we derive the provision rule axiomatically rather than search for welfare optimal mechanisms? The answer is twofold. First, we are interested in a general rule that does not require explicit knowledge of certain aspects of the proper game like the true valuations of the bidders and their beliefs about the others' true valuations.² Second, we want the rule to be appealing from an ethical point of view. In particular, the provision rule that we propose is procedurally fair. Procedural fairness is insured by our basic equality axiom requiring that the individual group members are treated equally according to an objective criterion, namely their bids. This holds even if the implemented project is not ex post valued the same by all group members. In this way, our approach differs from previous models that define fairness with respect to the final outcome (the so-called allocative fairness).³

The remainder of the paper is organized as follows. Section 2 outlines the

¹This is reminiscent of the auction mechanism for public goods proposed by Smith (1977).

²Common knowledge of all such aspects is, for example, necessary for applying the revelation principle (Myerson 1979).

³Chassang and Zehnder (2011) highlight the distinction between procedural and allocative fairness.

axiomatic characterization of the procedurally fair game form. Sections 3 and 4 report on two related past experiments and their main findings. Section 5 presents a new experimental study where we allow for negative “costs”. Section 6 concludes.

2 The procedurally fair provision rule

Let $\Omega = \{P_1, P_2, \dots, P_m\}$ be a finite set of m (≥ 2) indivisible public projects, and let $N = \{1, \dots, n\}$ denote a group of n (≥ 2) individuals facing the problem of determining which $P_\ell \in \Omega$ ($\ell = 1, \dots, m$), if any, should be provided.⁴ We assume that the cost of providing any particular $P_\ell \in \Omega$, denoted by $C(P_\ell) \in \mathbb{R}$, is commonly known, and that, if no project is provided, $C(\emptyset) = 0$.

Each individual $i \in N$ can influence the choice of P_ℓ by reporting the maximum that he is willing to pay for each project. Thus, each i submits a bid vector $\mathbf{b}_i = (b_i(P_\ell) \in \mathbb{R} : P_\ell \in \Omega)$. Without loss of generality, we set $b_i(\emptyset) = 0$ for all $i \in N$. The bid vectors of all n group members result in the bid profile $\mathbf{b} = (\mathbf{b}_1, \dots, \mathbf{b}_n)$. We refer to the difference between the sum of bids for P_ℓ and its cost as the surplus that P_ℓ generates “with respect to bids”, $S^{\mathbf{b}}(P_\ell) = \sum_{i=1}^n b_i(P_\ell) - C(P_\ell)$.

For all possible profiles \mathbf{b} , the provision rule must specify, first, which project $P_\ell^* := P_\ell^*(\mathbf{b}) \in \Omega$ should be provided, and, second, which amount $c_i(P_\ell^*, \mathbf{b}) \in \mathbb{R}$ should be paid by each group member i . We perform the analysis to derive this rule in objective terms, namely in terms of observable monetary bids, and disregard the subjective valuations for the public

⁴In our specification, P_ℓ is a single element of Ω . It is also possible to let the individuals choose among all non-empty subsets of a given set of projects, but this would require further assumptions about the complementarity or substitutability between the individual projects in the subset.

projects (which are hardly ever commonly known). The reason is that we want the rule itself (not necessarily the final outcome) to guarantee an equitable allocation of the surplus with respect to the maximal contributions that the individuals are willing to make. Hence, we define fairness with respect to bids and characterize the provision rule by the following three axioms.⁵

(A.1) *Profitability with respect to bids* requires that the chosen P_ℓ^* satisfies

$$\sum_{i=1}^n b_i(P_\ell^*) - C(P_\ell^*) = \max_{P_\ell \in \Omega} \{0, S^b(P_\ell)\},$$

i.e., P_ℓ^* guarantees the maximal non-negative surplus with respect to bids.

(A.2) The basic *equality axiom* affirms that if P_ℓ^* is provided, then

$$b_i(P_\ell^*) - c_i(P_\ell^*, \mathbf{b}) = b_j(P_\ell^*) - c_j(P_\ell^*, \mathbf{b}) \quad \forall i, j \in N \text{ and } \mathbf{b}.$$

That is, the difference between bid and payment (or one's net benefit with respect to bids) should be the same for all group members.

(A.3) *Cost balancing* means that the individual payments for the provided P_ℓ^* add up to its cost.⁶ Formally,

$$\sum_{i=1}^n c_i(P_\ell^*, \mathbf{b}) = C(P_\ell^*).$$

Thus, if there is no $P_\ell \in \Omega$ such that $\sum_{i=1}^n b_i(P_\ell) \geq C(P_\ell)$, no public project is provided and $c_i(P_\ell^*, \mathbf{b}) = 0$ for all $i \in N$.⁷ If, instead, there exists

⁵See Güth and Kliemt (2011) for a more elaborate discussion of these axioms.

⁶We impose this axiom, although one does not have to rule out taxing or subsidizing public project provision. See Güth et al. (2012) for an experiment investigating the robustness of procedurally fair bidding to the introduction of taxes and subsidies.

⁷If no project is provided, (A.2) and the assumption $b_i(\emptyset) = 0$ imply $0 - c_i(P_\ell^*, \mathbf{b}) =$

a $P_\ell^* \in \Omega$ such that $\sum_{i=1}^n b_i(P_\ell^*) \geq C(P_\ell^*)$ and $\sum_{i=1}^n b_i(P_\ell^*) - C(P_\ell^*) \geq \sum_{i=1}^n b_i(P_k) - C(P_k)$ for all $P_k \in \Omega$, then (A.2) can be reformulated as

$$b_i(P_\ell^*) - c_i(P_\ell^*, \mathbf{b}) = \Delta \quad \forall i \in N. \quad (1)$$

Aggregating over all n group members yields

$$\sum_{i=1}^n b_i(P_\ell^*) - \sum_{i=1}^n c_i(P_\ell^*, \mathbf{b}) = n\Delta,$$

which, using (A.3), can be written as

$$\Delta = \frac{\sum_{i=1}^n b_i(P_\ell^*) - C(P_\ell^*)}{n}.$$

Substituting for Δ in Eq. (1) we obtain

$$\begin{aligned} c_i(P_\ell^*, \mathbf{b}) &= b_i(P_\ell^*) - \frac{\sum_{j=1}^n b_j(P_\ell^*) - C(P_\ell^*)}{n} \\ &= b_i(P_\ell^*) - \frac{S^b(P_\ell^*)}{n} \quad \forall i \in N. \end{aligned} \quad (2)$$

Hence, the procedurally fair provision rule selects the public project that generates the maximal non-negative surplus with respect to bids, and imposes on each group member the payment given in Eq. (2).

Since $S^b(P_\ell^*) > 0$ is equally distributed among all group members, no group member has to pay more than his bid. Actually, by bidding either negatively or even sufficiently low for a specific project $P_\ell \in \Omega$ each member can either prevent it from being implemented or demand compensation in case it gets implemented. The provision rule therefore grants, in line with the Wicksellian unanimity rule, “veto rights” to all group members.⁸

$0 - c_j(P_\ell^*, \mathbf{b}) \quad \forall i, j \in N$. Thus, $c_i(P_\ell^*, \mathbf{b}) = c_j(P_\ell^*, \mathbf{b}) = 0$ due to $C(\emptyset) = 0$ and cost balancing.

⁸The principle of universal voluntary consent has also inspired the ‘action mechanism

Sections 3 to 5 report on experimental studies based on the above-described procedurally fair provision rule.⁹ Obviously, implementing the rule in the laboratory entails specifying a proper game with experimentally induced valuations for the public projects. For each player $i \in N$, let $v_i(P_\ell) \in \mathbb{R}$ denote i 's induced valuation for $P_\ell \in \Omega$. Then, under our provision rule, the payoff function of i is:

$$\pi_i(\mathbf{b}) = \begin{cases} 0 & \text{if } \sum_{i=1}^n b_i(P_\ell) < C(P_\ell) \quad \forall P_\ell \in \Omega, \\ v_i(P_\ell^*) - b_i(P_\ell^*) + \frac{\sum_{j \in N} b_j(P_\ell^*) - C(P_\ell^*)}{n} & \text{if } \sum_{i=1}^n b_i(P_\ell^*) \geq C(P_\ell^*) \\ \text{and } \sum_{i=1}^n b_i(P_\ell^*) - C(P_\ell^*) \geq \sum_{i=1}^n b_i(P_k) - C(P_k) \quad \forall P_k \in \Omega. \end{cases}$$

Finally, an additional property of the rule is overbidding proofness, meaning that any bid vector prescribing overbidding for a project is weakly dominated.¹⁰

3 Do mixed feelings matter more than efficiency?

The main aim of the experimental study by Güth et al. (2011) is to explore whether, under the procedurally fair provision rule delineated above, a public project that causes mixed feelings stands a fair chance of being provided in the face of competition from a less efficient public good. Efficiency is measured in terms of the project's social benefit, defined as the sum of the induced valuations for the project minus its provision cost (i.e., $\sum_{i=1}^n v_i(P_\ell) -$

for public goods' proposed by Smith (1977). Here, however, this principle is implied by our axioms (it is not an additional requirement).

⁹All three experiments were programmed in z-Tree (Fischbacher 2007) and conducted in the experimental laboratory of the Max Planck Institute of Economics (Jena, Germany). Participants were recruited from the undergraduate population at the University of Jena.

¹⁰The provision point rule, however, is not incentive compatible because it is not underbidding proof. Imposing, additionally, incentive compatibility would result in impossibility statements. Note that legal mechanisms typically do not satisfy incentive compatibility (public tenders, for instance, rely on the lowest bid-price rule with overbidding incentives).

$C(P_\ell)$.

3.1 Experimental design and parameters

The authors focus on the simplest possible scenario, that with two players, $N = \{1, 2\}$, and two public projects, $\Omega = \{x, y\}$. The players' induced valuations for the two projects are $v_1(x) = -40$, $v_2(x) = 140$, $v_1(y) = 40$, and $v_2(y) = 80$. In words, the provision of x yields mixed feelings, whereas y qualifies as a public good. Since $C(x) = 30$ and $C(y) = 70$, the social benefit generated by x exceeds that generated by y ($-40 + 140 - 30 > 40 + 80 - 70$).¹¹

In the main treatment, labeled M , each player $i \in N$ submits bids for both projects, $b_i^M(x)$ and $b_i^M(y)$. In the two control treatments, labeled X and Y , only one project is at stake. Each player i submits $b_i^X(x)$ in treatment X and $b_i^Y(y)$ in treatment Y . Bids are always integer numbers between -200 and 200 ECUs.

The three treatments are run one-shot in a within-subject design. Instead of considering all possible permutations of X , Y , and M , the authors implement only treatment sequences where M is played either first or last. They refer to the MXY and $M Y X$ (XYM and YXM) between-subject sequences as the M^F (M^L) sequences. At the beginning of each session, each participant is assigned the role of either low-value or high-value bidder, a role that he retains throughout the session. The matching protocol ensures that nobody meets the same participant more than once.

To minimize path dependence and learning effects, subjects did not receive any feedback about the others' bids, the provided project, and the resulting payoffs until the end of the session. To discourage portfolio diversification possibilities, one treatment was selected at random for payment

¹¹Valuations and costs are expressed in terms of ECUs (Experimental Currency Unit), with 5 ECUs = €1.

at the end of the session.

Inducing common knowledge of the experimental payoffs yields a complete information game with many pure strategy equilibria. In particular, in treatment M , besides non-provision equilibria in which the bidders veto both projects, there exists an abundance of provision equilibria requiring bids that (a) result in a non-positive surplus with respect to bids for one project, and (b) add up to the project's cost for the other project.

3.2 Results

The authors run one session for each of the four sequences (MXY , MYX , XYM , and YXM). Each session involves 32 inexperienced participants matched in pairs. Statistical tests indicate that the data can be pooled according to whether M is played first or last. Thus, the analysis relies on 64 independent observations per sequence (32 for low-value and 32 for high-value bidders).

There is an interesting order effect for $b_i^M(y)$: the M -treatment bids for y tend to be larger when M is played last. The histograms in Figure 1 show that while negative bids for y are far from being rare in the M^F sequence (left pane), they are non-existent in the M^L sequence (right pane). Experiencing both projects separately induces participants to increase the likelihood of providing y when the two projects are made available in tandem. This result holds more strongly for the high-value bidders.

[Figure 1 about here.]

Are bids for x affected by the availability of y ? Figure 2 compares kernel density plots of the observed bids for x in treatments X and M , conditioned on whether M is played first (left pane) or last (right pane). Even though the

M^F sequences exhibit a gap between the M - and the X -treatment estimates, a binomial sign test indicates no significant difference between the two sets of bids. The same holds for the M^L sequences for which the kernel density estimates are very close.

[Figure 2 about here.]

How do individuals modify their bids for x between treatments? In the M^F sequences, the majority of subjects either increase (42.2%) or do not change (28.1%) their bids when moving from M to X . In the M^L sequences, 39.1% of the participants bid the same amount in both treatments. Switching from X to M , 29.7% of the participants increase their bids by an average amount of 19.4 ECUs, and 31.3% of them decrease their bids by an average amount of 53.7 ECUs (thus the overall effect is negative). In sum, participants bid less for x when it faces competition from y but this difference is not statistically significant.

Actually, the finding that players do not differentiate their bids for x holds even when the sample is restricted to either the low-value or the high-value bidders. This is evident from the inspection of Figure 3, which also reveals that low-value bidders place predominantly negative bids.

[Figure 3 about here.]

Bidders veto the project that causes mixed feelings more often than the public good project, but vetoing is far from common practice. This is reminiscent of Buchanan's (1975) contractarian paradigm and suggests that people do not attempt to impose their will on others: if the agent that attaches a negative value to project x is sufficiently compensated by the other party, then he has no reason to a priori reject an agreement.

We now turn to the inspection of the provision rates of the two projects. Table 1 displays the percentage of successful provision of x and y in each of the three treatments under both sequences. The provision rate of x in treatment X is quite high (65.6% and 87.5% in the M^F and M^L sequences, respectively) and similar in magnitude to the provision rate of y in treatment Y (68.8% and 81.3%, respectively). Hence, it is rather the coordination problem than the presence of mixed feelings that should be held responsible for the provision failure of x in X . Further evidence that participants assign little importance to mixed feelings is given by the fact that in M they provide x more often than y .

[Table 1 about here.]

Thus, the presence of mixed feelings is not detrimental to cooperation, provided of course (as the authors assume) that the project causing these feelings is relatively efficient, and that the party that gains from the project can compensate the party that suffers.

4 Are the results sensitive to the definition of Ω or the type of provided information?

Cicognani et al. (2012) enrich Güth et al.'s (2011) experimental setting to examine (a) how bid levels and provision rates are affected by changes in the induced valuations associated with Ω , and (b) whether the implementation of the most efficient project depends on the arguably unrealistic assumption of complete information.

4.1 Experimental design and parameters

Cicognani et al. (2012) consider groups of three individuals, $N = \{1, 2, 3\}$,

and five alternative Ω sets, each one of them consisting of seven public projects.¹² Let us indicate the generic set of projects by $\Omega^s = \{P_1^s, \dots, P_7^s\}$, $s = 1, \dots, 5$. For each P_ℓ^s , where $\ell = 1, \dots, 7$ and $s = 1, \dots, 5$, Table 2 reports the project's cost, $C(P_\ell^s)$, the induced valuations for the project, $v_i(P_\ell^s) \forall i \in N$, and the resulting social benefit, $\sum_{i=1}^3 v_i(P_\ell^s) - C(P_\ell^s)$.¹³

[Table 2 about here.]

Ω^1 is the reference set from which all other sets are derived. The projects in Ω^2 are equally efficient with but less costly than those in Ω^1 . P_1^3 is a public bad, that is all group members attach a negative value to it. The projects in Ω^1 and Ω^4 generate identical social benefits, the projects in Ω^4 however are valued the same by all group members. Finally, while the maximal social benefit in Ω^1 to Ω^4 equals 54, Ω^5 contains the most efficient project (namely P_6^5 with a social benefit of 60).

Each participant is exposed to all five project sets and to all three induced valuations, implying that the experiment is conducted over a sequence of 15 independent periods. In each period, each group member $i \in N$ submits a bid vector \mathbf{b}_i with seven elements, one element for every project in Ω^s . The bids are not restricted to a pre-specified interval. In line with Güth et al. (2011), (a) participants receive no feedback throughout the session, and (b) one of the 15 periods is randomly selected for payment at the end of the session.

To assess the efficacy of the provision rule in informationally limited settings, two treatments are implemented in a between-subject design. Participants in a public information (*PUBL*) treatment know the other group

¹²Actually, Cicognani et al. assume that each set consists of three projects and consider the seven possible non-empty subsets of each set. We regard each subset as an alternative project in order to be consistent with the other experiments presented in the paper.

¹³All monetary amounts are expressed in ECUs, with 1 ECU = €1.

members' induced valuations, whereas participants in a private information (*PRIV*) treatment have no knowledge about any valuation other than their own.

4.2 Results

The authors ran one session per treatment: 30 (27) students participated in the treatment with public (private) information. Since the participants experienced all three induced valuations, their numbers correspond to the number of independent observations in the two treatments.

For all $i \in N$ and $P_\ell^s \in \Omega^s$, the relative deviation between observed bid and induced valuation is measured by the variable $R_i(P_\ell^s) = \frac{b_i(P_\ell^s) - v_i(P_\ell^s)}{|v_i(P_\ell^s)|}$. Figure 4 shows boxplots of the average (over subjects and projects) $R_i(P_\ell^s)$ values for all project sets and information conditions. There is a widespread, strong tendency to underbid, i.e., to post bids which are lower than one's own valuations of the projects.¹⁴

Underbidding is particularly prevalent in the case of Ω^2 , a project set that comparatively allows for more underbidding before provision is jeopardized. On the other hand, the magnitude of the average underbid is slightly smaller in the case of Ω^4 , where the group members' induced valuations are all positive and homogeneous. These findings suggest that negative and heterogeneous induced valuations are likely to result in more underbidding, irrespective of the information condition.

[Figure 4 about here.]

Even if underbidding behavior may endanger the provision of any public

¹⁴The data are therefore not consistent with the hypothesis that in a complex environment subjects use the simple heuristic of truthful bidding.

project, the data of the present study show otherwise. In Table 3,¹⁵ the sum of all seven projects' provision rates ranges from 63.7% (Ω^3 , private information) to 91.8% (Ω^2 , private information). Moreover, for each Ω set and for both information conditions, the most frequently provided project is the most efficient one.

[Table 3 about here.]

We conclude that private information about valuations does not significantly affect either bidding behavior (players underbid by roughly the same amount in both information conditions) or the proportion of successful provision. The participants apparently focus on their own valuations when deciding on their bids.

5 Is the most efficient project implemented when “costs” are negative?

The experiments discussed in the previous sections have revealed that the proposed procedurally fair provision rule is rather effective in implementing the most efficient project, notwithstanding the presence of mixed feelings (Güth et al. 2011) and private information (Cicognani et al. 2012). Herein, we test the robustness of these findings to the inclusion of projects with negative “costs” (namely revenue-generating projects). The empirical questions we are primarily interested in answering are the following. (i) Will the presence of revenue-generating projects endanger the provision of the most efficient, but costly, project? (ii) Does this depend on the existence of mixed feelings? (iii) How do negative “costs” affect the behavior of low-value and

¹⁵The numbers in the table are computed by randomly matching participants in three-person groups; the actual groups are disregarded. This procedure is justified on the grounds that participants received no feedback.

high-value bidders? (iv) Will private, rather than public, information about induced valuations influence bids when some projects have negative “costs”?

5.1 Experimental design and parameters

Subjects are divided into groups of two, $N = \{1, 2\}$, and confronted with two alternative Ω sets only once. Each Ω^s ($s = 1, 2$) consists of four projects, $\Omega^s = \{P_1^s, \dots, P_4^s\}$. Table 4 displays, for each Ω^s , the costs, induced valuations, and resulting social benefits of each of the four constituent projects.¹⁶

[Table 4 about here.]

The projects in Ω^1 can be ordered by their efficiency, the most efficient being the project that causes mixed feelings and has positive costs. The provision rates of each of the four projects in Ω^1 allow us to assess whether, in line with the results of Güth et al. (2011) and Cicognani et al. (2012), the most frequently implemented project remains the most efficient one even when it competes with revenue-generating projects (question (i) above).

Two projects in Ω^2 are equally maximally efficient (P_2^2 and P_4^2), and both have positive provision costs. The other two projects (P_1^2 and P_3^2) generate the same (lower) social benefit, and both cost -25 . Additionally, while P_1^2 and P_2^2 cause mixed feelings, P_3^2 and P_4^2 are public goods. By comparing $b_i(P_2^2) - b_i(P_1^2)$ to $b_i(P_4^2) - b_i(P_3^2)$, we can examine whether a project with negative “costs” affects bidding behavior differently depending on whether mixed feelings are present or not.

In the one-shot experiment, each group member i ($= 1, 2$) submits two bid vectors \mathbf{b}_i , one for every Ω set. Each vector has four components (expressing i 's bid for the four projects in the corresponding set). Bids are always integer numbers between -500 and 500 ECUs.

¹⁶All variables are expressed in ECUs with $5 \text{ ECUs} = \text{€}1$.

To exclude possible order effects, the two Ω sets are presented on the same screen in a randomized manner (Ω^1 appears on the left for half of the participants and on the right for the other half) and the four projects in each set are reordered (renumbered 1 to 4) randomly for each subject. At the end of the session, one set is chosen randomly and subjects are paid according to their bids for the projects in that set.

To investigate whether low-value bidders are more likely than high-value bidders to be affected by the presence of revenue-generating projects (question (iii) above), each participant is assigned one of the two roles, either bidder 1 or bidder 2, in both Ω sets.

Although Cicognani et al.'s (2012) study finds no significant difference in bidding behavior when the others' valuations are known and unknown, the question can be raised as to whether or not this result would hold up in the presence of projects with negative "costs" (question (iv) above). To shed light on this question, we compare two treatments in a between-subjects design: one where valuations are public information (treatment *PUBL*) and the other where valuations are private information (treatment *PRIV*).

5.2 Results

We ran two sessions per treatment (*PUBL* and *PRIV*). Each session involved 32 participants matched in pairs so that, in total, our analysis relies on 64 individuals (32 low-value and 32 high-value bidders) in each of the two treatments.

We present the results following the order of the four research questions. The first question relates to the effect of negative "costs" on the provision of the most efficient project. To examine this question, we look at the provision rates of the four projects in the two Ω sets, focusing in particular

on Ω^1 where the projects can be ordered by their efficiency. The provision rates are displayed in Table 5, separately for the two information conditions (see also Figure 5).

[Table 5 about here.]

[Figure 5 about here.]

The most efficient project in Ω^1 (namely P_2^1) is not the most frequently implemented project, regardless of the information condition. Actually, in treatment *PUBL*, P_2^1 is the least provided project (9.4%). Provision rates are the highest for the two revenue-generating projects (P_1^1 : 43.7% in *PUBL* and 40.6% in *PRIV*; P_3^1 : 31.2% in both *PUBL* and in *PRIV*). It seems that, when the projects can be ordered by their efficiency, participants are first attracted by negative “costs”, and then, given that the projects generate the same revenue, they provide the more efficient between them. In Ω^2 , where the two revenue-generating projects (P_1^2 and P_3^2) are equally efficient, they remain the most frequently implemented ones and their provision rates are very similar. These findings suggest a positive answer to the first research question: under the described procedurally fair rule, the provision of the most efficient project is endangered by the existence of negative “costs”.

The second research question concerns whether the influence of negative “costs” is different for mixed-feelings projects and public goods. To answer this question, we concentrate on Ω^2 and take into account $b_i(P_2^2) - b_i(P_1^2)$ (both these projects cause mixed feelings, but P_1^2 has negative “costs”) and $b_i(P_4^2) - b_i(P_3^2)$ (both these projects qualify as public goods, but P_3^2 has negative “costs”). A graphical representation of these differences is given in Figure 6, which suggests that $b_i(P_2^2) - b_i(P_1^2)$ and $b_i(P_4^2) - b_i(P_3^2)$ are rather similar for both information conditions. The lack of significant difference is

confirmed by two-sided Wilcoxon rank-sum tests: the p-values equal 0.247 for *PUBL* and 0.809 for *PRIV*. We conclude that the second research question has a negative answer.

[Figure 6 about here.]

Turning to the third research question (whether the two types of bidders are affected differently by negative “costs”), Table 6 reports, for each Ω set and information condition, summary statistics of the relative deviations between observed bids and induced valuations (i.e., the variable $R_i(P_\ell^s) = \frac{b_i(P_\ell^s) - v_i(P_\ell^s)}{|v_i(P_\ell^s)|}$ with $s = 1, 2$ and $\ell = 1, \dots, 4$), separately for low-value and high-value bidders.

[Table 6 about here.]

The mean and median values in Table 6 indicate that for the projects with negative “costs” (i.e., P_1^s and P_3^s) low-value bidders tend to overbid (relative deviations are positive) and high-value bidders tend to underbid (relative deviations are negative), whatever the Ω set and the information condition. In contrast, there is a generalized tendency to underbid for the projects entailing positive costs (i.e., P_2^s and P_4^s).

On the basis of two-sided Wilcoxon rank-sum tests, the null hypothesis that the $R_i(P_\ell^s)$ values of the two types of bidders have identical distributions can be rejected (i) at the conventional 5% level for P_1^1 and P_1^2 in *PUBL* and for P_3^2 in *PRIV*, and (ii) at the 10% level for P_3^2 in *PUBL* and for P_1^1 , P_3^1 , and P_1^2 in *PRIV*. If we pool the data from both information conditions, the differences in $R_i(P_\ell^s)$ (with $l = 1, 3$) between low-value and high-value bidders are always highly significant (all p-values ≤ 0.033).¹⁷ The

¹⁷For all the other comparisons, these differences are not significant.

results concerning the third research question show thus that the bidding behavior of low-value and high-value bidders differs significantly in case of negative “costs” (low-value bidders tend to overbid relative to their induced valuations and high-value bidders tend to underbid), whereas no systematic differences in relative underbidding are observed in case of positive costs.

The fourth and last research question pertains to the impact of private information on bid levels when some projects have negative “costs”. Figure 5 hints that the average surplus with respect to bids does not differ between the two information conditions. Wilcoxon rank sum tests confirm that switching from public to private information does not affect bids for the same project (all p-values exceed 0.528), which provides a negative answer to the fourth research question.

6 Conclusions

We proposed and experimentally tested a bidding mechanism for public project provision. The mechanism always relies on a procedurally fair rule (or game form), which we derived from three intuitive and appealing axioms.

The experimental studies conducted so far mainly served to evaluate the practicability of this mechanism. They demonstrated its potential not only to induce high rates of successful provision, but also to implement the most efficient project. Yet, the latter holds only when the public project entails positive costs. The findings from our third experiment show, indeed, that the presence of revenue-generating projects endangers the provision of the most efficient, but costly, project.

The mechanism can be easily applied to specific situations such as international voluntary activities for environmental protection. This application requires (i) a set of public projects directed at, e.g., reducing pollutants or

securing renewable energy supply (like solar and wind), and (ii) a group of cooperating countries. The individual veto rights (which are implied, rather than required, by our axioms) allow each country in the group to prevent the implementation of a project that it deems undesirable. Thus, participating in such a group is rather unproblematic. Additionally, although the possibility of veto may confer power upon a single country, our experiments show that the procedural fairness of the mechanism causes the involved parties to not a priori reject an agreement.

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Table 1: Rates of provision of projects x and y in all treatments and sequences

	M		X	Y
	x	y		
M^F sequences	43.8	15.6	65.6	68.8
M^L sequences	50.0	43.8	87.5	81.3

Note Güth et al. (2011, Table 4).

Table 2: Alternative Ω^s , $s = \{1, \dots, 5\}$, presented to the participants

Set	P_ℓ^s	$C(P_\ell^s)$	$v_1(P_\ell^s)$	$v_2(P_\ell^s)$	$v_3(P_\ell^s)$	$\sum_{i=1}^3 v_i(P_\ell^s) - C(P_\ell^s)$
Ω^1	P_1^1	30	30	-30	45	15
	P_2^1	60	0	24	45	9
	P_3^1	36	6	18	18	6
	P_4^1	90	30	-6	105	39
	P_5^1	45	36	-12	75	54
	P_6^1	96	6	42	63	15
	P_7^1	135	36	12	75	-12
Ω^2	P_1^2	15	27	18	-15	15
	P_2^2	30	27	0	12	9
	P_3^2	18	9	6	9	6
	P_4^2	45	-6	30	60	39
	P_5^2	24	60	-12	30	54
	P_6^2	48	33	3	27	15
	P_7^2	69	33	18	6	-12
Ω^3	P_1^3	30	-24	-30	-6	-90
	P_2^3	60	0	24	45	9
	P_3^3	36	6	18	18	6
	P_4^3	90	-24	-6	36	-84
	P_5^3	45	-18	-12	12	-63
	P_6^3	96	18	60	72	54
	P_7^3	135	-9	33	75	-36
Ω^4	P_1^4	30	15	15	15	15
	P_2^4	63	24	24	24	9
	P_3^4	48	18	18	18	6
	P_4^4	105	48	48	48	39
	P_5^4	45	33	33	33	54
	P_6^4	93	36	36	36	15
	P_7^4	138	42	42	42	-12
Ω^5	P_1^5	30	78	-30	-12	6
	P_2^5	60	0	24	45	9
	P_3^5	36	-6	18	18	-6
	P_4^5	63	30	-18	105	54
	P_5^5	45	6	-24	105	42
	P_6^5	57	15	42	60	60
	P_7^5	141	72	12	51	-6

Note Cicognani et al. (2012, Table 1).

Table 3: Rates of provision of the seven projects in each Ω^s , $s = \{1, \dots, 5\}$, and information condition

Proj.	Ω^1		Ω^2		Ω^3		Ω^4		Ω^5	
	<i>PUBL</i>	<i>PRIV</i>	<i>PUBL</i>	<i>PRIV</i>	<i>PUBL</i>	<i>PRIV</i>	<i>PUBL</i>	<i>PRIV</i>	<i>PUBL</i>	<i>PRIV</i>
P_1^s	1.8	2.2	4.3	3.5	0.0	0.0	1.7	0.1	2.4	2.0
P_2^s	0.6	0.3	0.5	0.3	1.6	2.1	0.0	0.0	0.1	0.0
P_3^s	0.0	0.1	1.2	0.0	2.1	0.1	0.0	0.0	0.0	0.0
P_4^s	12.5	9.6	23.4	28.6	0.0	0.0	1.5	0.3	29.3	18.8
P_5^s	62.7	65.9	59.4	59.3	0.0	0.0	79.2	87.8	2.7	4.9
P_6^s	2.5	0.0	1.2	0.1	69.3	61.5	0.0	0.0	56.3	63.5
P_7^s	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Note Cicognani et al. (2012, Table 3). The bold font identifies the most efficient project in each Ω^s .

Table 4: Alternative Ω^s , $s = \{1, 2\}$, presented to the participants

Set	P_ℓ^s	$C(P_\ell^s)$	$v_1(P_\ell^s)$	$v_2(P_\ell^s)$	$\sum_{i=1}^2 v_i(P_\ell^s) - C(P_\ell^s)$
Ω^1	P_1^1	-25	-20	100	105
	P_2^1	20	-20	160	120
	P_3^1	-25	20	50	95
	P_4^1	20	20	110	110
Ω^2	P_1^2	-25	-10	90	105
	P_2^2	20	-10	150	120
	P_3^2	-25	15	65	105
	P_4^2	20	15	125	120

Table 5: Rates of provision of the four projects in each Ω^s , $s = \{1, 2\}$, and information condition

Project	Ω^1		Ω^2	
	<i>PUBL</i>	<i>PRIV</i>	<i>PUBL</i>	<i>PRIV</i>
P_1^s	43.7	40.6	31.2	40.6
P_2^s	9.4	18.7	18.7	12.5
P_3^s	31.2	31.2	46.8	40.6
P_4^s	12.5	6.2	12.5	12.5

Note The bold font identifies the most efficient project(s) in Ω^s .

Table 6: Summary statistics of relative deviations of observed bids from induced valuations for each Ω^s , $s = \{1, 2\}$, and information condition, separately for low-value and high-value bidders

Treatment	Set	Bidder type	P_1^s	P_2^s	P_3^s	P_4^s	
<i>PUBL</i>	Ω^1	Low-value	Mean	0.33	-1.63	0.19	-0.51
			Median	1.00	0.00	0.00	-0.50
			Std. Dev.	5.14	6.08	2.07	1.40
		High-value	Mean	-0.28	-0.42	-0.40	-0.40
			Median	-0.20	-0.38	-0.40	-0.32
			Std. Dev.	0.53	0.38	0.93	0.45
	Ω^2	Low-value	Mean	1.72	-1.48	0.58	-1.07
			Median	1.00	0.00	0.00	-0.33
			Std. Dev.	2.47	11.45	3.30	7.22
		High-value	Mean	-0.29	-0.36	-0.39	-0.39
			Median	-0.11	-0.33	-0.19	-0.32
			Std. Dev.	0.53	0.39	0.87	0.43
<i>PRIV</i>	Ω^1	Low-value	Mean	-0.15	-3.19	0.39	-2.36
			Median	0.50	-0.25	0.13	-0.38
			Std. Dev.	5.45	7.91	3.34	6.86
		High-value	Mean	-0.08	-0.25	-0.51	-0.28
			Median	-0.15	-0.25	-0.20	-0.22
			Std. Dev.	0.74	0.62	1.52	0.77
	Ω^2	Low-value	Mean	0.23	-7.69	1.07	-4.98
			Median	0.25	0.00	0.33	-0.33
			Std. Dev.	10.70	17.29	3.96	11.78
		High-value	Mean	-0.17	-0.25	-0.65	-0.26
			Median	-0.23	-0.30	-0.23	-0.18
			Std. Dev.	0.83	0.51	1.83	0.57

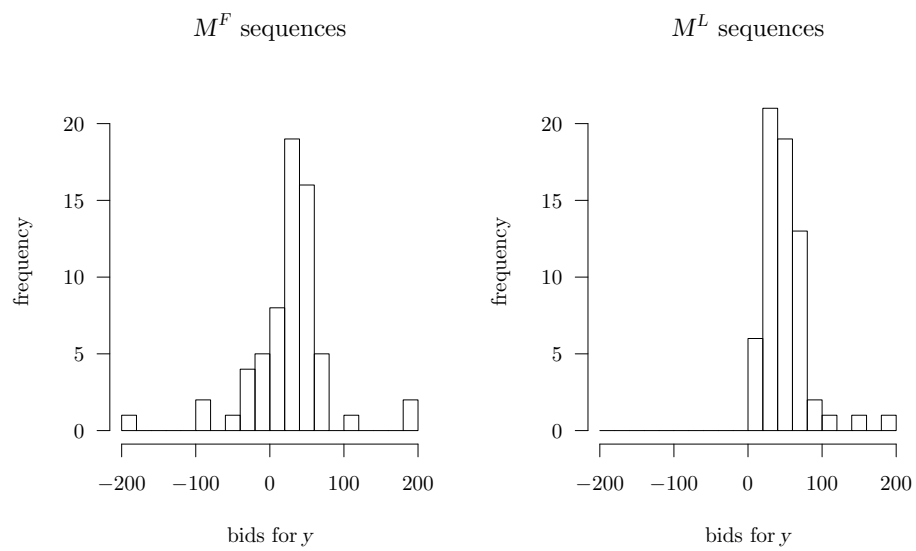


Figure 1: Histograms of bids for y in treatment M , separately for the M^F and M^L sequences (Güth et al. 2011, Figure 1).

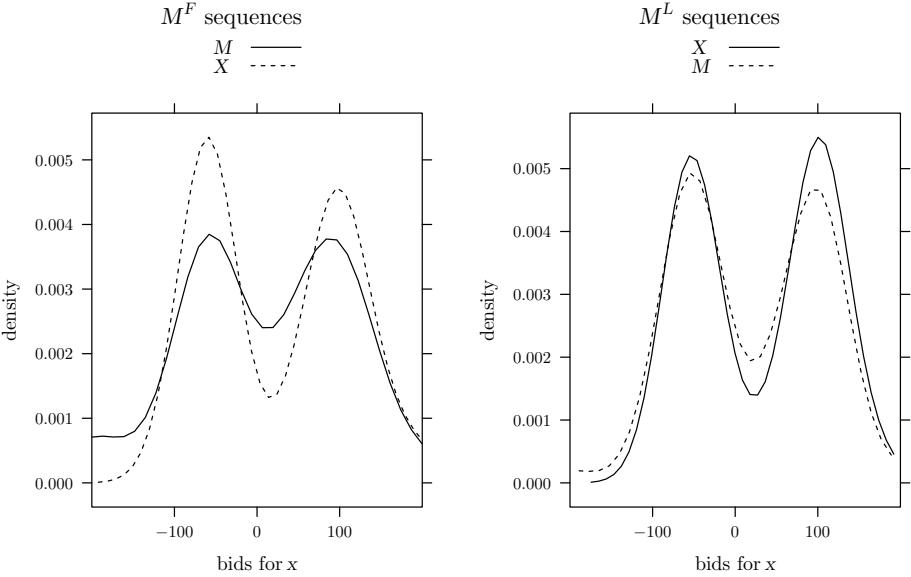


Figure 2: Kernel density estimates of bids for x in treatments M and X , separately for the M^F and M^L sequences (Güth et al. 2011, Figure 2).

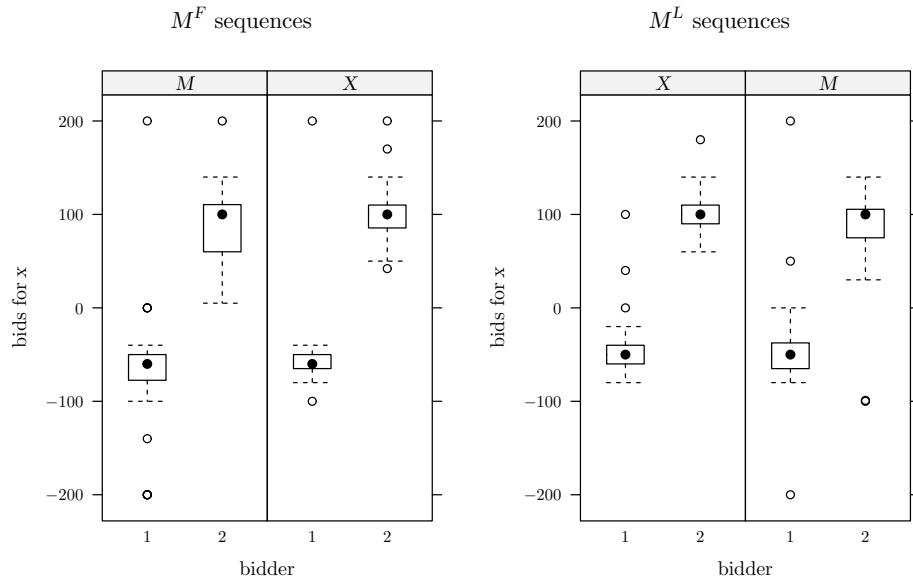


Figure 3: Boxplots of bids for x in treatments M and X , separately for low-value (labeled 1) and high-value (labeled 2) bidders (Güth et al. 2011, Figure 3).

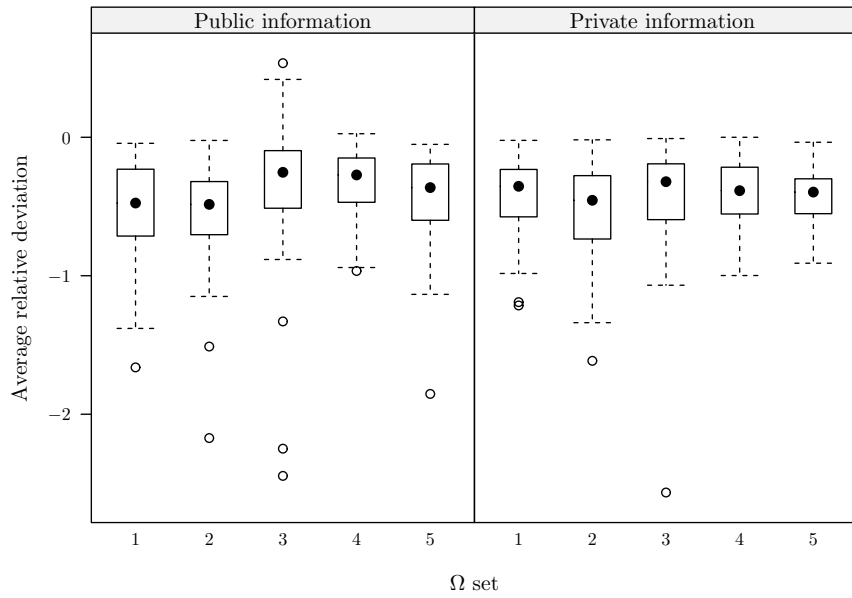


Figure 4: Boxplots of the average $R_i(P_\ell^s)$ values, representing the relative deviations of observed bids from induced valuations, separately for each Ω set and each information condition (Cicognani et al. 2012, Figure 3).

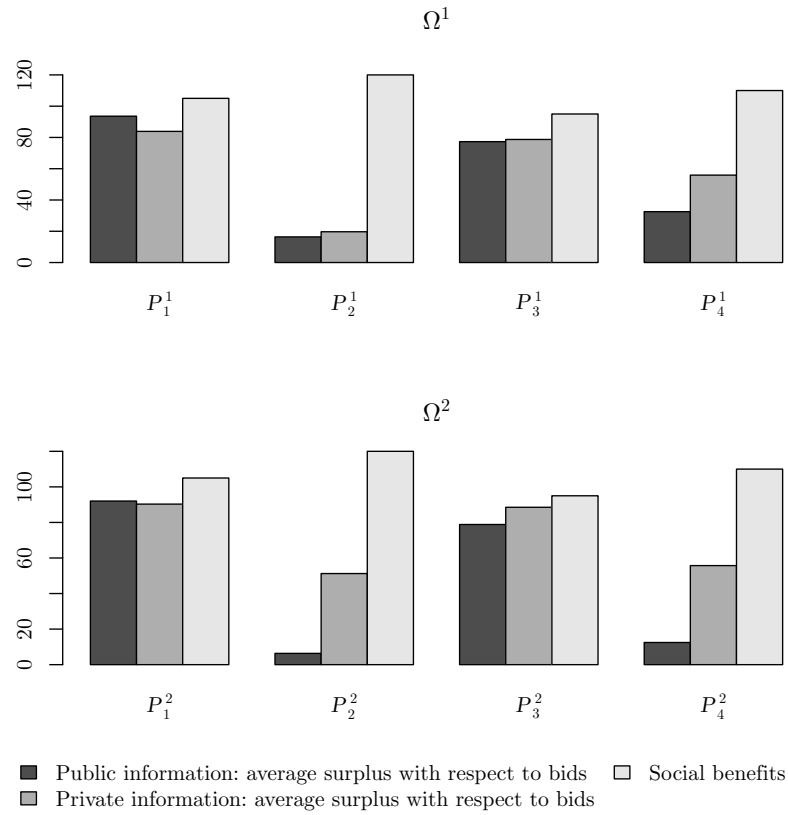


Figure 5: Average surpluses with respect to bids and corresponding social benefits for each project, each Ω set, and each information condition.

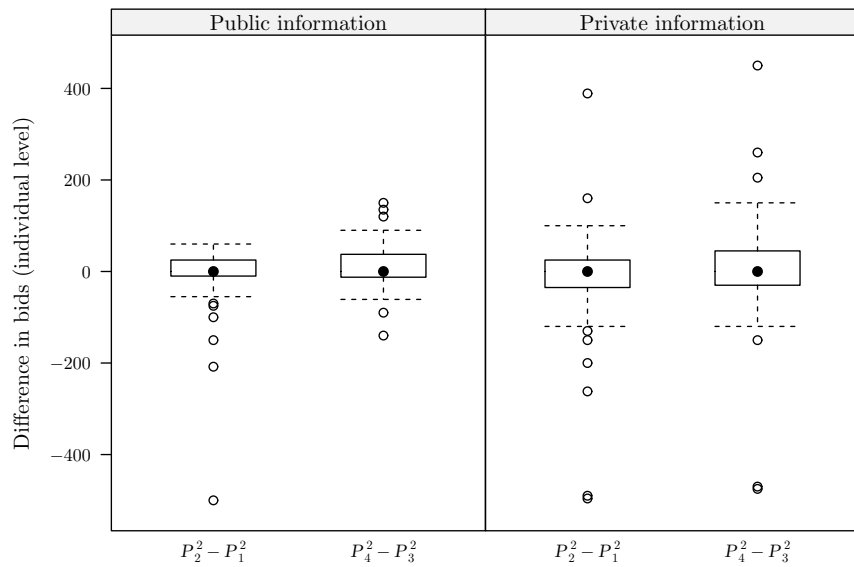


Figure 6: Boxplots of the differences in bids between projects with positive costs and projects with negative costs, separately for mixed-feelings projects ($b_i(P_2^2) - b_i(P_1^2)$) and public goods ($b_i(P_4^2) - b_i(P_3^2)$).