Stated Preference Questions: Context and Optimal Response*

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Abstract

Businesses and governments devote substantial resources to the collection and analysis of survey data concerning the public's preferences. The possibility of strategic responses to such surveys is analyzed. Consequential and hypothetical surveys are formally defined. For the former the question is posed: what form should strategic behavior take? The particular form is shown to be context dependent. Key features of context such the question response format and the nature of the potential change in the agent's choice set are examined and several propositions concerning optimal strategic response are derived. In a number of important cases, the strategic response is shown to coincide with truth-telling and, in other instances, valuable information can be extracted from a strategic response if its nature is understood. Hopeless cases are identified.

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1 Introduction

Economists, by virtue of their professional training, instinctively tend to dismiss the credibility of responses to survey questions. Effectively, their argument is that nothing is at stake for the survey respondent in answering a question. This rather automatic dismissal seems a bit odd in light of the billions of dollars spent each year by businesses and governments to collect and analyze survey data. [16, 17] From a substantive perspective, this dismissal can be seen as inappropriate if either of two conditions holds. The first occurs if survey respondents are motivated to seriously consider the questions asked and they answer truthfully. This is the basic assumption of the other social sciences, which explains to a large degree their enthusiastic embrace of the use of survey data. The second occurs if respondents believe that businesses and the governments consider their survey answers in making decisions. In a world where a frequent criticism of governments is that they pay too much attention to the public's stated preferences in surveys and of businesses is that they are not willing to gamble with products or prices which do not fare well in survey-driven marketing research tests, this would appear to be not an unreasonable assumption. In this situation, an economist's first reaction to a survey question with real consequences might be to argue for the strong possibility of a strategic response. The pitfall economists tend to fall into here is not in considering the possibility of strategic behavior, but rather in jumping to the conclusion that if respondents behave strategically their answers can not provide useful information. This is obviously not true if optimal strategic behavior coincides with truth-telling or if the influence of the strategic behavior can be at least partially unraveled.

Having invoked the possibility of strategic behavior in consequential surveys, the inter-

esting economic question to ask is what form it should take? The short answer is that it depends on the context in which the question is asked. This answer hints at the nature of the problem and why the literature, principally in environmental and experimental economics, is so full of contradictory statements and conflicting empirical evidence concerning the modeling of stated preference data. In this paper, we employ mechanism design theory in considering the form of optimal strategic behavior where the influence of question context can be examined. Along the way we propose formal definitions for consequential and hypothetical surveys and consider how well the proposed theoretical framework helps to explain the existing pattern of empirical evidence. We anticipate that our results will be helpful to researchers in choosing question response formats and extracting information them.

The outline of the paper is as follows. Section 2 sets out notation and assumptions about agent, characterizes preference revelation contexts, defines consequential and hypothetical surveys, introduces the mechanism design framework which will be used, and describes various survey question response formats. Section 3 provides some general theorems for a single binary discrete choice question which apply to various contexts. Section 4 provides concluding remarks and suggestions for future research.

2 Model: Agents, Choices, Mechanisms

2.1 Agents

We consider an economy with $i = 1, ..., N$ **agents**, referred to as survey respondents, voters or consumers. It will often be useful to consider a random sample of $i = 1, ..., n$

agents from this economy. Agents are assumed to participate fully in all survey, voting, and purchase opportunities unless noted otherwise.

The focus of our interest is the choice of a good by an **agency**. This good may be a public, private, or quasi-public good. The agency may be a government or a private firm. Its decision problem is to decide whether or not to provide the good and, if so, at what price or tax cost to the agents.

Although this decision problem could be embedded in a more general model with multiple private goods provided on competitive markets by private firms and public or quasi-public goods provided by government, it suffices for our analysis to specify the preferences of the agents for the good in question and general purchasing power, e.g. money. If the good is a public good, we assume, for simplicity, that it is consumed by all agents at a fixed level. If it is either a private or quasi-public good, then it may be consumed in different amounts by different agents. We denote by z the decision whether or not to provide the good, i.e.

$$z = \begin{cases} 0, & \text{if agency does not make commodity available;} \\ 1, & \text{if agency makes commodity available for purchase or in fixed amount } \bar{y}. \end{cases} \tag{1}$$

If the commodity is offered at variable amounts for purchase at price q (if it is a private or quasi-public good) or at tax prices t_i for each agent i, we assume each agent's utility is quasi-linear in money:

$$v_i(z, q, t_i) = v_i(z, q) - t_i \tag{2}$$

Under this assumption, an agent's **willingness to pay (WTP) for the good (given q)** is:

$$WTP_i(q) = v_i(1, q) - v_i(0, q) \tag{3}$$

If the commodity is a private good, note that the willingness to pay (WTP) is an **option value**, that is, it is the maximum amount the agent would be willing to pay in order to have the commodity available for purchase and consumption at the price q. It is specifically not the expenditure the agent would make on the good were it made available at price q.

2.2 Agency Objectives

The basic decision facing the agency is to make the decisions z, q, and T; that is, to choose whether or not to make the good (public, private, or quasi-public) available (the decision $z = 0$ or 1) either in a fixed amount to be financed with taxes T, or variable amount for purchase at price q.

The **objective** of the agency depends on whether it is the government (providing, say, a public good, for example) or a private company (deciding on producing and marketing a new product, for example). We assume that if the agency is a private firm, its objective is straightforward **profit maximization**; that is, it will attempt to determine (a) if it can make a profit at all by supplying the good under consideration and, if so, (b) what the profit maximizing price to charge would be. Note that, in principle, a private agency interested in profit maximization would like to know the potential consumers' **(aggregate) demand function**; that is, their demands at various prices. This is not the same as knowing the (aggregate) willingness to pay to have the product available, as defined above in equation 3.

If the agency is the government, there are several different objectives that we consider. Traditionally economists have only considered the single objective of **(Pareto) Efficiency**, that is, to maximize (net) consumer surplus or, in our model, to maximize the difference between the aggregate willingess to pay and the (social) cost of providing the good under consideration. More recently, an alternative political objective has been advanced by analysts considering political (as opposed to bureaucratic) procedures for making public decisions. Since many public decisions are made through public referenda, that is, by direct voting on whether or not to adopt a proposal making available some public good at some tax cost, we consider the alternative objective of the government to be **Majority** (or, more generally, any **Plurality**) **Choice**, that is, to adopt a project if and only if a majority (or plurality) of the agents prefer it, or, in our model, if the willingness to pay exceeds the tax cost for a majority (or plurality) of the agents.

2.3 Random Procedures

It is frequently the case that the decision to be taken by the agency is contingent on outside factors that may not be known at the time the agency considers a project. Indeed, since the desireability of the project depends ultimately on the preferences of the agents, the stronger these preferences are – either in terms of a greater proportion of agents favoring the project or in the aggregate surplus (excess of benefits over costs) – the more likely it will be that the project will be adopted. Commissioning a survey of agents' preferences may be just the first stage of a process leading to the decision and *at the time the survey is conducted* it may not be known precisely how the survey results will affect the decision. It

may be reasonable to assume that the likelihood of an adoption of the project is increasing in the agents' support (however measured), but not possible to specify a precise level of the support necessary to ensure the adoption of the project.

At one extreme are decision procedures that *are* definite or non-random. For example, a bond issue referendum placed on a ballot will either result in the project being adopted or not. However, it is of interest to consider broader classes of procedures that admit probabilistic outcomes – that is, procedures such that the greater the support for a project the greater is the likelihood that it will be adopted.

2.4 Mechanism Design Framework

All the alternative agency objectives share the property that they depend on the preferences of the agents. Thus, whatever process the agency uses to make its decisions, it must obtain information about the agents' preferences from the agents themselves.

A central issue arises from this fact of asymmetric information, namely, that agents have private information about their preferences that the agency needs to acquire somehow. Whatever means the agency uses to obtain this information it must confront the motivation and behavior of the agents in releasing this information. It is not plausible merely to assume that the agents will reveal whatever information is requested by the agency – especially when the agents are interested in the use to which this information is put. Whether the information is gathered by means of surveys of one kind or another or directly through voting on referenda or by purchasing goods, it is essential to an understanding of how well the agency succeeds in realizing its objectives to understand how presumably self-interested

agents will behave when faced with these opportunities.

We formalize the process of obtaining information about the individual agents, plus the way this information is used in making the agency's decision, by the concept of a **Mechanism**. The model of mechanism theory [14, 11] is a powerful tool for analyzing respondent behavior when faced with different types of choice situations, especially when comparing different contexts or "preference revelation opportunity", such as voting, survey responses, or purchase decisions.

At the most abstract yet simple and all-encompassing level a mechanism is defined as follows: let the group of agents ("survey respondents", "voters", or "consumers") be indexed by $i = 1, ..., N$ (as defined above in Section 2.1) Let A denote a set of alternative (feasible) outcomes that can result from the agents' decisions combined with the "government's" actions based (in part) on the agents' decisions. For example, an element, a, of A may be a specific quantity (or quantities) of a (public, quasi-public, or publicly-provided private) good q, plus an allocation of costs to all the agents.

A mechanism $\mathcal{M} = [M, \rho(.)]$ consists of two components: (a) a language (or message space) M – a set of elements, m, that are responses or messages an agent may choose – and (b) an outcome function, $\rho(\cdot)$, that specifies an outcome a in the outcome space A for every N-tuple of messages $m = (m_1, ..., m_N)$ (one from each agent i).

For example, suppose the 'type of good' being considered is, say, a 0-1 public project, such as a bridge, a dam, an air pollution control program, or the like, and the 'preference revelation opportunity' is a referendum vote of the N agents. Then, the outcome set A consists of the two elements (i) the do-nothing status quo, $a = 0$, and (ii) the adoption of the project plus the specifics of the taxes to be paid by each agents, $a = 1$. The referendum

mechanism is given by the message space M containing the two elements, a "yes" vote, $m = 1$, and a "no" vote, $m = 0$, and the outcome function $\rho(m_1, ...m_N) = 1$ if and only if the number of "yes" votes exceeds the number of "no" votes, i.e., if $\sum_{i=1}^{N} m_i \geq \frac{N}{2}$.

For a survey type of 'preference revelation opportunity' the message space consists of all possible responses an agent might give to the survey questionnaire. The outcomes in the outcome space, A, may be quite complicated. For instance, an element might specify separate quantities of a quasi-public or private good consumed by each agents and the costs assessed each agent for the agent's consumption. Or, for instance, the outcomes associated with a survey mechanism might be a probability distribution over possible actions the government might take given the responses to the survey (i.e., given the messages chosen by each survey respondent).

The power of this formal model results from the observation that since each agent is assumed to have individual preferences over all possible outcomes (i.e., a preference relation on A), a mechanism induces (or defines) an N-person game where the strategies of the individual players (the N agents) are just the messages of the message space and the players' preferences over the joint-strategy space, MN, are those induced by their preferences over the outcomes and the (inverse) outcome function, $\rho^{-1}(\cdot)$. Thus, all the tools of N-person game theory may be applied to the problem and one can ask such questions as: Is the truth-telling joint message an equilibrium of the game defined by a particular referendum or survey mechanism? Or, at an equilibrium of the game defined by a particular voting or survey mechanism, is the outcome efficient (in the Pareto sense) or "fair" or consistent with a particular normative criterion for evaluating alternative outcomes relative to the preferences of the agents?

2.5 Examples of Mechanisms

(A) Non-random:
  (1) Private purchase
  (2) Binding referendum vote
(B) Random:
  (1) Advisory referendum vote
  (2) Advisory survey
(C) Mixtures
  (1) Survey followed by binding referendum
  (2) Survey followed by purchase opportunity

2.6 Agent Behavior

Given a mechanism, $\mathcal{M}$, and the resulting induced game, Γ, we assume agent behavior is consistent with *monotonicity*.

Definition: (a) Given the mechanism $\mathcal{M}$, agent i's preferences over the message space M_i, $\succ$ satisfies **monotonicity** if $m_i' \succ m_i$ whenever
(i) $w_i(\bar{m}/m_i') \geq w_i(\bar{m}/m_i)$ for all $\bar{m}$
and
(ii) $w_i(\bar{m}'/m_i') > w_i(\bar{m}'/m_i)$ for some $\bar{m}'$ where
$w_i(m) = v_i(\rho(m))$ is agent i's payoff function (indirect utility) over . joint messages m.
(b) Given a mechanism $\mathcal{M}$, the message m_i^* is **dominant** if $m_i^* \succ m_i$ for all $m_i \neq m_i^*$

An agent's behavior, then, is consistent with monotonicity if he/she always chooses a dominant message, *whenever one exists.* It is important to note that dominant messages often do not exist. That is, in some situations, given a particular mechanism, it might be better for an agent to choose m_i^1 when the other agents choose m^1 and to choose m_i^2 when the others choose m^2. Without further specification of agent behavior – in particular, what they may believe about other agents' messages or strategy choices – we cannot predict how an agent in this situation will respond. For this reason, it is highly desireable to use mechanisms that have **dominant strategy equilibria**, that is, are such that every agent has a

dominant message – as long as, if at such an equilibrium, the mechanism selects an outcome satisfying the agency's objective!

The concept of dominance can be contrasted with a weaker form of monotonicity that is sometimes assumed. A **weakly monotonic message**, m_i', is such that only part (a)(ii) of the monotonicity definition is satisfied. Thus, whereas any dominant message (if one exists) must be unique, many *weakly* dominant messages may exist. It is sometimes assumed that if several weakly dominant messages exist, then the agent will choose the particular one preferred by the agency. While this may seem a mild assumption, it is actually very strong and, more importantly, strongly refuted by much empirical evidence of agent behavior.

In particular, weakly dominant messages will always exist in a **hypothetical** situation – that is, if, given a mechanism, the agent can never affect the outcome, regardless of the messages of all the other agents. In such a case, *all* messages are weakly dominant and there is no basis within the model for assuming the agent will choose one message over another.

A hypothetical situation can arise in different ways. One way is if respondents may reasonably believe that their answeres will not affect any outcome that is relevant to them. Mechanism theory, based on a model of individual economic rationality, makes no predictions about respondents' verbal behavior in such hypothetical situations.

In non-hypothetical situations, that is, when the agent can, at least, sometime actually affect the outcome, there are two cases to distinguish. One is a situation that is similar to (but not the same as) a hypothetical situation arises when an agent is indifferent among all possible outcomes the mechanism can select. As in a hypothetical situation, in this case all messages are also weakly dominant. This situation is particularly vexing since it is not controllable by the choice of mechanism. For example, suppose the agency's choice

problem is whether or not to undertake project A and that its objective is to accept A only if a plurality of all voters favor A. A simple referendum will have the property that all those strictly preferring A will vote for it whereas those strictly preferring the status quo (not A) will vote against A. But, if there are a significant number of individuals truly indifferent between A and not A, their votes can determine the outcome regardless of the relative size of the groups strictly preferring A and not A. This still holds if the referendum also would allow for a vote of indifference (in addition to votes either in favor or against A). A truly indifferent voter has no basis to choose between a vote for, a vote against, or the "true" vote of indifference. It is sometimes held that the mere cost of voting will induce the indifferent voter to abstain. But, if the information is acquired in a survey, rather than a referendum, then it may indeed be easier to answer questions randomly rather than refuse to answer at all!

There appears to be no good way around this problem. Indeed, much effort is expended in actual survey practice to exclude truely indifferent respondents from the survey sample. Our point is that while non-hypothetical surveys – that is, surveys that are used to influence (however slightly) real decisions – can minimize the subsample of indifferent respondents, they may not eliminate them entirely. But, hypothetical surveys make *every* respondent indifferent (in the sense defined here).

The other non-hypothetical case arises when an agent does have a strong preference ordering over some of the alternatives whose selection by the mechanism he can affect, at least under some conditions and to some degree. We refer to these cases as **consequential**. These situations are addressable by mechanism theory since the theory of rational economic behavior makes predictions in such cases.

3 Results on Some Selected Survey Mechanisms

3.1 Private Good Provision

Frequently surveys are undertaken to determine whether or not to provide a new (or redesigned or reformulated) private good on the market. From the point of view of the model formulated in the previous section it is sometimes difficult to understand how such surveys can provide the agency (here, the private firm) with meaningful information. Two cases can be distinguished.

In case 1, consider a private firm wishing to find out if consumer tastes are sufficiently positive towards a new product to warrant putting it on the market. Assume, as is typically the case for such new product introductions, that no other choice opportunity would be affected by the agency's decision. In this case, it is **never** a dominanting strategy for an agent to express anything other than the response that would have the greatest impact on increasing the likelihood of the product being introduced. Since an agent can always decline to purchase the product if it is made available, having it made available cannot decrease his utility. If there is any chance that he might wish to avail himself of an opportunity to purchase the good if it is available, then he is strictly better off when the good is provided than when it is not. Note that it is not always a dominant strategy to express a maximal preference for the good's provision, but it is always a **weakly** dominating strategy to do so. Since economic theory does not make sharp predictions of behavior when dominant strategies are not available (in the context of the model we discuss here), it follows that survey respondents' behavior in such survey contexts is not predictable from economic analysis.

In case 2, the introduction of the new or newly formulated product displaces some other product. In this case, it now may be a dominant strategy to respond to a survey about the new product in whatever way maximally increases or reduces the likelihood of the product being introduced. In such situations, every survey question will be answered (by an economically rational agent) in such a way as to have a maximal impact on either having the new product offered or having it killed. In this respect, this type of private good situation is similar to a public project choice in which the alternatives are either the status quo or a public project that is financed at a specific tax cost for every agent. A rational agent will prefer the new opportunity at the cost of the loss of the old opportunity only if utility is higher under the new opportunity than under the old one.

3.2 Limitations of WTP Surveys when Costs are Known

Although a survey may be only a small part of a complicated decision process, as long as the survey respondents believe there is some relationship between their responses and the ultimate decision, they have, in general, an incentive to respond strategically – that is, in such a way as to maximize their utility taking account of how their responses may affect the decision. In fact, the strategic incentives an agent has are equivalent for a broad class of mechanisms ranging from an official binding referendum to a survey undertaken to merely advise policy makers about some public project. Furthermore, for the simple class of binary decision processes such that the likelihood of the project being ultimately adopted strictly increases with positive response ("message"), it is a dominant strategy generally for a respondent (voter or survey participant) to honestly reveal his/her preference. Formally

we can state the general proposition as:

Proposition 1. *Consider any binary choice mechanism $\mathcal{M}$ such that (a) each agent's message space is the set $\{0, 1\}$, (b) the outcome space A is any family of probability distributions over the binary set $\{a_0, a_1\}$, and (c) the outcome function ρ is weakly responsive in each agent's message m_i in the sense that:*

$$Prob\{a_1|\rho(m/1_i)\} \geq Prob\{a_0|\rho(m/0_i\} \quad \forall \quad \textit{joint-messages} \quad m \tag{4}$$

It is a dominating strategy for every agent to report "honestly", i.e. to report $m_i = 1$ if and only if alternative $a_1 \succ_i a_0$.

Observation 1: This Proposition implies that, from the perspective of the strategic incentives of the agents, the binding referendum, the advisory referendum, and the advisory survey are all equivalent. In other words, in the same way a voter has an incentive to vote honestly for a public project (say) as long as his willingness to pay for the project exceeds his tax cost, a survey respondent has an incentive to answer honestly the question "Would you be willing to pay your tax cost for public project A?" even if a positive response will only increase the likelihood of the adoption of project A by a small (but strictly positive) amount.

Observation 2: As is well known, the standard referendum mechanism, which adopts an alternative only if it receives a plurality (typically, a majority) vote, is not, in general *efficient*. That is, even though voters have an incentive to vote honestly, the chosen alternative may not be Pareto efficient, since there is no guarantee that the aggregate willingness to pay of those voting in favor of the winning alternative exceeds the loss of aggregate willingness to pay of those voting against. The strategic equivalent advisory survey also is limited in use for making efficient decisions. Asking only if a respondent would be willing to pay his tax cost can provide no information how much greater (or smaller) his true willingness to pay

is than his tax cost.

Although many surveys make no attempt to uncover agents' willingness to pay – being instruments for assessing political support for a project only – many other surveys *do* attempt to acquire willingness to pay information either because such information, if known, would allow more efficient public or more profitable private decisions to be made. A canonical form of the survey designed to elicit willingness to pay is the open ended survey format which simply asks agents what their willingness to pay for a specified project is. While common, from a mechanism theory perspective, such formats cannot be expected on incentive grounds to yield truthful responses. A respondent, asked the question, "How much would you be willing to pay for project A?", would (under our assumption of economic rationality and a specification of the government's decision criterion to maximize net reported benefits) be expected to make the following strategic analysis: If he would vote for the project at his likely tax cost if the project is adopted, then he should report the highest believable willingness to pay; alternatively he should report the lowest believable willingness to pay if he would vote against the project.

Recognizing the strategic limitations of this open-ended survey format, a more sophisticated survey form has become widely used. This form randomly divides the survey population into a number, say n, subsamples and asks each respondent in each subsample j: "Would you be willing to pay t_j if project A were adopted?" This *binary choice* survey format is *thought* to avoid the incentive difficulties of the open-ended survey, since it appears to be similar to the simple binary choice referendum, which, as we saw above, is incentive compatible. By observing the fraction of each subsample willing to pay the hypothesized cost (tax price t_j), one can construct an approximation to the population's underlying true

Willingness to Pay distribution. [2] Furthermore, as the number and size of the subsamples grow, the better the approximation is. It is then claimed that the agency can use the (approximate) WTP distribution to make (approximately) efficient decisions, since it then would have the requisite information to determine if aggregate WTP exceeds the project cost.

Closer analysis of this argument from the mechanism theory point of view uncovers a major assumption. A necessary condition for a rational respondent to answer truthfully if he is willing to pay a proposed value, t_j, is that he believes he would indeed be charged this amount were the project to be adopted. This may be an especially difficult assumption to make for survey values at the extremes of any plausible cost distribution. A rational respondent should be expected to interpret any proposed value, t_j, of his tax cost in light of his understanding of how his actual taxes would be affected by the adoption of the project. And, in particular, if he is at all aware of how the value was assigned, he would realize that it has little relation to his actual tax cost, if the project were adopted.

Formalizing this analysis, the following proposition establishes that only if the respondents assume their actual (ex post) tax cost, if the project is adopted, is equal to the survey value, will they respond truthfully to the binary choice survey.

Proposition 2. *Consider a binary choice survey such that each respondent is asked the question: "Would you be willing to pay (a tax cost of) t_j if project A is adopted?". Further, suppose that the result of a difference between a positive and a negative answer to this question by any respondent is always a non-negative and sometimes a strictly positive increase in the likelihood of the project eventually being adopted. If the respondent is risk-neutral and believes his response has the stated impact on the likelihood of the project being adopted, his dominant strategy response is to respond positively if and only if his (true) willingness to pay is greater than his expected tax cost of the project if it is adopted.*

Observation: This proposition points out the crucial relation between a survey respondent's

response and the expected tax cost he would face if the project were adopted. Mechanism theory typically assumes that all agents know the (mechanism's) outcome function or the precise mapping between all agents' reponses and the outcome chosen – whether a definite outcome or a particular probability distribution over outcomes. In the context of our model, there are two elements of the outcome that are relevant to an agent – the probability of the project being adopted and the likely tax cost to the agent. A survey instrument that asks respondents about their willingness to pay a specific tax cost that may not be at all reasonable, given what is commonly known or believed about the project's cost and the nature of the tax structure, cannot expect to elicit very reliable responses. This can be appreciated most readily in a case, say, in which everyone knows the specific cost of the project under consideration. In such a case, a rational agent would disregard the value mentioned by the survey questioner and answer simply on the basis of whether or not the project would leave him with a net surplus after paying his tax share of the known cost.

3.3 Unknown Cost; Honest Responses

Although we may be willing under some circumstances to assume agents believe whatever valuation they happen to be asked would be their cost if the project is adopted, it is of interest to explore alternative beliefs that are more plausible in other situations. One such situation that has been discussed arises when a survey is undertaken either before or concurrent with studies (e.g. engineering studies) to estimate the cost of a project. In such a situation, it is entirely plausible for survey respondents to believe that the agency does not have a good estimate of costs and thus that the survey value about which they are asked

could turn out to be the relevant cost for them.

However, even if a respondent can plausibly be assumed to believe that the value they are asked about could possibly turn out to be their actual cost, *at the time* they respond to the question, it is only (for risk neutral agents) the *expected* cost whenever their response is counted that matters. This is a direct consequence of the above proposition.

Consider the example of an agent who values a project at, say, $200. Suppose that he is asked if he would be willing to pay $250 and that a 'yes' response would increase the likelihood of the project being adopted. Then, even if it is possible that *ex post* the cost to him of the project might turn out to be $250, his best response to the question would be positive if, at the time of his answer, his *expected* cost is any value less than $200.

Recognizing that agents in such situations can have incentives to respond in a manner other than that desired by agency surveyers, the following modification in the way the respondents' responses will be counted may be made: For each subsample j, the survey respondents' answers will be counted only if the *ex post* cost (per person) is the value at which the subsample is queried. Under this modification in the mechanism, the relevant expected cost for a respondent is then exactly the cost about which he is asked. Formally:

Proposition 3. *Consider a binary choice survey such that each respondent is asked the question: "Would you be willing to pay (a tax cost of) t_j if project A is adopted?". Further, suppose that the result of a difference between a positive and a negative answer to this question by any respondent is zero unless ex post the per person cost turns out to be t_j, in which case it is always a non-negative and sometimes a strictly positive increase in the likelihood of the project eventually being adopted. The respondent's dominant strategy response is to answer positively if and only if his (true) willingness to pay is greater than the queried value t_j.*

Proof: The mechanism considered here is a simple variant of the classic Becker-DeGroot-Marschak [1] mechanism for eliciting an agent's true value for an object. In that mechanism,

the cost at which the object will be sold to a respondent is written on a piece of paper and placed face down in front of the respondent. The respondent then states a value for the object and if and only if it is greater than the amount written, he receives the value at the written amount. It is a dominant strategy for the respondent to state his true valuation since, whenever it turns out *ex post* that his value is greater than the written amount, he receives the object and a surplus equal to the difference. Whenever his value is less than the written amount he avoids a loss in surplus of the difference. Were he to respond with any other value, if the written amount turns out to be between his true and reported value, he does strictly worse than if he had reported his true value since he loses the surplus if the reported value is less than his true value or he suffers the loss if he reports a value above his true value and the written value turns up between the two.

In the mechanism of the proposition, the survey value t_j is analogous to the written value of the Becker-DeGroot-Marschak mechanism, and a 'yes' response is analogous to reporting a true value greater than t_j and vice versa for a 'no' response. □

Observation: While providing incentives to respondents to report truthfully to the survey, this mechanism ignores the information provided by all the respondents in subsamples other than the one corresponding to the *ex post* cost t_j. Thus, the agency could possibly find itself in the situation where, *ex post* the decision it takes is known to be not only inefficient but not even supported by a majority of all agents. Although no mechanism based on the binary choice survey with tax prices that are independent of individual valuations can ever be guaranteed to be efficient, if the subsamples are large enough, the likelihood of the decision not satisfying whatever plurality rule is specified (e.g. majority) can be made arbitrarily small.

In practice it is not possible to divide the sample of respondents into sufficiently numerous subsamples to cover every possible *ex post* cost. Instead, only a relatively small number of subsamples can be sampled. The mechanism is then modified to use only the answers of respondents in adjacent subsamples whose queried values t_j and t_{j+1} bracket the *ex post* cost, once it is learned. Typically the responses are then weighted inversely by the distance

from the survey value t_j or t_{j+1} and the *ex post* cost.

A direct corollary of the previous two propositions establishes that:

Corollary 1. *Under the conditions of Propositions 2 & 3, for respondents whose true values lie outside the interval* $[t_{j-1}, t_{j+1}]$*, it is still a dominant strategy to respond truthfully to the question: "Would you be willing to pay (a tax cost of)* t_j *if project A is adopted?". However, if the respondent's true value* v_i *lies in the interval* $[t_{j-1}, t_{j+1}]$*, and he is risk neutral, his best response is to answer positively if and only if his conditional expected cost is less than his true value, where the expected cost is conditional on the event that it ex post cost lies in the interval* $[t_{j-1}, t_{j+1}]$*.*

4 Further Directions

(1) Consideration of how the stated cost in the survey should influence the respondent's expectation about actual costs.

(2) Consider explicitly the incentive possiblities of non-binary discrete choice formats. These include double bounded dichotomous choic, multinomial choic, bidding games, payment cards, and opend-ended questions.

(3) Consider how information about costs provided (or not provided) in the survey should influence optimal responses. Initial work suggests that optimal strategies "anchor" in some way on the cost information provided in the survey.

(4) Consider the role of risk-aversion when there is uncertainty over costs and/or benefits.

(5) Determine how well the model's predictions are verified by empirical tests already in the literature. Also, suggest new experiments.

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