**Farmers' Heterogeneous Valuation of Laser Land Leveling in Eastern Uttar Pradesh: An Experimental Auction to Inform Segmentation & Subsidy Strategies**

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For most of the rural poor in developing countries, improving day-to-day quality of life requires improvements in agricultural productivity. With the gradual reduction of government support for public agricultural research, extension, and marketing in many of these settings, the dissemination of new agricultural technologies is increasingly shaped by the private sector(Feder, Willett and Zijp 2001). When the private agro-services sector thrives, farmers often benefit from better information, more options and, ultimately, higher productivity. For many agricultural technologies, however, the private sector lacks the incentives and information needed to successfully serve the needs of poor farmers. In these cases, targeted subsidies are often proposed as a way to encourage broader technology dissemination – but the lack of information about poor farmers' valuation of new agricultural technologies typically remains a constraint. Consequently, even when there is a political will to target poor farmers with subsidy support, a vague and incomplete understanding of how

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famers value a technology differently often prevents this political will and these subsidies from translating into agricultural productivity gains for the poor.

We aim to fill this void in the case of a new agricultural technology in Eastern Uttar Pradesh, India (EUP). We use experimental auctions to better understand heterogeneity of farmers' demand for Laser Land Leveling (LLL) services in this region. Technology demand can be shaped by a variety of farm and farmer characteristics such as farm size, risk preferences, education, experience, wealth, and access to markets, information, credit. Understanding how demand varies across observable variables is a necessary first step at designing market segmentation strategies.

The rice-wheat cultivation system that prevails in this area relies on flood irrigation. Since farmers must flood each plot to its highest point, the leveling precision that is possible with LLL appears to dramatically reduce water usage (Jat et al. 2006). While any public benefits associated with reduced groundwater pumping in a given region are shared, the private benefits of LLL can vary widely across different farmers and plots. This mix of public benefits and heterogeneous private benefits associated with LLL makes novel market segmentation strategies and targeted subsidies particularly potent as a means of improving social welfare.

Experimental auctions have become a popular approach to better understand heterogeneity in individual valuation of goods and services. As argued by Lusk and Shogren(2008, p.4), "relative to other value elicitation techniques, experimental auctions provide the richest description of heterogeneity in valuations across people and goods with minimal assumptions." Because such auctions are binding, hypothetical bias is mitigated (Harrison and Rutström 2008). Experimental auctions have been used widely to assess consumer valuation of agricultural products in developed countries. Indeed, food is by far the most commonly auctioned item, where valuation dimensions include quality attributes (e.g., marbling in pork chops), production conditions (e.g., organic, genetically modified organisms, growth hormones), and risk and information (e.g., food safety) (Alfnes and Rickertsen 2003, Hayes et al. 1995, Melton et al. 1996). In developing countries, experimental auctions have shed light on heterogeneity of valuation of health and nutrition products such as bed nets, fortified foods, and infant foods of certified quality (De Groote, Kimenju and Morawetz 2011, Dupas 2010, Hoffmann, Barrett and Just 2009, Masters and Sanogo 2002). Our experimental auction approach to understanding farmers' valuation of LLL builds on these recent efforts and incorporates a WTP-conditioned lottery to enable the rigorous evaluation of LLL impacts.

**BACKGROUND ON LASER LAND LEVELING (LLL)**

LLL is a resource conserving technology new to EUP, but available in other areas of the Indo-Gangetic Plains (IGP). In surfaceirrigated rice-wheat systems in the IGP, 10-25% of irrigation water is lost because of poor management and uneven fields. Uneven fields also lead to inefficient use of fertilizers and chemicals, increased biotic and abiotic stress, and lower yields (Jat et al. 2006). Laser leveling is a process of smoothing the land surface using a laser-equipped drag scraper for precision resulting in land that is smoothed to within 1-2 cm of its average elevation. In comparison, traditional leveling methods used in the region can reduce variation to within 4-5 cm of its average elevation (Jat et al. 2006).

After LLL was introduced in western Uttar Pradesh in 2001, the number of laser land levelers rose to 925 and land leveled grew to 200,000 hectares by 2008. LLL trials in rice-wheat systems of the IGP have found 10-30% irrigation savings, 3-6% effective increases in farming area, 6-7% increases in nitrogen use efficiency, 3-19%increases in yield, and increases in annual farm revenue of $200-300 per hectare(Jat et al. 2006). LLL could also have public benefits in the form of reduced groundwater depletion and chemical use. Jat et al. (2006) estimate that extended use of LLL to 2 million hectares of rice-wheat land in the IGP could save 1.5 million hectare-meters of irrigation water and 200 million liters of diesel, improve crop yields by $500 million, and reduce greenhouse gasemissions by 0.5 million metric tons over three years.

**RESEARCH SETTING & DATA**

Our research setting encompasses the Maharajganj, Gorakhpur, and Deoria districts of EUP. This region is situated in the fertile grounds of the IGP, yet nearly 70% of the 192 million people in Uttar Pradesh state live in poverty (Alkire and Santos 2010). During the summer *kharif* growing season, when rice is grown, the southwest monsoons provide much of the water, whereas the wheat crop in the dry *rabi* season relies primarily on irrigation from nearby rivers. The three districts chosen for this study represent the regional spectrum of productivity in rice-wheat cropping systems. From each district, we randomly selected eight villages, omitting any villages from the sample frame that might have been exposed to LLL by technology hubs operating in the area. As a result, only six farmers reported ever having heard of LLL. Within each village we then randomly selected 20-24 farmers from amongthose cultivating plots of at least 0.2 acres (the minimum plot size to physically conduct LLL).

In each village, werandomly selected households from a village census and convened an information session with these farmers to discuss the mechanics of LLL and its potential benefits and drawbacks. The information session consisted of a shortvideo on LLL, the distribution of a picture brochure, and a question and answer session with a non-sample farmer who had previously received LLL services. We strived toprovide complete and objective information without promoting the technology. We informed farmers that recent LLL prices in other parts of India varied between Rs. 400-800 per hour. During the information session we told farmers they would get an opportunity to bid on LLL and that the bid options would range from Rs. 250-800 per hour. This price range was printed on the picture brochure for reference. As our second step, we conducted a baseline survey to collect information on the economic activities, demographics and assets of the household, as well as key information about all the plots cultivated or owned by each farmer.

Finally, we held a binding experimental auction in each village to elicit willingness-to-pay (WTP) for LLL custom hire services. Each farmer was assigned an enumerator to privately guide them through the auction process and record their responses. Since no one else was offering LLL services in this area, the auction was the only way farmers could obtain LLL services on their plots that season. In theauction, each farmer listed up to three plots he or she would most like leveled. For each, the farmer estimated how long it would take to level the plot using traditional techniques. This estimate would be a benchmark for understanding how long LLL might take. Then, plot by plot, the enumerator recorded whether or not the farmer was willing to pay for leveling at ten different prices between 250 and 800 Rupees per hour. Once the entire price card was completed and in the spirit of a Becker-DeGroot-Marschak(1964) mechanism, we revealed the pre-selected binding LLL price (250 Rs/hour). Before auctioning off LLL services, we used candy to teach farmers the structure and mechanics of the auction and held one practice LLL auction was completed before conducting the real one. At the conclusion, enumerators described over 80% of farmers as having understood the experiment very well or fairly well.

**DEMAND HETEROGENEITY&ELASTICITIES**

Summary statistics on plot and farmer characteristics are given in table 1, first for the whole sample (column 1) and for those with WTP below and above 250 Rs/hour (columns 2 and 3, respectively). While these mean comparisons suggest some systematic heterogeneity, the design of theauction also enables us to depict the heterogeneity of LLL demand directly. Figure 1 shows the WTP for different subsets of farmers depicted as demand curves with prices in Rs/hour shown on the y-axis and the corresponding percentage of land each subset of farmers was willing to level on the x-axis. The horizontal line at 500 Rs/hour indicates the approximate current market rate elsewhere in India. Since differences in demand are the crux of any segmentation strategy, we indicate the number of p-values below 10% from pairwise Kolmogorov-Smirnov tests of differences in the underlying WTP distributions for these farmer subsets (e.g., ^^ on the fourth landholding quartile indicates that the WTP distribution for this quartile is pairwise different than two other landholding quartiles with $p<0.10$).

The demand curves in figure 1 are very elastic below the market price of 500 Rs/hour, which implies that subsidies could dramatically expand LLL adoption. Less than 5% of the land covered by our sample in any district would be leveled at the market price, but nearly 50% would be leveled at half that price. These graphs indicate potentially useful dimensions of demand heterogeneity. Along most dimensions, much of the demand heterogeneity occurs below the uniform market price, which further implies that segmentation strategies that lower prices for some farmer subsets might be promising. There are some pronounced demand differences by district and caste.[1]Nearly half of our sample farmers carry an official below-poverty-line (BPL) card, which could be a straightforward segmentation approach. Surprisingly, however, those with BPL cards are willing to level more than those without at nearly every price (top right panel of figure 1).In the bottom three panels of figure 1, we disaggregate farmers by different quantile dimensions. In all three dimensions, there are few if any demand differences at the market price, but significant differences below this price. Farmers in the lowest total landholding quartile demand twice as much LLL at 450 Rs/hour than the other quartiles. Plot size differences are more systematic, with the highest quartile having the highest LLL demand below the market price. The relationship between ownership and operation of land may partially explain these differences.

Finally, differences in demand by credit access suggest that liquidity constraints may have constrained LLL demand: farmers with no self-reported access to credit (first quartile) demand less LLL at every price below the market price than farmers who in a pinch could get a loan of Rs. 20,000 or more (third and fourth quartiles). While credit access is not a potential segmentation dimension per se, these differences do suggest that relieving liquidity constraints with microfinancing options for LLL might be worth exploring as part of any segmentation strategy. As a methodological note, even though characterizing demand just below a market price is essential to any subsidy or segmentation strategy, it is difficult to learn much about demand in this price region from markets since these individuals are typically priced out. In this case, experimental auctions can be especially insightful.

Since the price elasticity of demand for LLL below the market price is relevant to the formulation of segmentation or subsidy strategies, we compute simple arc elasticitiesusingthe auction data. Specifically, we calculate how a 20% price reduction from 500 to 400 Rs/hour changes the area that farmers want to laser level. For our full sample, this arc elasticity is 6.3, indicating very elastic demand for LLL just below the prevailing market price. LLL demand elasticity is highest in Gorakhpur district (7) and lowest in Deoria(5.9). To compare price sensitivity across the wealth distribution, we compute arc elasticities for each quartile at 10%, 20%, and 30% price reductions from the market price. For each reduction level, the highest wealth quartile is most responsive to price, but LLL demand among the lowest wealth quartile is still quite elastic. Furthermore, these quartile differences are less pronounced for bigger price reductions.

In ongoing analyses of the determinants of LLL demand, we usequantile regression to more carefully assess the determinants of demand heterogeneity. This approach will enable us to explore specifically the determinants of demand among farmers who would be priced out of the LLL market based on uniform pricing. Since targeted subsidies ostensibly target these farmers – i.e., those whose demand for LLL is below the market price but for whom LLL is still viable – understanding the structure of demand at WTP quantiles below the market price becomes especially important.

### MARKET SEGMENTATION SIMULATIONS

To demonstrate how demand analysis can be used to inform market segmentation strategies, we simulate LLL uptake in our sample using several candidate subsidy and segmentation plans. These plans include uniform subsidies of 100, 150, 200, and 250 Rs/houron LLL custom hire rates and four market segmentation strategies informed by our demand analysis. From figure 1it is apparent that uniformsubsidizationcould increase the rate of diffusion of LLL. Proper market segmentation could make subsidieseven more efficient by targeting particular types of farmers according to their price sensitivity. Here we compare the performance of five market segmentation strategies against uniform subsidies and each other.

***Geographic segmentation by district***: Since LLL services are rendered directly to a given immobile plot, geographic segmentation is perhaps the easiest departure from uniform pricing to envision. Under this strategy, service providers would charge different prices in separate districts depending on demand for LLL. Arbitrage and leakage are insignificant concerns with this strategy since plots are immobile. However, while there are some demand differences between the three districts in our sample, the three districts are relatively similar in many regards, which limits the potential for welfare gains from this strategy.

***Wealth segmentation based on poverty status or caste*****:** Although segmenting by wealth is a popular strategy in theory, implementation may be challenging. One option for segmenting markets in this way is to offer vouchers to those with BPL cards, but note that figure 1 suggests that those above the poverty line might need more (not less) encouragement to level their plots. Another way to achieve a similar goal might be to segment based on caste – a popular preferential treatment criteria in India(Sheth 1987).

***Landholdings segmentation****:* Although a broadwealth index might make sense as a segmentation dimension, total landholdings are easier to observe and, therefore, easier to implement. Furthermore, there are non-wealth reasons for demand for LLL andother agricultural technologies being higher for farmers with more land, such as the ability to experiment or manage risk (Feder 1980).

***Plot size segmentation***: Explicitly segmenting on plot size could involve offering vouchers for plots that are viable for LLL but below a given threshold. This strategy would be less prone to underreporting than segmentation by total landholdings and, based on figure 1, potentially effective given systematic demand heterogeneity below the market price.

Soon, we will have detailed data on heterogeneous benefits from LLL and costsof laser leveling on LLL provision, which will enable us to use social welfare analysis to evaluate market segmentation strategies. For now, we evaluate the subsidy-segmentation plansmentioned above using a simple simulationand the following metrics: total acreage in the sample under LLL, percent of land in the sample under LLL, total cost of the subsidy, and cost per *additional* acre of LLL as compared to a scenario of no subsidies.

Consider how a uniform market price of 500 Rs/hour compares to a uniform subsidy of 150 Rs/hour in table 2. Based on the demand curves, this subsidy will increase the number of households adopting LLL by five times and the amount of acres in LLL by almost 10 times. The cost effectiveness of such a uniform subsidy can be assessed based on cost of the subsidy[2] per added household or added acre. Using a market segmentation strategy that offers differential subsidies by district (Rs. 100 in Maharajganj, 150 in Deoria, and 200 in Gorakhpur), a higher adoption rate can be obtained at a slightly lower cost: 145 acres (21%) leveled at a total cost of Rs. 871 per additional household and Rs. 609 per additional acre. A subsidy based on BPL status (Rs. 100 for APL farmers and Rs. 250 for BPL farmers)is slightly cheaper per additional household but more expensive per additional acre because the additional plots that are leveled tend to be owned by relatively poorer households and to be relatively small. Segmentation by caste (lower caste farmers receive a Rs. 250 subsidy)is even cheaper per household and more expensive per acre.

Since demand differences by landholding quartiles are not monotonic, a monotonic progressive subsidy on this dimension (Rs. 200 for the first quartile, Rs. 150 for the second and third, and Rs. 100 for the fourth) seems unpromising – but turns out to be the most cost effective way to bring additional acres into LLL. In contrast, demand by plot size quartile is monotonic such that progressive subsidiesat the plot level (Rs. 200 for the first quartile, 150 for the second and third, and 100 for the fourth) strike a more balanced tradeoff between the cost of expanding LLL to more households and the cost of adding more acres in LLL.

These simulation results demonstrate that market segmentation can result in more land leveled at lower costs than uniform subsidies. The relative strengths of different subsidies depend not only on the amount of land leveled andthecost, but also on socialobjectives such as targeting female farmers and poor farmers or villages, budget constraints, political feasibility and environmental objectives such as reduced groundwater pumping.Regardless of the tradeoffs policy makers might make between these different objectives, understanding demand heterogeneity – particularly for those normally priced out of the market – is crucial to the design ofthese subsidies and segmentation strategies.

## DISCUSSION

In this analysis, we argue that experimental auctions are a useful tool for informing the design and evaluation of alternative market segmentation and subsidy strategies. The mix of public benefits and heterogeneous private benefits associated with LLL in eastern Uttar Pradesh, India makes these strategies particularly potent as a means of improving social welfare. Our analysis of farmers' demand for LLL showcases their heterogeneity of valuation for this technology. Specifically, among those who would be priced out of a uniform-price-based LLL market we find marked demand differences by district, wealth, caste, landholding, and plot size.Simple arc elasticities suggest considerable price sensitivity just below the market price for all farmer types. Simulations show how it is possible to draw more land under LLL at a lower cost by segmenting markets by observable characteristics across which technology demand differs. Demand differences by credit access suggest that liquidity constraints may affect LLL uptake and that bundling segmentation strategies with credit might further encourage uptake. Although further work is needed, this preliminary analysis demonstrateshow experimental auctions can improve our understanding demand heterogeneity and its underlying determinants and how this, in turn, can inform novel segmentation and subsidy strategies.

The project described in this paper incorporated a randomized control trialof LLL into the design of the experimental auctionby using a post-auction lottery. We will use this aspect of the project to evaluate the impact of LLL on inputs, yield and profits. These impact results will enable us to explore more precisely the private and public benefits of different segmentation and subsidy strategies. In ongoing work, we are using more complete social welfare metrics to assess the relative performance of these strategies in consumer and producer surplus terms. In this work, we refine market segmentation and subsidy strategies, develop welfare-based metrics for assessing the performance of different strategies, and articulate cost recovery constraints that must be satisfied to sustain a private LLL services market. Because this research is part of the broader Cereal Systems Initiative for South Asia that links public institutions tothe private sector, we hope to collaborate with LLL service providers and government officials to use this demand information to encourage the diffusion of LLL among poor Indian farmers.

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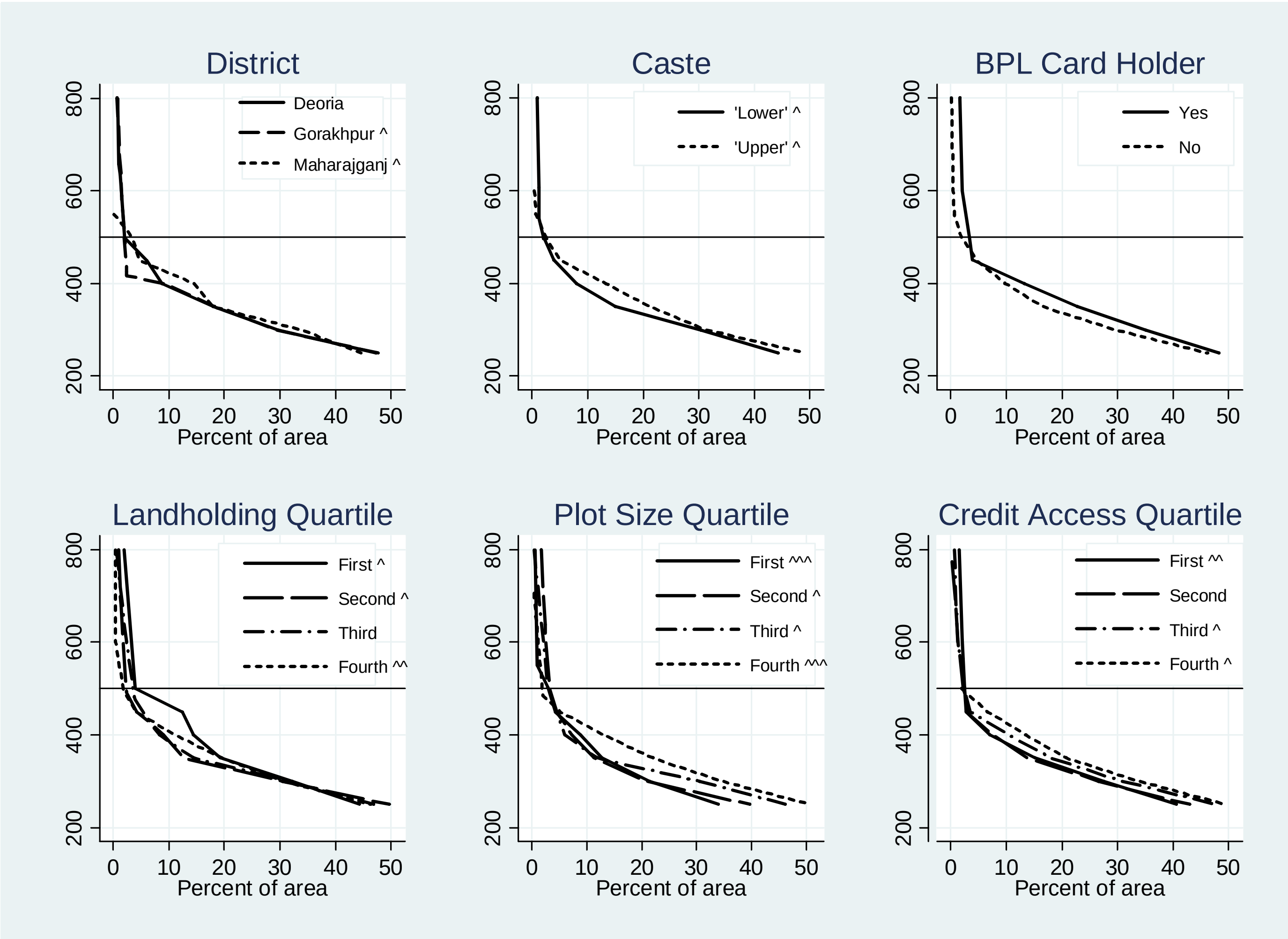


**Figure 1.Disaggregated demand curves for LLL with WTP in Rs./hour on y-axis (^, ^^ and ^^^ indicate the number of significantly different pairwise Kolmogorov-Smirnov comparisons of the underlying WTP distributions at the 10% level; see footnote 1 for the definition of 'upper' and 'lower' caste)**

**Table 1.Means (Standard Deviation) for Selected Variables for the Full Sample and for Three Sub-samples from the Experimental LLL Auction**

| | Full Sample (N=478) | | WTP <price[a] (N=192) | | WTP ≥ price (N=286) | |
|---|---|---|---|---|---|---|
| Age of HH head | 50.09 | (15) | 49.11 | (14.8) | 50.87 | (15.1) |
| Male HH head | 0.82 | (0.38) | 0.76***[b] | (0.43) | 0.87 | (0.34) |
| Education of HH head (years) | 6.27 | (5.51) | 5.6** | (5.37) | 6.78 | (5.56) |
| HHs in upper caste | 0.22 | (0.42) | 0.16*** | (0.37) | 0.27 | (0.44) |
| Wealth Index[c] | 0.50 | (0.29) | 0.48 | (0.28) | 0.52 | (0.29) |
| BPL card holder | 0.47 | (0.50) | 0.50 | (0.50) | 0.46 | (0.50) |
| Willingness to take risks (1=unwilling, 7=willing) | 4.55 | (1.51) | 4.25*** | (1.59) | 4.78 | (1.39) |
| Area Owned (acres) | 2.06 | (4.29) | 1.62** | (5.02) | 2.42 | (3.58) |
| Plot Size (acres) | 0.72 | (1.11) | 0.50*** | (0.69) | 0.88 | (1.31) |

[a]Indicates the final binding price in the auction. [b]Test of nonzero difference in means between WTP < price and WTP ≥ price (***p < .01, **p < .05, *p < .10). [c]Factor analytic index that includes a livestock index, amount spent on Diwali, monthly phone bill, condition of house, household participation in MGNREGA, domestic and international remittances, whether farmers custom-hired a thresher combine, and whether households owned a tractor.

**Table 2. Results and Costs of Several Candidate LLL Subsidy and Segmentation Plans**

| | **Uniform Price** | **Uniform Subsidy** (Rs/hr) | | | | **Segmentation Dimension** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (500 Rs/hr) | 100 | 150 | 200 | 250 | *District* | *BPL* | *Caste* | *Land* | *Plot* |
| HHs with LLL | 18 | 53 | 93 | 187 | 289 | 107 | 139 | 201 | 100 | 109 |
| (% of HHs) | (4%) | (12) | (21) | (42) | (65) | (24) | (31) | (45) | (22) | (24) |
| Acres in LLL | 17.8 | 82.3 | 153.6 | 276.4 | 406.9 | 145.4 | 157.1 | 162.9 | 116.8 | 112.0 |
| (% of area) | (3%) | (12) | (22) | (40) | (59) | (21) | (23) | (24) | (17) | (16) |
| Subsidy cost (1000 Rs) | 0 | 23.9 | 66.8 | 166.0 | 317.6 | 77.6 | 89.3 | 109.0 | 47.3 | 48.5 |
| Cost/HH (Rs) | 0 | 683.4 | 891.2 | 982.4 | 1172 | 871.4 | 738.4 | 595.8 | 576.3 | 533.2 |
| Cost/acre (Rs) | 0 | 371.1 | 492.4 | 642.0 | 816.2 | 607.9 | 641.4 | 751.5 | 477.5 | 515.0 |

[1]Per the Government of India, caste affiliation is broadly divided between general ('upper') caste and 'lower' caste, with the latter sub-divided into scheduled caste (SC), scheduled tribe (ST) and other backwards caste (OBC). Within the sample, 26% of households classified themselves as SC, 2% as ST, and 50% as OBC. Only 14 farmers (3%) in the sample were Muslims, four of which classified themselves as upper caste, one as SC, and nine as OBC.

[2] Total subsidy cost is computed based on the actual time required to level a given plot or, in the case of a plot that was not leveled, a propensity score-based matched plot.