Multiple Units Public Good Provision Using Individualized Price Rules: Experimental Evidence

Pengfei Liu

pengfei.liu@uconn.edu

Department of Agricultural and Resource Economics,

University of Connecticut, 1376 Storrs Road, Unit 4021, Storrs, CT, 06269

Stephen K. Swallow

stephen.swallow@uconn.edu

Department of Agricultural and Resource Economics and

Center for Environmental Sciences and Engineering

University of Connecticut, 1376 Storrs Road, Unit 4021, Storrs, CT, 06269

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Pengfei Liu, Department of Agricultural and Resource Economics, University of Connecticut, Email: pengfei.liu@uconn.edu
Stephen Swallow, Department of Agricultural and Resource Economics, and Center for Environmental Sciences and Engineering, University of Connecticut , Email:stephen.swallow@uconn.edu

1. Introduction

The problem of public good provision has attracted attention from both theoretical and experimental economists. Based on Lindahl (1919) and the more structured presentations from Samuelson (1954, 1955), the Lindahl pricing turns out to be an efficient solution to implement public goods provision by balancing the marginal social cost (MSC) of delivery against the marginal social benefit (MSB). In this research, we widen the applicability of Lindahl pricing by experimentally studying a Lindahl-based pricing mechanisms in delivering multiple units of a public good.

We examine a set of auction approaches to provide multiple units of a public good, which we call the individualized price auction (IPA), following a similar auction procedure described in Smith and Swallow (2013) and Swallow (2013). The IPA approach could prove useful in establishing markets for a previously non-marketable good, and thus improve the efficiency regarding the provision of various types of public good previously fundable only by government or through traditional non-profit donations

2. Provision Mechanism

In the IPA mechanism, a group of individuals are trying to provide multiple units of a public good through collective effort. The market-clearing rule is a mapping from the individuals' value space to potential outcomes, e.g., the number of units provided by the group. We compare two market clearing rules. 1) The ascending-unit auction (AU), where we compare the total bids from the individual with the cost of the public good, starting from the first available unit. If the total bids on the first unit, aggregated across individuals, is higher or equal to the cost for the first unit, we continue to compare the total of bids on the second unit with the cost of that unit, and so on. The auction stops when the total of bids for a unit is smaller than the unit cost. For example, if the total of bids on the first unit, second unit and third unit are all higher than the respective cost, but the aggregate offer on fourth unit is smaller than its cost, the auction will provide three units in total. 2) The descending-unit auction (DU), under which we compare the total of bids from all individual with the cost of the public good, starting from the last available unit J. If the total offers on the last unit is higher or equal to the cost for the last unit, the auction will provide all J units; if the total offer is smaller than the cost of the last unit, the auctioneer will continue to compare the total offer on the second-to-last unit, J-1, with the cost of that unit, providing all J-1 units if the offer is higher; otherwise the auction continues to unit J-2 and so on. The auction stops when the total bids for a unit is larger than the respective unit cost. For example, if the total bids on the Jth unit, J-1st unit and J-2nd unit are all lower than their cost, but the offer on the J- 3rd unit is sufficient to cover its cost, then all J-3 units are provided.

Pricing rules determine individuals' payoffs and influence individuals' contribution strategies. Particularly, we consider three pricing rules: 1) pay-your-bids auction (PYP), where each individual pays exactly the amount she bids on each unit that is provided. This pricing mechanism is similar to the provision point mechanism with no rebate in the single unit provision; 2) individualized price auction using marginal bid (MB), where the individual pays the same price for all the units provided, and her price equals her bid on the last unit provided; 3) individualized price auction using the marginal pivotal price (MP), where each individual still pays the same price for all the units provided, however, the price is now based on the pivotal price (or the Clark tax) calculated based on offers for the last unit provided. For behavioral considerations, we also added a cheap-talk treatment and a treatment where we changed the number of units that are optimal to provide from a societal perspective, from 4 to 6.

3. *Experimental Design and Procedure*

We conducted 10 experiment sessions in the CANR (College of Agriculture and Natural Resources) Lab at the University of Connecticut (UConn). Our main treatments include the pay-your-bids auction (PYP) as a baseline treatment, two ascending units auctions: AU-MB and AU-MP, and two descending units auctions: DU-MB and DU-MP. In each session, subjects were asked to make decisions in two treatments. In each treatment, we separated all the subjects into two isolated groups. Group membership was kept the same after each decision period, but changed after each treatment. There were 10 decision periods in each treatment. At the beginning of each decision period, individuals were told their induced values for six units of public good, which simulate the valuations for the public good. Individuals' induced values follow a decreasing marginal benefit curve, which decreases from Unit 1 to Unit 6. All the induced values are rounded to the nearest tenth in the experiment. Subjects only know their own induced values, but not the induced value of the others. The induced values were constant for ten decision periods, but changed at the beginning of a new treatment. The unit cost, C, was public information. We set the provision cost such that in Session 1-8, it was socially optimal to provide 4 units; in Session 9-10, individuals have a higher value for each unit and it was socially optimal to provide 6 units. A total of 122 subjects participated in the experiment, producing 14,640 individual level observations (122 individuals*20 decision periods*6 units).

3. *Experiment Results*

3.1 *Provision Frequency*

Table 1 below reports the provision frequency in an accumulative manner: each column summarizes the provision frequency where at least a certain number of units is provided, e.g., the 2 Units or more column counts all the occasions where at least 2 units are provided. We find that when providing 4 units is optimal, subjects rarely reach the efficient provision level. Subjects never provide more than 4 units in any cases. When providing 6 units is optimal, subjects provided 5 units in several occasions; they did not reach the efficient provision level.

Provided	1 Uuit or more	2 Units or more	3 Uuits or more	4 Uuits or more	5 Uuits or more	6 Uuits
PYP-AU	90%	47.5%	20%	0%	0%	0%
MB-AU	96.25%	75%	30%	0%	0%	0%
MP-AU	85%	65%	45%	2.5%	0%	0%
MB-DU	75%	55%	27.5%	0%	0%	0%
MP-DU	80%	65%	32.5%	5%	0%	0%
MB-AU-CT	92.5%	67.5%	32.5%	0%	0%	0%
MB-DU-CT	97.5%	67.5%	32.5%	0%	0%	0%
PYP-AU-6	95%	75%	60%	37.5%	10%	0%
MB-AU-6	95%	85%	72.5%	40%	5%	0%

Table 1. Accumulative Provision Frequency

3.2 *Average Marginal Contribution*

Table 2 reports average marginal contribution in the last 5 periods in provision mechanism. In addition to average marginal contribution results, we also find that in the descending-unit auctions, there is a larger proportions of low contributions (which is defined as the contribution smaller than or equal 1 experimental dollar) compared to their ascending counterparts on the first two units.

Marginal Contribution	1 Uuit or more	2 Units or more	3 Uuits or more	4 Uuits or more	5 Uuits or more	6 Uuits
PYP-AU	9.30	8.20	6.88	4.93	3.33	0.99
MB-AU	12.04	8.94	6.88	4.83	3.31	1.26
MP-AU	11.44	7.73	7.37	4.99	3.40	1.49
MB-DU	10.33	8.72	6.85	5.12	3.42	1.53
MP-DU	10.44	7.74	7.34	4.91	3.52	1.63
MB-AU-CT	11.07	9.08	6.94	4.27	2.96	0.91
MB-DU-CT	10.86	8.19	7.00	4.84	3.35	1.51
PYP-AU-6	10.08	8.68	8.33	7.26	5.40	3.90
MB-AU-6	15.26	11.50	8.50	6.77	4.82	3.20

Table 2. Average Marginal Contribution

3.3 *Social Efficiency and Surplus Allocation*

We summarize the experimental results from a social planner's perspective; particularly, we are interested the realized social surplus, as well as the split of the social surplus between consumers and producers.

In Table 3, we summarize the maximum social surplus, realized social surplus and producers' net revenue by each treatment in the last 5 periods. We observe that the overall efficiency level ranges from 58% to 72% (when providing 4 units is optimal, without cheap-talk treatment), with the MB-AU being the highest and the MB-DU being the lowest. We also find the cheap-talk treatment increases the overall efficiency for MB-DU from 58% without the cheap-talk to 70% with the cheap talk, while for the MB-AU, the cheap talk treatment does not change much in terms of overall social efficiency; the efficiency level changes from 72% without cheap talk to 71% with cheap talk. When providing 6 units are optimal, the overall efficiency level is higher for MB-AU compared to PYP-AU.

Table 3. Realized Social Surplus, Consumers' Surplus and Producers' Net Revenue in the last 5 periods (Numbers are adjusted to be comparable with a group size of 5)

	Maximum Social Surplus	Realized Social Surplus	Consumers' Surplus	Producers' Net Revenue
PYP-AU	158	84(53%)	75(89%)	9(11%)
MB-AU	159	110(69%)	96(87%)	14.5(13%)
MP-AU	159	100.5(64%)	133.5(133%)	-32.5(-33%)
MB-DU	158	90.5(57%)	79(87%)	11.5(13%)
MP-DU	158	105.5(67%)	142(135%)	-36.5(-35%)
MB-AU-CT	158	109(69%)	97.5(90%)	11(10%)
MB-DU-CT	160	107(67%)	100(93%)	7(7%)
PYP-AU-6	322	212.5(66%)	188.5(80%)	24(11%)
MB-AU-6	322	237(73%)	222(94%)	15(6%)