ECONOMIC JURY RECRUITMENT AND MANAGEMENT

Public Project Evaluation with Manski Set-Identified Selection Effects

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ABSTRACT

Juries charged with evaluating economic policy alternatives are the focus of this study. The recruitment and management of juries is a principle-agent problem involving the design of incentive mechanisms for participation and truthful revelation of values. This paper considers a simple general equilibrium economy in which juries of consumers are used to estimate the value of public projects. The impact of participation fees on jury selection and representativeness, and on statistical mitigation of response errors, is analyzed. Manski set-identification is used to bound selection bias and determine participation fee treatments that minimize welfare regret from imperfect jury findings.

KEYWORDS: set_identification, principal-agent_problem, juries, welfare_theory

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1. Economic Juries

A *jury* is a body of experts utilized to reach a valuation, finding, or verdict. Examples are committees used to judge paintings or wines, juries empaneled to determine remedies in civil litigation, elected legislatures, and subjects in surveys or experiments who are asked to rank or value public projects such as cleaning up hazardous waste sites. Jury responses may fail to represent the public interest if selection makes a jury unrepresentative, or if jurors do not receive, recognize, and respond rationally to incentives to provide accurate assessments. If one thinks of jurors as agents with information sought by the jury organizer, then the design of mechanisms to ensure representative recruitment and accurate reporting is a *principal-agent* problem. For example, survey subjects are experts on their own preferences, and the survey design problem is to mitigate the effects of sample selection and strategic misrepresentation. This paper considers the problem of selecting and managing economic juries where elicitation of information is the primary concern. Important questions that arise in legal and elected juries regarding rules for agenda-setting, deliberation, and action, and bargaining and collusion among jurors, are outside the scope of this paper.

In principal-agent problems, statistical corrections using experimental treatments in agent incentives may sometimes be more effective and less costly than direct control mechanisms such as audits and legal sanctions. *Ex ante*, jurors may be offered incentives for participation, effort, and truthful responses. *Ex post* statistical analysis of treatments embedded in incentives can identify and mitigate response errors. Considering incentive mechanisms and statistical mitigation in tandem has the potential to improve the reliability of information collected from juries.

This paper builds on the literature on principal-agent theory and the theory of mechanism design; e.g., Green and Laffont (1977, 1978, 1979), Maskin (2004ab), and Laffont and Martimont (2000, 2002). This theory has been applied to control of survey selection bias in the important papers of Philipson (1997, 2001). Also relevant is the literature on the effect of incentives (Camerer and Hogarth, 1999), and studies of the effect on litigation outcomes of legal jury selection procedures; see Devine et al (2001), Guamaschelli et al (2000), Nagel and Neef (1975), and Saks and Marti (1997). King and Nesbit (2009) pose the question of optimal jury size and voting rules in litigation when juror time is valued.

This paper concentrates on the direct elicitation of preferences for public projects. Section 2 sets out a simple general equilibrium economy that is convenient for analyzing public projects, describes the role that juries of consumers can play in public project decisions, and outlines an incentive-compatible mechanism that can be used to elicit truthful valuations from jurors. Section 3 examines the impact of participation fees on jury selection and representativeness. Section 4 concludes with possible generalizations, and with comments on behavioral evidence on the performance of jury incentive mechanisms.

2. Optimal Provision of Public Projects

I adapt the general equilibrium framework of Green and Laffont (1977, 1979) to describe the public project decision problem; the following setup also draws upon Groves and Leob (1975), Groves and Ledyard (1977), Laffont and Martimort (2002), Maskin (2004ab), and McFadden (1999, 2004). Suppose that possible public projects are indexed by vectors $\mathbf{x}$ in a compact set $\mathbf{X}$ that includes the status quo $\mathbf{x}_0$. Beyond compactness, the set $\mathbf{X}$ is not restricted, so that it can index provision of discrete public projects, such as a decision to ban whale hunting, or continuous provision, such as hectares of tropical forest protected from development. Mutually exclusive or linked public projects can be analyzed since $\mathbf{X}$ need not be convex. One can also interpret $\mathbf{x}$ to include hedonic characteristics of public and private goods regulated by a social planner.

The Economy. Consider an economy with N consumers, indexed n = 1,...,N. To simplify the determination of market equilibrium and the welfare calculus, I will assume that each consumer has a risk-neutral indirect utility function of Gorman polar form,

$$(1) \qquad u = V(y,\mathbf{p},\mathbf{x};\theta) \equiv [y - B(\mathbf{p},\mathbf{x},\theta)]/A(\mathbf{p}) ,$$

where $\mathbf{p}$ is a finite-dimensional vector of prices of private market goods, contained in a cone $\mathbf{P}$ whose interior is the positive orthant, and y is consumer income net of taxes earmarked to pay for $\mathbf{x}$. Consumers types are heterogeneous, described by vectors (ω,θ) with θ in a compact universe Θ characterizing tastes and ω in a compact set Ω characterizing resource endowments. The functions A and B are continuous in their arguments and conical, concave, closed, and non-decreasing in $\mathbf{p}$.[2]

[2] I use the conventional terminology that a concave function A($\mathbf{p}$) is *conical* if it is homogeneous of degree one, and *closed* if its epigraph $\{(\mathbf{p},a)\in\mathbf{P}\times\mathbb{R} | a\leq A(\mathbf{p})\}$ is a closed set. A closed concave function is continuous on the interior of $\mathbf{P}$, and upper semicontinuous on $\mathbf{P} \equiv \{\mathbf{p}|A(\mathbf{p}) > -\infty\}$. The same terminology will be used for a convex function, with the conditions imposed on its negative. When income net of tax is sufficient to cover committed expenditure, the Gorman polar form is dual to the preferences U($\mathbf{z}$,$\mathbf{x}$,θ) =

The function B($\mathbf{p}$,$\mathbf{x}$,θ), committed expenditure, is heterogeneous in consumer preference type. The preferences (1) are well-defined when after-tax consumer income is sufficient to cover committed expenditure.

The function A($\mathbf{p}$), a price index, is common to all consumer preference types. This implies that indirect utilities in the Gorman preference field (1) average to a utilitarian social per capita indirect utility function

$$(2) \qquad W(Y,\boldsymbol{p},\boldsymbol{x},\boldsymbol{\theta}) \equiv [Y - \textstyle\sum_{n=1}^{N} B(\boldsymbol{p},\boldsymbol{x},\theta_n)]/N{\cdot}A(\boldsymbol{p}),$$

where Y is aggregate consumer income net of the cost of the public project, and $\boldsymbol{\theta} = (\theta_1,...,\theta_N)$ is the vector of consumer preference types in the economy. As long as all incomes net of tax are sufficient to sustain committed expenditure, the average of private good demands obtained from (1) coincide with demands that satisfy Roy's identity applied to (2), so that (2) is the indirect utility of a *representative* consumer for the economy and this economy has the *parallel Engle Curves* property that market demands are invariant with respect to the distribution of income.[3] This property makes (1) consistent with the quasi-linear utility assumption of Green and Laffont (1977) in their analysis of incentive-compatible mechanisms for eliciting consumer types. The Gorman preferences (1) give a simple, explicit characterization of private good equilibrium and optimal public project provision, but are less general than the treatment of public goods preferences by Groves and Ledyard (1980). Further discussion of the aggregation properties of Gorman preference fields is given in Chipman and Moore (1980, 1990) and McFadden (1999, 2004).

Assume that the economy has aggregate income Y = F($\mathbf{p}$,$\mathbf{x}$,ζ) net of the cost of providing $\mathbf{x}$, obtained from private good endowments and production; this will depend on $\mathbf{x}$ through public project cost, and may also be influenced by $\mathbf{x}$ if public projects affect infrastructure or restrict private good

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$\inf_{\mathbf{p}\in\mathbf{P}} V(\mathbf{p}{\cdot}\mathbf{z},\mathbf{p},\mathbf{x};\theta) \equiv \inf_{\mathbf{p}\in\mathbf{P}} [\mathbf{p}{\cdot}\mathbf{z} - B(\mathbf{p},\mathbf{x},\theta)]/A(\mathbf{p})$.

[3] Private good demands $\mathbf{z} \in \nabla_{\mathbf{p}}B(\mathbf{p},\mathbf{x},\theta) + [y - B(\mathbf{p},\mathbf{x},\theta)]\nabla_{\mathbf{p}}A(\mathbf{p})/A(\mathbf{p})$ are obtained by applying Roy's identity to (1), where "$\nabla_{\mathbf{p}}$" denotes the subgradient correspondence, which because A and B are concave always exists, and is almost everywhere single-valued. Aggregating gives

$$\boldsymbol{Z} \in \textstyle\sum_{n=1}^{N} \nabla_{\boldsymbol{p}}B(\boldsymbol{p},\boldsymbol{x},\theta_n) + [Y - \textstyle\sum_{n=1}^{N} B(\boldsymbol{p},\boldsymbol{x},\theta_n)]\nabla_{\boldsymbol{p}}A(\boldsymbol{p})/A(\boldsymbol{p}),$$

which coincides with the result of applying Roy's identity to W(Y,$\mathbf{p}$,$\mathbf{x}$,$\boldsymbol{\theta}$).

attributes. The term ζ is a stochastic variable that is unknown to consumers when their preferences for public projects are elicited, but is known to the planner before $\mathbf{x}$ is fixed; this represents a realistic aspect of public project evaluation that the costs of projects are not fully determined when projects are valued. Note that aggregate income $F(\mathbf{p},\mathbf{x}_0,\zeta)$ at the status quo $\mathbf{x}_0$ is independent of ζ, and write it as $F(\mathbf{p},\mathbf{x}_0)$. The factor ζ is not a barrier to estimation of benefits in the usual benefit-cost calculus, and can actually help incentive-compatibility for some elicitation mechanisms under future counter-factual conditions; see Olszewski and Sandroni (2006). Assume that F is continuous in its arguments, and convex, conical, and closed in $\mathbf{p}$.

A common assumption is that the consumer's endowment type ω is a vector of private goods, but more generally it will describe the consumer's share in profits from production and entitlements in government transfer programs. Assume that ω is observable to the planner, and determines the consumer's after-tax income $y = f(\mathbf{p},\mathbf{x},\zeta,\omega)$. Assume that the income function does not depend on consumer preference type θ; specifically, y includes the value of the full endowment of discretionary leisure, and demand for leisure which may depend on θ is determined through committed expenditure $B(\mathbf{p},\mathbf{x},\theta)$. Assume that the consumer income functions f inherit the properties of F (e.g., f is convex, conical, and closed in $\mathbf{p}$), and satisfy the adding-up condition

$$(3) \qquad Y = F(\boldsymbol{p},\boldsymbol{x},\zeta) \equiv \textstyle\sum_{n=1}^{N} f(\boldsymbol{p},\boldsymbol{x},\zeta,\omega_n),$$

and a condition that each consumer is always provided with sufficient after-tax income to cover committed expenditure, $f(\mathbf{p},\mathbf{x},\zeta,\omega) > B(\mathbf{p},\mathbf{x},\theta)$, in every event ζ in which $\mathbf{x}$ might be provided.[4]

Assume that prices are normalized so that the price index $A(\mathbf{p}) \equiv 1$. The private goods market clears when prices, given $\boldsymbol{\theta},\mathbf{x},\zeta$, and incomes and tax policy, satisfy[5]

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[4] The assumption of sufficiency is satisfied, for example, if the value of each consumer's private endowment exceeds committed expenditure, there is a public endowment, and public projects in $\mathbf{X}$ are considered only if the value of the public endowment covers their cost. Sufficiency may also be achieved as a result of incomes policy when $F(\mathbf{p},\mathbf{x},\zeta) > \sum_{n\le N} B(\mathbf{p},\mathbf{x},\theta_n)$ is required for $x \in X$ to be considered. If the technology of the economy is compact, then F is finite for $\mathbf{p}$ in the non-negative unit simplex $\mathbf{S}$ and all $\mathbf{x} \in \mathbf{X}$. Application of Shephard's identity gives private good supply $\mathbf{Q} = \nabla_{\mathbf{p}}F(\mathbf{p},\mathbf{x},\zeta)$ net of inputs to public projects, where $\nabla_{\mathbf{p}}$ denotes the almost everywhere single-valued subgradient correspondence.

[5] The assumptions on A, B, and F, and sufficiency of income net of taxes, guarantee that the social indirect utility function $W(F(\mathbf{p},\mathbf{x},\zeta),\mathbf{p},\mathbf{x},\boldsymbol{\theta})$ is non-negative, convex, closed, and homogeneous of degree zero in $\mathbf{p}$ on $\mathbf{P}$, and is continuous on $\mathbf{X}$. Hence the minimum of this function in $\mathbf{p}$ with $A(\mathbf{p}) \equiv 1$

(4) $\mathbf{p}(\boldsymbol{\theta},\mathbf{x},\zeta) \in \text{argmin}_{\mathbf{p}\in\mathbf{P}\&A(\mathbf{p})=1}\, W(F(\mathbf{p},\mathbf{x},\zeta),\mathbf{p},\mathbf{x},\boldsymbol{\theta})$.

At the status quo $\mathbf{x}_0$, equilibrium prices $\mathbf{p}_0 = \mathbf{p}(\boldsymbol{\theta},\mathbf{x}_0)$ are obviously independent of ζ.

The socially optimal provision of public projects when consumer types **θ** are known is

(5) $\mathbf{x}^*(\boldsymbol{\theta},\zeta) \in \text{argmax}_{\mathbf{x}\in\mathbf{X}}\, W(F(\mathbf{p}(\boldsymbol{\theta},\mathbf{x},\zeta),\mathbf{x},\zeta),\mathbf{p}(\boldsymbol{\theta},\mathbf{x},\zeta),\mathbf{x},\boldsymbol{\theta})$.

Combining (4) and (5), the competitive equilibrium in private goods and the optimal provision of public projects are jointly determined by the saddle point

(6) $\max_{\mathbf{x}\in\mathbf{X}} \min_{\mathbf{p}\in\mathbf{P}\&A(\mathbf{p})=1}\, W(F(\mathbf{p},\mathbf{x},\zeta),\mathbf{p},\mathbf{x},\boldsymbol{\theta})$.

Let $\mathbf{p}^*(\boldsymbol{\theta},\zeta) = \mathbf{p}(\boldsymbol{\theta},\mathbf{x}^*(\boldsymbol{\theta},\zeta),\zeta)$ denote the equilibrium private goods prices and $\mathbf{x}^*(\boldsymbol{\theta},\zeta)$ denote the optimal public projects provision obtained from (6).[6]

Consumer's Willingness-to-Pay. A consumer's value of public project **x** and accompanying prices **p**, relative to status quo public project provision $\mathbf{x}_0$ at market prices $\mathbf{p}_0$ and incomes $y_0 = f(\mathbf{p}_0,\mathbf{x}_0,\omega)$ is

exists for each **x** and is continuous in **x**, and the minimand $\mathbf{p}(\boldsymbol{\theta},\mathbf{x},\zeta)$ is a upper hemicontinuous correspondence on **X**. The private good excess supply of the economy is contained in the scaled subgradient correspondence

$$N\cdot A(\mathbf{p})\cdot\nabla_{\mathbf{p}}W(F(\mathbf{p},\mathbf{x},\zeta),\mathbf{p},\mathbf{x},\boldsymbol{\theta}) = \nabla_{\boldsymbol{p}}F(\boldsymbol{p},\boldsymbol{x},\zeta) - \sum_{n=1}^{N}\nabla_{\boldsymbol{p}}B(\boldsymbol{p},\boldsymbol{x},\theta_n) - [F(\boldsymbol{p},\boldsymbol{x},\zeta) - \sum_{n=1}^{N}B(\boldsymbol{p},\boldsymbol{x},\theta_n)]\nabla_{\boldsymbol{p}}A(\boldsymbol{p}).$$

The minimand $\mathbf{p}(\boldsymbol{\theta},\mathbf{x},\zeta)$ achieves balance in private goods markets and defines a competitive equilibrium for each **x**,ζ and profile **θ** of consumer preference types. This characterization of competitive equilibrium as a solution of an optimization problem, facilitating computation and characterization, is an important consequence of Gorman preferences with parallel Engle curves, and is a special case of the constructive approach to the existence of equilibrium proposed by Harold Kuhn (1997) and Rolf Mantel (1968).

[6] Welfare $W(F(p(\boldsymbol{\theta},\mathbf{x},\zeta),\mathbf{x},\zeta),p(\boldsymbol{\theta},\mathbf{x},\zeta),x,\boldsymbol{\theta})$ evaluated at private-market equilibrium prices $p(\boldsymbol{\theta},\mathbf{x},\zeta)$, is continuous on the compact domain **X**, so that $\mathbf{x}^*(\boldsymbol{\theta},\zeta)$ and $\mathbf{p}^*(\boldsymbol{\theta},\zeta) = p(\boldsymbol{\theta},\mathbf{x}^*(\boldsymbol{\theta},\zeta),\zeta)$ exist. They are not necessarily unique. The vector $(x^*(\boldsymbol{\theta},\zeta),p^*(\boldsymbol{\theta},\zeta))$ defines an equilibrium when true consumer preference types are known, and consumers treat $\mathbf{p}^*$, $\mathbf{x}^*$ and their income functions as given and not subject to strategic manipulation. The setup given here coincides with Green and Laffont (1977), with minor exceptions to allow the quasi-linear Gorman utility to be influenced by interactions between public projects and private goods, and to include the public project cost factor ζ that is unknown to jurors when they communicate with the planner.

measured by the *Hicksian compensating variation*, the net reduction of income from y_0 after providing **x** and adjusting market prices to **p** that makes that alternative indifferent to the status quo. This measure, also called the consumer's *Willingness-to-Pay*, WTP($\mathbf{p}$,$\mathbf{x}$,θ,y), satisfies

$$V(y_0 - WTP(\mathbf{p},\mathbf{x},\theta),\mathbf{p},\mathbf{x},\theta) = V(y_0,\mathbf{p}_0,\mathbf{x}_0,\theta),$$

which for Gorman preferences (1) with the parallel Engle curve property and A($\mathbf{p}$) ≡ 1 is independent of y_0 and reduces to the net decrease in committed expenditure due to **x**,

$$\text{(7)} \qquad WTP(\mathbf{p},\mathbf{x},\theta) = B(\mathbf{p}_0,\mathbf{x}_0,\theta) - B(\mathbf{p},\mathbf{x},\theta);$$

see McFadden (2004). The change in per capita welfare in general equilibrium due to a move from the status quo to **x** is the average of consumers' partial equilibrium counter-factual WTP measures (7) plus the net increase in aggregate after-tax income,

$$\text{(8)} \qquad \Delta W(\mathbf{p},\mathbf{x},\zeta,\boldsymbol{\theta}) = W(F(\mathbf{p},\mathbf{x},\zeta),\mathbf{p},\mathbf{x},\theta) - W(Y_0,\mathbf{p}_0,\mathbf{x}_0,\theta)$$
$$= \{\textstyle\sum_{n=1}^{N} [B(\mathbf{p}_0,\mathbf{x}_0,\theta) - B(\mathbf{p},\mathbf{x},\theta)] + F(\mathbf{p},\mathbf{x},\zeta) - Y_0\}/N$$
$$= \{\textstyle\sum_{n=1}^{N} WTP(\mathbf{p},\mathbf{x},\theta_n) + F(\mathbf{p},\mathbf{x},\zeta) - F(\mathbf{p}_0,\mathbf{x}_0)\}/N,$$

evaluated at the associated equilibrium prices $\mathbf{p} = \mathbf{p}(\boldsymbol{\theta},\mathbf{x},\zeta)$.

In many applications, **X** is a finite set containing K possible discrete, mutually exclusive projects, indirect utility is $V(y,\mathbf{p},\mathbf{x},\theta) = [y - B(\mathbf{p},\beta)]/A(\mathbf{p}) + v_1x_1 + ... + v_Kx_K$, where v_k is the consumer's real value of project k (relative to the status quo), aggregate consumer after-tax income specializes to $F(\mathbf{p},\mathbf{x},\zeta) = F(\mathbf{p},\mathbf{x}_0) - N\cdot A(\mathbf{p})\cdot[\zeta_1x_1 + ... + \zeta_Kx_K]$, where ζ_k is the real per capita cost of project k, and β determines the consumer's committed expenditure type, $\theta = (\beta,v_1,...,v_K)$. With A($\mathbf{p}$) ≡ 1, the social per capita indirect utility function specializes to

$$\text{(9)} \qquad W(F(\mathbf{p},\mathbf{x},\zeta),\mathbf{p},\mathbf{x},\boldsymbol{\theta}) \equiv [F(\mathbf{p},\mathbf{x}_0) - \textstyle\sum_{n\le N} B(\mathbf{p},\beta_n)]/N + \sum_{k\le K} (\sum_{n\le N} v_{kn}/N - \zeta_k)x_k.$$

Then the market-clearing private good prices **p*** minimize [F(**p**,$\mathbf{x}_0$) - $\sum_{n\le N}$ B(**p**,β_n)] over **p** $\in$ **P** subject to A(**p**) $\equiv$ 1, and are independent of ζ and **x**. Consumer n's willingness-to-pay for **x** $\in$ **X** is WTP(**p**,**x**,θ_n) = $\sum_{k\le K} v_{kn}x_k$, and the socially optimal **x***($\boldsymbol{\theta}$,ζ) is a maximand over **x** $\in$ **X** of the criterion $\sum_{k\le K}$ ($\sum_{n\le N} v_{kn}$/N - ζ_k)x_k, and is independent of private good prices.

Incentive-Compatible Elicitation of WTP. Now suppose that consumer preference types are not known to the social planner, and the value of public projects must instead be elicited from consumers. Groves and Loeb (1975) and Clarke (1971) propose a strongly individually incentive-compatible *provision point mechanism* that implements a public project if its average reported value exceeds its cost; see Palfrey and Srivastava (1991). This mechanism applies to consumers with the Gorman preferences (1), and will elicit truthful statements of preference type if consumers understand and respond rationally to the offered incentives

The use of a jury for public projects decisions, rather than the full population, was first suggested by Green and Laffont (1978) in their analysis of the Groves-Clarke mechanism. One reason to consider public project juries is that incentive mechanisms to induce truthful value reports from the whole population may require income transfers that are inconsistent with general equilibrium balance. This difficulty is eliminated if non-jurors are assigned residual income. Second, a population-wide elicitation will as a result of attrition lead to a *de facto* self-selected jury. It is statistically sounder to control jury selection through random sampling and fees for participation. Third, if juries are small and members are elicited independently, then there is less opportunity for formation of coalitions that can upset the incentive-compatibility of mechanisms. Fourth, the effectiveness of incentives for truthful reporting of values requires respondents to recognize and respond rationally to the possibility that they will be pivotal. However, humans are inconsistent in their perceptions of low probability events, and in very large juries the possibility of being pivotal may be too remote to induce rational response.

The social planner can recruit and manage a jury using incentive mechanisms to identify and mitigate expected welfare losses from selection bias, reporting error due to strategic misrepresentation or carelessness, and statistical variation. Three aspects of jury operation, all of which can be considered for experimental variation in treatment, are the *payment vehicle*, including participation fees and the coupling that links chosen projects to juror after-tax income; the *elicitation format*, how valuation questions are put and what response is required; and the *implementation* *frame*, the probability that the jury is consequential and a juror is pivotal, so that her response decides what project is undertaken.

The elicitation of stated values from a jury is a game of incomplete information played by the planner and jurors j = 1,...,J, with each juror having private information on her true values, and the planner having private information on the project cost factor ζ. I will describe the optimal strategies for the players in this game under the Groves-Clarke-Green-Laffont (GCGL) mechanism when jurors treat private goods prices as parametric and beyond their strategic influence.

Suppose the planner in this game announces to the jurors that the project provided will maximize in $\mathbf{x} \in \mathbf{X}$, given private good prices $\mathbf{p}$, the jury-based welfare criterion

$$(10) \qquad \textstyle\sum_{n=1}^{J} \mathrm{WTP}_n'(\mathbf{p},\mathbf{x})/J + [F(\mathbf{p},\mathbf{x},\zeta) - F(\mathbf{p}_0,\mathbf{x}_0)]/N,$$

where $\mathrm{WTP}_n'(\mathbf{p},\mathbf{x})$ is the stated willingness-to-pay for juror n. The planner assigns juror j an after-tax income schedule

$$(11) \qquad f^*(\mathbf{p},\mathbf{x},\zeta,w_{-j}) = y_{0j} + w_{-j} + ([F(\mathbf{p},\mathbf{x},\zeta) - F(\mathbf{p}_0,\mathbf{x}_0)]J/N,$$

which depends on $\mathbf{p}$, $\mathbf{x}$, ζ, status quo income y_{0j}, and the sum of stated WTP of the remaining jurors, $w_{-j} = \sum_{n=1\&n\neq j}^{J} \mathrm{WTP}_n'(\mathbf{p},\mathbf{x})$. The planner then elicits from this juror a stated willingness-to-pay schedule $\mathrm{WTP}_j'(\mathbf{p},\mathbf{x})$ for each $(\mathbf{p},\mathbf{x})$; this schedule cannot depend on ζ or w_{-j}. If juror j treats $\mathbf{p}$ as parametric and beyond her strategic influence, she then has a weakly dominant strategy that with a mild condition is strongly dominant, which is to truthfully report $\mathrm{WTP}_j'(\mathbf{p},\mathbf{x}) = \mathrm{WTP}(\mathbf{p},\mathbf{x},\theta_j)$. To demonstrate this, note that a truthful report reduces the jury-based welfare criterion to

$$\begin{aligned}
&\{\mathrm{WTP}(\mathbf{p},\mathbf{x},\theta_j) + w_{-j}\}/J + [F(\mathbf{p},\mathbf{x},\zeta) - F(\mathbf{p}_0,\mathbf{x}_0)]/N \\
&\qquad = \{\mathrm{WTP}(\mathbf{p},\mathbf{x},\theta_j) + f^*(\mathbf{p},\mathbf{x},\zeta,w_{-j}) - y_{0j}\}/J \\
&\qquad = \{[f^*(\mathbf{p},\mathbf{x},\zeta,w_{-j}) - B(\mathbf{p},\mathbf{x},\theta)] - [y_{0j} - B(\mathbf{p}_0,\mathbf{x}_0,\theta)]\}/J,
\end{aligned}$$

which is a scaled version of juror j's indirect utility gain from $(\mathbf{p},\mathbf{x})$. Then, this strategy leads the social choice to maximize juror j's utility, given her assigned income and given $\mathbf{p}$, and hence is a dominant strategy. If the juror instead reports $WTP_j'(\mathbf{p},\mathbf{x}) \neq WTP(\mathbf{p},\mathbf{x},\theta_j)$, then the jury-based welfare criterion reduces to

$$\{WTP_j'(\mathbf{p},\mathbf{x}) - WTP(\mathbf{p},\mathbf{x},\theta_j)\}/J + \{[f^*(\mathbf{p},\mathbf{x},\zeta,w_{-j}) - B(\mathbf{p},\mathbf{x},\theta)] - [y_{0j} - B(\mathbf{p}_0,\mathbf{x}_0,\theta)]\}/J,$$

which differs from the scaled version of juror j's indirect utility by a term that varies with the misreport. If the cost factor ζ has a support broad enough so that juror j believes there is a positive probability that this added term could cause the social decision to fail to maximize j's indirect utility, then a truthful report is a unique strongly dominant strategy, independent of the strategies of other jurors. In general, equilibrium in this game requires that the planner commit to provide the upper hemi-continuous schedule $\mathbf{x}(\mathbf{p},\zeta)$ that maximizes (10) for each $(\mathbf{p},\zeta)$ and then leave it to private markets to determine equilibrium $\mathbf{p}^*(\boldsymbol{\theta},\zeta)$ and $\mathbf{x}^*(\boldsymbol{\theta},\zeta)$.[7] If Gorman preferences specialize further to the form leading to the welfare criterion (9), the optimal strategies are unchanged, but WTP for **x** no longer depends on accompanying prices **p**.

In the GCGL mechanism, non-juror incomes are assigned to achieve income balance,

$$(12) \qquad \sum_{n=J+1}^{N} f(\boldsymbol{p},\boldsymbol{x},\zeta,\omega_n) = \sum_{n=J+1}^{N} y_{0n} + ([F(\boldsymbol{p},\boldsymbol{x},\zeta) - Y_0](1 - J^2/N) - (J-1)\sum_{n=1}^{J} WTP(\boldsymbol{p},\boldsymbol{x},\theta_n).$$

It may be necessary to use additional lump-sum transfers between jurors and non-jurors that are independent of **p**,**x**, but can depend on ζ, to ensure that jurors and non-jurors all have net incomes sufficient to cover committed expenditures. For juries of modest size in large populations, sufficiency for jurors will be the primary concern, as the average impact on non-jurors will be close to the per capita real cost of a project, which by the definition of **X** is generally affordable. Lump-sum transfers to jurors then may have the dual purpose of minimizing juror attrition and ensuring that the incentive-compatible mechanism is feasible.

The GCGL mechanism can fail if preferences are not of the Gorman form (1), or jurors fail to understand and believe the implementation frame and payment vehicle established by (10) and (11);

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[7]Alternately, the planner knowing ζ could find a saddle point $(\mathbf{p}`,\mathbf{x}`)$ of the jury-based criterion (10), which is an approximation to $(\mathbf{p}^*(\boldsymbol{\theta},\zeta),\mathbf{x}^*(\boldsymbol{\theta},\zeta))$, announce that $\mathbf{x}`$ will be provided, and then let the private market mechanism determine $\mathbf{p}(\boldsymbol{\theta},\mathbf{x}`,\zeta)$. This may however strain the assumption that jurors treat prices as parametric and beyond their strategic control.

see McFadden (2009) . However, if (1) holds, subjects comply with the offered incentives, and do not respond strategically to the impact of their valuations of **x** on equilibrium prices and income, then the GCGL mechanism is incentive-compatible.[8] Details of the elicitation frame, such as whether values are reported as functions of **x**,**p**, as open-ended responses to elicitations at specific **x**,**p** values, or as "yes/no" responses to "referendum" questions, will not matter.

3. Jury Selection and Participation Incentives

Agent participation in the case of a single agent has been studied by Grossman and Hart (1983), Jewitt (1988), Philipson and Malani (1999), and Laffont and Martimort (2002, Ch. 3,5). Philipson (1997, 1999, 2001), and Ryu, Couper, and Marans (2005) show that sample recruitment is a similar problem, except that rather than elicit the participation of a single agent, the principal now wants to control selection bias by recruiting a representative jury of agents. Factors entering this problem are the costs of contacting prospects and eliciting information from jurors, the effect of fees on participation, and the expected welfare costs of suboptimal project choices due to a non-representative jury. An important feature of this problem is that participation fees, public projects presented, and incentives are treatments under the control of the planner that can be designed to identify and mitigate response errors. An issue that may be important is that jury sizes that are sufficient to estimate a model of participation with acceptable precision, particularly if the specification is non-parametric, may be much larger than optimal jury sizes for effective project decisions. Large "training juries" or strong Bayesian priors may be needed in a first stage to provide sufficient information on the distribution of project valuations to design a jury in a second stage that has the consequential task of determining project provision.

In the following analysis, participation fees will be defined broadly to include appearance and performance fees and in-cash or in-kind lotteries, equipment such as web-TV boxes to encourage and facilitate participation, and the administrative costs of converting potential jurors to participants. I will assume for the development of a model of the effects of jury participation that the set of possible projects is finite, $\mathbf{X} = \{\mathbf{x}_0,\mathbf{x}_1,...,\mathbf{x}_K\}$, with status quo $\mathbf{x}_0$, and the social welfare function has the special form (9), so that the planner seeks to maximize $\sum_{k\le K} [\sum_{n\le N} v_{kn}/N - \zeta_k]x_k$ over $\mathbf{x} \in \mathbf{X}$.

[8] Gibbard (1973) and Satterthwaite (1975) show that in general no non-dictatorial balanced mechanism in an economy with a finite number of consumers can be strategy-proof, so restrictions on juror beliefs and behavior necessary to assure that a mechanism is strongly individually incentive compatible require something less than total rationality and understanding.

The Model. I will analyze juror participation and response using a variant of the bivariate selection model originally introduced by Heckman (1974), and analyzed by Imbens and Newey (2002) and Chesher (2005). This model extends the univariate selection analysis of Philipson (1997), and is a special block-triangular case of systems of nonparametric simultaneous equations for which Matzkin (2008) has provided identification conditions and estimators.

Assume that participation (d=1) or attrition (d= -1) by a prospective juror is determined by

(13) $$d = \text{sign}(g(z,m) - \eta)$$

where g is a function that is increasing in the participation fee m and influenced by observable exogenous variables z, and η is a disturbance that I assume without loss of generality is standard normal.[9] Then, the conditional probability of participation given z,m is $\text{Prob}(d|z,m) = \Phi(d \cdot g(z,m))$. The specification (13) is consistent with an assumption that consumers decide on participation to maximize utility, given circumstances z, a participation fee m, and any other financial incentives associated with the effect of participation and juror reports on after-tax income.

Suppose that for the public projects $\mathbf{x}_k \in \mathbf{X}$, k = 1,...,K, prospective jurors have values v_k corresponding to the specialized social welfare function (9), and elicited using the incentive-compatible mechanism described in (10) and (11). Suppose the responses satisfy the model

(14) $$\varepsilon_k = h(v_k,z,\mathbf{x}_k,\eta)$$

for k = 1,...,K, where h is a function increasing in v_k and influenced by exogenous variables z and the disturbance η, and $(\varepsilon_1,...,\varepsilon_K)$ is a vector of disturbances with a multivariate CDF $Q(\varepsilon_1,...,\varepsilon_K \mid \eta)$ that I assume without loss of generality has one-dimensional standard normal marginals that are independent of η.[10]

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[9]If a model $d = \text{sign}(g^*(z,m) - \eta^*)$ with η^* has a CDF F, then the model $d = \text{sign}(g(z,m) - \eta)$ with η standard normal and $g(z,m) = \Phi^{-1}(F(g^*(z,m)))$ has the same probability law, $\text{Prob}(d=1|z,m) = F(g^*(z,m))$.

[10]From a model $\varepsilon^*_k = h^*(v_k,z,\mathbf{x}_k,\eta)$ with a CDF $Q^*(\varepsilon^*_1,...,\varepsilon^*_K \mid \eta)$ and marginals $Q^*_k(\varepsilon^*_k \mid \eta)$, transform $\varepsilon_k = \Phi^{-1}(Q^*_k(\varepsilon^*_k \mid \eta))$, $Q(\varepsilon_1,...,\varepsilon_K \mid \eta) = Q^*(Q^{*\,-1}_1(\Phi(\varepsilon_1) \mid \eta),...,Q^{*\,-1}_K(\Phi(\varepsilon_K) \mid \eta) \mid \eta)$, and $h(v_k,z,\mathbf{x}_k,\eta) = \Phi^{-1}(Q^*_k(h^*(v_k,z,\mathbf{x}_k,\eta) \mid \eta))$. The Spearman rank correlation of ε_j and ε_k in the CDF Q is the same as that of ε^*_j and ε^*_k in Q*. In this sense, Q preserves the multivariate structure of Q*, and is termed a *copula*; see Sklar (1959). Note that $(\varepsilon_1,...,\varepsilon_K)$ can be dependent on η even though its components are not; e.g., a bivariate standard normal can have a covariance depending on η. An implication of the transformation to

Consider a project $\mathbf{x} = \mathbf{x}_k$ in $\mathbf{X}$ other than $\mathbf{x}_0$. Let $F_{V|z,\mathbf{x}}(v) = \int_{-\infty}^{+\infty}\Phi(h(v,z,\mathbf{x},\eta))\varphi(\eta)d\eta$ denote the population CDF of v given z,$\mathbf{x}$. The conditional CDF of v in the participating jury is

$$(15) \qquad F_{V|\mathbf{x},z,m,d=1}(v) = \int_{-\infty}^{g(z,m)}\Phi(h(v,z,\mathbf{x},\eta))\varphi(\eta)d\eta/\Phi(g(z,m)).$$

If attrition occurs "at random", then h(v,z,x) and $F_{V|z,x}(v) = \Phi(h(v,z,x))$ do not depend on η, and their estimation is not influenced by attrition. In this case, the only purpose of participation fees is to minimize expected cost per participating juror. However, if h does depend on η, attritors have a different distribution of values than participants, and consistent estimation of juror mean values must account for the effects of attrition.

Identification. Assume that m is drawn from a design distribution $F_M(m)$ chosen by the planner, and that the population density $f_Z(z)$ and the population average participation rate $p(m) \equiv \int_z\Phi(g(z,m))F_Z(dz)$ are known or can be estimated consistently from population data and observations on attrition. Let $f_{Z|m,d=1}(z)$ denote the conditional density of z, given m, among participants. Then, Bayes' law yields

$$(16) \qquad \text{Prob}(d=1|z,m) \equiv \Phi(g(z,m)) = f_{Z|m,d=1}(z)p(m)/f_Z(z),$$

and hence $g(z,m) = \Phi^{-1}(f_{Z|m,d=1}(z)p(m)/f_Z(z))$. Then, g(z,m) is identified on the support of (z,m).

Following Manski (2005), $F_{V|z,\mathbf{x}}(v)$ is bounded for given z,m by

$$(17) \qquad F_{V|\mathbf{x},z,m,d=1}(v)\Phi(g(z,m)) \le F_{V|z,\mathbf{x}}(v) \le F_{V|\mathbf{x},z,m,d=1}(v)\Phi(g(z,m)) + \Phi(-g(z,m)),$$

or $F_{V|\mathbf{x},z,m,d=1}(v) - F_{V|\mathbf{x},z,m,d=1}(v)\Phi(-g(z,m)) \le F_{V|z,\mathbf{x}}(v) \le F_{V|\mathbf{x},z,m,d=1}(v) + (1 - F_{V|\mathbf{x},z,m,d=1}(v))\Phi(-g(z,m))$.

normality is $\sup_v h(v,y,\mathbf{x},\eta) = +\infty$ and $\inf_v h(v,y,\mathbf{x},\eta) = -\infty$.

Assume that v has a known finite lower bound $v_{min} \le 0$ and upper bound $v_{max} > 0$. Let $\mu_k(\mathbf{x},z,m) = \mathbf{E}_{V|\mathbf{x},z,m,d=1}(v^k) = \int_{v_{min}}^{v_{max}} v^k F_{V|\mathbf{x},z,m,d=1}(dv)$ denote the k^{th} conditional moment of v among participating jurors. Then (17) implies for odd k that

$$\Phi(g(z,m))\mu_k(\mathbf{x},z,m) + \Phi(-g(z,m))(v_{min})^k \le \mathbf{E}_{V|z,\mathbf{x}}(v^k) \le \Phi(g(z,m))\mu_k(\mathbf{x},z,m) + \Phi(-g(z,m))(v_{max})^k,$$

and for even k that

$$\Phi(g(z,m))\mu_k(\mathbf{x},z,m) - \Phi(-g(z,m))[(v_{max})^k-(v_{min})^k] \le \mathbf{E}_{V|z,\mathbf{x}}(v^k) \le \Phi(g(z,m))\mu_k(\mathbf{x},z,m) + \Phi(-g(z,m))[(v_{max})^k+(v_{min})^k].$$

When the unconditional population distribution $F_{V|\mathbf{x}}(v) \equiv \mathbf{E}_z F_{V|z,\mathbf{x}}(v)$ and its moments are the targets of estimation, taking expectations with respect to z of the moment bounds above and using (14) gives

(18) $$p(m)\mu_k(\mathbf{x},m) + (1-p(m))(v_{min})^k \le \mathbf{E}_{V|\mathbf{x}}(v^k) \le p(m)\mu_k(\mathbf{x},m) + (1-p(m))(v_{max})^k$$

for odd moments and

$$p(m)\mu_k(\mathbf{x},m) - (1-p(m))[(v_{max})^k-(v_{min})^k] \le \mathbf{E}_{V|\mathbf{x}}(v^k) \le p(m)\mu_k(\mathbf{x},m) + (1-p(m))[(v_{max})^k+(v_{min})^k]$$

for even moments, where $\mu_k(\mathbf{x},m) = \mathbf{E}_{Z|m,d=1}\mathbf{E}_{V|\mathbf{x},z,m,d=1}(v^k)$ are the corresponding unconditional moments among participating jurors.[11]

[11]When h is known to be non-increasing in η, the bound (17) can be sharpened to

$$F_{V|\mathbf{x},z,m,d=1}(v)\Phi(g(z,m)) \le F_{V|z,\mathbf{x}}(v) \le F_{V|\mathbf{x},z,m,d=1}(v)\Phi(g(z,m)) + \Phi(h(v,z,\mathbf{x},g(z,m)))\Phi(-g(z,m)),$$

and when h is known to be non-decreasing in η, to

$$F_{V|\mathbf{x},z,m,d=1}(v)\Phi(g(z,m)) + \Phi(h(v,z,\mathbf{x},g(z,m)))\Phi(-g(z,m)) \le F_{V|z,\mathbf{x}}(v) \le F_{V|\mathbf{x},z,m,d=1}(v)\Phi(g(z,m)) + \Phi(-g(z,m)),$$

and the Manski bounds on conditional moments can be correspondingly tightened.

The distributions $F_{V|z,\mathbf{x}}(v)$ and $F_{V|\mathbf{x}}(v)$ and their moments do not depend on m. Then, one can choose a participation payment design F_M with finite support, and evaluate the bounds above at the maximum fee m* in the support. If $\lim_{m^*\to\infty} g(z,m^*) = +\infty$, then one has "point identification at infinity". However, full recovery of the structural function h(v,z,**x**,η) will require that the exogenous variables z and the payment design F_M be configured so that the range of g(z,m) is the entire real line.

Estimation. Consider estimation of the model described by (13) and (14). First, g(z,m) can be estimated on the support of (z,m) by plugging in non-parametric estimates of the terms on the right-hand-side of $g(z,m) = \Phi^{-1}(f_{Z|m,d=1}(z)p(m)/f_Z(z))$. It may be useful to test if a semi-parametric structure, such as $g(z,m) = g_1(z) + g_2(z)\cdot m^\gamma$, adequately approximates g(z,m). Alternately, if g(z,m) is parametric, then log Φ(g(z,m)) is the kernel of the log likelihood of z, given m and participation. Such specializations allow the tail behavior of g(z,m) to be inferred from an experimental design with moderate participation fees. Otherwise, set identification of $F_{V|z,\mathbf{x}}(v)$ and its moments is improved by increasing the maximum design fee m*, other things equal.

When attrition is not "at random", differentiate (15) with respect to m,

$$\partial F_{V|\mathbf{x},z,m,d=1}(v)/\partial m = [\Phi(h(v,z,\mathbf{x},g(z,m))) - F_{V|\mathbf{x},z,m,d=1}(v)]g_m(z,m)\varphi(g(z,m))/\Phi(g(z,m)),$$

and invert to obtain

$$(19) \qquad h(v,z,\mathbf{x},g(z,m)) = \Phi^{-1}(F_{V|\mathbf{x},z,m,d=1}(v) + [\Phi(g(z,m))/g_m(z,m)\varphi(g(z,m))]\cdot\partial F_{V|\mathbf{x},z,m,d=1}(v)/\partial m).$$

One can plug kernel estimates of g(z,m) and $F_{V|\mathbf{x},z,m,d=1}(v)$, and their derivatives with respect to m, into (19) to obtain an estimate of h(v,z,**x**,g(z,m)) on its support, and then vary m to map out the function h(v,z,**x**,η). Note that in a fully nonparametric setup, the curse of dimensionality will limit the accuracy with which g(z,m) and $F_{V|\mathbf{x},z,m,d=1}(v)$ can be estimated.[12] Limiting large participation fees to control costs limits the precision of estimates of h at large η, and consequently the precision of estimates of

[12]One can skirt this problem by assuming that the number of configurations of (z,**x**) is finite, that $p(m) = \mathbf{E}_Z\Phi(g(z,m))$ is known, that the design density $f_M(m|z)$ is continuous and positive, and that h is at least twice continuously differentiable in v and η with h_v bounded positive. Then, $F_{V|\mathbf{x},z,m,d=1}(v)$ and the moments $\mu_k(\mathbf{x},z,m)$ are estimable from J observations at a $J^{1/3}$ rate, and $\mathbf{E}_M\mu_k(\mathbf{x},z,m)$ is estimable at a $J^{1/2}$ rate. Alternately, if the design distribution F_M has finite support, then $F_{V|\mathbf{x},z,m,d=1}(v)$ and $\mu_k(\mathbf{x},z,m)$ are estimable at a $J^{1/2}$ rate.

$F_{V|\mathbf{x},z,m}(v)$ and its moments. If $g(z,m^*) < +\infty$, where m^* is an upper bound on participation fees, then h is unidentified for $\eta > g(z,m^*)$ and $F_{V|z,\mathbf{x}}(v)$ is identified only up to the bounds (17). The methods of Horowitz and Manski (1995), Manski (2005), and Imbens and Manski (2004) can be used to attach confidence intervals to the set-identified distributions $F_{V|z,\mathbf{x}}(v)$ and $F_{V|\mathbf{x}}(v)$ and their set-identified moments.

An assumption that may be plausible for some applications is that η enters (14) additively, giving the semi-parametric model $h(v,z,\mathbf{x},\eta) = (1+\lambda^2)^{½}\, h^*(v,z,\mathbf{x}) - \lambda\eta$, or $\varepsilon' = h^*(v,z,\mathbf{x})$, where (η,ε') are bivariate standard normal with correlation $\lambda/(1+\lambda^2)^{½}$. This implies

$$(20) \qquad F_{V|z,\mathbf{x}}(v) = \Phi(h^*(v,z,\mathbf{x})),$$

giving $\mathbf{E}_{V|z,\mathbf{x}}(v^k) = v_{\min}{}^k + k\int_{v_{\min}}^{v_{\max}} v^{k-1}\Phi(-h^*(v,z,\mathbf{x}))dv$; and the condition

$$(1+\lambda^2)^{½}h^*(v,z,\mathbf{x}) = \lambda g(z,m) + \Phi^{-1}(F_{V|\mathbf{x},z,m,d=1}(v) + [\Phi(g(z,m))/g_m(z,m)\varphi(g(z,m))]\cdot\partial F_{V|\mathbf{x},z,m,d=1}(v)/\partial m).$$

This condition and the requirement that its right-hand-side be invariant in m can be used to estimate λ and $h^*(v,z,\mathbf{x})$, and hence $F_{V|z,\mathbf{x}}(v)$, and to test the consistency of the specification.[13]

The unconditional bounds (18) can be estimated at a $J^{½}$ rate from the sample of participating jurors, first by using the empirical moment $\sum_{n\le J} v_n{}^k/J$ to estimate $\mu_k(\mathbf{x},m)$.[14]

Optimal Jury Design. The mechanism design problem is to choose a jury size J and a distribution of participation fees $F_M(m)$ to minimize welfare loss due to jury cost and inaccurate estimation of the social value of public projects. Assume that $\mathbf{X} = \{\mathbf{x}_0,\mathbf{x}_1\}$, so that there is a single proposed public project $\mathbf{x}_1$, and that the per capita cost ζ of the proposed project has a positive density f(ζ) over the relevant range. Recall that $p(m) = \mathbf{E}_Z\Phi(g(z,m))$ is the mean participation rate at a fee m, and note that

[13] Difference the condition for $m' < m''$ in the support of F_M to obtain an expression linear in λ with observable coefficients. Solve this for λ, and substitute the result into the condition to give an expression for $h^*(v,z,\mathbf{x})$ in terms of observables.

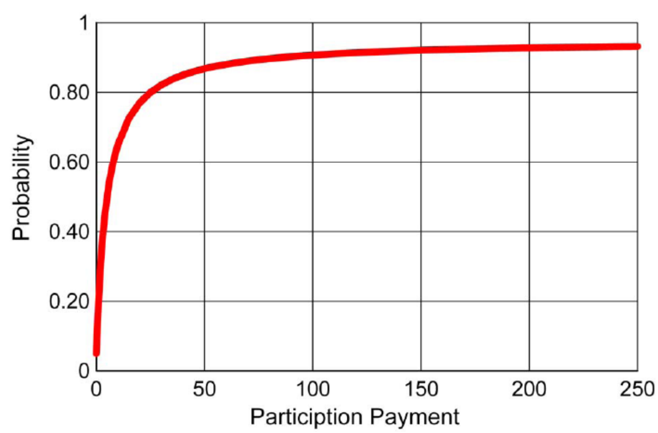
[14] Alternately, if one first estimates $F_{V|z,\mathbf{x}}(v)$ or its moments conditioned on z, and then wishes to use the empirical distribution of z in the participating jury to remove the conditioning on z, it is necessary to form weights $w_n = f_Z(z_n)/f_{Z|m,d=1}(z_n)/\sum_{n'\le J} f_Z(z_{n'})/f_{Z|m,d=1}(z_{n'})$ and take weighted averages.

$\int_0^\infty p(m)F_M(dm)$ is the probability that a prospective juror will participate. Then $p(m)f_M(m)/\int p(m')F_M(dm')$ is the density of fees paid to participants. Assume that there is a real cost c_1 of contacting a potential juror and a real cost c_2 of collecting a participating juror's information on values. Then the expected real cost per juror is the sum of expected contact cost, data collection cost, and expected participation payments,

(21) $$C = c_1/\int_0^\infty p(m)F_M(dm) + c_2 + \int_0^\infty mp(m)F_M(dm)/\int_0^\infty p(m)F_M(dm).$$

To illustrate this formula, make the fairly realistic assumption that for a 30 minute telephone interview in the U.S. in 2007, the costs were c_1 = \$5 and c_2 = \$60, and the probability of participation was roughly $p(m) = (0.01+0.19\ m)/(1 + 0.2\ m)$, illustrated in Figure 1. Then, if jury costs were the only consideration, they would be minimized by setting a single participation fee at m = \$5, yielding a participation rate of 50 percent and an expected cost per juror of \$75. Alternately, the common standard of an 80 percent participation rate for a "representative" survey would require a participation fee of \$25 and a total cost of \$91.25 per juror.

Figure 1. Participation Probability



Consider the expected per capita welfare loss from using the jury mechanism to choose public project compared to the (unattainable) ideal in which the true population per capita value of the public project $v^* = \mathbf{E}_Z \mathbf{E}_{V|z,\mathbf{x}}(v)$ is known and the project is undertaken when $v^* > \zeta$, the project cost. Let v' denote the provision point obtained from the self-reported values of jurors, and let $G_{V'}(v')$ denote its CDF. Sub-optimal provision occurs when $v' < \zeta < v^*$, and the project is not provided even though it is socially desirable, or when $v^* < \zeta < v'$, and the project is provided even though it is not socially desirable. In either of these events, the per capita welfare loss is $|v^* - \zeta|$. Then, the expected value of the welfare loss per capita from sub-optimal provision is

(22) $$\mathbf{E}_V\left|\int_{v*}^{v'}(\zeta - v^*)f(\zeta)d\zeta\right| = \int_{v_{min}}^{v^*}(v^* - \zeta)G_{V'}(\zeta)f(\zeta)d\zeta + \int_{v^*}^{v_{max}}(\zeta - v^*)(1 - G_{V'}(\zeta))f(\zeta)d\zeta .$$

This expression will be small if v′ is concentrated tightly around v* or there is a low probability of project costs near v*.

Suppose that as a result of correction for selection and the use of an incentive-compatible elicitation of juror values, the distribution $G_{V'}$ of the provision point v′ has a mean equal to the true project value v*, and a variance σ^2/J. When attrition occurs at random, v′ is the average of juror responses, and jurors comply with the offered incentives, then this will be true with σ^2 equal to the variance of $F_{V|x}$(v). More generally with attrition that is not at random, let $v^\#$ denote the mean of $G_{V'}$ and let σ^2/J continue to denote its variance. If $G_{V'}$ is tightly concentrated and f(ζ) is relatively flat around $v^\#$, then (22) is closely approximated by

(23) $$f(v^\#)\left[\int_{v_{min}}^{v^*}(v^* - \zeta)G_{V'}(\zeta)d\zeta + \int_{v^*}^{v_{max}}(\zeta - v^*)(1 - G_{V'}(\zeta))d\zeta\right] = \frac{f(v^\#)}{2}\left[\frac{\sigma^2}{J} + (v^\# - v^*)^2\right] .$$

From (18), $(v_{min} - v^\#)(1\text{-}p(m^*)) \le v^* - v^\# \le (v_{max} - v^\#)(1\text{-}p(m^*))$, where m* is the largest participation fee in the design. Use this to bound the last term in (23) where $v^\# = (v_{max} + v_{min})/2$ in the worst case,

(24) $$\mathbf{E}_V\left|\int_{v*}^{v'}(\zeta - v^*)f(\zeta)d\zeta\right| \le \frac{f(v^\#)}{2}\left[\frac{\sigma^2}{J} + \frac{(v_{max} - v_{min})^2\cdot(1 - p(m^*))^2}{4}\right].$$

Now add the bound (24) on the welfare loss per capita from sub-optimal project decisions and the cost C of jury recruitment and management, from (21). One question is whether participation fees included in (21) are transfers that should wash out of the calculation of social welfare. If so, transfers to jurors can be made sufficiently high to drive p(m) nearly to one and eliminate most selection problems, subject only to the requirement that income to non-jurors be sufficient to cover committed expenditures. For the current analysis, I assume that participation fees are the market wage for a prospective juror's foregone leisure and administrative cost of converting these prospects to participate, and entail a real social welfare cost. Then, the expected welfare loss per capita from a jury-based decision on the public project is bounded by

(25) $$Loss = \frac{J}{N}C + \frac{f(v^{\#})}{2}\left[\frac{\sigma^2}{J} + \frac{(v_{max} - v_{min})^2 \cdot (1 - p(m^*))^2}{4}\right].$$

This is minimized when $J^2 = f(v^{\#})\sigma^2 N/2C$, and at this minimand the loss is bounded by

(26) $$Loss = \sqrt{\frac{2C\sigma^2 f(v^{\#})}{N}} + \frac{f(v^{\#}) \cdot (v_{max} - v_{min})^2 \cdot (1 - p(m^*))^2}{8}.$$

In most cases, f will be inversely proportional, and σ will be proportional, to the value of the project. Then, the optimal jury size will rise with the square root of the population and the project value, and fall with the square root of the expected cost of a juror.

For example, if f and $f_{V|\mathbf{x}=1}$ are uniform on $[0,v_{max}]$, then the numerical values C = \$75, v_{max} = \$100, and N = 240,000, which might correspond to provision of a public park in a small city, give an optimal J = 115. Suppose for this example that a single participation fee m* is used, that the jury recruitment and management costs, $C = c_1/p(m^*) + c_2 + m^*$, and participation probabilities p(m) are the same as in the example following (21). Then (26) is minimized numerically at m* = \$170. This induces a cost per juror C = \$235, a participation rate p(m*) = 92.5%, and an optimal jury size J = 65. The expected loss per capita is bounded by \$0.20, or about 1.6 percent of the expected increase in welfare from optimal provision of the public project. Thus, a jury of modest size and cost, although with participation fees substantially higher than are considered the norm in survey research, ensures a relatively negligible welfare loss from jury-based estimation of the true value of the public project.

Additional prior information on the structure of the response model, or less weight on the worst case, will reduce the loss associated with attrition, reducing the need to attain very high participation rates, and leading to lower participation fees. For example, the semi-parametric specification (20) allows an unbiased estimate of v* using a two-point design distribution $F_M(m)$ located near the jury cost-minimizing level. In the previous numerical example, one can use a design with participation fees of \$4 and \$6 with equal probability and a jury of size J = 115, and achieve an expected loss per capita of about \$0.07, or 0.6 percent of the expected welfare gain from the public project.

The approximate calculations above omit two important factors, the contribution to the dispersion of the distribution of provision points from imprecision in the estimation of structural functions and parameters, which will tend to make J larger, and declining effectiveness of incentives for truthful response with jury size, which will tend to make J smaller. The calculations also leave unexplored the possibility that more sophisticated econometric mitigation of attrition bias in the design of the provision point estimator, and use of experimental treatments in jury selection to enhance the effectiveness of mitigation, could reduce further the expected welfare loss from using a jury estimate of value to determine public project provision.

4. Consumer Response to Incentives

The example in Section 3 shows that use of an economic jury of modest size, with high participation fees to minimize selection effects, and an effective incentive-compatible mechanism for eliciting juror values, leads to generally inconsequential errors in public project provision. This conclusion holds quite generally, as a consequence of the observation that the econometric task of estimating whether there is a social welfare gain from providing a public project is easy unless the cost and value of the project are close together, in which case the potential welfare loss is small.

Some additional considerations in jury design have already been mentioned. It may be useful to have auxiliary information, and Bayesian priors based on such information, to establish the structural background for designing juries for public project decisions. For example, experiments with participation fees may be used to estimate participation probabilities and effective framing of the solicitation to participate, and “training” juries with experimental design in the elicitation mechanism may be used to tailor incentives and frames that induce high rates of compliance and provide tests for individual compliance failures that could be used to disqualify non-compliant jurors. The Gorman preferences with parallel Engle curves that have been used in this paper are convenient for analysis, and may be a reasonable empirical approximation, but the design of incentive mechanisms and welfare calculus should ideally be robust to more general preferences.

Regarding consumer compliance behavior, an overview is that when incentives are large, consumers show little deviation from rationality, not only in familiar choice settings, but surprisingly even in complex, unfamiliar ones. There are exceptions. The quality of decision-making is heterogeneous, and there will usually be a fringe of consumers who are unable to get it right. When valuations involve remote future consequences, uncertainty, or affect, this fringe grows. When public projects involve social as well as individual benefits, jurors may be inconsistent in their reliance on "social norms". When incentives are small or unclear, less effort goes into determining best choices, and irrelevant factors play a larger role. Consumers are surprisingly truthful in circumstances where they don't need to be, but they may not supply the concentration and effort required to be accurate. Unfortunately, most economic juries recruited as survey subjects fit the case of small or unclear incentives, with little built-in control of effort and accuracy. The use of incentive theory, for example the Philipson (1999) suggestion to reward responses that are validated, is a promising avenue for bringing economic consumers up to the task of providing the reliable information needed to for accurate public policy decisions. It may also be possible to test for and screen out non-compliant jurors by extending the Groves and Ledyard (1977, 1980) incentive-compatible mechanism that rewards consistency with group tastes.

Public project choices in democracies are often done by referendum or by elected legislatures. There are good reasons to use these mechanisms to constitutionally constrain and validate democratic institutions, but if efficient resource allocation were the only consideration, then there would be a strong case for instead choosing public projects using incentive-compatible jury-based mechanisms, with careful management and mitigation of selection and non-compliant response effects.

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