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Social Preferences and Voting: An Exploration Using a Novel Preference Revealing Mechanism

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Social Preferences and Voting: An Exploration Using a Novel Preference Revealing Mechanism*

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Abstract
Public referenda are frequently used to determine the provision of public goods. As public programs have distributional consequences, a compelling question is what role if any social preferences have on voting behavior. This paper explores this issue using laboratory experiments wherein voting outcomes lead to a known distribution of net benefits across participants. Preferences are elicited using a novel Random Price Voting Mechanism (RPVM), which is a more parsimonious mechanism than dichotomous choice referenda, but gives consistent results. Results suggest that social preferences, in particular a social efficiency motive, lead to economically meaningful deviations from self-interested voting choices and increase the likelihood that welfare-enhancing programs are implemented.

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I. Introduction

Majority-voting rules are used extensively by representative legislative bodies and in ballot initiatives (referenda) to determine the provision of public goods. Such programs often impose unequal costs and benefits on individuals. If voters have social preferences, we should expect their decisions to be influenced by the perceived impact of the voting outcome on others. For instance, elderly "good citizens" may vote "yes" on referenda that are personally costly even though their own children are grown. On the other hand a strong supporter of a school bond may be worried that voting "yes" on the associated tax may impose costs on the elderly that exceed their benefits

A number of empirical studies have investigated the presence of "other regarding" voting patterns in public goods referenda (e.g. Deacon and Shapiro, 1975; Mueller, 1989), but the very nature of the data used precludes identification of the form that such social preferences take. Holmes (1990) used county level results of a California referendum on the Safe Drinking Water and Safety Enforcement Act. He inferred from instrumenting aggregate data that care for other's well-being had a statistically significant but small positive effect on the probability of voting in favor of the water quality protection proposal. Shabman and Stephenson (1992, 1994) relied instead on individual survey data collected in the wake of a city-wide referendum to fund flood protection projects that would protect fewer than 10% of Roanoke (Virginia) residents. They too report that concerns for others increased the likelihood of voting in favor of the referenda that would impose net costs on themselves while benefits of the public program accrued to others. More recently, using data on 122 open-space referenda that took place in Massachusetts between 1998 and 2003, Kotchen and Powers (2006) find evidence that voters favor policies that exempted low-income families and low to mid-income senior citizens from tax increases. In all, following the lexicon recently applied by Bergstrom, evidence from actual voting patterns suggest that individual votes are motivated, at least in part, by sympathetic *gains* obtained from others' enjoyment of public goods as well as "sympathetic *losses* that each bears for the share of costs paid by others" (2006 p. 399).

In parallel, mounting evidence from the fields of experimental and behavioral economics suggests that in some situations individuals are motivated by both self-interest as well as social preferences, with several efforts seeking to isolate behavioral patterns. Fehr and Schmidt (1999; hereafter FS) and Bolton and Ockenfels (2000; hereafter ERC) propose theoretical models of inequality aversion, which explain the oft-observed cooperative behavior in simple bargaining games (e.g. gift exchange game) and public goods games where there is a punishment mechanism. Charness and Rabin (2002; hereafter CR) propose an alternative model which characterizes what they label as quasi-maximin preferences – individuals are motivated by social efficiency and maximin preferences (i.e. preference for maximizing the welfare of the worst-off individual) – and provide evidence from two and three-person dictator games and response games that this specification is better at explaining experimental game behavior than inequality aversion.

A handful of recent laboratory studies have used simple distribution experiments, similar in spirit to CR, to examine social motives (e.g. Engelmann and Strobel, 2004; Bolton and Ockenfels, 2006; Fehr, Naef and Schmidt, 2006). A review of this class of games lead Engelmann and Strobel (2007) to conclude that models that capture both efficiency and maximin preferences appear to be the most successful. However, they find that preferences appear to be quite heterogeneous across games, and differ within and between subject pools. Of particular relevance to our study is Bolton and Ockenfels (2006), who conduct a distribution experiment in a majority voting context. In particular, they have three-person groups vote between an allocation that yields equal payoffs to all voters, and one with an inequitable, but more efficient allocation. They find that preferences for equity dominate those for efficiency. However, as correctly pointed out by Engelmann and Strobel (2006), the experiment is set up in such a way that favors equity. In particular, the group can achieve perfect equity with one option whereas the gain in efficiency (a 15% increase) for the inequitable allocation is quite modest.

The purpose of this study is to use laboratory experiments to better understand the nature and relative importance of social preferences in public goods referenda. Although it has desirable incentive compatibility characteristics and directly parallels real world referenda, it is well known that dichotomous choice (i.e. yes/no) voting is both theoretically demand revealing (Gibbard, 1973, Satterthwaite, 1975) and empirically demand revealing (Taylor, et al., 2001) but it is not an economical mechanism for obtaining detailed information on preferences, in that, very large sample sizes are required. Thus, the main design issue confronted in this study is how to parsimoniously elicit preferences in a referendum-voting situation. To overcome this design challenge, we propose a Random Price Voting Mechanism (RPVM), which is best thought of as a public goods extension of the Becker-DeGroot-Marschak (1964) or BDM mechanism.

In a (private good) BDM willingness to pay (WTP) setting, the participant places a bid for a good, and purchases it at a randomly selected price if the price is less than or equal to the bid. For expected utility maximizers, the "second price" property of the BDM mechanism eliminates the incentives for strategic bidding, making truthful revelation of one's value for the object a dominant strategy. In the RPVM, each individual in a group places a bid for a public program, and the program is implemented (i.e. the vote passes) if the majority of individuals place a bid higher than or equal to the randomly selected price. In this case, all individuals must pay the price.[1] This coercive tax feature closely parallels the format of many referenda. Similar

[1] In a willingness to accept (WTA) setting with losses, an individual indicates her minimum WTA. If a randomly chosen compensation level is equal to or exceeds the individual's signal, this amount of compensation is paid. If not, no payment is made and the loss is incurred.

to the BDM, the RPVM elicits a point estimate of value and is incentive compatible under the expected utility framework.[2]

Social preferences in a voting context are investigated using an experimental design that uses homogeneous and heterogeneous group payoff vectors, and includes all four Hicksian welfare settings. Participant decisions in homogenous payoff settings suggest that the RPVM is empirically demand revealing. This is consistent with laboratory evidence on the BDM (Irwin et al., 1998) and the referendum voting mechanism (Taylor et al., 2001). The existence and nature of social preferences is explored using a simple structural estimation approach. In particular, experimental data are used to estimate the unknown parameters of optimal RPVM bid functions coincident with the FS, ERC and CR behavioral theories. This analysis, along with systematic patterns readily observed in the aggregated experimental data, leads us to conclude that voters in our experiments were motivated by the appeal of their own potential gains as well as by a concern for the overall social efficiency of proposed programs consistent with both directions of altruism as described by Bergstrom, 2006).

II. The Random Price Voting Mechanism and Theoretical Predictions

In this section, we formally introduce the RPVM and develop theoretical predictions of bidding behavior for it. As Karni and Safra (1987) and Horowitz (2006) demonstrate, the simpler BDM is not always incentive compatible outside of the expected utility framework. For this reason, we limit our analysis to expected utility. For ease of exposition, we focus the presentation on the case where the game is played in the WTP for gains domain, and for the case where

[2] The RPVM is less complex than other incentive compatible public goods funding mechanisms, such as the Smith (1979) Auction and the Groves-Ledyard (1977) mechanism. More importantly for our purposes, unlike these mechanisms, the RPVM does not seek to efficiently provide the collective good. Rather, it is constructed to elicit the value that an individual places on the good in a voting context.

individuals have social efficiency motives (Charness and Rabin, 2002). These results are readily extended to the other three Hicksian measures (WTP to avoid a loss and WTA a loss or forego a gain) and for three other forms of preferences considered in this paper. Once the results for the social welfare function have been established, we briefly discuss these extensions.

The RVPM works as follows: *N* individuals are asked to signal the maximum amount of money they would be prepared to pay for a program defined by a known vector $\prod = \left(\pi_1, \pi_2, ..., \pi_N\right)$. In the WTP for gains domain, π_i represents the gross monetary benefits to individual *i* if the program is implemented.

The public program that is submitted to a "vote" has two components: 1) the induced values $\prod$ and 2) a transfer payment (*C*) from individuals to the implementing authority. This cost (uniform tax) is randomly drawn from a distribution with probability density p(C) over the interval $[0, C_{\max}]$, after individuals have signaled their WTP. In what follows, we refer to individual *i*'s signal as his "bid" and denote it by B_i.

For implementation of the program, a majority of individuals (>50%) must have bids that exceed a per-person cost *C*.[3] If a majority of bids are greater than or equal to *C,* individual *i* receives a monetary payoff $\pi_i - C$ (the sum of which could be negative) to be added to an initial endowment *Y* for a utility level $U_i = u_i(Y + \pi_i - C)$. If the majority of bids are below *C*, the program is not implemented and subjects retain their initial endowment for utility $U_i = u_i(Y)$. We assume that *U* is increasing in income.

Denote a vector of strategies chosen by the *N*-1 other players by B_{-i}. For our purposes, it will be sufficient to characterize an admissible strategy profile simply by the pair of numbers (B_m, B_k). B_m is defined as the $Round[(N+1)/2]^{\text{th}}$ largest bid in the vector and B_k as the

[3] To simplify exposition, we restrict the presentation to the situations where *N* is an odd number. Minor modifications are required to prove the claim when *N* is even, but the same conclusion is reached.

$Round[(N-1)/2]^{\text{th}}$ largest bid in B_{-i}. For N=3, for example, B_m is the smallest and B_k is the largest of the two bids in B_{-i}. In general, B_m and B_k bound the range of value in which player i's bid would be pivotal (i.e. the range in which i is the median voter).

A. Bidding Behavior of Players without Social Preferences

A key characteristic of the RPVM is that, similar to a dichotomous choice referendum with a majority vote implementation rule, a purely self-interested individual has a weakly dominant strategy to bid her value. The basic intuition is that, when a voter is pivotal, bidding below (above) her value decreases (increases) the probability that programs that yield positive (negative) monetary payoffs will be implemented, thus decreasing the individual's expected payoff. It is only a weakly dominant strategy as situations arise where the voter is not pivotal and thus bidding below or above her value has no influence on whether the program is implemented. Truthful revelation by all players is a Bayesian Nash Equilibrium of the RPVM game.

Proposition: For a purely self-interested, expected utility maximizing agent, $B_i^* = \pi_i$ is a weakly dominant strategy for the RPVM.

Proof: See Appendix

B. Bidding Behavior of Players with Social Preferences

B.1 Social Efficiency

From this framework, we can look more closely at theoretical predictions emanating from more explicit models of individuals with other-regarding preferences. Following recent developments in the behavioral economics literature, we impose structure on the utility function and focus on linear Nash equilibria of the RPVM game. We present with some detail the solution for individuals with social efficiency preferences (Charness and Rabin, 2002) who are asked to signal their WTP for a program conferring gains. We then summarize the predictions for four alternative models and for the remaining three welfare settings.

An individual *i* with social efficiency preferences is postulated to have utility that is increasing in the gains of others such that $U_i = u\left(Y + \pi_i - C + \sum_{j \neq i} \left(\alpha_i \cdot (\pi_j - C) \right) \right)$. Here $\alpha_i \geq 0$ parameterizes the intensity of individual *i's* altruism (for pure selfishness, $\alpha_i = 0$). This is a purely altruistic individual who weighs equally the gains and losses to others.

To compute the Bayesian Nash Equilibrium we rely on the critical values B_m and B_k, the interval defining the range over which the bid of voter *i* makes this individual the median voter. Thus, *i*'s expected utility can be expressed as

$$
\begin{aligned}
EU_i\left(B_i, B_{-i}\right) = & \int_0^{B_m} p(C)U\left(Y + \pi_i - C + \alpha_i \sum_{j \neq i} (\pi_j - C) \right) dC \\
& + \int_{B_m}^{B_i} p(C)U\left(Y + \pi_i - C + \alpha_i \sum_{j \neq i} (\pi_j - C) \right) dC \\
& + \int_{B_i}^{B_k} p(C)U\left(Y\right) dC + \int_{B_k}^{C_{\max}} p(C)U\left(Y\right) dC
\end{aligned} \quad (1)
$$

The first term is the expected utility conditional on the randomly drawn cost being below B_m. Here, *i*'s bid is irrelevant since there is already a majority of voters willing to pay more than the cost of implementing the program. The second and third terms cover the interval over which the bid of individual *i* will have a marginal effect on the probability that the program is implemented. Conditional on *C* falling in that range, B_i is effectively the median bid. The last term is the interval over which *i* has no effect on the outcome since no matter how large B_i is, too few individuals have bids high enough to implement the program.

We focus on affine bidding strategies. Let individual i conjecture that all others (m and k in particular) choose bids of the form

$$B_m = \gamma_m \left(\pi_m + \sum_{j \neq m} \alpha_m \, \pi_j \right) \tag{2}$$

and

$$B_k = \gamma_k \left(\pi_k + \sum_{j \neq k} \alpha_k \, \pi_j \right). \tag{3}$$

where γ_k and γ_m are positive (still unknown) constants. Substituting these expressions in Equation 1 and maximizing with respect to B_i yields the first order condition:

$$p(B_i)U\left(Y + \pi_i - B_i + \sum_{j \neq i} \left(\alpha_i \cdot (\pi_j - B_i) \right) \right) = p(B_i)U(Y). \tag{4}$$

This equation has a degenerate solution at $p(B_i) = 0$ that can safely be ignored. The interior solution equates expected utility under the two states of the world (the program is funded or not). Solving for B_i, the optimal bid is then given by:

$$B_i^* = \frac{\pi_i + \sum_{j \neq i} \alpha_i \, \pi_j}{1 + (N-1)\alpha_i}. \tag{5}$$

The optimal strategy has a form that matches the conjecture of individual i regarding the bidding strategies of players m (Equation 2) and k (Equation 3) for $\gamma_i = 1 \big/ \left(1 + (N-1)\alpha_i\right)$. Thus, if all N players adopt this linear conjecture and bid their optimum, all conjectures are simultaneously proven correct and no one has incentives to deviate from their optimal bidding function. This establishes that (Equation 5) is a Bayesian Nash Equilibrium. Note that an individual's optimal bid does not require knowledge of the α_j of other individuals. Note also that the private BDM is nestled in the RPVM: setting N=1 yields the familiar BDM result that $B_i^* = \pi_i$.

A number of behavioral predictions emerge from this solution.

1. If $\pi_j = \pi_i \; \forall j$, $B_i^* = \pi_i$. Bidding one's own private value is optimal when all players have equal payoffs since bidding above induced value increases the probability that the program will be funded in the range where costs exceed everyone's benefits. Bidding below value is also sub-optimal since it reduces the probability that the program will be implemented in the range where everyone would benefit.

2. Not surprisingly, the optimal bid is increasing in one's induced value:

(6) $$\frac{\partial B_i^*}{\partial \pi_i} = \frac{1}{1+(N-1)\alpha_i} > 0 .$$

3. An increase (decrease) in the sum of gains of others increases (decreases) i's optimal bid:

(7) $$\frac{\partial B_i^*}{\partial \pi_j} = \frac{\alpha_i}{1+(N-1)\alpha_i} > 0 .$$

4. By direct extension of Equation 7, individual i will increase (decrease) his bid when moving from a homogenous distribution where $\pi_i = \pi_j = \pi \; \forall j$, to a heterogeneous distribution where all payoffs other than his own are increased (decreased).

B.2 WTA compensation to Forego Gains, WTP to avoid Losses, and WTA Compensation for Losses

The theory can be reinterpreted to describe the optimal bidding strategy of individuals faced with the other Hicksian measures of welfare change. In the case of a group asked to express their individual minimum WTA compensation to forego gains, C represents the randomly determined compensation to be paid in exchange for not receiving a payoff defined by $\prod$. B_i then denotes the smallest amount that individual i would accept. If a majority of bids are less than or equal to *C,* compensation *C* is paid but the gains $\prod$ are not, for a utility level $U\left(Y+C+\alpha_i\sum_{j\neq i}C\right)$. Otherwise, $\prod$ is paid and utility is $U\left(Y+\pi_i+\alpha_i\sum_{j\neq i}\pi_j\right)$.

Re-deriving the optimal bidding strategy for social efficiency preferences yields exactly Equation 5 and the same theoretical predictions, although the vector $\prod$ now represents individual opportunity costs of implementing the compensation program. An increase in the opportunity cost to any player implies a decrease in the social value of the compensation program, and therefore increases the minimum acceptable level of compensation required by voters.

The optimal strategies for the WTA compensation for a program that imposes a loss and for the WTP for a program that eliminates a loss also replicate Equation 5 and can be interpreted with similar adjustments of the language.

B.3 Other Forms of Social Preferences

Using a similar approach, we characterize bidding behavior separately for the ERC and FS forms of inequality aversion, and maximin preferences, and for reasons given in the analysis section, combined social efficiency and maximin preferences (i.e. CR quasi-maximin preferences). Under ERC equity preferences, it is hypothesized that individuals like their own payoff to be as close as possible to the group average. To capture this, the social component of utility is assumed to be (in a WTP gains context) $-\alpha_i\left|\left(\pi_i-C\right)-\frac{1}{N}\sum_{j=1}^{N}\left(\pi_j-C\right)\right|$. Under FS equity preferences, individuals incur disutility when their own payoff differs from the payoff of another other player. The social component of utility is given by $-\frac{\alpha_i}{N-1}\sum_{j\neq i}Max\left[(\pi_j-C)-(\pi_i-C),0\right]-\frac{\beta_i}{N-1}\sum_{j\neq i}Max\left[(\pi_i-C)-(\pi_j-C),0\right].$, which corresponds directly with FS's specification of the utility function. FS postulate that individuals are less affected by differences in their favor than by situations where they are the poor party in the comparison (i.e. $\alpha_i \geq \beta_i$). The social component of the utility function for maximin preferences is $+\alpha_i\left(\pi_w - C\right)$, where π_w is the payoff for the worst-off player. Finally, the social component of utility considering both social efficiency and maximin preferences is given by $+\alpha_i \sum_{j \neq i} (\pi_j - C) + \beta_i\left(\pi_w - C\right)$.

Bayesian Nash Equilibrium bid functions for all forms of social preferences considered are presented in Table 1. For ERC and FS preferences, the two bid functions are presented as they differ slightly between gains (WTP & WTA) and losses (WTP & WTA) welfare settings. Table 2 presents behavioral predictions for each type of social preference, considering all welfare settings and possible induced values. In particular, Table 2 shows how bids relate to induced value under the various permutations. For example, predictions for social efficiency preferences are given in the first row. In heterogeneous value settings, the theory predicts that someone with an induced value equal to the group average will bid her value. An individual with a value below the mean will bid above value, and an individual with a value above the mean will bid below her value. These predictions hold regardless of welfare setting. For maximin preferences, a low-valued individual (i.e. $\pi_i = \pi_w$) bids her value (regardless of welfare setting), whereas all others bid below value in a WTP setting (gains or losses) and bid above value in a WTA setting (gains or losses).

III. Experimental Design

Two hundred and seventy-six students, recruited from a variety of undergraduate business and economics courses at XXXX, participated in the experiment. Experimental sessions were conducted in a designated experimental laboratory, in cohorts ranging in size from 12 to 24. A session lasted approximately 90 minutes and average earnings were $35.

A. Session Overview

Each session consists of either two WTP experiments, WTP-Gains and WTP-Losses (*n*=138), or two WTA experiments, WTA-Gains and WTA-Losses (*n*=138). Subjects receive written instructions and are permitted to ask questions at the beginning of each part of the experiment [Instructions are included as a Reviewer Appendix.].

Each session uses one of three possible induced value vectors: ($2, $5, $8), ($1, $5, $9), and ($4, $5, $9). Costs in the WTP experiment (compensation in the WTA experiment) are randomly determined from a uniform distribution on the interval [$0.00, $9.99], in one-cent increments. WTP participants receive a $10 endowment in each experiment. To avoid income effects, the endowment is $5 in each WTA experiment, which equates expected earnings with the WTP experiment.

In each experiment, participants make nine distinct bid (offer) decisions involving the RPVM Decisions are made simultaneously and without feedback. To control for order effects, the order of the experiment decisions and whether they are involve gains or losses varies across sessions. At the end of the session, one of the nine decisions is used to determine earnings (one from each experiment), by having a volunteer draw from a bag of marked poker chips. The cost (compensation) associated with each selected decision is determined using a random numbers table.

Three of the decisions involve a group of size one (i.e. a private goods setting; RPVM is identical to BDM), with one decision corresponding with each value in the chosen vector. Three more decisions involve a group of size three, where all group members have the same value. In particular, three unique homogeneous value vectors are constructed from the chosen induced value vector (e.g. from the [$2, $5, $8] vector stems vectors of [$2, $2, $2], [$5, $5, $5], and [$8, $8, $8]), and each decision involves a different vector. Seating and groups are assigned by random and subjects are able to visually identify the other members of their group, but all members are seated apart by a minimum of one seat and no communication is allowed. The final three decisions involve a group of size three, using the induced value vector. The participant makes one decision corresponding with each possible value. With a ($2, $5, $8) vector, for example, the participant makes one decision as the $2 individual (the other two group members are assigned $5 and $8), one as the $5 individual (the others have $2 and $8), and one as the $8 individual (the others have $2 and $5). The induced values of all group members are common knowledge, though subjects did not know which of the other two values are assigned to which of the other group members.

Similar to studies using the BDM mechanism (Boyce et al., 1992; Irwin et al., 1998), prior to each experiment participants go through ten low-incentive practice rounds with the private goods BDM. They face all three session-specific induced values (with the same cost [compensation] distribution) and are paid for all decisions. The goal of the low-incentive practice rounds is to give subjects an opportunity to gain experience with the mechanism before facing the complexity of a public goods setting. Repeated low incentive private rounds provided subjects an opportunity to receive feedback on how their bids (offers) interact with the randomly determined cost (compensation) to affect their payoff. The welfare setting for the practice rounds is the same as in the subsequent experiment.

B. Framing and Execution

For both individual and group decision settings, the instructions use language parallel to that found in public referenda. The WTP instructions direct each subject to *vote* whether to *fund* a *program* by submitting a *bid* that represents the "highest amount that you would pay and still vote for different programs." For the WTP-Gains experiment, if the majority of group members place a bid *greater than or equal to* the randomly selected cost, the program is "funded" and everyone receives her induced value and pays the cost. Otherwise, the program is "not funded", and no one receives her induced value nor pays the cost. For the WTP-Losses experiment, if the majority of bids are *greater than or equal to* the determined cost, the program is "funded" and all group members pay the determined cost but do not have the personal loss amount (induced value) deducted. Otherwise, the program is "not funded", the determined cost is not paid, but all group members have to pay their induced loss amount.

For the WTA-Gains experiment, subjects are directed "to indicate the lowest amount of money you would accept as compensation and still vote *against* different programs." If the majority of the offers are *greater than* the random compensation, the program is "implemented" and group members receive their induced values instead of the compensation amount. Otherwise, the program is "not implemented," in which case all group members receive the compensation instead of their induced values. In the WTA-Losses experiment, the subjects indicate "the lowest amount of compensation you would accept to vote *in favor* of the program." If the majority of offers are *less than or equal to* the random compensation, the program is "implemented" and all group members receive the compensation, but have to pay their induced loss amount. If the majority of the offers are *greater than* the random compensation, the program is not implemented and all group members neither receive compensation nor pay their induced loss.

IV. Analysis of Experiment Data

A. RPVM Bids (Offers) in Relation to Induced Values

The RPVM experiments yield 76 unique treatments, where a treatment is defined by a specific welfare setting (e.g. WTP-Gains), the subject's induced value, and the other players' values (if any). To facilitate comparisons between bidding behavior and induced values, we pool the data from all treatments and regress individual bids on 76 indicator variables to produce estimates of the average bid in each treatment. As each individual produces multiple observations, we estimate robust standard errors adjusted for clustering at the individual level. Given that all decisions from the individual are made without feedback until the end of the session, there are no controls for learning behavior. Tables 3 and 4 present the treatment-specific mean bids for the gains and loss settings, respectively, for both WTP and WTA. Estimates that are statistically different than induced value at the 5% level are italicized. Inspection of these results suggests that behavior does not appear to exhibit WTP/WTA discrepancies. To convey information on bidding heterogeneity, Figure 1 presents empirical cumulative distributions functions for the WTP-Gains setting for the ($2, $5, $8) value vector.[4]

Mean bids are statistically equal to value in 39 of the 40 treatments involving private good or homogeneous value settings. This provides evidence that the RPVM is approximately demand revealing, as well as confirms demand revelation for the BDM (consistent with Irwin et al. 1998). Bidding behavior for the heterogeneous value treatments suggests that social preferences do play a role, as there are many instances in heterogeneous treatments where mean bids are statistically different than induced value. Overall, as illustrated in Figure 1, low-value subjects tend to bid above value and high-value subjects to bid below value. Further, high- and

[4] Similar patterns exist for the other three welfare settings and value vectors.

low-value bidders in heterogeneous treatments tended to bid systemically different than those in either the private treatments or the public homogeneous value treatments.

As can be seen by inspecting Tables 3 and 4, in seven out of the eight treatments where the lowest-value subject has an induced value more than a dollar less than the middle-value subject (subjects with induced gains and losses of \$1 and \$2), subjects significantly raise their WTP or WTA relative to the induced value. Likewise, when the highest-value subjects had an induced value that was more than a dollar higher than the middle-value subject (\$8 and \$9 values), subjects significantly lowered their WTP or WTA in seven of the eight treatments. When the low-value (high-value) subject has a value close to the middle-value subject, statistical differences between bids and induced values are not generally observed.

There is not a systematic divergence from induced values for middle-value (\$5) subjects. Symmetric distributions produce bids that are roughly equal with value, although in one of four cases there is a statistical difference. In asymmetric distribution treatments, there is a weak tendency for middle-value subjects to bid below value when their value is above average (i.e. the \$1, \$5, \$6 vector) and a weak tendency to bid average value when their value is below average (i.e. the \$4, \$5, \$9 vector).

B. Estimated Bid (Offer) Functions and the Nature of Social Preferences

We investigate the extent to which the social welfare theories discussed in Section II are consistent with observed bidding behavior using data from public good treatments. In particular, we estimate the unknown parameters (i.e. α and β) of the optimal bid functions presented in Table 1. Estimated parameters that are statistically different than zero, with the correct sign, provide evidence that a particular theory has the ability to organize the data. Further, estimated parameters shed light on the relative importance of social versus selfish preferences on bidding behavior.

Consistent with our previous econometric framework, we use a linear regression approach to estimate unknown parameters; to allow for heteroscedasticity and the correlation of individual-level responses, we estimate robust standard errors adjusted for clustering at the subject level. The bid function parameters for the two equity models are directly estimable (imposing the constraint that the coefficient on π_i equals one). However, the bid functions for the social efficiency, maximin, and the combined efficiency-maximin theory are nonlinear in the unknown parameter(s). This does not preclude linear regression as the bid functions can be re-written as linear in unknown parameters and our estimates of interest recovered from these in a straightforward fashion. For example, we can express the maximin bid function as:

(8) $$B_i = \delta_1 \pi_i + \delta_2 \pi_w$$

where $\delta_1 = 1/(1+\alpha_i)$ and $\delta_2 = \alpha_i/(1+\alpha_i)$. The parameter α_i is overidentified. It can be easily shown that $\delta_2 = 1 - \delta_1$, and we can impose this restriction directly into the model to resolve the identification issue. The restricted model is:

(9) $$B_i - \pi_w = \delta_1 (\pi_i - \pi_w).$$

With an estimate of δ_1 in hand, an estimate of α_i and its standard error can be obtained using the delta-method. In a similar vein, exactly identified specifications that correspond to the efficiency and the combined efficiency-maximin theories can be constructed.

Not enough participant decisions are made to estimate precisely participant-specific coefficients from our design. We instead constrain the unknown parameters to be equal across individuals, and what we estimate are best thought of as bid functions for the representative individual in the sample. Further, for estimation purposes, we include an error term and an overall model constant. Although the theoretical bid functions do not imply a constant term, whether or not one should be included is essentially an empirical question. If the mean of the error term is not zero, for instance, omitting the constant term would serve to distort coefficient estimates.

Table 5 presents bid functions, estimated by pooling the entire sample as well as estimated separately for the WTP and WTA treatments. Pooling WTP (WTA) gains and loss data is justified by statistical tests, and data from all welfare settings can be justifiably pooled for all but the Maximin specification. The two equity-based specifications are not supported by the data. The parameter of the ERC model is not statistically different than zero and has the incorrect sign. The two parameters of the FS model are statistically different than zero. However, the result $\alpha < 0$ is inconsistent with the theory. In particular, it suggests that individuals bid to *increase* disadvantageous inequality (i.e. reduce equality).

Consistent with the theories, the estimated parameter for both the Social Efficiency and Maximin model is positive and statistically different from zero at the 1% level. The estimate of $\alpha = 0.057$ in the WTP Efficiency model implies that the weights on self-interest, $1/(1+2\alpha)$, and efficiency, $\alpha/(1+2\alpha)$, are equal to 0.90 and 0.05, respectively. This suggests that if own payoff from a program increases by \$1, ceteris paribus, the average individual increases her bid by \$0.90. If the program payoff to another group member increases by \$1, ceteris paribus, an individual increases her bid by \$0.05. This suggests an individual is willing to give up \$0.05 in order to give a \$1 to someone else. In a similar vein, the WTP Maximin model implies that an individual, ceteris paribus, increases his bid by \$0.92 for a \$1 increase in own payoff and by \$0.08 for a \$1 increase in the payoff to the worst-off group member.

The empirical support of both the social efficiency and maximin theories motivated an examination of whether a model that accounts for both motives (along with self-interest) would be a better depiction of observed behavior. However, the estimated parameters of this Efficiency-Maximin model lend support for a Social Efficiency-only model. In particular, we find that $\alpha > 0$ and $\beta = 0$. This suggests that efficiency is a significant motive and, once efficiency preferences are controlled for, maximin preferences explain little about bidding behavior. Thus, the combined theory model essentially breaks down to a pure social efficiency model and, if anything, the inclusion of maximin preferences simply serves to add noise to the relationship between efficiency and bidding behavior.

A casual comparison between theoretical predictions and simple tests of mean bid against induced value provides further evidence that maximin preferences, if present, are not a main driving force. For instance, in the heterogeneous treatments with a symmetric distribution one would expect that both middle- and high-value respondents would bid below value to help the worst-off individual. However, middle-value respondents tended to bid equal to value. Further, we should see worst-off individuals bidding at value, but it is clear that these individuals have concerns for the persons with higher values. In sum, while some evidence exists that Maximin considerations may drive observed bidding behavior; preferences for efficiency seem most consistent with the data and explain a wider range of observed bidding patterns.

V. A Comparison of Dichotomous Voting with the RPVM

In this section, we check the robustness of our RPVM results through targeted comparisons with experimental dichotomous choice referenda. In particular, we investigate whether heterogeneous value groups in a WTP-Gains setting, employing the ($2, $5, $8) distribution, exhibit behavior consistent with social efficiency preferences. These experiments were also conducted in XXXXX using students drawn from undergraduate business and economics classes. The sample size for the dichotomous choice experiments is 174 subjects.

Subjects received written instructions and were permitted to ask questions at the beginning of the experiment.[5] Subjects were randomly placed in groups of three voters and given an initial endowment of $10. In each vote, the subject was assigned one of three possible induced values: $2, $5, or $8, which was the amount that the individual would receive if the majority of group members vote in favor. Each participant made six confidential and independent voting decisions where her own value, the values of other group members, and the implementation cost varied across decisions. After all of the votes were cast, a volunteer subject randomly selected one of these voting decisions to generate payoffs.

In half of the sessions, participants cast votes for programs with heterogeneous distributions of values (one subject with a value of $2, one subject with a value of $5 and one subject with a value of $8). In the other half of the sessions, participants first cast votes for programs with homogeneous distributions of values (for example, each subject had a value of $2) and then voted for programs with heterogeneous distributions of values. The order of decisions was reversed to control for potential order effects. The uniform cost (tax) were set to favor detection of social efficiency preferences behavior based on the results of the RPVM experiments described above. A $7.50 cost was used to examine the behavior of voters with an induced value of $8, costs of $4.50 or $5.50 were imposed on participants with a $5 induced value, while a $2.50 cost was utilized to examine responses from those with a $2 induced value.

Direct comparisons can be made between the dichotomous choice results and treatments from the RPVM WTP-Gains experiment that use the ($2, $5, $8) value distribution. First, we find a close correspondence between dichotomous choice voting at a particular cost and the

[5] All instructions are available from the authors by request.

number of RPVM subjects who bid at or above that same cost (and are thus indicating they would vote “yes” at this cost). For example, 23.7% of RPVM subjects with a \$2 value indicated that they would pay at least \$2.50 for a program in the heterogeneous value setting. This percentage is statistically indistinguishable from the 18.6% of subjects who voted yes in the similar dichotomous choice setting (p = 0.410). As shown in Table 6, in fact, none of the dichotomous choice voting treatments yielded results that was statistically different than the results of the RPVM.

Second, the differences between RPVM homogeneous and heterogeneous treatments mirror that found for dichotomous choice referenda. For \$2 value subjects, a statistically different and higher percentage of subjects in heterogeneous value treatments bid at or above \$2.50 (p = 0.004). This difference across treatments, -11.9%, is quite similar to the -12.9% difference in the dichotomous choice experiment. For \$8 value subjects, a statistically different and lower percentage of subjects in heterogeneous value treatments bid at or above \$7.50 (p = 0.003). This difference across RPVM treatments, 10.8%, is quite similar to 13.1% difference in the dichotomous choice experiment. Similar to dichotomous choice, no difference across RPVM treatments is found for \$5 subjects at costs of \$4.50 (3.2% difference, similar to 4.0% in dichotomous choice) (p = 0.320) or \$5.50 (-4.3% difference, similar to -7.7% in dichotomous choice) (p = 0.320). Overall, there is a very close correspondence between dichotomous choice referenda voting and RPVM bidding both in levels and in terms of homogeneous versus heterogeneous treatment differences. Thus, we cannot reject the hypothesis that the RPVM predicts voting patterns in dichotomous choice voting.

VI. Conclusion

With strong empirical evidence of social efficiency preferences, a compelling question is whether such behavior increases the likelihood that the outcome with maximal net benefits is realized? To address this issue we examine all the possible voting outcomes that could have occurred for the two asymmetric heterogeneous value vectors. Thus, since there are 1000 possible costs for WTP and 1000 possible compensation amounts for WTA, there are 1000 possible voting situations associated with a particular value vector. Note that in many cases selfish voting will result in efficient outcomes. We are interested in the percentage of inefficient outcomes under selfish voting that are eliminated by social preferences, so we calculate the following measure:[6]

$$(10) \qquad \frac{\#\mathit{efficient\ outcomes}(\mathit{actual\ bids}) - \#\mathit{efficient\ outcomes}(\mathit{bid} = \mathit{value})}{\#\mathit{total\ outcomes} - \#\mathit{efficient\ outcomes}(\mathit{bid} = \mathit{value})} \times 100\%$$

Pooling across welfare settings, for the ($1, $5, $6) value vector, the reduction in inefficient outcomes attributable to social preferences is 19%, whereas for the ($4, $5, $9) vector it is 18%. Reductions are slightly larger for WTA (22% and 21%) than WTP (16% and 15%) when considered separately.

This paper proposes a new elicitation mechanism, the Random Price Voting Mechanism (RPVM), and uses it to investigate the role of social preferences in referendum voting. The RPVM, which is best thought of as a public goods extension of the private goods BDM, is more parsimonious than the simple (yes/no) referendum voting mechanism, which only reveals crude information on preferences. Using induced-value laboratory experiments, where the distribution of group values is common knowledge, we find that individuals with relatively high induced-valuations bid below induced value, whereas those with relatively low values bid above value.

[6] Note that with a symmetric value vector ($2, $5, $8) and social efficiency preferences, theory predicts no increase in the likelihood of an efficient outcome. This is because the $5 bidder bids her value and is always the pivotal voter. We thus forego this calculation.

These deviations from own payoff are both statistically significant and economically meaningful. Further, behavior is most succinctly explained by a preference for efficiency (or, similarly, pure altruism). Inequality aversion or maximin preferences are largely inconsistent with the data.

Our results are consistent with Engelmann and Strobel's (2007) assessment of the distribution game literature with respect to efficiency and equity preferences, but not with the evidence they provide for maximin preferences. There are two characteristics of our experiments, in relation to those in the distribution game literature, that are worth noting. In particular, the RPVM elicits a point estimate of value, and individuals have a continuum of possible choices. The distribution games have individuals choose between a small number (usually two or three) of discrete group-payoff allocations. A result is that preferences are coarsely measured, and the choices can be constructed in ways that may favor identification of a particular motive (see, for example, Engelmann and Strobel, 2006). Participants in our experiment have the possibility of achieving a perfectly equitable outcome as well as outcomes that involve a balance between efficiency and equity.

The experiments described here represent a first step from which a number of issues related to voting and social preferences can be examined further. Extensions include changes in voting group size, changes in the distributions and probabilities of group payoffs, uncertainty in the distribution of payoffs, multiple-round voting, voting on non-monetary public goods, and field application of the RPVM in situations where costs are unknown. Of particular importance is the impact of increasing stakes and group size. Whereas the impact of higher stakes is an open empirical question, a straightforward assertion is that efficiency preferences are even more likely to increase the probability of efficient programs being funded for larger group sizes.

Consider a referendum on a program which has positive total net benefits but, because of heterogeneous benefits, the median voter has a selfish benefit slightly less than cost. If she has efficiency concerns similar to those found in a number of studies, including our own, she will take into account that the sum of the net benefits to others is positive and weight those in her decision along with her own selfish net benefit. With a sufficiently large number of other voters, the effect of positive net benefits could easily outweigh her negative net benefit and result in a vote against the program. This assertion is supported by the RPVM comparative static when individuals have social efficiency preferences. In particular, for an increase in group size (holding the mean valuation constant), individuals with valuations below the group mean (further) increase their bid and those with valuations above the mean (further) decrease their bid.[7] Thus, as the group increases in size, valuations tend towards the group mean and as such the median voter is more likely to vote in favor of programs with positive net benefits.

[7] In particular, $\frac{\partial B_i^*}{\partial N} = \frac{\alpha_i\left(\overline{\pi} - B_i^*\right)}{1+\left(N-1\right)\alpha_i}$. Since $B_i^* > \pi_i$ $\left(B_i^* < \pi_i\right)$ for individuals with $\pi_i < \overline{\pi}$ $\left(\pi_i > \overline{\pi}\right)$, it follows that $\frac{\partial B_i^*}{\partial N} > 0$ $\left(\frac{\partial B_i^*}{\partial N} < 0\right)$.

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Table 1. Optimal Bid (Offer) Functions for Alternative Social Preferences

<table>
<tr><th></th><th>GAINS
(WTP & WTA)</th><th>LOSSES
(WTP & WTA)</th></tr>
<tr><td>Social Efficiency (Pure Altruism)</td><td colspan="2">$$\frac{\pi_i + \sum_{j \neq i} \alpha_i \ \pi_j}{1 + (N-1)\alpha_i}$$</td></tr>
<tr><td>ERC Equity</td><td>$$\pi_i - \alpha_i \left| \pi_i - \sum_{j=1}^{N} \frac{\pi_j}{N} \right|$$</td><td>$$\pi_i + \alpha_i \left| \pi_i - \sum_{j=1}^{N} \frac{\pi_j}{N} \right|$$</td></tr>
<tr><td>FS Equity</td><td>$$\pi_i - \frac{\alpha_i}{N-1} \sum_{j \neq i} Max\left[(\pi_j - \pi_i, 0\right] - \frac{\beta_i}{N-1} \sum_{j \neq i} Max\left[(\pi_i - \pi_j, 0\right]$$</td><td>$$\pi_i + \frac{\alpha_i}{N-1} \sum_{j \neq i} Max\left[\pi_i - \pi_j, 0\right] + \frac{\beta_i}{N-1} \sum_{j \neq i} Max\left[\pi_j - \pi_i, 0\right]$$</td></tr>
<tr><td>Maximin</td><td colspan="2">$$\frac{\pi_i + \alpha_i \pi_w}{1 + \alpha_i}$$</td></tr>
<tr><td>Efficiency and Maximin</td><td colspan="2">$$\frac{\pi_i + \alpha_i \sum_{j \neq i} \pi_j + \beta_i \ \pi_W}{1 + (N-1)\alpha_i + \beta_i}$$</td></tr>
</table>

Table 2. Behavioral Predictions for Alternative Social Preferences

	PRIVATE (N=1) or HOMOGENEOUS DISTRIBUTION	HETEROGENEOUS DISTRIBUTION		
Social Efficiency (Pure Altruism)	$B_i^* = \pi_i$	For $\pi_i = \overline{\pi}$	$\pi_i < \overline{\pi}$	$\pi_i > \overline{\pi}$
		$B_i^* = \overline{\pi}$	$B_i^* > \pi_i$	$B_i^* < \pi_i$
ERC Equity	$B_i^* = \pi_i$	$\pi_i = \overline{\pi}$	Gains; $\pi_i \neq \overline{\pi}$	Losses; $\pi_i \neq \overline{\pi}$
		$B_i^* = \overline{\pi}$	$B_i^* < \pi_i$	$B_i^* > \pi_i$
FS Equity	$B_i^* = \pi_i$		Gains; all π_i	Losses; all π_i
			$B_i^* < \pi_i$	$B_i^* > \pi_i$
Maximin	$B_i^* = \pi_i$	$\pi_i = \pi_w$	WTP; $\pi_i > \pi_w$	WTA; $\pi_i > \pi_w$
		$B_i^* = \pi_w$	$B_i^* < \pi_i$	$B_i^* > \pi_i$
Efficiency and Maximin	$B_i^* = \pi_i$	π_w	WTP; $\pi_i > \pi_w$	WTA; $\pi_i > \pi_w$
		WTP: $B_i^* > \pi_w$ WTA: $B_i^* < \pi_w$	$B_i^* < \pi_i$	$B_i^* > \pi_i$

Table 3. Random Price Voting Mechanism Experiment Results, Induced Gains.

	Private[a]			***Homogeneous***[b]			***Heterogeneous***[c]	
Value	**WTP**	**WTA**	**Others**	**WTP**	**WTA**	**Others**	**WTP**	**WTA**
$1			**$1, $1**	$1.25	$1.28	**$5, $6**	*$1.40*	*$1.91*
$2	$2.10	$1.96	**$2, $2**	$2.06	$2.06	**$5, $8**	*$2.64*	*$2.47*
$4			**$4, $4**	$4.06	$3.90	**$5, $9**	$4.26	*$4.77*
						$1, $6	$4.95	$4.74
$5	$5.09	$5.12	**$5, $5**	$5.10	$5.03	**$2, $8**	$5.19	$5.06
						$4, $9	$5.31	$5.35
$6			**$6, $6**	$6.08	$6.14	**$1, $5**	$5.90	$5.64
$8	$8.11	$8.15	**$8, $8**	$8.14	$8.18	**$2, $5**	$7.78	*$7.75*
$9			**$9, $9**	$8.75	$8.84	**$4, $5**	*$8.24*	*$8.41*

Note: estimates that are statistically different than induced value at 5% level are *italicized*.

[a] For both WTP and WTA, n=93.

[b] For both WTP and WTA, n = 138 for the homogeneous distribution of values of $5; n = 93 for the homogeneous distribution of values of $2 and $8; and n = 45 for the homogeneous distribution of values value of $1, $4, $6, and $9.

[c] For both WTP and WTA, n = 93 for the heterogeneous distribution of values of $2, $5, $8 and n = 45 for the heterogeneous distribution of values of $1, $5, $6 and $4, $5, $9.

Table 4. Random Price Voting Mechanism Experiment Results, Induced Losses.

	Private[d]		*Homogeneous*[e]			*Heterogeneous*[f]		
Value	**WTP**	**WTA**	**Others**	**WTP**	**WTA**	**Others**	**WTP**	**WTA**
$1			**$1, $1**	$1.04	$1.07	**$5, $6**	$1.24	*$1.77*
$2	$2.23	$2.06	**$2, $2**	$2.14	$2.11	**$5, $8**	*$2.67*	*$2.54*
$4			**$4, $4**	$3.93	$3.98	**$5, $9**	$4.18	$4.47
						$1, $6	$4.74	*$4.36*
$5	$5.19	*$4.68*	**$5, $5**	$4.98	$4.92	**$2, $8**	*$5.38*	$4.82
						$4, $9	$5.05	$5.67
$6			**$6, $6**	$6.01	$6.26	**$1, $5**	$5.73	*$5.42*
$8	$7.99	$7.91	**$8, $8**	$7.80	$7.94	**$2, $5**	*$7.68*	*$7.29*
$9			**$9, $9**	$8.91	$8.87	**$4, $5**	*$8.30*	*$8.35*

Note: estimates that are statistically different than induced value at 5% level are *italicized*.

[d] For both WTP and WTA, n=93.

[e] For both WTP and WTA, n = 138 for the homogeneous distribution of values of -$5; n = 93 for the homogeneous distribution of values of $2 and $8; and n = 45 for the homogeneous distribution of values value of $1, $4, $6, and $9.

[f] For both WTP and WTA, n = 93 for the heterogeneous distribution of values of $2, $5, $8 and n = 45 for the heterogeneous distribution of values of $1, $5, $6 and $4, $5, $9.

Table 5. Estimated Bid Functions[†]

	Efficiency	Maximin	ERC	FS	Efficiency and Maximin
			WTP Data, n = 2106		
α	0.057**	0.082**	-0.013	-0.108**	0.069**
	(0.013)	(0.023)	(0.019)	(0.025)	(0.016)
β	–	–	–	0.097**	-0.037
				(0.023)	(0.023)
			WTA Data, n = 2106		
α	0.084**	0.140**	-0.023	-0.164**	0.087**
	(0.017)	(0.032)	(0.021)	(0.029)	(0.019)
β	–	–	–	0.125**	-0.009
				(0.028)	(0.030)
			WTP & WTA Data, n = 4212		
α	0.070**	0.070**	-0.018	-0.136**	0.076**
	(0.011)	(0.018)	(0.014)	(0.019)	(0.014)
β	–	–	–	0.111**	-0.019
				(0.018)	(0.024)

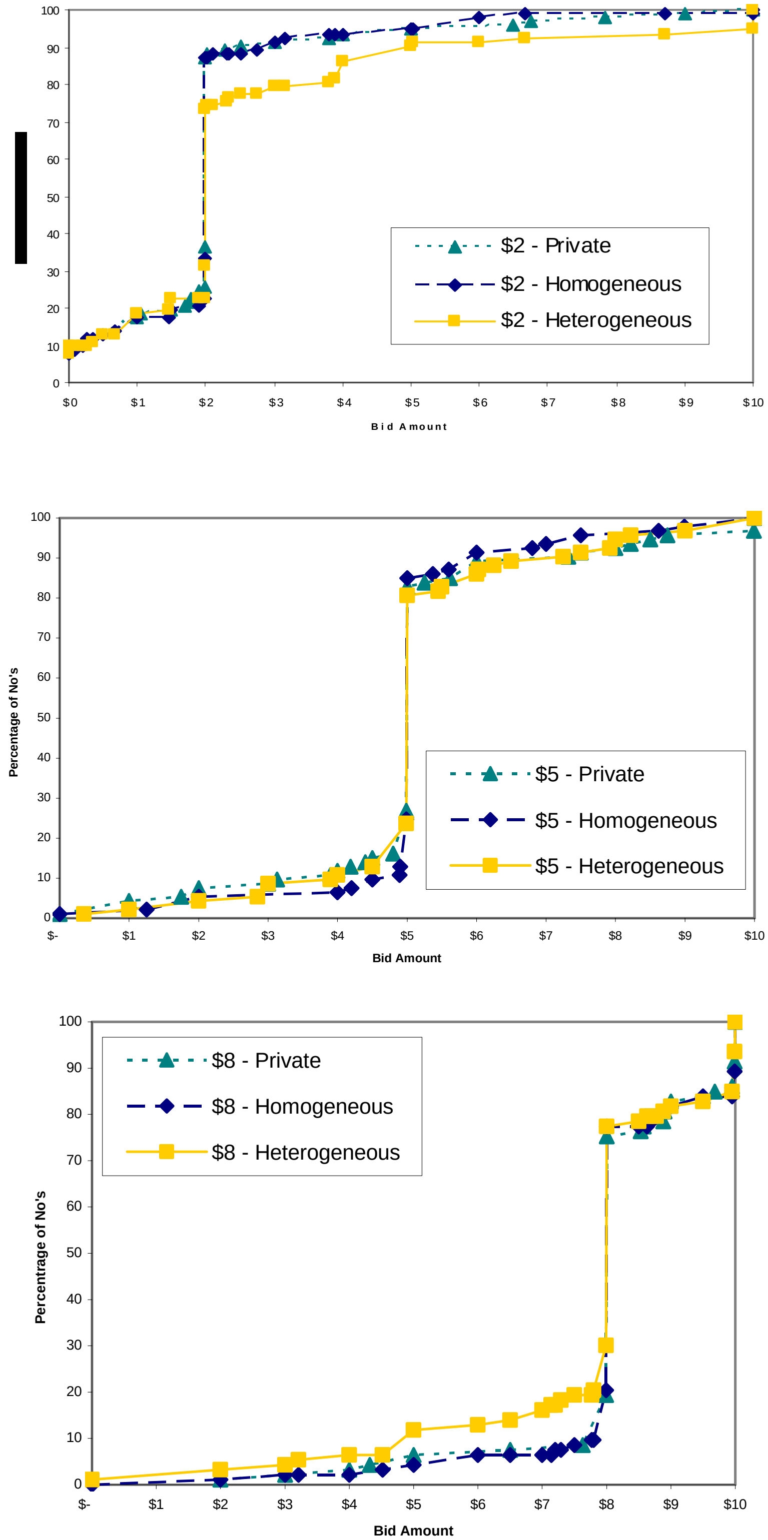
Notes: *, ** denote estimate is statistically different than zero at 5% and 1% level, respectively.
[†] Pooling the WTP & WTA data is not supported statistically for the Maximin model.
Standard errors in parentheses.

Table 6. Selected Comparisons between Dichotomous Choice and RPVM in a WTP-Gains Setting and Symmetric Value Distributions[a]

Mechanism	Value	Cost	Distribution of Values	Percent "Yes"	t-stat	p-value
DC Voting	$2	$2.50	Heterogeneous	18.6%	0.825	0.4102
RPVM	$2	$2.50	Heterogeneous	23.7%		
DC Voting	$2	$2.50	Homogeneous	5.7%	1.469	0.1436
RPVM	$2	$2.50	Homogeneous	11.8%		
DC Voting	$8	$7.50	Heterogeneous	73.3%	1.350	0.1787
RPVM	$8	$7.50	Heterogeneous	81.7%		
DC Voting	$8	$7.50	Homogeneous	86.4%	1.330	0.1854
RPVM	$8	$7.50	Homogeneous	92.5%		

[a] Sample size is 93 for RPVM, 88 for Homogeneous DC Voting, and 86 for Heterogeneous DC Voting.

Figure 1. Cumulative Distributions of WTP-Gains Experiment, ($2, $5, $8) Value Vector



APPENDIX.

Proof of RPVM Value Revelation as a (Weakly) Dominant Strategy of Selfish Players

The proof proceeds from a standard second price argument. To establish that $B_i^* = \pi_i$ is a weakly dominant strategy it suffices to establish that $EU_i(B_i = \pi_i, B_{-i}) \geq EU_i(B_i \neq \pi_i, B_{-i}) \forall B_{-i}$. We proceed by considering different subsets of B_{-i}, defined by the location of B_m or B_k relative to π_i. For all possible configurations, we show that no strategy exists for player *i* that provides greater expected utility than $B_i = \pi_i$.

Case 1: $\pi_i < B_m$

Consider the subset of all strategy profiles B_{-i} for which $\pi_i < B_m$ and the impact of deviating from $B_i = \pi_i$ on player *i*'s expected utility. First, examine alternative bids where $B_i < \pi_i$. Note that for any bid such that $B_i \leq \pi_i < B_m$, the probability that the program is implemented remains unchanged at $\int_0^{B_m} p(C)\, dC$ since, in this range of *C*, a majority of other players form a majority. Since the utility of player *i* is independent of her bid, $U_i = u_i(Y + \pi_i - C)$ whenever $C \leq B_m$ and $u_i(Y)$ otherwise. Therefore, lowering B_i below π_i leaves player *i*'s expected utility unchanged at $\int_0^{B_m} p(C)u_i(Y + \pi_i - C)\, dC + \int_{B_m}^{C_{\max}} p(C)u_i(Y)dC$. There are no gains (nor any losses) to be realized by reducing one's bid below π_i.

Next, consider the possibility of increasing B_i above π_i. By the same argument we just made, increasing the bid beyond π_i has no consequences on *i*'s expected utility if the new bid is $\tilde{B}_i \leq B_m$. Once again, increasing B_i up to B_m has no effect on *i*'s expected utility.

Bidding above B_m would, however, decrease expected utility. For $B_m < \tilde{B}_i \leq B_k$, $\tilde{B}_i$ becomes the pivotal bid in the sense that it defines the largest realization of *C* that leads to the implementation of the program. Expected utility is now equal to $\int_0^{\tilde{B}_i} p(C)u_i(Y+\pi_i - C)\, dC + \int_{\tilde{B}_i}^{C_{\max}} p(C)u_i(Y)dC$ but this is less than the expected utility derived from $B_i = \pi_i$ since the increase in the probability of funding the program (i.e. for $C \in (B_m, \tilde{B}_i])$ is associated with instances where $C > \pi_i$.

Finally, consider $\tilde{B}_i > B_k$. For all such strategies, B_k is the highest value of *C* leading to implementation of the program and the expected utility is always equal to $\int_0^{B_k} p(C)u_i(Y)\, dC + \int_{B_k}^{C_{\max}} p(C)u_i(Y+\pi_i - C)dC$. It follows that any strategy $\tilde{B}_i > B_k$ leads to the same expected utility as the strategy $B_i = B_k$, which we have just established as being dominated by $B_i = \pi_i$.

By virtue of the above discussion, we conclude that for any strategy profile B_{-i} such that $\pi_i < B_m$, $EU_i(B_i = \pi_i, B_{-i}) \geq EU_i(B_i \neq \pi_i, B_{-i})$.

Case 2: $B_k < \pi_i$

We now turn to the subset of B_{-i} strategy profiles for which $B_k \leq \pi_i$. First consider any bid $\tilde{B}_i > B_k$. Since $B_k \leq \pi_i$, it follows as previously discussed that the probability of implementing the program remains unchanged for all $B_i \geq B_k$ and $EU_i(B_i \geq B_k, B_{-i}) = EU_i(\pi_i, B_{-i})$.

Next, consider the possibility of reducing *i*'s bid from $B_i = \pi_i > B_k$ to $\tilde{B}_i < B_k$. Such a bid strictly reduces expected utility since it lowers the probability of implementing the program from

$\int_0^{B_k} p(C)\,dC$ to $\int_0^{\tilde{B}_i} p(C)\,dC$ if $B_m < \tilde{B}_i < B_k$, or to $\int_0^{B_m} p(C)\,dC$ $\tilde{B}_i \le B_m$). Unfortunately, this reduction in probability is associated with a range of costs for which $C < \pi_i$ and thus can only prevent the implementation of programs that would benefit player *i*.

Collecting the results establishes that $EU_i(B_i = \pi_i, B_{-i}) \ge EU_i(\pi_i, B_{-i})$ for all B_{-i} such that $B_k < \pi_i$.

Case 3: $B_m \le \pi_i \le B_k$

This last case includes all remaining strategy profiles B_{-i} not yet considered. As we have pointed out in the analysis of previous cases, these strategy profiles make the strategy $B_i = \pi_i$ the median bid and determines the probability that the program will be implemented. Deviating from $B_i = \pi_i$ to $\pi_i < \tilde{B}_i \le B_k$ increases the probability of funding but the higher probability is associated with cases where $C > \pi_i$ and lowers expected utility. As before, further increases of $\tilde{B}_i$ beyond B_k do not result in additional changes in probability of funding nor in expected utility. It follows that the strategy $B_i = \pi_i$ strictly dominates $\tilde{B}_i > \pi_i$ when B_{-i} is such that $B_m \le \pi_i \le B_k$.

By similar reasoning, $B_i = \pi_i$ also strictly dominates $\tilde{B}_i < \pi_i$. The reduction in bid into the region $\tilde{B}_i \le B_m$ decreases the probability that beneficial programs (with $C < \pi_i$) will be implemented but offers no offsetting gain. A further decrease in $\tilde{B}_i$ below B_m has no additional effect on expected utility. Thus, we conclude that $EU_i(B_i = \pi_i, B_{-i}) > EU_i(B_i \ne \pi_i, B_{-i})$ for all B_{-i} such that $B_m \le \pi_i \le B_k$.

With Cases 1, 2 and 3, we have explored the entire strategy space of the *N*-1 other players and considered all possible deviations from the strategy $B_i = \pi_i$. Departing from the strategy

$B_i = \pi_i$ always results in either no change or in a reduction in the expected utility of player *i*. $B_i = \pi_i$ is therefore a weakly dominant strategy. With all players postulated to be self-interested and with an increasing utility function, all other players also have a weakly dominant strategy to play $B_j = \pi_j$. This establishes that truthful revelation by all players is a Bayesian Nash Equilibrium of the RPVM game (though it may not be unique).