Demand-side Value for Ecosystem Services and Implications for Innovative Markets: Experimental Perspectives on the Possibility of Private Markets for Public Goods

Stephen K. Swallow

Environmental economists invest in measuring the value of the environment but put less effort toward integrating that value directly into the economy. Experimental economists evaluate the performance of mechanisms to fund public goods but in some cases offer limited insight into practical implications for developing markets. This discussion presents initial insights into applying mechanisms for private provision of public goods based on demand-side values rather than regulatory-based market incentives such as cap-and-trade policies. Consideration of mechanisms to generate revenue inspires field tests that could direct experiments using threshold public goods and Lindahl's framework toward applications that transform value into revenue.

Key Words: aesthetic value, auction, cultural ecosystem services, Lindahl pricing, nonmarket valuation, provision point, rebate, wildlife habitat

The concept of ecosystem services places emphasis on the benefits that nature provides for human well-being and has become a significant topic in discussions of market-like or incentive-based approaches to provision of public goods. My purpose here is to stimulate further a research agenda regarding market-based approaches, an agenda at the frontier of environmental economics. This agenda comes, in part, from a simple observation exemplified by a comment by Geoffrey

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Heal as we took an academic break at the foot of the Front Range of Wyoming (about 1999). Professor Heal observed that our profession spends an awful lot of effort trying to estimate values for the environment and not much effort in attempting to integrate those values directly into the economy. So my purpose here is to offer some initial insights, to outline some conceptual challenges and example issues surrounding the potential for economists to expend effort toward incorporating individuals' environmental values into the economy.

First, we should consider whether there is evidence that private markets for public goods will work. After all, we know that free-riding is a robust individual-level strategy. Yet we also know that philanthropic organizations exist and have a substantial impact for ecosystem services. Second, in an experimental market to support grassland nesting habitat for birds, Swallow et al. (2008) and Swallow, Anderson, and Uchida (2012) generated around $9,000 in revenue despite not yet having the ability to optimize the price or marketing strategy. Third, Smith (Smith 2012, Smith and Swallow *forthcoming*) ran a successful field experiment in Virginia's two poorest counties and obtained substantial monetary support for restoration of sea grass and habitat for fall-migrating birds. The perspective I offer here comes from thinking about these latter experiences.

Environmental policy and management for rural lands, including agricultural, forest, and wild lands, in the United States has moved from multiple-use management through ecosystem management as key foundational concepts, contributing to development of new, interdisciplinary fields such as conservation biology (Swallow 1996) and sustainability science (Hart and Bell 2013). Over the last decade or so, science and policy discussions have developed the concept of ecosystem services as a focus that motivates humans to support conservation. The ecosystem service concept might enable managers to leverage the power of self-interest by placing an explicit emphasis on the benefits that ecosystems and the environment provide to humans. This process led to the Millennium Ecosystem Assessment (2005), which produced a widely adopted taxonomy of ecosystem services. That system identified provisioning services (e.g., seafood, water, wood), regulating services (e.g., climate mitigation, wetlands buffering capacity for flood mitigation), cultural services (e.g., hunting, fishing, hiking, landscape appreciation), and supporting services (e.g., ecosystem processes that support production of the other services).

Recently, Johnston and Russell (2011) contributed explicit and flexible criteria linking ecosystem services to a general and delightfully parsimonious model of human utility. They identified principles to aid us in mitigating ambiguity in applications of the ecosystem service concept while averting double-counting, which can result from overly casual applications.[1] To summarize and, necessarily, to oversimplify Johnston and Russell's (2011) already straightforward framework, I note that they designate biophysical outcomes of ecosystems as final services when at least one fully informed, rational person is willing to pay to increase the delivery of that outcome under the condition that nothing else in the environment changes, and they recommend that only final services should be counted in benefit measurement and that those involve biophysical outcomes that occur prior to the input of any human-made capital or labor. While I may not completely avoid casual application of the ecosystem service concept, the existence of a willingness to pay for a change in

[1] Johnston et al. (2013) in this issue of *Agricultural and Resource Economics Review* provide an application of valuation that strives to apply Johnston and Russell's (2011) principles.

biophysical outcomes, even if directed at management actions that target what Johnston and Russell (2011) rightly characterized as intermediate services, is my point of departure or motivation.[2] Natural heterogeneity in individual (and group) preferences may place a single biophysical outcome as a final service or as an intermediate service, or ecological (or agro-ecological) production might involve points of management intervention in ecosystem structures and functions that precede the critical final outcomes that directly contribute to human well-being. In addition, many valuable ecosystem services are well characterized as public goods. These factors—heterogeneous preferences, points of intervention in production, and public goods—(perhaps with other factors) imply that ecosystem services and markets, when based on consumer values, will necessarily be quite messy. Market activities that involve payment for actions may not focus purely on what Johnston and Russell identify as final services. Yet these markets may nonetheless rely on the ecosystem service concept.

I cannot pretend that this paper will resolve the potential messiness—it may be necessarily messy simply because people making payments in markets need those payments to be tied to identifiable, deliverable actions or products. Identifiable products may not be the final services, particularly if a household uses its own production process to create the good of final interest. What I will emphasize is conceptual insight based on experience with field experiments.

Objectives

My pursuit of this topic began with an introduction to experimental economics, particularly for mechanisms that provide public goods by generating voluntary donations. Some initial work involved adapting or adopting experimental methods to test the (convergent) validity of stated preference approaches to valuation (Newell and Swallow *forthcoming*, Newell 2002, Newell and Swallow 2002, Spencer, Swallow, and Miller 1998, Swallow, Anderson, and Philo 2003). I will consider some of the potential foundations for marketing public goods based on experimental economics methods or on mechanisms tested experimentally. I also will consider connections between these approaches and market equilibrium, which will motivate another potential approach.

I offer these perspectives in the spirit of a challenge. In particular, I appreciate the perspectives of well-regarded applied-welfare economists such as Portney (2004) and Krutilla (1981) who caution that a blind pursuit of theoretical ideals, such as insistence on market methods that produce a Pareto efficient outcome, can misdirect our professional efforts away from opportunities to improve social welfare by leading us to develop less-than-ideal mechanisms of practical value to potential or existing policy, business, or market settings. My

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[2] For noneconomists, I wish to stress the generality of economists' valuation concepts, which are not really "all about money" even though we commonly use willingness to pay to measure value in monetary units (since Hicks (1943)). In particular, the economic concept of value is based on constrained choice: what good thing(s) is a person willing to *sacrifice* to obtain more of some other good, desirable thing. This is based on a personal pursuit of our own subjective preferences and happiness. Money simply provides a convenient metric by which we can say that a person is willing to sacrifice all the stuff that a certain amount of money could have helped him or her obtain otherwise. Thus, an international land conservancy could express the "value" of acres preserved on Block Island in Rhode Island in terms of money (a purchase price for those acres) or in terms of foregone preservation of acres of tropical rainforest to which those dollars might have been redirected.

fundamental challenge is to ask environmental economists to consider whether it truly is not possible to develop markets for public goods. I encourage that we direct more of our effort toward topics that boldly go where even our basic textbooks suggest we should not.

As an introductory example, I am questioning whether the field of economics has been wise in its conclusion regarding Lindahl's (1919) fundamental insight that asking individuals to reveal their marginal value for a public good should be a foundation for an efficient market designed to enable private provision of public goods. Our textbooks, such as Nicholson (2005, p. 602), conclude that Lindahl's framework is impractical. Yet I have not been able to find an example in which that conclusion has actually been tested in empirical work, at least not prior to Smith (Smith 2012, Smith and Swallow *forthcoming*).

This discussion, then, advocates empirical research and development "to do better," even if we cannot achieve Pareto optimality. Government-moderated approaches to environmental public goods will remain important in the long run, as will philanthropic action by land trusts, conservancies, and others. But markets constitute a powerful mechanism for solving complex problems with minimal cost. Can environmental economists develop mechanisms that unleash the power of markets to provide public goods and thereby to address many of the ecosystem services our economy currently undervalues? I am not referring here to green or eco-friendly marketing of private goods (e.g., Sedjo and Swallow 2002, Swallow and Sedjo 2000). Rather, I mean to link payments by beneficiaries directly to providers of a specific ecosystem service.[3] Can we do substantively better in squeezing out incentives to free-ride to enable those in a position to provide more ecosystem services—often forest or farm owners—to better consider everyone's values in their business plans? Can we invent tools to enable providers to earn revenue from ecosystem services? Can environmental economists lead society by creating and testing institutions to stimulate incentives for ecosystem-service public goods? Will some novel institutions require that the transaction costs be less than those incurred in familiar government processes? This agenda may demand collaboration with ecologists, perhaps within a research framework such as that presented by Collins et al. (2011). Can we create "experimental market ecology" to provide a means for such discovery?

A Selective Overview of Experimental Economics for Public Goods

For a basic perspective on experimental economics, let us consider work that evaluates the incentives or mechanisms under which individuals contribute, or could contribute, to support public goods financially (Liu, Swallow, and Anderson 2011). One line of literature concerns a linear public good game in which individuals consider whether to contribute a dollar to a public fund knowing that the marginal benefit to the individual is less than one dollar while the benefit across all participants in a group exceeds one dollar. In this game, the group gains a greater profit if everyone contributes a dollar than if one or a

[3] Already I may have run afoul of Johnston and Russell's (2011) rules. If final ecosystem services can be produced only "naturally," without a human-associated input, then perhaps I am talking here about commodities built on or from an ecosystem service. But if laissez-faire management of a hayfield provides wildlife habitat, or if a restored wetland enables ecosystem processes to unfold and produces the service of carbon sequestration or water-quality improvement with no further human interference, then we may have resolved the apparent conflict in some cases. I leave the other cases for creative thinking by readers.

few people choose not to contribute to the fund. Numerous studies have built on this game, often to address basic questions associated with distinguishing the motives of free-riding, altruism, or even simple confusion (e.g., Andreoni 1988, 1995, Isaac, McCue, and Plott 1985, Palfrey and Prisbrey 1996).

I have not used the linear public good game as a foundation for testing incentives for support of public goods because the linear game requires or asks each individual to go beyond the usual incentive to free-ride by taking a marginal action that is clearly against his or her own immediate self interest. The individual's marginal cost exceeds his or her marginal benefit. However, understanding motives actually exhibited by individuals or groups in contributing to public goods could certainly generate some marketing advantages for ecosystem-service entrepreneurs. For instance, if individuals react to social (rather than to strictly economic or financial) incentives, which may come, for example, through a reputation for cooperation or simply through a personal altruistic interest in helping others who care about ecosystem goods, the experiments could illuminate co-benefits that a potential contributor might pursue and an ecosystem-service provider might leverage.[4] For example, the benefit that birdwatchers might gain from farmers who protect hayfields from harvest during the nesting season for grassland birds could provide not only personally important wildlife and scenic benefits but also help sustain local farms, generating the potential to give local schoolchildren an appreciation for the foundation of food systems.

A second important line of literature in experimental economics concerns public goods that require a threshold level of funding, often called a provision point, that a fundraiser or market-maker must reach to provide a unit of the public good. In these experiments, the researcher provides individuals with a budget that they can keep or from which they can choose to contribute (offer) an amount toward a "group fund." The group fund pays benefits to every member, including noncontributors, thereby mimicking the benefits of a public good. The individual's benefit, which is assigned by the experimenter, gives each participant an "induced value" that establishes each individual's Hicksian willingness to pay for the public good. For a threshold public good, the group fund must reach a minimum aggregate contribution for the fund to provide any payoff; if group contributions fail to meet this minimum, the money-back guarantee would refund all contributions. Solicitations for offers may use methods similar to contingent-valuation questions with open-ended or discrete choice approaches. Participants may offer any amount, but their maximum utility does not require an offer that exceeds the individual's marginal value.

Nature may create circumstances in which thresholds are critical to production, such as when grassland birds need a field of a minimum size to even attempt nesting or when a highly fragmented landscape threatens the survival of an interior-forest species (cf., Swallow 1996, Lewis, Plantinga, and Wu 2009, Lewis et al. 2011). However, a provision point also could be established by a market-maker, auctioneer, or coordinator; setting the provision point can be a control variable. This mechanism basically involves soliciting a voluntary contribution to support provision of the public good with the rules of exchange known *a priori* to contributors. The rules may involve a money-back guarantee

[4] These considerations have been explored in various experiments that identified framing effects or effects of allowing group discussion (e.g., Brosig, Weimann, and Ockenfels 2003, Isaac and Walker 1988, Kotani, Messer, and Schulze 2010, Messer et al. 2007, Messer, Suter, and Yan *forthcoming*).

in the event the coordinator fails to achieve the provision point and, therefore, fails to provide the good.

Poe et al. (2002) and Rose et al. (2002) provide a good review of this experimental literature, noting that provision points have increased contributions to public goods relative to standard donation mechanisms (cf., Rondeau, Schulze, and Poe 1999, Rondeau, Poe, and Schulze 2005). Spencer et al. (Spencer, Swallow, and Miller 1998, Spencer et al. 2009) and Newell and Swallow (Newell and Swallow *forthcoming*, 2002, Newell 2002, Swallow, Anderson, and Philo 2003) used the provision point approach in studies that tested the convergent validity of stated preference valuation and found evidence of correspondence between stated values and values consistent with contributions, particularly for the marginal dollar contributed.[5] Some of those studies incorporate a rebate of excess funds as part of the rules of exchange. For example, Marks and Croson (1998) considered a "proportional rebate:" if the aggregated contributions (or binding pledge) exceed the provision point threshold by *X* percent, contributors receive a rebate of *X* percent of their contribution and the coordinator retains only enough funds to cover the provision point.

The provision point establishes the possibility of nonprovision without contribution, and rebates reduce or mitigate the cost to individuals of contributing an excess dollar beyond the funding threshold. These features reduce the expected value of strategies to withhold contributions, such as free-riding (withholding a contribution on the assumption that others will contribute sufficiently to provide the good anyway) or cheap-riding (whereby an individual makes a contribution that is less than his or her full Hicksian value).[6] The provision point mechanism provides, in principle, a means to solicit voluntary contributions from individuals willing to pay for a unit of the public good, and existing theory and laboratory evidence suggest that contributions can or do exceed standard voluntary donations in the absence of a provision point. In principle, this approach is consistent with individual marginal incentives because, while the individual could make a contribution that exceeds her marginal benefit, she is not asked to do so. Because provision-point-with-rebate mechanisms do not require marginal action against a contributor's self-interest (relative to the status quo), this experimental economics approach seems attractive as a potential avenue for creating markets in which consumers can connect their values for particular ecosystem services to actions a particular provider takes. But how might it work? And how might the outcome measure up on standard criteria?

The Lindahl Framework and Efficiency

It is natural for economists to think of pursuing Pareto efficiency. Following Lindahl (1919) and the structure provided by Samuelson (1954, 1955), we know that a Lindahl equilibrium is an efficient equilibrium for public goods

[5] Messer et al. (Messer, Schmit, and Kaiser 2005, Messer, Kaiser, and Poe 2007, Messer, Kaiser, and Schulze 2008) provided examples in a nonenvironmental agricultural marketing context.

[6] With too many free-riders, individuals learn that the hoped-for benefits will not arrive unless enough individuals contribute. The proportional rebate reduces the individuals' cost of contributing a dollar beyond the provision point, thereby reducing the incentive to attempt to cheap-ride since *X* percent will be rebated, although *X* is endogenous to the mechanism based on aggregate contributions relative to the provision point.

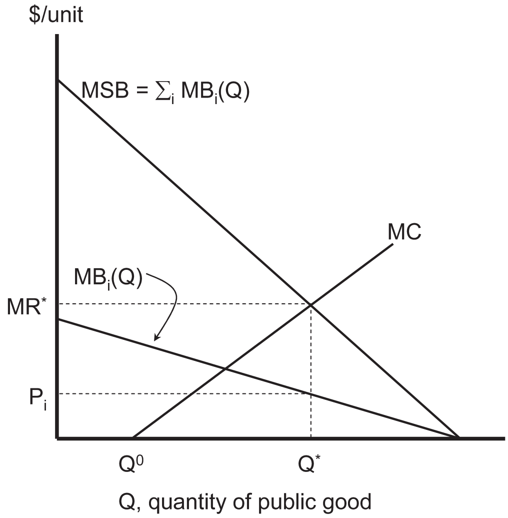

Figure 1. Essentials of Lindahl Equilibrium for a Pareto Efficient Provision of Ecosystem-Service Public Goods

because it balances the marginal cost (MC) of delivery against the marginal social benefit (MSB). Of course, the MSB is the sum of the marginal benefit (MB) to all beneficiaries (each person *i*) for the last unit. Figure 1 captures this idea, illustrating a single person *i*'s MB relative to the MSB of each unit of the public good. In this case, person *i* would pay an individualized price, P_i, which represents his or her share of MSB on the efficient quantity provided, Q^*. With heterogeneity in preferences, different individuals might pay different prices but the total of the payments would aggregate to the marginal revenue level (MR) equaling MC.

Note here, however, that Figure 1 portrays marginal cost as initially zero up to unit Q^0, which represents the idea that a farmer, landowner, or ecosystem component under laissez-faire management might provide some units of ecosystem service as part of traditional operations. For example, birds who nest in grasslands may achieve some degree of breeding success if constraints (including random events) prevent a farmer from harvesting every acre of hay at peak nutritional value (late May to early July in much of the northeast United States), a time that devastatingly conflicts with the critical nesting season for species like the Bobolink (Bollinger, Bollinger, and Gavin 1990, Perlut et al. 2006). Under this framework, as yet hypothetical, if providers of ecosystem services receive marginal revenue, *MR* (Figure 1), these landowners would earn a producers' surplus represented by the area below MR^* out to Q^* less the area representing costs (perhaps foregone opportunities to replace or alter nature) below the *MC* curve. The existence of a non-zero initial provision of ecosystem services at Q^0 raises the potential of a moral hazard issue if landowners attempt to profit from services already provided as an external benefit of their normal business operations. So market structures or contracts and policies might limit the potential for profit to the producers' surplus between Q^0 and Q^*. However, that question falls outside the scope of this discussion.[7] Nevertheless, the

[7] In this case, the moral hazard would arise if the profit potential on the first Q^0 units motivated landowners to take actions they would not otherwise take to create a real or credible threat of

Lindahl framework stands as a pinnacle for economists; Lindahl equilibrium balances MC and MSB.

Building a Market on the Provision-point Mechanism

There are challenges in using provision-point mechanisms to develop real markets that connect individual beneficiaries to particular ecosystem services and their providers. First, the mechanism is not incentive compatible. That fact turns away too many economists.[8] It is not absent of incentives, so I encourage economists to think about—to innovate—ways to exploit existing incentives to generate contributions in excess of what philanthropy can accomplish. Philanthropic approaches are valuable, but different. Contributors generally give to an organization with a rather open-ended objective; if the nonprofit organization fails to complete a project, particularly one that initially attracted a contributor, the donor generally expects her money to be reallocated to alternative good works. The contributor is not necessarily buying a particular action. In contrast, for ecosystem service markets to develop to integrate environmental benefits directly into business plans (for-profit or otherwise), approaches must tie provision of specific units to specific payments. Provision-point mechanisms do this, but the mechanisms offer imperfect controls to the market-maker or broker—controls that are analogues, at best, to controls that exist in markets for private goods.

One rather subtle control is the ability of a market-maker or broker (possibly with government authority) to set the size of a group charged with paying the threshold cost for a unit. Group size may affect the stability of contributions; a larger group of beneficiaries may create more opportunities for free- or cheap-riding. However, the relationship or ratio between a typical beneficiary's value for a unit of the public good and the provision point for the unit means that group size can be a control for making the threat of nonprovision more or less credible.[9] When nonprovision occurs, laboratory experience indicates that beneficiaries are reinvigorated to contribute. If, after repeat transactions, cheap-riding causes aggregate contributions to fall below the provision point, beneficiaries may increase their offers to make provision occur, increasing the individual and group net benefit above the status quo of complete market failure. Of course, real markets would have a supply curve and multiple units while threshold public-good experiments have focused on single units.[10] So how might provision-point methods be exploited to drive provision of multiple units? This is where group size as a control variable becomes important.

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eliminating units of ecosystem service their lands may have been providing under the status quo in the absence of an ecosystem-service market. For example, a hay farmer could threaten to mow down all of his or her hayfields during the bird nesting season, even if such mowing would never have occurred as part of normal farm operations, in the absence of consideration of the cultural (aesthetic) ecosystem services provided by wildlife habitat benefiting birdwatchers. In severe cases, a sufficient profit potential could, in principle, motivate such a farmer to mow hay in a manner that even foregoes the value of the hay for livestock.

[8] Recall Portney's (2004) and Krutilla's (1981) admonitions.

[9] Liu, Swallow, and Anderson (2011) and Li, Anderson, and Swallow (2012) provide preliminary experiments addressing these conjectures.

[10] Messer et al.'s (Messer, Schmit, and Kaiser 2005, Messer, Kaiser, and Poe 2007, Messer, Kaiser, and Schulze 2008) works represent exceptions but involve feedback between successful provision of the good (advertising food products) and the motivation for demand for that good (increased demand for milk may raise the derived value for additional advertising).

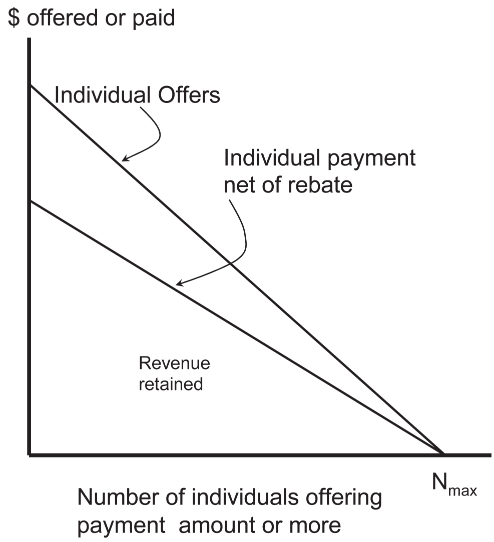

Figure 2. Provision Point Offer Curve and Revenue Retained under Proportional Rebate for One Unit Paid for by One Group with N_{max} Participants Making Non-Zero Offers

Note: individuals are ordered from highest offer made to lowest.

First, consider how provision-point methods work. A market-maker solicits offers from a group of potential beneficiaries. In laboratory experiments, the group is defined by the number of participants recruited with benefits induced by the experimental administrator. Figure 2 shows a potential distribution of offers with the horizontal axis showing the number of people making an offer of a particular amount or greater. Effectively, this offer curve places individuals in order from highest to lowest offer made. Because the method is not incentive compatible, it is possible (even likely) that these offers are less than Hicksian willingness to pay for the good. If the total of offers exceeds the provision point, then the good is provided. If the aggregate offer exceeds the provision point, a rule would determine the use of the excess funds. Figure 2 illustrates a proportional rebate rule in which individuals pay approximately two-thirds of their offers and receive a rebate of one-third, allowing the market-maker to retain the revenue represented by the lower triangle. This revenue would exactly equal the unit's provision point.

With colleagues, I have been involved in using provision-point-based methods to develop a market for hayfields serving as habitat for grassland-nesting birds in Jamestown, Rhode Island (Swallow et al. 2008, Swallow, Anderson, and Uchida 2012). This application represents a small-market problem with a localized public good. Rhode Island is the smallest state in the nation and is heavily urbanized, with Jamestown covering the roughly two-mile by eight-mile area of Conanicut Island (including water, 9.7 square miles of land). Jamestown had six farms with approximately 120 to 200 acres of hayfield serving as potential habitat for Bobolink, a species that is not endangered but has lost about 40 percent of its population in the United States in the last 25 years or so. That project leveraged group size as a control in making a market:

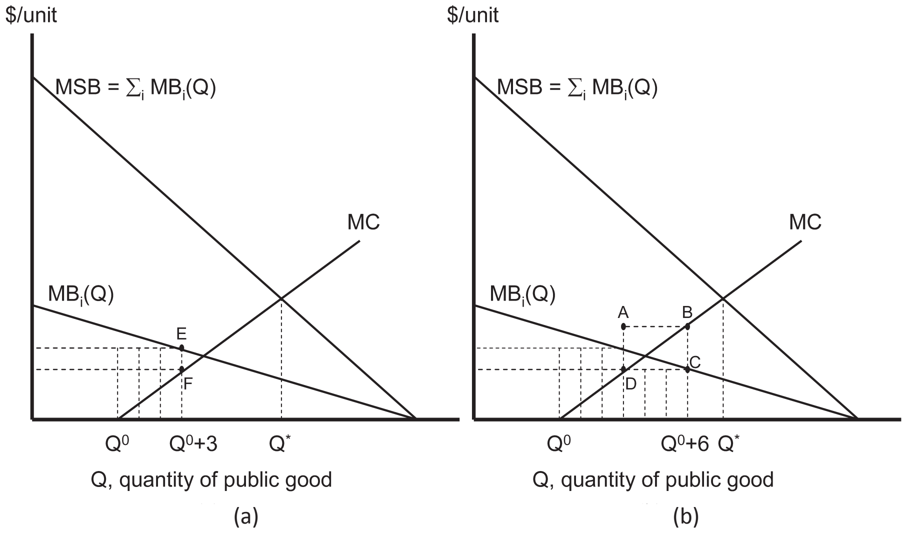

Figure 3. Consideration of Incentives to Contribute and Market Equilibrium under Provision-Point Mechanisms for Public Goods

Note: Panel (a) is one group, one unit; panel (b) is one group, two units.

Jamestown's 2,400 or so homes were randomly assigned to groups, and each group was assigned a field that a farmer had agreed to manage in consideration of nesting birds in exchange for compensation. Fields were ten acres and typically surrounded by another ten or so acres of grassland, so the project created a meaningful habitat-unit and the provision point was established in consideration of nature's constraints and the farmers' opportunity costs. Here I would like to introduce the idea of what a market equilibrium would look like based on this approach: creating groups, linking each group to a particular unit, and considering how those who value wildlife habitat services would respond.[11]

One-Group, One-Unit with Provision-Point Mechanisms to Solicit Contributions

In Figure 3, we return to consideration of marginal social benefits in relation to the quantity of public good that may be provided. However, now the index "i" represents a group identifier. These figures are scaled to designate three groups within a potential market for a public good; the MB_i curve is approximately one-third the height of the *MSB* curve, which aggregates benefits across individuals. Thus, in Figure 3, the MB_i curve itself aggregates the marginal benefits perceived by members of group *i* in the manner discussed for *MSB* in Figure 1. If the market-maker or broker randomly assigns households to groups, each group will be reasonably represented by this same MB_i curve in Figure 3; the groups will, on average, have identical aggregate preferences. Alternatively, a market-maker could assign groups systematically by, for example, geographically

[11] Uchida, Anderson, and Swallow (2007) provided stated preference evidence that the cultural ecosystem service(s) valued by Jamestown residents could include not only aesthetically pleasing wildlife viewing but also a value for expanding hayfields as a land use that produces pastoral views and a view reaching to Narragansett Bay.

defined neighborhoods or by income categories (which might correlate with individual WTP). Any group-assignment process that creates or sustains heterogeneity in group-specific MBs could complicate the graphics, but the basic principles discussed here would hold.

Consider Figure 3a, which allocates one unit to each group beginning from Q^0. The one-group, one-field (one-unit) approach would solicit contributions from individuals with a provision-point based on covering the cost of the marginal unit (e.g., a hayfield) that could be provided. Here, if unsubsidized, the marginal field might cost-out at the level indicated by point F (Figure 3a), say MC_F.[12] If providers (farmers) participate through a uniform-price reverse auction, all providers will be paid MC_F.[13] This payment makes it possible for providers to earn a producers' surplus that would be analogous to their opportunities in markets for private goods. In contrast, philanthropic or government programs paying for ecosystem services might attempt to identify the marginal cost for each unit and pay a break-even fee to providers. But such an approach raises a number of concerns about incentives for providers to reveal their opportunity costs (see footnote 13; cf., Kirwan, Lubowski, and Roberts 2005) and may create adverse selection (Arnold, Duke, and Messer *forthcoming*). These concerns fall outside the scope of this discussion.

Currently, the provision point approach to the consumer side of the problem involves soliciting offers from each member of each group to support the group's field. In this example, the groups' marginal willingness to pay is represented by the level of point E, MB_E. If all funding must come from the beneficiaries, the size of the groups and their share of the overall MSB, as represented by MB_i, creates a limiting factor for the market in Figure 3a. As illustrated, we assume that the market-maker establishes the number of groups such that each group's value for the marginal unit will equal or exceed the marginal provision cost. The market-maker must define the groups so that each group's aggregate MB, such as MB_E, equals or exceeds the provision point (less any subsidy, here assumed to be zero). If groups have adequate information, such as would come from an annual transaction to sustain ecosystem services, members of the groups will realize that the potential outcome will add three units beyond the status quo of Q^0, so their bids will be based on the perception that each is adding on the last unit, the marginal unit labeled $Q^0 + 3$.

Of course, the solicitation of voluntary contributions is not incentive compatible, so individuals might offer less than their MB and the amount of revenue offered by a group might fall short not only of MB_E but also of the

[12] To simplify the graphics, I am using linear curves while the discussion involves discrete units (e.g., one ten-acre field needed for a meaningful unit of grassland bird-nesting habitat). Thus, MC_F would approximately equal the rectangle of a height represented by point F (Figure 3a) times the width of one unit. This width is represented by the distance between the vertical dashed line through points EF (at $Q^0 + 3$) and the next vertical dashed line to the left of EF, which is the vertical line for unit number $Q^0 + 2$.

[13] The uniform-price reverse auction asks farmers to, for example, enter bids offering to manage one hayfield for birds. In this example, the three lowest bids would be accepted (if all three groups meet the provision point MC_F) and the last (lowest) bid rejected would set the price received by all farmers. Such a reverse auction creates incentives for providers to identify their minimum willingness to accept because doing so raises their chance of earning a producer's surplus from having a field included in the winning set of fields. If the marginal farmer bids his or her willingness to accept, that farmer would gain from the difference between his or her bid and the lowest bid rejected. Nonetheless, details of the auction can create incentives for strategic bids that exceed willingness to accept (cf., Cummings, Holt, and Laury 2004, Hill et al. 2011, Latacz-Lohmann and Van der Hamsvoort 1997).

provision point, MC_F in Figure 3a. Such an outcome is the mechanism by which the provision point creates an incentive for individuals to contribute. Unlike a philanthropic operation, a market-maker must be committed to the predetermined provision point to avoid re-establishing the opportunity for a group to hold back in an effort to free-ride on an outside Samaritan.[14] Since individuals wish to generate some consumer surplus, one can expect offers to fall below Hicksian willingness to pay for the marginal field, so it is likely wise for the market-maker to assign groups, when feasible, to leave a bit of space (a non-zero difference) between marginal benefits (MB_F) and the marginal provision cost (MC_E).[15] Figure 3a illustrates a possible example in which the market-maker knows that MB_i crosses MC near a fourth additional field. Achieving that fourth unit would require either a fourth group, which would lower MB_i to $MSB/4$, or some other accommodation.

So there are researchable questions here. They concern how group configuration, within a beneficiary community, can be established to fund the most units for the greatest net benefit while balancing each group's MB_i with MC and pushing a community closer to the efficient quantity, Q^*. However, since the approach is constrained by configuration of discrete groups matched to units, we are in a second-best world that can, on its own, alter the quantity that is optimal.

An alternative could be to consider a modification of the rebate rule of Marks and Croson (1998) identified as "extended benefits" to employ excess funds. For example, rather than rebating excess contributions, the rebate could be designated to provide the fourth unit if the aggregate rebate amount is sufficient. However, that potentially alters consumers' view that they are buying the third marginal unit beyond Q^0, which could lead consumers to base offers on the MB of the fourth unit rather than of the third unit and thereby make it more challenging to achieve MC_F for each group.[16]

One-Group, Two-Units with Provision-point Mechanisms

Recently, laboratory work by Liu, Swallow, and Anderson (2011) examined whether a one-group, one-unit approach is necessarily the best one for a market-maker. The work provides an example of researchable questions raised by this framework. Suppose the market-maker recognizes that the market equilibrium will fall below the efficient level of ecosystem service units at Q^*, as shown in Figure 3a. One approach could be to assign each group to two units with contributions from the group being used to cover the provision point on both units if possible. Any rebates would be issued only after evaluation of the ability of the group's contributions to cover either one or two units.

Figure 3b helps us develop initial insights into using this adaptation of provision-point mechanisms for real ecosystem-service markets. First, note that the scenario strives to use our three groups to provide six units beyond

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[14] This condition is analogous to Taylor's (1998) discussion of using real money referendums and experimental methods in the valuation of public goods; there must be a closed market.

[15] Li, Anderson, and Swallow (2012) provides some laboratory evidence that could guide market-makers in balancing the relative magnitude of the provision point and aggregate marginal benefits within a group. A higher provision point relative to MB can drive contributions higher, but the contributions may be biased toward a moderate or middle level (cf., Li, Anderson, and Swallow 2012). This result is also consistent with Messer, Schmit, and Kaiser (2005).

[16] The situation in which MB for the fourth field is less than the MC for that field creates effects that are similar to considerations I cover in discussing Figure 3b.

the status quo of Q^0 so that group members are expected to make offers relative to unit $Q^0 + 6$ in the graph with MB at the level associated with point C (Figure 3b), level MB_C. If successful, this approach would bring the market closer to the efficient quantity, but MB_C clearly is less than the marginal delivery cost at the level of point B, MC_B. It becomes an empirical question whether each group's aggregate offer will approach $MB_E + MB_C$ or something like two times MC_C (or some other amount), but even thinking optimistically, it seems unlikely that groups would cover all of the provision costs.[17] Laboratory results from Liu, Swallow, and Anderson (2011) show that per capita contributions within a group are greater if each group is responsible for a single unit but the frequency with which at least one of two units is provided—by a single large group comprised of the two smaller groups[18]—is greater if a group is responsible for two fields. In the latter case, however, successful provision may mean provision of a single field (out of two). There remains plenty of room for research to identify how a market-maker might balance these considerations.

One approach could be to use this type of provision-point-based market as a complement to publicly funded programs that make payments for ecosystem services. Policymakers could be concerned that such payments do not necessarily provide services of interest to the public, and an innovative market-maker (a broker) could play a role in linking revealed preferences to expenditures of public funds. So consider the effort to fund up to unit $Q^0 + 6$. If group contributions actually establish per-field revenue of MB_C, there would be a delivery-cost deficit given by the area BCD on the last three units in Figure 3b. A public entity (or a philanthropic group) could pre-commit to covering such a deficit but only if contributors met a pre-specified provision point such as MB_C or perhaps MC_F.[19] This approach might facilitate a potential Pareto improvement from the status quo (Q^0) beyond just one unit per group via a cost share paid by contributors. In some recent works, there is evidence that the availability of public funds can increase willingness to pay for local environmental programs (Kafle, Swallow, and Smith 2011). However, if the external funds only cover a deficit such as BCD, this approach could make it challenging to discover the providers' opportunity cost. A larger subsidy to providers based on a uniform-price reverse auction that paid providers at the level near point B, MC_B, would re-establish the potential of producer surplus but raise the prospect that the required subsidy would approach area ABCD in Figure 3b. This approach would be appropriate in treating ecosystem services as a business opportunity like any other traded good. Breaking away from the view that providers should only "break even" may be essential to development of ecosystem-service markets.

[17] Even if the potential producer's surplus from Figure 3a with providers receiving MC_F could be transferred to cover part of the cost of reaching unit $Q^0 + 6$, the slope of the marginal cost curve clearly affects whether such an approach would work to cover any deficit to the right of unit $Q^0 + 3$, particularly since one expects offers to fall below MB_C on a per-field basis due to the absence of incentive compatibility.

[18] Liu, Swallow, and Anderson's (2011) laboratory work fits better but still is not fully consistent with examining the issue of whether two of the groups in Figure 3a should be merged to provide the second and third of the first three units beyond Q^0.

[19] I have intentionally labeled the same marginal cost level with different points (using D in Figure 3b and E in Figure 3a). As drawn in the example diagrams, $MC_F = MC_D$ since both correspond to unit $Q^0 + 3$. However, the discussion of Figure 3b presumes a provision point linked to a portion of the MC on unit $Q^0 + 6$, which may not be the same as MB_C or MB_D. These graphs illustrate a special case, and space limitations preclude an attempt to illuminate all of the potential implications of the details. I encourage research in this area.

Prospect for Lindahl: A Consumer Auction Process to Determine Quantity

Economists typically have set aside the Lindahl framework (Figure 1) in response to the robustness of the free-riding strategy. The framework has been used in laboratory experiments but mainly, it seems, as a foundation for "cheap talk" to explain to experiment participants the challenge of the public good problem in an effort to encourage cooperation under some other framework (e.g., Isaac, McCue, and Plott 1985, Isaac, Schmidtz, and Walker 1989). Yet it is clear that the hypothesis that free-riding breaks *any* scheme for private provision of public goods is false under numerous, not necessarily uncommon circumstances (e.g., Marwell and Ames 1979, 1981). Approaches like the Groves-Ledyard mechanism (Groves and Ledyard 1977) and various Clarke-Groves mechanisms (Clarke 1971, Groves 1973) have been around a long time but are commonly viewed as impractical because auction participants (consumers) fail to find the mechanisms particularly intuitive (e.g., Kawagoe and Mori 2001).[20] Nonetheless, widespread evidence suggests that individuals—potential consumers—will contribute toward public goods, particularly when they have a strong personal interest, so environmental economists may be able to do much more to create mechanisms that can convert the willingness to pay that we commonly measure into revenues to drive ecosystem service values into the (commercial) economy.

The Lindahl framework shown in Figure 1 suggests that we should strive first to identify means by which to get the marginal valuation right by creating and testing rules of exchange that may stimulate consumers to make contributions that are closer to their full value at the margin. We do not need to know the total value of a good or have a mechanism that causes every person to reveal his or her value for every potentially available unit of public good. If a market process gets the marginal values right (or close) nearer to the Lindahl equilibrium point, we can achieve some Pareto improvements over a status quo level of provision and create potential opportunities for profit that cause firms to pay more attention to ecosystem service values. Consider again Figure 1. The consumer surplus produced by achieving, or moving toward, a Lindahl equilibrium represents an incentive for consumers to buy-in. Can we exploit it?

The experiments of Smith (Smith 2012, Smith and Swallow *forthcoming*) suggest that there is the potential for success in the field. I am not looking for perfection, just policy relevance and practical improvement in the spirit of Portney's (2004) advice. My thinking here develops from integrating provision-point mechanisms for single units with the observation that people actually do contribute to public goods and imagining a possible process that could be simple enough to engage consumers and produce success. A challenge for environmental economists, including me, is to be more creative and help society do better.[21]

The provision point concept provides a control variable, and the proposal for a practical, Lindahl-based approach builds on using that concept sequentially—

[20] Referees in experimental economics may question whether a mechanism "works" if investigators explain the intuition of the incentives in too much detail. I speculate that excess attention to theoretical purity in the refereeing process could be discouraging innovative research and impeding our progress toward social-welfare-improving discoveries (again, consider Portney (2004) and Krutilla (1981)).

[21] Aside from the example that follows, I believe there are opportunities with menu auctions or combinatorial auctions that may enhance success with multiple ecosystem services.

asking consumers to make a series of offers to pay a marginal price contingent on successfully funding the provision point for each infra-marginal unit. Consider Figure 4a, which expands a portion of Figure 1 to focus on individual *i*'s marginal benefit curve (MB_i) and how it could interact with a process for soliciting bids in a Lindahl-inspired auction (cf. Smith 2012, Smith and Swallow *forthcoming*). Here, Q^* remains the efficient quantity, which is determined by the aggregated benefits represented by the MSB interacting with the MC. This auction process might work regardless of whether the MC follows the straight line emanating from the zero price-quantity or the curved line that starts with a positive level of MC even on the first unit beyond the status quo, Q^0. If the initial level of MC is high enough, it may exceed the MB for a typical person. What is important here, however, is that Q^* occurs at a rather large number of units so that it may be excessively challenging for the one-group, one-unit approach previously discussed to approach Q^*. The Lindahl-inspired approach might better handle a more open-ended market setting.

A Lindahl-inspired auction solicits bids on units, asking consumer-beneficiaries to offer a maximum price they would be willing to contribute for each unit. We use the idea of an auction, however, to establish how the bid process would be settled; we create rules of exchange that encourage potential participants to see the provision point as an incentive to participate and continue to offer bids. Of course, the key will be in discovering some rules that work. But if provision points with money-back guarantees or proportional rebates improve contributions, such a combination of incentives could improve contributions made to support the first unit.

An approach to investigate is as follows, and all steps would be known to bidders (consumers) at the outset.

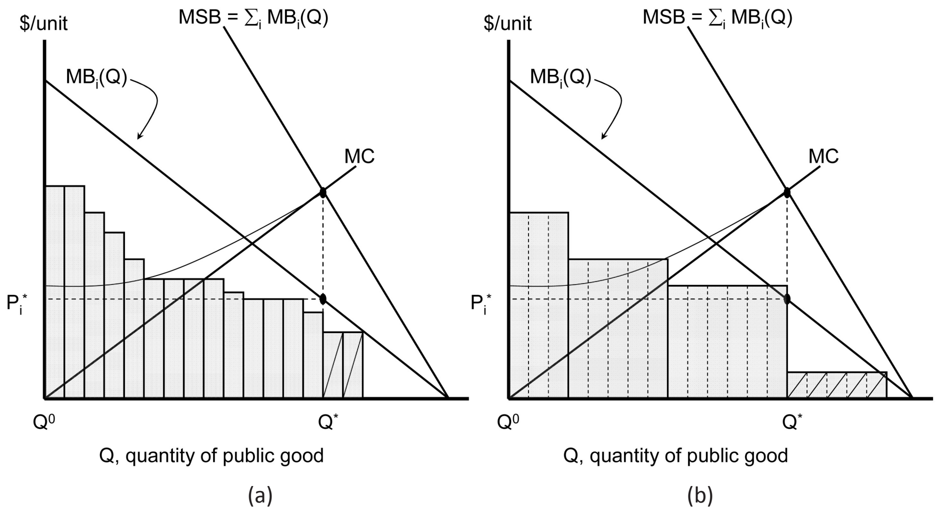

Figure 4. Developing a Sequential Offer Process for a Lindahl-inspired Framework for Private Provision of Public Goods

Note: Vertical bars represent individual *i*'s bid on each successive unit and $Q^* = 14$ is the Pareto efficient number of units.

Step 1: Solicit a bid on each unit over the range of quantities that could be provided in the relevant region for beneficiaries of the ecosystem-service public good. The bidder completes a schedule across the relevant quantity range (out to Q^*) and submits all bids simultaneously. Consumer-beneficiaries make the bids with the understanding that they will pay the bid on the last unit provided and on all infra-marginal units. This process allows bidders to reduce their offers on successive units since they realize that an auction that settles on a larger number of units will generate a discount on all earlier (infra-marginal) units. The process is designed to allow bidders to build up their consumer surplus: as more units can be provided, the individual's price can decrease, adding to surplus on the infra-marginal units.

Step 2: The broker-auctioneer or market-maker evaluates all bids at a specified time beginning with the first unit. If the aggregate amount of the bids can pay the provision point of the first unit, that unit will be provided. The auctioneer will consider bids on the second unit only if the first unit can be provided.

Step 3: Assuming that unit one can be provided, the auctioneer evaluates the aggregate amount of the bids on the second unit. If those bids cover the provision point on the second unit, that unit also will be provided and bidders become obligated to pay for the two units based (at most) on their bids for the second unit.

Step 4: The evaluation of the aggregate amount of bids per unit continues until the auctioneer can no longer cover the provision point on the next unit.

Step 5: The auction settles on the highest number of units for which the aggregation of the marginal bids can cover the provision point. Each bidder is charged his or her bid on that unit and on all infra-marginal units subject to whatever rebate rule applies.

For example, consider the illustration in Figure 4a. The vertical bars represent individual *i*'s bid on each successive unit allowing that such bids may fall below *i*'s MB for that unit. We presume here that bids are non-increasing. Suppose, for this discussion, that the auction settles on the thirteenth unit, one unit less than the Pareto efficient level of Q^*. Settlement would occur because the sum of bids on unit Q^* taken across all individuals fell short of the marginal cost for Q^* while the sum of such bids for $Q^* - 1$ (the thirteenth unit) actually was sufficient to cover the marginal cost of that unit. Individual *i* would pay P_i^*on all of the first units. In this example, we presume that P_i^* leaves the broker (or provider) with just enough revenue to cover the marginal cost on the thirteenth unit. If there is an excess of funds, the auction could involve a rebate of that excess on all bidders' offers in proportion to their bids' contribution on the thirteenth unit to the aggregate amount of the bids for the unit. While the auction may have collected bids on the fifteenth and sixteenth units (beyond unit Q^*), the auctioneer never evaluated those bids; in this example, the aggregate of individual bids on the fourteenth unit (Q^*) was insufficient to cover the marginal cost on that unit so the auction settled at the thirteenth unit.[22]

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[22] Numerically, suppose that (i) this individual bids \$20, \$18, \$16, and \$14 on units 11, 12, 13, and 14, respectively; (ii) the aggregate amount of the bids on unit 14 falls short of the MC on unit 14 so bids for subsequent units are irrelevant by rule; (iii) the aggregate amount of bids on units 1 through 13 covers the respective MCs of those units; and (iv) the aggregate amount of bids

Notice in Figure 4a that, as the auction progresses, individual *i* is able to accumulate consumer surplus in the triangle above P_i^* and below *i*'s true MB. This accumulation is a key incentive to participate; only if the auction succeeds in providing initial units does the surplus of additional units become available. If participants do not yet know the market-clearing (individualized) price (the price that each individual pays based on his or her own bids), they have a marginal incentive, thanks to the first-unit provision point, to initiate the market process. This marginal incentive remains for successive units. As is illustrated, individual *i* is bidding closer to his or her marginal benefit curve as the auction reaches higher units. Thus, while early bids may depart substantially from revealing the MBs, if the market is likely to clear at a high number of units, the auction process may allow bidders to make offers that converge toward their marginal value. As the participant-group's offers approach a potential auction settlement, participants may make offers that are closer to marginal value while realizing that their marginal offers could help push the auction to provide more consumer surplus without generating a commitment to overpay relative to their full value on a particular unit.

The description in the foregoing paragraph is largely conjectural. Certainly there is much room here to consider strategic bidding within this auction. But the description fits qualitatively with experience presented in Smith's work (Smith 2012, Smith and Swallow *forthcoming*) involving both laboratory experiments using induced values and framed-field experiments involving actual ecosystem restoration. Other ongoing work is needed to explore strategic opportunities and the need for additional auction rules. For example, the assumption of non-increasing bids might deserve consideration as an enforceable rule within the auction.[23]

Still, the main purpose here is to encourage economists to consider how to configure this, or more creative, auctions to leverage incentives for participation when looking for ways to pay for provision of public goods. One challenge I have not addressed regards the difference between incentives to participate at the margin (one unit or one bid at a time) versus incentives to decline to participate at all on the assumption that the individuals' community could produce substantially more than Q^0 without person *i*'s participation (even if person *i* always bids zero). Open areas for research then include developing incentives to stimulate initial participation and establish the confidence among consumers that participating in such an auction may lead to greater consumer surplus from the public good than nonparticipation.[24] Such incentives could

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on unit 13 would provide 10 percent more money than needed for unit 13. In this example, the auction settles on unit 13, and the individual pays $14.40 per unit on all thirteen units, reflecting a rebate of 10 percent ($1.60) on the marginal bid. (This numerical example does not fully match Figure 4a, where, at least, the bids on units 11 through 13 are all equal, such as equal to $16.)

[23] In some preliminary game theoretic analyses, Pengfei Liu has been identifying conditions under which a Nash equilibrium is achievable near Q^* when bidders cannot increase their bids on successive units.

[24] Note that the auction moderator can define the size of a unit, and unit-size can even be varied as long as unit-sizes are clear to auction participants. For example, the auction moderator could establish a rule that the minimum delivery from the auction must be five units of the size depicted in Figure 4a; such a rule is tantamount to defining the size of the first unit as five times the biophysical size of successive units. Such an approach would mean that bids on the minimum delivery (that is, on the aggregation of the first five units in Figure 4a) must be sufficient to cover the marginal cost of that minimum delivery before bids on the next individual unit (the sixth in Figure 4a) would be considered. Also, nothing in the process previously described requires that the MC must be increasing; certainly the MC could be constant.

develop, for example, through hybrid approaches, such as using matching funds: for example, a philanthropic or government-provided source of base funding could be established and become available only if a community of bidders met a set of criteria that demonstrated, through actual offers, that the community valued the ecosystem-service good enough to justify release of the match.

The Lindahl-inspired auction framework brings forth other practical considerations that might affect transaction costs and efficiency outcomes. For example, the auction uses the provision point and the auctioneer's ability to define a unit as controls to stimulate participation. As previously described, bidders are asked to submit a potentially large set of bids with the possibility that many early or later bids will be made on units far removed from the quantity at which the auction will settle. Figure 4b allows consideration of how a creative auctioneer might respond to these practical considerations. For example, the auctioneer could request bids on physically larger units or on blocks of units. In that case, Figure 4b would set an initial block of three units, followed by blocks of five units, of six units, and of five units. The auction envisioned here requests that bidders submit a *per-unit* bid on the first three units. If the aggregate bid is sufficient to deliver all three units, the auctioneer will evaluate bids on a subsequent block of five units where the bids represent an offer to pay a *per-unit price* on all of the units provided up to the eighth unit. As is illustrated in Figure 4b, we presume that this auction settles at Q^* based on aggregation of the bids on the block of six units—offers to pay a *per-unit price* on each unit up to the fourteenth (which is Q^* in this illustration). Meanwhile, the aggregate amount of the bids on the last block of five units presumably falls short of covering provision costs on any of the units beyond Q^*. In Figure 4b, I also illustrate that individual *i*'s price, P_i^*, might reflect a rebate of a small percentage below his or her actual bid (represented by the height of the bar at Q^*) in the case where the aggregate bid would yield a surplus of revenue beyond the marginal provision cost for the final unit delivered.[25]

The example here (Figure 4b) simplifies individual *i*'s task in the sense that *i* need only identify a maximum of four bid levels (one for each block) rather than submitting the larger number of individual-unit bids anticipated in the auction previously described (Figure 4a). Again, my point is not to be definitive in all details but rather to encourage creative thinking about how economists could establish auction processes that address the challenges in provision of public goods with ecosystem services as a major area for potential applications.

Example Considerations for Equilibrium in a Lindahl-inspired Auction

The Lindahl-inspired auction described here provides an example of considerations that will need to be addressed if experimental market approaches are to gain traction for real ecosystem-service markets. In particular, will these types of approaches be stable or will short-run success erode over time as participants weigh the advantages of free-riding? For the present example,

[25] If the aggregate bid falls short of the provision cost for a unit at, say, $Q^* - 3$ units, then the auction would settle at $Q^* - 4$ units and individual *i*'s payment would be based on her or his bid (and any rebate) within that block. Individual *i* would pay only for the units provided. Because of the proportional rebate rule applied at the margin, such a payment could be lower than P_i^* while nonetheless being derived from the same bid.

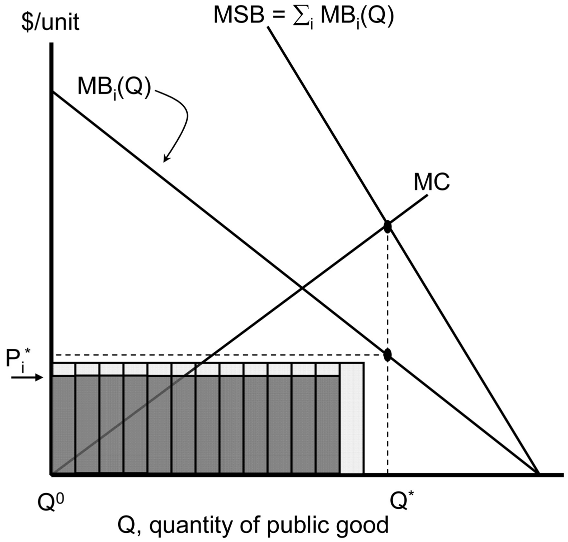

Figure 5. Consideration of Incentives for Unilateral Action by One Individual Bidder in a Lindahl-inspired Auction Process That Could Settle at Provision of *Q Units**

consider briefly an individual who bids in an auction that settles at Q^*, resulting in an individualized price of P_i^*. Will such an individual have an incentive to change his or her bid unilaterally in an effort to reduce personal cost without an offsetting loss of benefits?

If the individual lowers the bid, P_i^*, by one dollar, he or she stands to lose the marginal net benefit on the last unit provided in the auction while reducing her or his personal cost on infra-marginal units. As illustrated in Figure 5, a marginal bidder making this decision would undermine the provision of unit Q^*, cutting the auction settlement back toward unit $Q^* - 1$, while reducing her or his personal cost on units 1 through $Q^* - 1$ by a dollar (the slice between the horizontal dashed line at P_i^* and the light grey rectangle of bars). Individual *i* might again consider lowering the bid, this time on $Q^* - 1$, to the level indicated by the arrow in Figure 5 (at the level of the dark grey bars). The result would be loss of a larger net benefit on unit $Q^* - 1$ with a gain in surplus on the remaining, shrinking number of infra-marginal units provided. Clearly, this process suggests the individual is balancing the gains from adjustment of the marginal bid with the loss of net benefits from the marginal unit. Again, the purpose here is not to sort through the potential outcomes for a particular auction but rather to illustrate the types of tradeoffs implied by more careful thinking about incentives to reduce or mitigate the challenges presented by the advantages of free- and cheap-riding.

Such considerations motivate research that evaluates various rules of exchange that could help sustain a provision process based on private actions for public goods. A formal rule requiring that bids be non-increasing between successive units would limit the opportunity for strategic gain from unilateral action at the margin. Under such a rule, if the individual causes the auction to pull back from, say, unit Q^*, then his or her bid of P_i^* may no longer be operational and the auction would fall back on the individual's bid on unit $Q^* - 1$, which must have been at least as large as the P_i^* that individual i bid on Q^*. The rule, then, eliminates the potential for bidders to gain additional surplus by reducing the personal cost of infra-marginal units 1 through $Q^* - 1$.

Marketing, or marketing communication, may also play a role in the functionality or implementation of such auctions. Previously, I discussed a Lindahl-inspired auction from the perspective of a forward process that evaluates bids from the first unit that is potentially available. As an alternative, an auctioneer could consider a backward process for evaluating bids. In a backward process, the auctioneer would evaluate the collection of bids working down from the highest number of units that potentially could be provided in the auction, say from $Q^* + 5$ in any of the situations previously illustrated. If the aggregated bid on unit $Q^* + 5$ covered the MC of that unit, the auction would settle there; otherwise, the auctioneer would back up to unit $Q^* + 4$ and continue to go backward until she found a balance between the aggregate bid and the marginal cost of provision, or until she failed to find such a balance. When the balance occurs, the auction settles and the individualized prices are determined by the individual bids for that unit. Such a backward process might (perhaps) be simpler to communicate to participants or could induce some clarity regarding the implications of the series of bids since it evokes a process of searching for the lowest individualized price-set that covers the marginal unit's cost.[26] Some participants might find the approach more intuitive. That question and analogous issues remain for creative researchers to evaluate.

Some Final Observations and Speculations

We cannot expect to find easy, transparent rules of exchange that are incentive compatible for private provision of public goods. If we could, economists (or smart policymakers) likely already would have established such rules. The policy-relevant question is not whether Pareto efficiency through private action is out of reach but whether Pareto improvement over current philanthropic approaches or regulatory authority is possible. What creative approaches might give society Pareto-improving opportunities? Perhaps we can reconsider, or refine, the role of government or philanthropic organizations by leveraging their funds to back a private process for auctions that would generate revenue across marginal units.

For example, we know that for a single unit the Clarke (1971) tax or a pivotal mechanism is weakly incentive compatible (Kawagoe and Mori 2001). The pivotal mechanism collects revenue only from bidders whose offers straddle the balance between aggregate revenue and provision cost on the single unit so it is a weakly dominant strategy for an individual to reveal her or his full Hicksian value in case that individual's offer is pivotal to the decision on whether the good is provided.[27] The pivotal mechanism generally fails to fund a public good because typically few, if any, individuals are pivotal. Yet in provision of the first unit through a Lindahl-inspired auction, the pivotal mechanism could stimulate

[26] Throughout discussion of the potential auction processes inspired by Lindahl's insights, I have generally assumed, perhaps unnecessarily, that the MCs are constant or increasing. In the backward auction, this assumption may be necessary or there would need to be an outside subsidy to cover any deficit if the MC curve declines over infra-marginal units.

[27] That is, a bidder pays only if her offered payment represents the last dollars needed to cover a provision point when all of the other bids have already been collected.

participation in the auction, and an auctioneer could evaluate bids on each successive unit under a pivotal-mechanism rule that would also establish an individualized price on infra-marginal units.[28] Such a process would likely yield revenue that falls short of covering all of the costs, in which case government or philanthropic funds could cover the deficit within the scope of a process that has revealed that the public benefit exceeds the cost.

The research I hope to encourage here sheds light on the need to break through social attitudes that private actions can fund public goods through philanthropic donations alone and that these donations potentially go to open-ended or fairly generic causes. Part of the challenge is to tie payment to specific services people actually want or to clearly defined actions that people view as providing service. Adopting this perspective is not necessarily better, but it is different from philanthropic solicitations for good causes. Can economics provide additional tools for private action on public goods? There is clearly demand for these tools; we see novel approaches for crowd-source funding on internet platforms, as represented by *kickstarter.com* or *cleanwaterfuture.org*, the latter of which is sponsored by the Connecticut River Watershed Council.

Markets can only form around payments for transparent actions. Laissez-faire management of ecosystems or landscapes is one form of action, but sustaining a larger level of ecosystem services may require human providers to take actions that are more explicit. That is why I cannot limit definition of (final) ecosystem services to nature-based services that remain untouched by human hands. Farms are managed ecosystems that provide extensive environmental benefits (often public goods) even though working farms and forests are not "natural." Landowners and farm managers can influence the mix of joint products flowing from such land, and creative approaches to generating revenue through private action remain an under-explored, potentially powerful tool to enhance ecosystem-service provision while complementing programs for farm viability. To fit within a formal framework for ecosystem services, Johnston and Russell (2011), for example, may require that markets form around intermediate services or services that mix nature's inputs with human inputs. The market-making context may differ from the context of benefit-cost analysis. Johnston and Russell (2011) rightly point out that the distinction between final and intermediate services can be crucial to sound policy analysis. Market efforts, including markets that could be created through brokers who implement hybrid approaches that help assure that public funds return public benefits, will have to operate on what people actually value and how that service or good is produced or packaged without obsessing with how pristine—or all natural—the production process is. Demand-side values for ecosystem services may enable innovative markets if more economists take on Portney's (2004) obligations, imagining and creatively testing as yet unrealized incentive-based institutions for ecosystem services and the public good.

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[28] For example, assuming non-increasing bids between successive units, the individualized price paid for units 1 through $n^* - 1$ might be the individual's bid on unit n^* where unit n^* is the last unit that is provided using aggregated bids on n^* under a pivotal-mechanism rule. This auction process would not be incentive compatible on units $n > 2$ because an individual's payment on infra-marginal units is linked to the individual's offer on the last unit.

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