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IFPRI Discussion Paper 01274

July 2013

Targeting Technology to Reduce Poverty and Conserve Resources

Experimental Delivery of Laser Land Leveling to Farmers in Uttar Pradesh, India

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ABSTRACT

Demand heterogeneity often makes it profitable for firms to price and promote goods and services differently in different market segments. When private consumption brings public benefits, this same heterogeneity can be used to target public subsidies. We explore the design of public–private targeting and segmentation strategies in the case of a resource-conserving agricultural technology in India. To understand farmers' heterogeneous demand for laser land leveling (LLL), we conducted an experimental auction for LLL services with an integrated randomized controlled trial to estimate the private benefits of the technology. We use graphical and econometric approaches to characterize farmer demand for LLL. We then add detailed cost data from LLL providers to simulate and evaluate several potential targeted delivery strategies based on measures of (1) the cost-effectiveness of expanding LLL dissemination, (2) water savings, and (3) market surplus in a welfare framework. These simulations demonstrate inherent tradeoffs between increasing the amount of land that is leveled and expanding the number of farmers who adopt the technology, and between adoption and water savings. While segmenting and targeting are popular elements of many public–private partnerships to develop and disseminate agricultural technologies, formulating and implementing effective delivery strategies requires a rich understanding of costs, benefits, and demand. Our experimental approach generates such an understanding and may be relevant in other contexts.

Keywords: laser land leveling, resource-conserving technology, demand heterogeneity, market segmentation, technology targeting, India

ACKNOWLEDGMENTS

This paper was prepared as a contribution to the Cereal Systems Initiative for South Asia (CSISA), a project supported with generous funding from the United States Agency for International Development (USAID) and the Bill and Melinda Gates Foundation. We thank R. K. Malik, Joginder Singh, Ajay Kumar Pundir, Raman Sharma, Shahnawaz Rasool Dar, Gautam Singh, Satyendra Kumar Singh, Hemant Pullabhotla, Sanjay Prasad, Vartika Singh, and our field team for their contributions to the fieldwork and data collection. We also thank M. L. Jat, M. S. Rao, J. K. Ladha, P. K. Joshi, Tony Cavalieri, Marco Gonzalez-Novarro, Saharah Moon Chapotin, John McMurdy, and Mark Rosegrant for providing their insights and support. Useful comments on earlier versions of this paper were received from participants at the 2011 Allied Social Science Association annual meeting, the 2012 Pacific Conference for Development Economics, the 2012 Midwest International Economic Development Conference, and the 2012 International Conference of Agricultural Economists, as well as at several seminars in 2011–12 organized by CSISA, IFPRI, and USAID in Bangladesh, India, and the United States. Any and all errors are the sole responsibility of the authors.

1. INTRODUCTION

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 techniques and technologies is increasingly shaped by the private sector (Feder, Willett, and Zijp 2001). When the private agroservices 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, a variety of mechanisms are often proposed to encourage broader technology dissemination, ranging from targeted subsidies provided by the public sector to marketing strategies such as promotional discounts used by the private sector (Aker et al. 2005). However, the lack of information about poor farmers' valuation of new agricultural technologies typically remains a constraint for both public- and private-sector providers. Consequently, even when there is a political or corporate willingness to target poor farmers with support, a vague and incomplete understanding of the various values that different farmers place on a technology often prevents this willingness and these targeted support mechanisms from translating into agricultural productivity gains for the poor. Motivated by this void, we use experimental methods to characterize farmers' heterogeneous demand for a new agricultural technology in eastern Uttar Pradesh, India, in order to inform segmentation and targeting strategies.

Farmers in the rice–wheat farming systems of this region of the Indo-Gangetic Plain (IGP) typically flood irrigate their fields using water extracted from tube wells by diesel pumps. To ensure that his or her plot is completely irrigated, each farmer must flood the plot to its highest point. Consequently, relatively small undulations in seemingly flat plots can increase the amount of water required to irrigate by up to 25 percent, leading to inefficient use of fertilizers and chemicals, increased biotic and abiotic stress, and lower yields (Jat et al. 2006, 2009). To reduce pumping costs[1] and improve production, farmers have devised rudimentary techniques to level their plots (for example, dragging wooden beams behind draft animals or tractors) with a precision of ±5 cm. Laser land leveling (LLL), an unfamiliar technology in our study area, uses a fixed laser emitter and a laser receiver mounted to an adjustable drag scraper to level plots with a precision of ±1–2 cm. Though clearly more sophisticated than traditional leveling techniques, LLL uses relatively basic equipment, requires minimal training, and is available in other areas of the IGP, generally as a custom-hire service at a flat hourly rate.

LLL was introduced in the western IGP in 2001 and had expanded to 200,000 hectares by 2008 across the states of western Uttar Pradesh, Haryana, and Punjab.[2]. More recent estimates from Jat (2012) suggest that the current leveling capacity from approximately 10,000 LLL units in operation across India exceeds one million hectares. In Punjab alone, there are an estimated 2,000 LLL units owned by farmers' cooperatives and individual farmers (Larsen, Sekhri, and Sidhu 2013), although Jat (2012) suggests that the figure may be as high as 5,000. Although the western IGP is richer and more agriculturally developed than our study area, LLL trial results from this region are promising. These trials have found 10–30 percent irrigation savings, 3–6 percent effective increases in farming area, 6–7 percent increases in nitrogen use efficiency, 3–19 percent increases in yield, and increases in annual farm revenue of US$80–120[3] per acre (Jat et al. 2006). Depending on the soil type and on cultivation and harvesting practices, a precisely leveled plot can reap these benefits for several years before needing to be releveled. While it is tempting to extrapolate these LLL impacts to the broader IGP and beyond,[4] substantial differences in

[1] Under most circumstances, Indian farmers do not pay for water directly, but they do pay for diesel fuel and therefore face strong incentives to reduce pumping time.

[2] To date, LLL providers have relied almost exclusively on word-of-mouth advertising. To expand into a new area, they often will contact a farmer and offer to level a plot with a money-back guarantee: If the farmer is not satisfied after the service is provided, he need not pay.

[3] All dollar amounts are in US dollars.

[4] Jat and others (2006) estimated 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 gas emissions by 0.5 million metric tons over 3 years.

average farm and plot size, poverty rates, and access to technology have important implications for the diffusion of LLL. Specifically, these differences and farmer heterogeneity have important implications for farmers' valuation of the technology and service providers' incentives to expand into poorer regions.

Although difficult to document, LLL may also generate important public benefits in the form of reduced groundwater depletion, chemical input use, diesel fuel consumption, and greenhouse gas emissions. In the case of groundwater depletion (Mukherji 2007; Shah 2007), even small reductions in pumping across a large population can lead water tables to rise, reduce pumping costs, and improve the sustainable use of groundwater for communities that share groundwater resources. Combined with potentially significant but heterogeneous private benefits, these public benefits make novel market segmentation strategies and targeted subsidies particularly potent as a means of improving social welfare.

In order to characterize the private and public benefits of LLL, it is first necessary to understand how demand for LLL varies spatially and across different types of farmers and farm systems. Such heterogeneous demand can arise because benefits of the technology are heterogeneous (Suri 2011) or because barriers to adoption are heterogeneous. Consequently, demand can be shaped by a variety of farm and farmer characteristics such as farm size, soil and climate characteristics, market access, risk preferences, education, experience, wealth, access to information, and access to credit. Understanding how demand varies across observable variables is a necessary first step to designing market segmentation strategies. We use experimental auctions for LLL services to estimate farmers' valuation of LLL in a way that allows us to simulate different targeting strategies. By taking farmers' valuation as the basis for simulating different delivery strategies, our approach is conceptually similar to that of Qaim and de Janvry (2003), who simulated the effect of different pricing models for Bt cotton in Argentina on adoption and corporate profit. While they used a hypothetical contingent-valuation module to elicit farmers' willingness to pay (WTP), we conduct incentive-compatible experimental auctions to acquire the WTP values for our simulations.[5] Experimental auctions such as ours are an increasingly popular way to characterize heterogeneity in individual valuation of goods and services, and are therefore well suited for informing delivery strategies. As Lusk and Shogren argued, "relative to other value elicitation techniques, experimental auctions provide the richest description of heterogeneity in valuations across people and goods with minimal assumptions" (2008, 4). 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, and its valuation dimensions include quality attributes (for example, marbling in pork chops), production conditions (for example, organic farming, genetically modified organisms, growth hormones), and risk and information (for example, food safety) (Alfnes and Rickertsen 2003; Hayes et al. 1995; Melton et al. 1996). In developing countries, experimental auctions have shed light on heterogeneity in the valuation of health and nutrition products such as bed nets, fortified foods, and infant foods of certified quality (Demont et al. 2013; De Groote, Kimenju, and Morawetz 2011; Dupas 2010; Hoffmann, Barrett, and Just 2009; Masters and Sanogo 2002). We aim to contribute to this recent work by exploiting experimental auction data to explicitly explore the tradeoffs associated with different targeting approaches. Although this analysis is the first to apply such an auction-based methodology to simulating different targeting strategies, a similar experimental approach has been used to simulate the design of payments for ecosystem services (Jack, Leimona, and Ferraro 2009).

As a point of departure we use econometric analysis to examine what observable variables are correlated with farmer WTP for LLL services. We use these initial estimates to devise a more rigorous and direct way to test segmentation and targeting strategies. Specifically, we construct farmer-level demand curves based on our experimental auction data. We use bootstrapping techniques to aggregate these curves into probabilistic demand curves for our sample farmers and for specific subsets of farmers. Based on detailed cost data from our LLL provider, we characterize the supply side as well. These probabilistic demand curves, together with our LLL costs, enable us to test the cost-effectiveness of

[5] In addition, whereas Qaim and de Janvry (2003) did not directly observe the benefits of Bt cotton to farmers, we are able to rigorously identify the benefits associated with LLL services.

specific targeting strategies based on several metrics, including LLL expansion over acres and households, as well as water savings. Using a welfare framework, we also estimate the market surplus effects of these strategies and the deadweight loss associated with strategies that involve targeted subsidies.

2. A THEORETICAL FRAMEWORK

Many technology adoption models use a dichotomous variable for adoption/nonadoption that is the observable manifestation of the expected net benefits of adoption (Feder, Just, and Zilberman 1985). Other models examine intensity of adoption to account for risk management, experimentation, or a combination thereof (Feder 1980; Leathers and Smale 1991; Smale, Just, and Leathers 1994). Hazard models can be used to estimate time until adoption of a new technology (Abdulai and Huffman 2005; Liu 2012). In our case, we have a somewhat continuous measure of farmers' valuation of a new technology based on WTP elicited in our experimental auction for LLL services. This section provides a microeconomic foundation for farmers' valuation of a new technology. This framework motivates our subsequent econometric specifications aimed at understanding correlates of demand for LLL. We then describe an aggregation approach to characterizing the demand for LLL from various farmer subgroups and quantifying the welfare implications of different targeting strategies. These different analytical perspectives on demand—at the individual and subgroup level—are complementary in important ways and provide a framework for structuring our subsequent empirical analysis.

A producer's willingness to pay (WTP) for a technology is based on the difference in indirect utility (in monetary units) between a scenario with and without the technology, allowing the optimal amounts of other inputs to differ in these two scenarios. To simplify this theoretical framework, we assume for now that farmers are risk neutral, profit-maximizers and have an option to level plots using LLL custom-hire services—an unfamiliar technique to remedy a familiar problem.[6] We assume that LLL is scale neutral and incurs no fixed costs to the farmer.[7] Farmer *i* maximizes expected profits for each plot *j* and for each technology *k*, where *N* = no leveling and *L* = LLL:

$$\max_{\mathbf{x}_{\mathbf{ij}}^{k}} E\pi_{ij}^{k} = E\left[y_{ij}^{k}\left(\mathbf{z}_{\mathbf{i}}, \boldsymbol{\varphi}_{\mathbf{j}}^{k\prime}\mathbf{x}_{\mathbf{ij}}^{k}, \mathbf{s}_{\mathbf{j}}\right) - \boldsymbol{\omega}_{\mathbf{i}}{}'\mathbf{x}_{\mathbf{ij}}^{k}\right] \text{ for } k \in \left\{N, L\right\}, \tag{1}$$

where y_{ij}^{k} is the expected value of total annual production; $\mathbf{z}_{\mathbf{i}}$ is a vector of farmer characteristics; $\mathbf{x}_{\mathbf{ij}}^{k}$ is a vector of $h = 1, 2, \ldots, H$ inputs (for example, water, labor, fertilizer, chemicals); $\mathbf{s}_{\mathbf{j}}$ is a vector of plot characteristics; and $\boldsymbol{\omega}_{\mathbf{i}}$ is a vector of farmer-specific prices.[8] The vector $\boldsymbol{\varphi}_{\mathbf{j}}^{k}$ contains an efficiency parameter for each input *h* that indicates the proportion of the input that goes to crop production, which is a function of plot characteristics, $\varphi_{jh}^{k} = \varphi_{jh}^{k}(\mathbf{s}_{\mathbf{j}})$. For a given vector $\mathbf{s}_{\mathbf{j}}$ and flood-irrigated water ($h = 1$), we assume $0 < \varphi_{j1}^{N} < \varphi_{j1}^{L} \leq 1$ since a portion of the water applied to an unleveled plot is used only to raise the water level to the highest point of the plot rather than to increase crop production directly. For other inputs ($h = 2, \ldots H$), we assume $0 < \varphi_{j1}^{N} \leq \varphi_{j1}^{L} \leq 1$ and expect this relationship will hold with strict inequality for some inputs based on (1) the pervasive complementarities between the efficiency of water use and that of inputs such as fertilizer and chemicals, and (2) more uniform crop establishment, which makes input demands across a given plot less variable.

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[6] In the context of the experimental auction, the decision is made in two stages. At the time of the auction, the farmer can either adopt LLL or not. If she adopts LLL, the technology choice is made. If not, she can wait several weeks to decide whether to use traditional leveling or to not level (but LLL is no longer an option). For modeling purposes, we assume the farmer is only choosing between LLL and no leveling.

[7] This is not entirely implausible given that the overwhelming majority of leveling is done by custom hire on small farms in northern India. In our sample, only 3 percent of farmers have their own traditional leveler.

[8] Prices can be either market or shadow prices. While prices for all inputs might vary depending on transaction costs, differential irrigation costs present the main motivation for allowing the model to accommodate farmer-specific input prices. Most farmers (86 percent) rely primarily on diesel-powered pumps, for which they pay fuel costs. Some farmers, however, use canal irrigation, for which they do not pay out of pocket but may face quantity constraints.

Once the farmer solves equation (1) for $\mathbf{x}_{\mathbf{ij}}^{k*}$ for all technology choices, the annual expected net benefits of LLL emerge from a simple comparison of expected profits with and without laser leveling:

$$\Delta E\pi_{ij}^{*} = E\left[y_{ij}^{L}\left(\mathbf{z_i}, \boldsymbol{\varphi}_{\mathbf{j}}^{L\prime}\mathbf{x}_{\mathbf{ij}}^{L*}, \mathbf{s_j}\right) - \boldsymbol{\omega}_{\mathbf{i}}{}'\mathbf{x}_{\mathbf{ij}}^{L*}\right] - E\left[y_{ij}^{N}\left(\mathbf{z_i}, \boldsymbol{\varphi}_{\mathbf{j}}^{N\prime}\mathbf{x}_{\mathbf{ij}}^{N*}, \mathbf{s_j}\right) - \boldsymbol{\omega}_{\mathbf{i}}{}'\mathbf{x}_{\mathbf{ij}}^{N*}\right]. \quad (2)$$

If leveling were an annual production input—as is the case for inputs such as seed and fertilizer in $\mathbf{x}_{\mathbf{ij}}^{k*}$ —these net benefits would be the basis for farmers' maximum WTP for LLL. But leveling is actually a durable input: A plot that is precisely leveled this year can provide benefits for several years before needing to be releveled. Since the duration of leveling benefits depends on factors such as soil type, local topography, and cultivation and irrigation practices, it is potentially plot specific, T_j . Thus, farmer *i*'s maximum WTP for LLL services on plot *j* hinges on this intertemporal expected profit:

$$WTP_{ij} = \begin{cases} \sum_{t=1}^{T_j} \delta_i^t \Delta E\pi_{ijt}^{*} & \text{if } \; 0 < \sum_{t=1}^{T_j} \delta_i^t \Delta E\pi_{ijt}^{*} < c_i \\ c_i & \text{if } \; 0 < c_i < \sum_{t=1}^{T_j} \delta_i^t \Delta E\pi_{ijt}^{*} \\ 0 & \text{if } \; \sum_{t=1}^{T_j} \delta_i^t \Delta E\pi_{ijt}^{*} < 0 \end{cases}, \quad (3)$$

where δ_i is farmer *i*'s discount factor and $c_i = c_i(\mathbf{z_i})$ indicates the farmer's liquidity constraint, which is a function of farmer assets, cash on hand, access to credit, and other characteristics in $\mathbf{z_i}$.[9] If this liquidity constraint is binding, then a farmer's WTP will reflect a mix of this constraint and the expected net benefits associated with the technology. In this framework, there are several potential sources of WTP heterogeneity, including farmers' discount rate, liquidity constraints, cultivation practices, input choices, and input efficiency factors. If we relax the risk neutrality assumption and allow for risk aversion, then farmers would base their WTP on expected utility changes instead of expected profit changes. While the structure in equation (3) remains the same under risk aversion, risk preferences would provide another source of WTP heterogeneity in this case. How risk preferences shape WTP is an open question: LLL may reduce production risk in practice by enabling greater precision in input application and more uniform crop establishment, but any benefits from LLL—an unfamiliar technique—are initially uncertain, which raises the risks of initial adoption. We include a proxy for risk aversion in $\mathbf{z_i}$ in the empirical analysis to follow.

Equations (2) and (3) suggest a reduced-form representation of farmers' WTP that can be estimated econometrically as

$$WTP_{ij} = f\left(\mathbf{z_i}, \mathbf{s_j}, \boldsymbol{\omega}_{\mathbf{i}}, c_i \,\middle|\, \boldsymbol{\beta}\right) + \varepsilon_{ij} \,. \quad (4)$$

[9] In this formulation, current liquidity constraints affect current WTP for LLL based on current and future benefits associated with LLL. To extend the model to WTP in future periods, these liquidity constraints would have to be specific to each time period.

This familiar determinants-of-demand estimation is a mainstay of analysis of data collected in experimental auctions or contingent-valuation exercises. Based on the dominant conditional-mean regression approach, the coefficients in the parameter vector $\boldsymbol{\beta}$ indicate how—on average—different farmer and plot characteristics influence a farmer's valuation of LLL for a given plot *ceteris paribus*. Both of these features of the dominant approach—that coefficients provide the average relationship between an independent and dependent variable, all else equal—merit some discussion. First, as Lusk and Shogren (2008) described, quantile regression techniques may provide a richer alternative to standard conditional-mean regression. This alternative perspective offered by quantile regression is particularly insightful for addressing questions about the determinants of demand among those with low demand who would be priced out of the market based on a uniform pricing strategy but might be brought into the market via tiered or targeted pricing strategies. While quantile regression characterizes portions of distribution of farmers' WTP away from the mean, ultimately depictions of the full distribution of demand for LLL may be most useful for analyzing and comparing different targeting strategies.

Second, while the conventional determinants-of-demand approach can provide insights into how different farmers might value LLL differently, it cannot inform targeting strategies as directly as one might think. The problem stems from the fact that it is infeasible to simultaneously target farmers along multiple dimensions. Instead, targeted strategies—whether so-called smart subsidies from a public entity or targeted promotional discounts given by a private firm—can typically target only one dimension at a time. Moreover, when the targeted dimension is not inherently categorical (for example, district of residence) and is instead measured by a continuous variable (for example, income), such strategies must impose discrete categories (for example, below the poverty line). These practical realities imply that a *ceteris paribus* analysis, while extremely insightful in some contexts, cannot inform targeting strategies as well as a *mutatis mutandis* approach that ensures that changing the targeted variable triggers associated changes in all other variables. For example, if an LLL provider (with public subsidy incentives) were considering a strategy that targets farmers below the poverty line, the provider would have to take into account the fact that several other farmer and plot characteristics are correlated with whether a farmer falls into this poverty category or not. Such farmers are likely to have, for example, smaller plots, smaller total landholdings, less education, or tighter liquidity constraints. Thus, a *ceteris paribus* coefficient on a dummy variable for "below the poverty line" in equation (4) potentially misinforms formulation of segmentation and targeting strategies. Instead, the provider needs to know how demand for LLL among farmers below the poverty line differs *mutatis mutandis* from LLL demand among other farmers.

In order to formulate a *mutatis mutandis* approach, we must look at farmers' WTP from a different angle. To begin with, we can use these data to construct an aggregate demand function as follows:

$$Q(p) = \sum_i \sum_j q_{ij} \times \mathrm{I}\left[WTP_{ij} \geq p\right], \tag{5}$$

where p indicates the price of LLL custom-hire services, q_{ij} is the area of plot j held by farmer i, and $\mathrm{I}\left[WTP_{ij} \geq p\right]$ is an indicator function that indicates whether farmer i is willing to pay at least p to level plot j.[10] This aggregate demand function characterizes the entire distribution of farmers' WTP for LLL, which is particularly useful for exploring deviations from uniform market prices. With a trivial extension, we can construct demand functions for a subset of farmers, M, who share an observable characteristic:

$$Q_M(p) = \sum_{i \in M} \sum_j q_{ij} \times \mathrm{I}\left[WTP_{ij} \geq p\right]. \tag{6}$$

[10] An alternative to this aggregate demand curve in acreage leveled is an aggregate demand curve that indicates how many farmers adopt LLL, as given by $H(p) = \sum_i \mathrm{I}\left[\sum_j \mathrm{I}\left[WTP_{ij} \geq p\right] > 0\right]$.

This demand function for segment M is particularly useful for testing different targeting strategies because it characterizes the full distribution of WTP for segment M farmers *mutatis mutandis.* Segment demand curves such as equation (6) also enable standard welfare analysis. Specifically, these curves can generate measures of consumer surplus to evaluate the welfare implications of a given targeting strategy, which consists of a specific price p_M for a defined segment M:

$$CS_M = \int_{p_M}^{\infty} Q_M(p)dp \ . \tag{7}$$

These segment-specific consumer surplus measures can be summed to measure overall consumer surplus. This approach can also accommodate situations in which social benefit curves deviate from private demand curves. In the case of LLL, any positive externalities associated with reduced groundwater extraction and reduced diesel fuel consumption could be captured by additional social welfare. Because this additional welfare is a function of the area of land leveled, one can directly incorporate a social benefit curve into a broader social welfare measure that includes the consumer surplus based on private LLL demand.

Characterizing demand for different consumer segments has obvious parallels to Pigou's (1932) classic taxonomy of price discrimination. In particular, strategies that target different segments with different subsidies or discounts (p_M) are analogous to third-degree price discrimination. A perfectly targeted subsidy that sets $p_{ij} = WTP_{ij}$ would be akin to first-degree price discrimination. A targeting approach in which price is a function of the amount demanded, for example, $p_{ij} = f(q_{ij})$, would implicitly segment consumers and be analogous to second-degree price discrimination. Below, we evaluate various delivery strategies from social-planner versions of these price discrimination perspectives in which the objective function is based on the private and public benefits associated with the uptake of a new technology, rather than monopoly profits.

3. RESEARCH SETTING AND DATA

Our research setting encompasses the Maharajganj, Gorakhpur, and Deoria districts of eastern Uttar Pradesh. This region is situated in the fertile grounds of the Indo-Gangetic Plain, yet nearly 70 percent of the 192 million people in Uttar Pradesh 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 from a population of villages that met specific criteria: (1) The villages shared a similar rice–wheat cropping system and were not consistently prone to flooding that would inhibit rice cultivation; (2) the population in each village was not less than 48 households but not larger than 400 households; and (3) the village was not within a 10 km radius of any other research or extension activities operating in the area that involved laser land leveling or other resource-conserving technologies.[11] With respect to this last criterion, only 1.5 percent of sample farmers reported ever having heard of LLL. Within each village we randomly selected 20–24 farmers from a village census, including only farmers cultivating plots of at least 0.2 acres, the minimum plot size on which LLL can be conducted. Our initial sample consisted of 478 farmers, all of whom remained in our panel over the 14 months of data collection activities (April 2011 to June 2012) described below. However, 15 farmers were not able to attend the auction in 2012. The analyses below assume these farmers have zero willingness to pay (WTP) on their plots.

In each village between April and May 2011, we first convened an information session with the sample farmers to discuss the mechanics of LLL and its potential benefits and drawbacks. The information session consisted of a short informational video on LLL, distribution of a picture brochure, and a question-and-answer session with a nonsample farmer who had previously received LLL services.[12] In these sessions, we strove to provide complete and objective information without promoting the technology, and to be highly consistent across villages. We informed farmers that recent LLL prices in other parts of India had varied between Rs. 400 (Indian rupees) and Rs. 800 per hour in recent years, but did not reveal any specific price points within this range. We also informed farmers they would have 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 that the farmers could bring home with them for reference. As our second step, we conducted a baseline survey to collect information on the economic activities, demographics, and assets of the selected farmers' households, as well as key information about all the plots cultivated or owned by each farmer.

Two to three days after the information session we held a binding experimental auction in each village to elicit the WTP for LLL, the full protocol for which is reported in Appendix A. In each auction, each farmer was assigned an enumerator to privately guide him or her through the auction process and record the farmer's 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 the auction, each farmer listed up to three plots he or she would most like to have leveled.[13] For each, the farmer estimated how long it would take to laser level the plot using as a benchmark the amount of time he or she thought it would take to traditionally level the plot. Enumerators used this estimate to help farmers estimate the total cost of leveling at different prices per hour. Then, plot by plot, the enumerator recorded whether or not the farmer was willing to pay for leveling at 10 different prices between Rs. 250 and Rs. 800 per hour. Once the entire price card was completed, and in the spirit of a Becker–DeGroot–Marschak (1964)

[11] To motivate a separate arm of this study that aims to measure intra- and intervillage social-network effects, the random selection of villages was actually conducted as follows. In each district, four randomly selected villages were initially chosen in accordance with the criteria set forth above. Once these were selected, a "paired" village for each was randomly selected from villages located at a 5 km radius from each initial village.

[12] The nonsample farmer was the same for all information sessions.

[13] Most of the farmers in our sample had three or fewer eligible plots (that is, plots of more than 0.2 acres); 75 percent had four or fewer eligible plots.

mechanism, we revealed the preselected binding LLL price (Rs. 350, Rs. 300, or Rs. 250 per hour).[14] After three rounds of practice auctions using traditional Indian sweets to familiarize farmers with the auction process, we held one practice LLL auction before conducting the real and binding auction. At the conclusion, enumerators described more than 80 percent of farmers as having understood the experiment very well or fairly well.

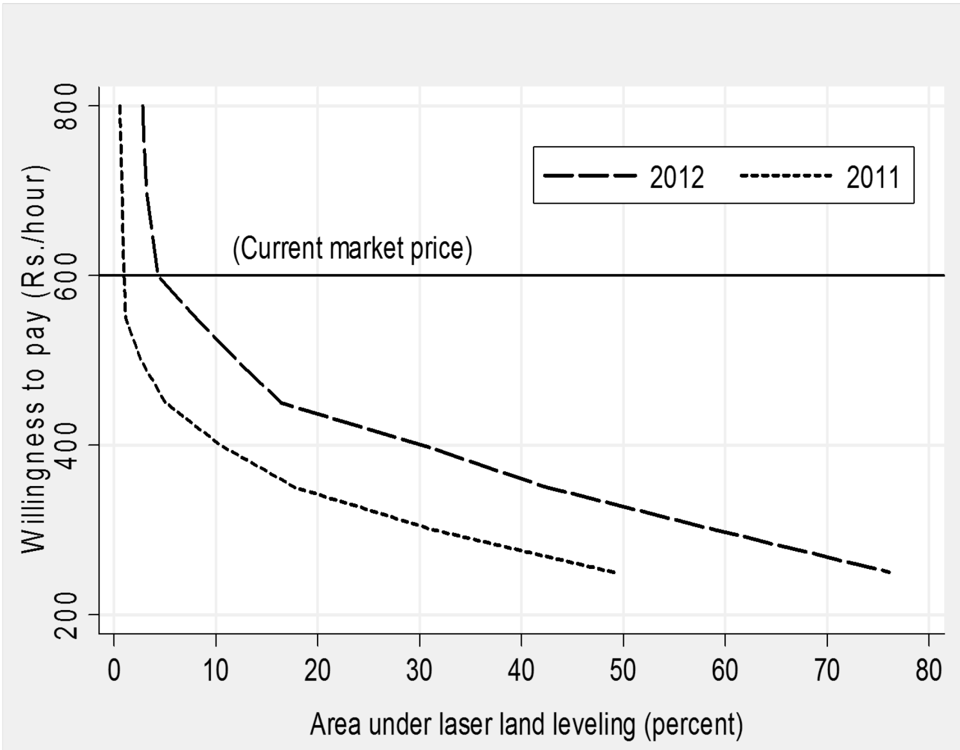
Before concluding the auction session, we divided farmers who bid at or above the preselected price into treatment and control groups to estimate the impact of LLL on input usage, production, and profits. To do this, farmers who stated a WTP for at least one plot at or above the drawn price were included in a 50/50 lottery stratified on maximum WTP to determine who would actually receive the LLL services at this price. We explained to the farmers that the lottery was the only fair way of determining LLL service recipients due to our limited capacity to provide LLL to all those qualifying in the auction. Construction of these treatment and control groups enabled us to evaluate the impact of LLL on input usage, yield, and profit, and to estimate network effects on demand for LLL in subsequent seasons—ongoing dimensions of the broader research that we briefly discuss later in this paper. Several days prior to the auction, we administered a detailed baseline survey of our sample farmers. The survey included detailed questions on household demographics, household assets, landholdings, poverty status, and social networks, as well as plot-level questions on cultivation and water management practices.

Next, for those farmers who won the lottery to receive LLL services, we coordinated the leveling services by deploying four LLL units and associated operating teams contracted through a single service provider. A member of our research team accompanied these providers as they leveled the plots to ensure compliance with the auction and lottery outcomes and to collect additional data on leveling time and nonleveling time (that is, setup and transportation time) required for each plot. These data on LLL costs from 2011 enabled us to capture the cost structure of LLL service providers when testing different targeting strategies. We obtained additional information on capital, labor, staff, maintenance and repair costs, and depreciation in order to characterize the cost structure of LLL providers through consultations with the LLL service providers contracted for this experiment, from other LLL service providers, and from experts involved in LLL research and extension activities in the region.

Following the auction and service delivery we conducted intraseasonal surveys at approximately three-week intervals coinciding with major activity phases of the cropping season to obtain information with lower recall error on seasonal crop management practices, farm labor allocations, input use, irrigation, and harvest. After the subsequent wheat and rice seasons, we administered a second LLL auction just before the wheat season in 2012. Almost all farmers in the sample bid on LLL a second time, whether he or she had received the services or not in 2011. As shown in Figure 3.1, in which we construct demand curves from the WTP data from each round of the LLL auction and indicate the current market price of Rs. 600 per hour, the demand curve for LLL shifted out in 2012—presumably due to greater familiarity with the technology from exposure in 2011. While it is possible that this valuation will continue to evolve as farmers' experience and familiarity with the technology grows, the 2012 auction data are ideal for assessing farmers' initial demand for LLL and associated adoption patterns because by the time of the 2012 auction, most farmers had seen the LLL equipment and knew how the technique compared with the very familiar traditional leveling techniques, but they had not yet experienced or witnessed any benefits beyond the first year. Because the 2012 auction provides a more accurate reflection of farmers' valuation of the technology, the analyses in this paper use these second-round auction data.

[14] In all but two villages a price of Rs. 250 per hour was selected. In one of the remaining villages we selected Rs. 300 and in the other we selected Rs. 350.

Figure 3.1—Demand curves for laser land leveling custom-hire services based on two rounds of experimental auctions eliciting willingness to pay, 2011 and 2012



Source: Authors.

Summary statistics on plot and farmer characteristics are given in Table 3.1, first for the whole sample and then for farmers who would be in or out of the LLL market at the current price of Rs. 600 per hour. If a market for LLL services existed in eastern Uttar Pradesh, a conventional technology adoption analysis would estimate the correlates of LLL adoption based on this binary, in-or-out-of-the-market comparison. While those in the LLL market are more likely to be male, of a lower caste, and less risk averse based on a willingness-to-take-risks elicitation technique proposed and tested by Dohmen et al. (2011),[15] none of these differences is statistically significant—possibly because relatively few of our sampled farmers (less than 5 percent) valued LLL at or above the current market price. In contrast, even with this small subsample, plots in the market are significantly larger than those out of the market.

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 market outcomes, since these individuals are typically priced out. We believe experimental auctions, which shed light on the full support of the demand curve, can be especially insightful in this regard.

[15] This elicitation device involves a series of hypothetical questions about farmers' willingness to take risks both in general and when trying new agricultural technologies. To be clear, farmers who express a willingness to take risks are still likely to be risk averse—just less risk averse than those who self-report being less willing to take these same risks.

Table 3.1—Means (standard deviation) for selected variables for the full sample and for three subsamples from the second round of experimental auctions eliciting willingness to pay, 2012.

Variable	Full sample (N = 478)		Out of LLL market WTP < Rs. 600/hour (N = 458)		In LLL market WTP ≥ Rs. 600/hour (N = 20)	
Age of HH head	*50.25*	*(14.95)*	*50.27*	*(14.98)*	*49.95*	*(14.51)*
Male HH head	*0.83*	*(0.37)*	*0.83*	*(0.38)*	*0.95*	*(0.22)*
Education of HH head (years)	*6.20*	*(5.50)*	*6.20*	*(5.54)*	*6.28*	*(4.7)*
HHs in upper caste	*0.22*	*(0.42)*	*0.23*	*(0.42)*	*0.15*	*(0.37)*
Wealth indexb	*0.50*	*(0.29)*	*0.50*	*(0.29)*	*0.48*	*(0.29)*
BPL cardholder	*0.47*	*(0.50)*	*0.47*	*(0.50)*	*0.45*	*(0.51)*
Willingness to take risks (1 = unwilling, 7 = willing)	*4.52*	*(1.51)*	*4.51*	*(1.51)*	*4.84*	*(1.61)*
Area owned (acres)	*3.05*	*(7.95)*	*3.04*	*(8.07)*	*3.06*	*(4.49)*
Plot size (acres)c	*0.67*	*(0.98)*	*0.66*[a]*	*(0.93)*	*0.93*	*(1.67)*

Source: Authors.

Notes: LLL = laser land leveling. WTP = willingness to pay. HH = household. BPL = below poverty line.

[a] Test of nonzero difference in means between WTP < price and WTP ≥ price (*** p < 0.01, ** p < 0.05, * p < 0.10).

[b] Factor analytic index that includes a livestock index, amount spent on Diwali, monthly phone bill, condition of house, whether household receives employment through the Mahatma Gandhi National Rural Employment Guarantee Act, domestic and international remittances, whether farmer custom hired a thresher–combine for harvesting, and whether household owns a tractor.

[c] The sample sizes in columns 1, 2, and 3 for this plot-level variable are 1,265, 1,155, and 53, respectively.

4. LASER LAND LEVELING DEMAND DETERMINANTS, DEMAND CURVES, AND COST STRUCTURE

This section presents the empirical methods and results that will enable us to formulate and test specific segmentation and targeting strategies for laser land leveling services. We begin with conventional *ceteris paribus* analyses of our experimental auction data, namely, regressions of demand determinants. Since targeted delivery strategies must commit to a single targeting dimension, we must move beyond these determinants and consider *mutatis mutandis* differences in demand distributions along one dimension at a time. We construct these demand distributions as demand curves. Finally, we use data from our LLL providers to characterize the costs associated with leveling.

Ceteris Paribus Determinants of Demand

To investigate farm and farmer characteristics that shape demand for LLL, we begin by estimating equation (4). The plot-level willingness to pay (WTP) data and farmer-level data in our sample include 43 percent and 17 percent zeros, respectively, where the latter measures the maximum farmer willingness to pay on his or her farm. Because the adoption decision is a two-step process—whether or not to bid, and then how much—we use a hurdle model to estimate equation (4) in addition to using OLS (Cragg 1971; Lusk and Shogren 2008).

In addition to these regression approaches that estimate conditional mean functions, we also estimate quantile regressions in order to characterize the determinants of farmers' valuation of LLL at points other than mean WTP. Quantile regression techniques are often useful approaches for analyzing auction data because these data rarely follow a normal distribution (Lusk and Shogren 2008). As discussed earlier, quantile regression also enables us to understand the determinants of demand at different distances from the market price for LLL, which is particularly useful for exploring different targeting strategies. Given this objective, which hinges on farmers' unconditional demand for LLL, we use the unconditional quantile regression estimator proposed by Firpo, Fortin, and Lemieux (2009).[16]

For the farm-level characteristics in $\mathbf{z_i}$, we select variables that have been shown in the literature to be associated with technology adoption (see Feder, Just, and Zilberman 1985; Foster and Rosenzweig 2010): age and education of household head, willingness to take agricultural risks, access to credit,[17] total cultivable land owned, membership in a group or cooperative, and a factor-analytic wealth index.[18] Because the policy instrument under investigation is not to change potentially causal variables to increase adoption but rather to develop strategies that use observable farm and farmer characteristics to segment the market for subsidization strategies, we are not immediately as concerned with causality as with association. For the plot-level characteristics in $\mathbf{s_j}$, we include variables likely to affect the input efficiency parameters $\boldsymbol{\varphi}_{\mathbf{j}}^{k}$ and the overall productivity of the plot. These variables are plot area, whether

[16] The conventional quantile regression estimator (Koenker and Bassett Jr. 1978) generates a conditional quantile function. Thus, a 25th percentile regression estimates a regression line fitted to the 25th percentile of the error term (that is, after conditioning out the effects of all the independent variables). In contrast, an unconditional quantile regression of the 25th percentile estimates a regression line fitted to the 25th percentile of the dependent variable (that is, before conditioning). Given that the level of our dependent variable (WTP) in general and the level of this variable relative to a given price level in particular are central to our analysis, this unconditional quantile regression is more useful in principle. In practice, the difference between conditional and unconditional quantile regression results is a function of the fit of the model: The higher the R-square, the greater the difference between the distribution of the dependent variable and the distribution of the error term and, therefore, the greater the difference between the conditional and unconditional quantile estimator.

[17] In the baseline survey, we asked farmers how large an agricultural loan they could get if they wanted to invest in their agricultural operation. They selected from the following loan sizes: Rs. 0, Rs. 5,000, Rs. 20,000, Rs. 50,000, and Rs. 100,000.

[18] The factor-analytic wealth index employed here consists of total landholdings, thresher hire, combine hire, tractor ownership, large livestock herd size, spending on the Diwali or Eid al-Adha festival, monthly mobile phone bill, house condition, participation in the Mahatma Gandhi National Rural Employment Guarantee Act public work program, and receipt of migrant remittances.

the plot is upland (not flood-prone) or lowland (flood-prone), time needed to irrigate (per acre), soil type, and the length of time the farmer estimates it will take (per acre) to laser level the plot. The estimated time-to-level variable is the best indicator available to us of how uneven the plot is, and it is also indicative of how much the farmer believes she will have to pay in total to level the plot.[19] The main resource LLL saves is irrigation water. Farmers that use rainwater or canal irrigation do not pay for water out of pocket, whereas farmers using (mainly diesel) pumps do. Therefore we include pump use to proxy for the price of pumping, $\boldsymbol{\omega}_{\mathbf{i}}$, and assume that other input prices do not vary among farmers. Because LLL offers benefits for several years after leveling, we include plot ownership in our regressions since it may influence willingness to make a multiyear investment.

Based on the results from the farmer-level specification in Table 4.1, a farmer's willingness to take risks, the amount of agricultural credit available to him, and his overall wealth are positively associated with WTP. Whereas both willingness to take risks and wealth significantly affect whether a farmer states a positive WTP in the auction, neither is associated with his bid conditional on clearing this hurdle. In contrast, access to credit affects the magnitude of WTP but not the probability of crossing the WTP > 0 hurdle. The unconditional quantile regression results suggest that willingness to take risks is associated with WTP at the 25th and 75th percentiles of WTP and that wealth is significantly associated with WTP at the lower percentiles of WTP. At higher percentiles of the WTP distribution, access to credit seems to influence WTP more strongly (and statistically more precisely). Given the recent market price range for LLL of Rs. 500–600 per hour, these quantile regression results indicate that access to credit is the only significant determinant of LLL demand among farmers who are just priced out of the market (that is, with WTP at the 90th percentile of Rs. 450 per hour).

Table 4.1—Farmer-level determinants of maximum willingness to pay for laser land leveling

Variable		Hurdle model		Unconditional quantile regression [xth percentile of WTP, in Rs./hour]			
	OLS	WTP > 0	WTP	25th [0]	50th [250]	75th [350]	90th [450]
Education	*-1.0*	*-0.0006*	*-1.5*	*0.3*	*0.9*	*-2.7*	*-4.7*
	(2.2)	*(0.02)*	*(1.4)*	*2.1*	*1.9*	*2.4*	*3.5*
Age	*0.6*	*0.008*	*-0.2*	*0.8*	*0.4*	*-0.05*	*0.6*
	(0.6)	*(0.006)*	*(0.4)*	*0.7*	*0.6*	*0.8*	*1.2*
Willingness to take risks	*16***	*0.1****	*4.5*	*15.0****	*7.8*	*11.3***	*13.1*
	(6.5)	*(0.05)*	*(4.8)*	*5.5*	*6.8*	*5.1*	*15.4*
Largest crop loan available	*0.8**	*0.006*	*0.5**	*0.4*	*0.3*	*1.1***	*1.6***
	(0.4)	*(0.004)*	*(0.3)*	*0.3*	*0.4*	*0.5*	*0.7*
Total land owned	*-2.1*	*-0.02*	*1.4*	*-2.9*	*-2.4**	*-0.6*	*0.7*
	(1.7)	*(0.01)*	*(3.2)*	*2.4*	*1.3*	*1.8*	*3.7*
Cooperative member	*-0.8*	*-0.2*	*15*	*-14.4*	*-4.2*	*40.5*	*1.6*
	(28)	*(0.3)*	*(17)*	*28.4*	*21.7*	*33.4*	*69.9*
BPL card	*-15*	*-0.05*	*-9.1*	*-8.2*	*-14.7*	*-20.1*	*45.3*
	(22)	*(0.2)*	*(15)*	*21.3*	*18.2*	*23.8*	*41.8*
Wealth index	*22***	*0.3****	*-3.3*	*26.5****	*22.8**	*-0.3*	*18.5*
	(9.4)	*(0.1)*	*(10)*	*9.8*	*12.5*	*14.1*	*26.9*
Constant	*190****	*-0.1*	*364.0****	*153.3****	*289.3****	*383.0****	*422.5****
	(42)	*(0.4)*	*(31)*	*46.8*	*36.9*	*51.7*	*104.8*
Sigma			*111****				
			(7.2)				
N	*409*	*409*	*327*	*409*	*409*	*409*	*409*
R-square	*0.071*			*0.07*	*0.05*	*0.05*	*0.03*

Source: Authors.

Notes: OLS = ordinary least squares. WTP = willingness to pay. Rs. = Indian rupees. BPL = below poverty line. Robust standard errors in parentheses, clustered at village level. *** p < 0.01, ** p < 0.05, * p < 0.10.

[19] During the information session, farmers were told that the time it takes to laser level a plot is proportionate and similar to the time it takes to traditionally level a plot, so even though farmers were not familiar with LLL they could estimate how long it would take to laser level their plots.

The plot-level results in Table 4.2 indicate that plot area, ownership, leveling time, and soil type are important determinants of farmers' WTP for leveling individual plots. The OLS results suggest that farmers have higher WTP for larger plots than smaller ones, but the hurdle model clarifies that this effect stems from the fact that farmers are more likely to place a positive bid on a larger plot than a smaller one and that WTP is not increasing in plot size beyond this hurdle. Plots that require more time to level are associated with higher WTP in a similar way. Since the specification controls for plot area, this result likely reflects how badly the plot needs leveling. In contrast to the area and leveling time results, the positive OLS coefficient on owned plots (compared with plots that are leased, shared, or rented) is due to its influence on WTP beyond the WTP > 0 hurdle. Finally, soil type clearly influences plot-level WTP for leveling. This finding is consistent with our understanding of how soil type affects the relative levelness of a given plot: Lighter soils such as sandy loam are more susceptible to erosion and undulations caused by continuous tillage and puddling, thus requiring more, or more frequent, leveling, which may be associated with a slightly higher WTP for such services by farmers.

Table 4.2—Plot-level determinants of willingness to pay for laser land leveling

		Hurdle model	
	OLS	**WTP > 0**	**WTP|WTP > 0**
Plot area	*18**	*0.2****	*6.3*
	(9.9)	*(0.06)*	*(9.6)*
Upland plot	*15*	*0.1*	*0.3*
	(17)	*(0.10)*	*(14)*
Owner operated	*54**	*0.2*	*42***
	(31)	*(0.2)*	*(21)*
Irrigation time	*0.002*	*-0.00003*	*0.007*
	(0.010)	*(0.00005)*	*(0.01)*
Pump as primary irrigation source	*-8.9*	*-0.09*	*1.3*
	(35)	*(0.2)*	*(22)*
Time to level plot	*3.0**	*0.04***	*-0.5*
	(1.7)	*(0.02)*	*(1.3)*
Kali (black) soil	*26*	*0.5*	*-69***
	(70)	*(0.5)*	*(32)*
Balvi domat (sandy loam) soil	*4.3*	*0.3*	*-68***
	(74)	*(0.5)*	*(35)*
Chikni domat (loam) soil	*-6.5*	*0.2*	*-73***
	(73)	*(0.5)*	*(31)*
Martika (clay) soil	*-0.9*	*0.3*	*-77****
	(74)	*(0.6)*	*(27)*
Constant	*183***	*-0.09*	*384****
	(77)	*(0.6)*	*(40)*
Sigma			*109****
			(5.3)
Observations [a]	*935*	*935*	*656*
R-square	*0.024*		

Source: Authors.

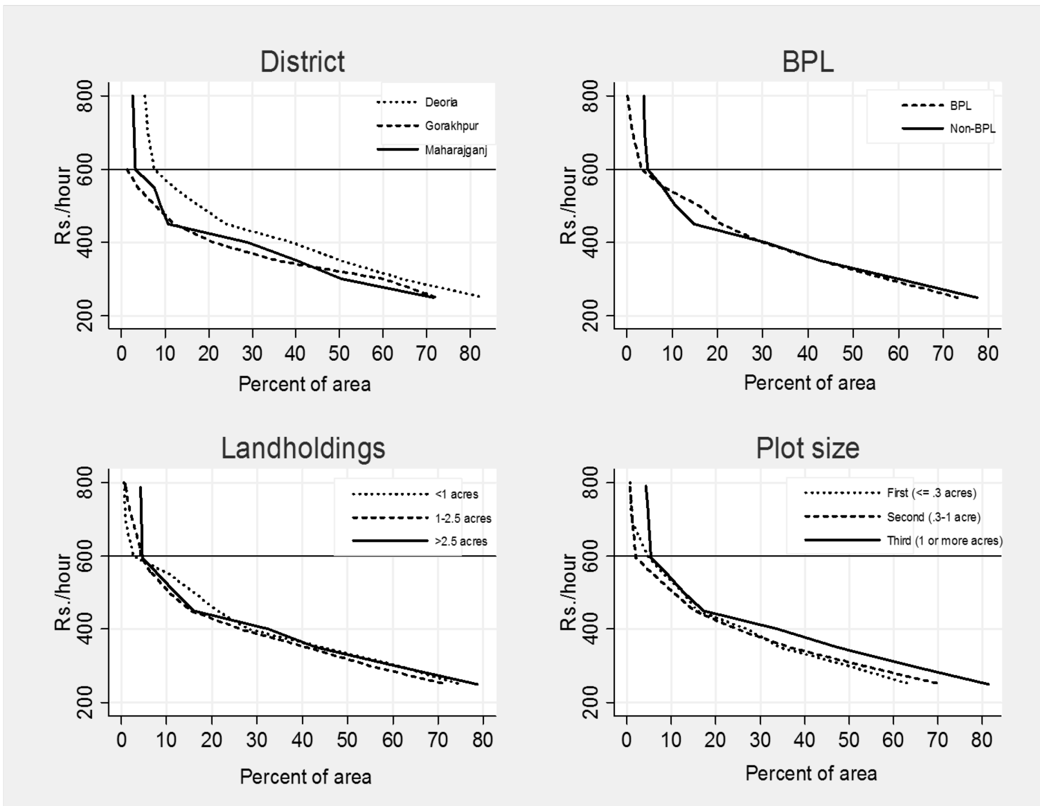
Notes: OLS = ordinary least squares. WTP = willingness to pay. Robust standard errors in parentheses, clustered at village level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

[a] Plots that are less than the minimum required area of 0.2 acres are excluded from this regression.

Mutatis Mutandis Differences in WTP Distributions: Demand Curves

While these *ceteris paribus* comparisons suggest some systematic heterogeneity, the design of the auction also enables us to depict the heterogeneity of LLL demand directly. Figure 4.1 depicts *mutatis mutandis* demand curves for different farmer segments. Of the four segmentation dimensions depicted, overall demand differences are most pronounced by district, with LLL demand in Deoria district higher than in the other two districts. The next most pronounced differences are in the plot size dimension: LLL demand is higher for plots of 1 acre or more. At lower prices, demand is monotonically increasing in plot size across the three plot size categories. This demand pattern may be explained by the fact that the advantage of LLL relative to traditional leveling techniques is likely to increase with plot size because the precision of traditional approaches quickly fades as plots increase in size. The other two dimensions—whether the household head has an official government-distributed below poverty line (BPL) card, and total farmer landholdings—yield demand curves that are nearly indistinguishable from each other.

Figure 4.1—Disaggregated demand curves for laser land leveling based on willingness to pay, 2012



Source: Authors.

Notes: Rs./hour = Indian rupees per hour. BPL = below-poverty-line status (whether household head has an official BPL card). The horizontal line shown at Rs. 600 per hour in each panel represents the current market price for LLL custom-hire services.

Across all farmer segments, the demand curves in Figure 4.1 are highly inelastic above the market price of Rs. 600 per hour but become very elastic below that price, which implies that subsidies could dramatically expand LLL adoption. Less than 10 percent of the land covered by our sample in any district would be leveled at the market price, but 50 percent or more would be leveled at half that price.

Laser Land Leveling Cost Structure

As mentioned above, the dominant pricing strategy for LLL custom-hire service providers is to charge farmers a fixed hourly rate for the leveling time required to level a given plot. In order to accurately test novel delivery strategies, we must understand the cost structure behind this simple price-per-hour model. This is particularly true because the kinds of strategies we explore aim to bring farmers into LLL who might otherwise be priced out of the market. The service costs associated with serving this different mix of farmers may be quite different than the service costs under simple uniform pricing. Any new business or delivery models must therefore reflect the actual cost structure of LLL custom-hire services. At the time our contracted LLL providers leveled the plots from the auction, a member of our team collected detailed data on travel time, setup time, and leveling time. Working with our service providers, we have since compiled additional data on capital, labor, maintenance and repair costs, and depreciation in order to characterize the cost structure of LLL providers.

For the purposes of this analysis, we are most interested in the cost of leveling the plots in our sample. Based on this cost per plot, we can compute how different targeting strategies affect the net returns of LLL providers. Because we have complete provider cost data for only the 260 plots that were actually laser leveled in either 2011 or 2012, whereas we have WTP data for nearly 900 plots, we must impute costs for the other plots in our sample. To do this we match each non-laser-leveled plot to a similar laser-leveled plot in the same village or its paired village using plot area, whether the plot is upland or lowland, and farmer WTP to level the plot. We then use these matches to estimate leveling, travel, and setup costs for nonleveled plots.

5. FORMULATING AND TESTING SEGMENTATION STRATEGIES

In this section, we formulate segmentation strategies according to specific objectives and the heterogeneity that is apparent from the analysis above. These strategies are formulated so as to be comparable in their "external" cost (for example, in the amount of subsidy allocated to the strategy) and evaluated based on their cost-effectiveness in bringing additional acres and farmers into laser land leveling. We also evaluate the different strategies in their cost-effectiveness at reducing water use. Using the cost analysis described above, we also evaluate the strategies according to how they change the net returns to private LLL providers. We begin with the status quo: a uniform market price. We then move to targeting strategies that provide different subsidy levels to different types of farmers to encourage LLL diffusion. We use current subsidies on direct purchases of LLL machinery as a benchmark for current public support for LLL and as the total subsidy budget available.

Targeting Objectives and Strategies

State-level governments in India offer many subsidies intended to increase agricultural production. Many states have recently introduced or are considering subsidies on the purchase of new LLL equipment. The most common level of subsidy support for this equipment would translate roughly into an effective subsidy of Rs. 45–80 per hour in eastern Uttar Pradesh.[20] We take this level of near-term public support for LLL as a benchmark, and derive and test targeted strategies that are comparable in total public cost to this apparently realistic subsidy level.

We consider two different targeting objectives. First, if policymakers are primarily concerned about excessive groundwater extraction (and possibly diesel fuel consumption for pumping this groundwater), then the primary objective of any targeted strategy should be to increase the land area that is leveled, especially in areas where groundwater extraction is high relative to recharge rates. We consider two metrics to capture this objective: total land leveled and estimated water savings due to LLL. Second, if policymakers are primarily concerned about the welfare and profitability of small-scale and generally poorer farmers, the primary objective of targeted strategies should be to increase the number of farmers who level their plots, which provides an obvious metric for evaluating different targeting strategies. In a dynamic sense, these two objectives are interrelated since increasing the number of households adopting the technology might increase the rate at which LLL diffuses across the landscape through farmer networks (a companion LLL paper, Magnan et al. 2013, measures these network effects).

With these objectives in mind, we formulate and evaluate different targeting strategies that we believe could conceivably be feasible to implement. We define feasibility by three dimensions. First, a feasible targeting strategy must use information that is readily observable as the basis for segmentation. To illustrate this dimension, segmenting on plot size—while potentially interesting based on the demand curves in Figure 4.1—is simply infeasible because plots are often defined somewhat arbitrarily by the levees farmers use for water control. Since plot size is mutable and may be endogenous, targeting based on plot size is not viable. For different reasons, segmenting on wealth is generally infeasible because of difficulties in measuring wealth accurately and easily. Proxies of wealth such as possession of a BPL (below poverty line) card offer a more feasible segmentation option, but in our case the limited demand differences between those with and without a BPL card (Figure 4.1) suggest that this proxy may not

[20] At the time this study was conducted, the state governments of Bihar, Odisha (formerly Orissa), and Gujarat were offering a subsidy on the purchase of an LLL unit at the rate of Rs. 150,000 per unit under the National Agricultural Development Scheme, with an additional subsidy in Bihar of Rs. 100,000 per unit provided by the state government. Uttar Pradesh did not have a subsidy. These subsidy programs vary between states in terms of the duration for which the subsidy is available to prospective LLL unit purchasers, the total resources available for subsidizing the purchase of LLL units, and the number of LLL units that can be subsidized in each district of the state. Irrespective of this variation, the Rs. 150,000 per unit subsidy works out to a discount of approximately 50 percent on the purchase price. Using provider cost breakdowns generated by extension economists in the region, we figured that the 50 percent equipment subsidy constitutes 26–37 percent of total hourly costs, or Rs. 45–80 per hour.

differentiate demand effectively. As a last example, targeting plots that most need to be leveled may be conceptually compelling, but such a strategy would be unfeasible for both the reasons above: The "need to be leveled" is not immutable and is difficult to measure or verify without real effort. Fortunately, the gains from LLL are likely to increase with this plot characteristic and to be at least partially reaped by the farmer, suggesting that the preexisting need for leveling should be reflected in farmers' willingness to pay.

As the second feasibility dimension, we assume that a targeted subsidy scheme must be progressive (or, at least, must not directly disadvantage smallholders relative to large farmers). This is particularly true given the politics of contemporary India. For example, in practice it may be hard to justify giving those above the poverty line a higher subsidy for LLL than those below, even if such a subsidy results in more land coming under LLL. Our general approach, therefore, is to formulate targeting strategies that are progressive and then to evaluate these strategies based on how well they achieve the two targeting objectives described above. As the final dimension, a targeted subsidy scheme that relies on the private sector (for example, the LLL service providers) can only be feasible in the long term (that is, sustainable) if it properly considers service provider costs alongside farmer benefits for each strategy. For private LLL providers to buy into any targeted subsidy scheme, the transfer they receive from the government must be high enough to offset their costs, which vary by targeting strategy. We acknowledge that there are deeper cost dimensions beyond these provider costs that shape the practical viability of different targeting strategies. For example, we do not include direct implementation costs in our simulations. We do, however, recognize that administration and monitoring costs are important in practice and that subtle differences in design and monitoring can create opportunities for cheating and rent-seeking behavior.[21]

Taking these feasibility dimensions into account, we formulate different targeting strategies and simulate their impact on LLL uptake using our farmer-specific demand curves. We begin with a status quo uniform market price strategy that simply applies the LLL business model from the western Indo-Gangetic Plain with the current market price of Rs. 600 per hour of leveling time. Next, we simulate a simple uniform subsidy of Rs. 80 per hour, which is the high-end estimate of the effective hourly subsidy of the LLL equipment subsidy that exists in other Indian states, as explained earlier. These two delivery strategies—a market price and a uniform subsidy—provide a benchmark against which targeted subsidies can be compared. To ensure that these strategies are cost comparable, we compute the total subsidy cost of the uniform Rs. 80 per hour subsidy when applied to our sample—roughly Rs. 18,000—and ensure that all targeted strategies exhaust this same subsidy budget. Below we describe five such targeting strategies.[22]

Perfectly targeted subsidies: This strategy, which is analogous to first-degree price discrimination, assumes that subsidies can perfectly target farmers who are priced out of the LLL market at a price of Rs. 600 per hour. Farmer *i* is given a subsidy for leveling his plot *j* equal to Rs. $600 - WTP_{ij}$. These targeted subsidies are sorted from smallest to largest and funded in this order until the subsidy budget is exhausted. Although unrealistic, this strategy provides a useful gold standard against which the other imperfect (but feasible) targeting strategies described below may be measured.

Targeting by district: For a variety of reasons, targeting subsidies based on geographic segmentation is perhaps the most feasible third-degree price discrimination (that is, targeting by segment) strategy. 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

[21] This issue indicates the need for exploration on how to measure the welfare outcomes from a targeting strategy—inclusive of implementation and monitoring costs as well as the costs of rent-seeking behavior—and how to compare these welfare outcomes with an untargeted (market or uniform) strategy with its own (presumably lower) implementation and monitoring costs and its own costs of rent-seeking behavior. This is a subject of future research.

[22] Additional targeting strategies considered were (1) caste, (2) membership in a cooperative or self-help group, and (3) whether the head of household was female. We excluded targeting on caste because it produces results that are quite similar to the BPL targeting. We excluded targeting on cooperative members and female-headed households because we had too few in our sample to statistically support a simulation exercise based on these subgroups.

plots are immobile. Given the *mutatis mutandis* demand differences in Figure 4.1, we formulate a strategy that offers a Rs. 130 per hour subsidy to two districts and no subsidy to the third.

Targeting by landholdings: The next third-degree strategy segments farmers by landholdings. Although there do not appear to be pronounced differences in demand by landholding, distributional objectives might make such a strategy appealing. Our analysis of this strategy highlights the opportunity cost of formulating progressive targeted strategies on this basis.

Targeting by poverty status: The final third-degree strategy segments farmers according to their official poverty status. In India, one option for segmenting markets in this way is to offer vouchers to those with BPL cards, but note that Figure 3.1 suggests few systematic demand differences between those with and without a BPL card. Since this is often a popular segmentation approach in India, simulating such a strategy again highlights the associated opportunity costs.

Implicit targeting by first-hour discount: The previous three strategies explicitly target defined farmer segments and are therefore analogous to third-degree price discrimination. While there is evidence of systematic demand heterogeneity by plot size in Figure 4.1, there is no feasible way to segment along this dimension because plot size is often malleable. But in order to exploit this dimension of demand heterogeneity, we formulate an implicit targeting strategy that is akin to second-degree price discrimination—a first-hour discount. By offering a discount on the first hour of leveling a given plot, the effective leveling price becomes plot specific and varies according to the factors that affect leveling time (for example, how large and how uneven the plot is). To simulate this strategy, we must assume that farmers in our sample would make LLL decisions based on this effective plot-specific leveling price, but we acknowledge that farmers may treat such a discount separately from the hourly rate rather than as something that simply changes the effective hourly rate. This potential simulation complication aside, a first-hour discount has the practical advantage of being potentially familiar to private-sector service providers as a marketing tactic. Based on the demand for LLL in our sample (and on the assumption that farmers translate the discount into an effective hourly rate), a first-hour discount of Rs. 182 exhausts the subsidy budget and generates an effective average leveling rate that ranges from Rs. 418–585 per hour with an average of Rs. 462 and a median of Rs. 418.

Testing Segmentation Strategies

We evaluate the targeting strategies above using the following metrics: (1) total acreage in the sample under LLL, (2) total number of farmers adopting LLL, (3) total water savings attributable to LLL, (4) cost-effectiveness of bringing additional acres and farmers into LLL (subsidy cost per additional acre or farmer), and (5) consumer surplus–based measures of welfare and welfare efficiency. Two of these metrics merit some attention. We estimate the water savings due to LLL using our detailed intraseasonal data after the first round of leveling (2011). In a separate analysis, we estimate an average water savings effect due to LLL of 21 percent. We apply district-specific estimates of this effect to the observed water usage for nonleveled plots as an approximation for (prospective) plot-specific water savings due to LLL. By aggregating these water savings over all the plots that are leveled under a given targeting strategy, we are able to estimate total water savings for each strategy. The final welfare metric is derived from the full farmer-specific demand curves. Specifically, consumer surplus for a farmer with a demand curve above a given price is simply the area between the price and his respective demand curve.

Table 5.1 summarizes the different targeting strategies we test and includes the percentage of farmers, acres in our sample that are brought into LLL, and total estimated water savings due to LLL. Relative to the status-quo market delivery model, the perfect targeting and first-hour discount strategies produce the largest increases by all three of these metrics. Since all the subsidy strategies exhaust the same subsidy budget, these added acres and farmers are directly comparable, suggesting that the perfect targeting strategy is the most cost-effective approach to expanding acres leveled by LLL and the first-hour discount strategy is most cost-effective for expanding the number of farmers using LLL. To construct confidence intervals around the acres added, we bootstrap this simulation (clustered at the village level) and depict 90 percent confidence intervals in Figure 5.1 for both acres leveled and water savings. In the top panel, we display the distribution of acres leveled across BPL cardholders and other farmers as an indication of how progressive the different strategies are in practice. Although the perfect targeting and first-hour discount strategies stand out as the most effective based on both these metrics and are significantly different than the market outcome, the confidence intervals of all six targeting strategies overlap.[23]

Table 5.1—Summary of targeting strategies and simulation results

Strategy	Description	Acres leveled	Farmers leveling	Water savings (m³ ’000)	Service provider		
					Total cost (Rs. ’000)	% fixed cost	Revenue (Rs. ’000)
Market	Rs. 600/hour uniform market price	34 (4.2%)	20 (4.2%)	76.0	30.1	19.6%	41.2
Uniform subsidy	Rs. 80/hour uniform subsidy on market price	83 (10.3%)	66 (13.7%)	162.7	91.2	18.8%	109.1
Perfect targeting[a]	Farmers with WTP ≥ Rs. 600/hour pay market price. Farmers with WTP between Rs. 475 and 600 pay their WTP.	113 (14.0%)	88 (18.3%)	214.7	122.5	19.5%	150.4
District[b]	Farmers in Deoria pay market price, while farmers in Gorakhpur and Maharajganj pay Rs. 470/hour.	73 (9.0%)	56 (11.8%)	129.1	115.7	19.5%	93.7
Land-holdings[b]	Farmers with more than 2.5 acres pay market price, those with 1–2.5 acres pay Rs. 500/hour, and those with less than 1 acre pay Rs. 475/hour.	63 (7.8%)	63 (13.2%)	145.8	138.2	19.6%	84.4
Below poverty line[b]	Farmers with BPL card pay Rs. 500/hour and all others pay Rs. 544/hour.	82 (10.1%)	65 (13.7%)	153.9	92.0	17.5%	125.3
First-hour discount[c]	Rs. 182 subsidy on the first hour of leveling by plot.	102 (12.7%)	111 (23.2%)	195.7	101.8	27.6%	102.3

Source: Authors.
Notes: Rs. = Indian rupees. WTP = willingness to pay. BPL = below poverty line. All targeting strategies exhaust a subsidy budget of Rs. 18,000.
[a] Analogous to first-degree price discrimination.
[b] Analogous to third-degree price discrimination.
[c] Analogous to second-degree price discrimination.

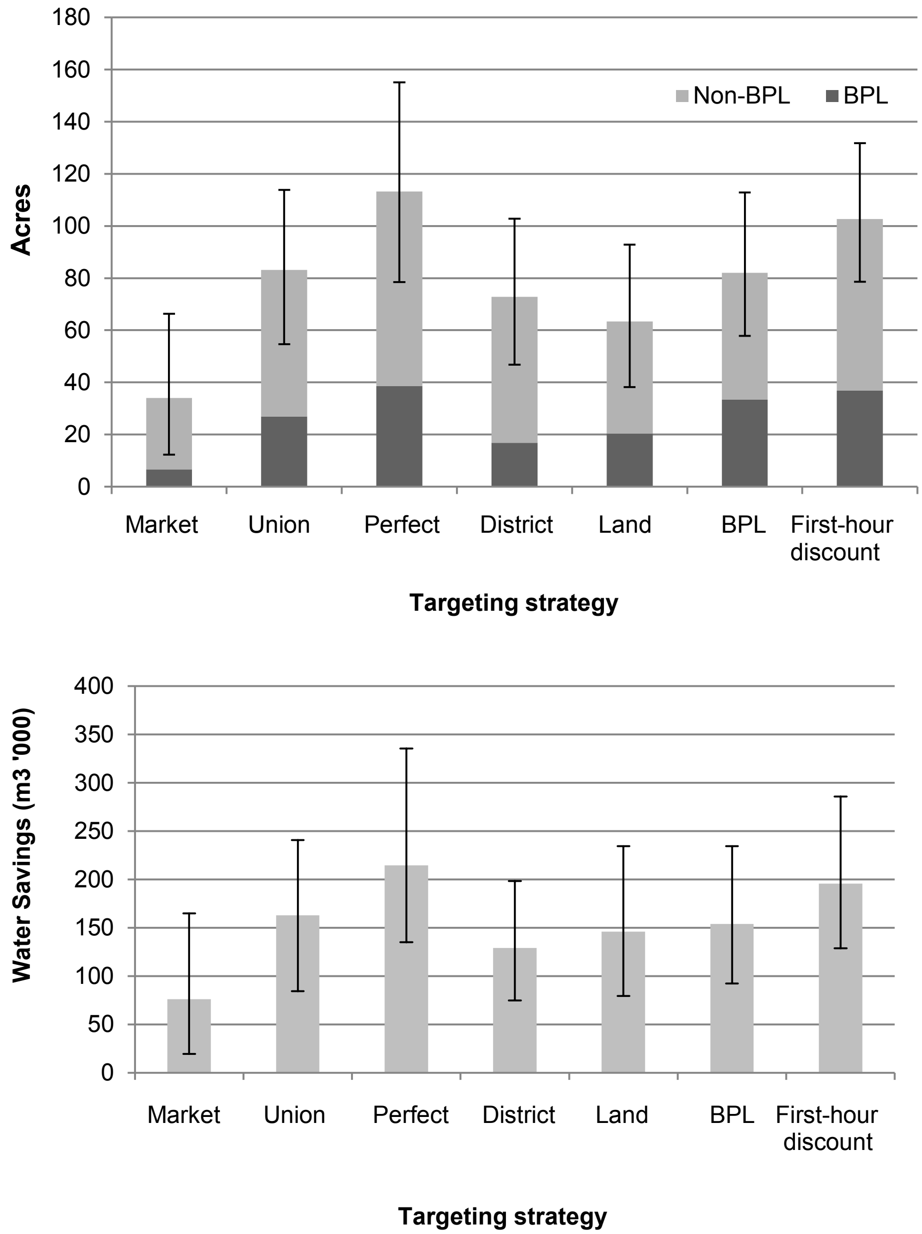
Table 5.1 also includes estimates of total provider costs associated with each strategy. We decompose these costs into fixed costs that do not vary with leveling time[24] (for example, transportation and setup time, tractor repairs associated with transport between plots) and variable costs that do (for example, leveling time and tractor and LLL equipment maintenance associated with actual leveling) and

[23] Note that when bootstrapped standard errors are not clustered at the village level, these confidence intervals are much tighter and there are significant differences among the targeting strategies. Because many factors that influence both willingness to pay for LLL and the prospective benefits of LLL are highly correlated within villages, adjusting for clustering reduces the precision of these estimates.

[24] We implicitly assume that the provider owns his own equipment (that is, services no debt) and does not incur overhead in the form of offices or nonleveling employees.

display the percentage of total costs that are fixed by this definition. The composition of plots drawn into LLL under the first-hour discount is such that this strategy has the highest share of fixed to total costs, but targeting on landholdings has the highest total provider costs. The revenue reported in this table is based on the hourly rates paid by different farmers in each strategy and does not include the subsidy.

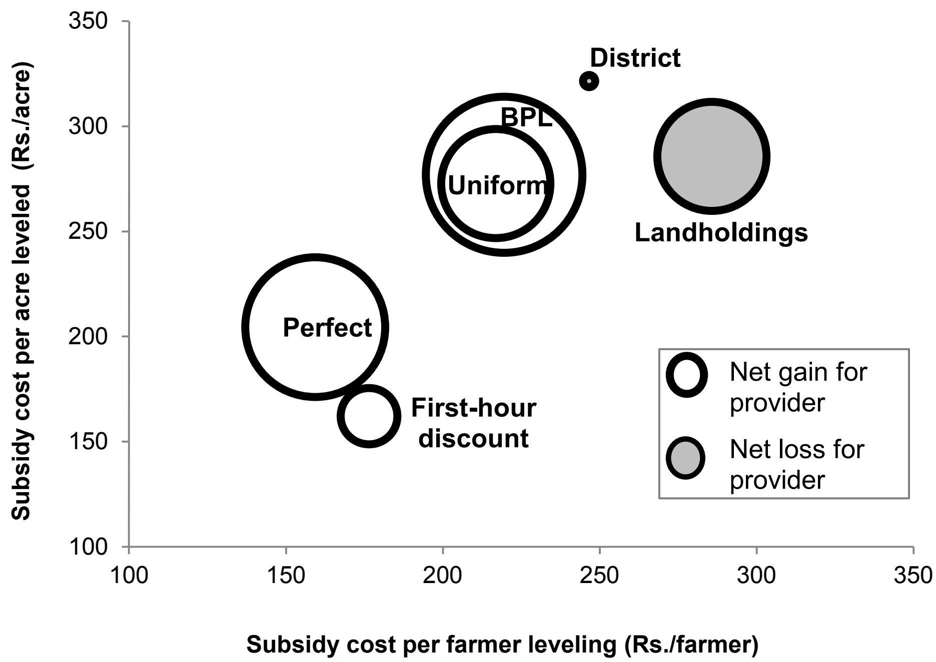
Figure 5.1—Simulation results by targeting strategy for acres leveled by below-poverty-line status (top) and water savings (bottom), with 90 percent confidence intervals



Source: Authors.
Note: BPL = below-poverty-line status (whether household head has an official BPL card).

To compare the cost-effectiveness of each of these strategies, we compute the subsidy cost per acre and per farmer, and compare these two dimensions of cost-effectiveness in Figure 5.2. The positive correlation between cost per acre leveled and cost per farmer leveling suggests that there are no stark tradeoffs between the two metrics and that the six strategies can be rank ordered by cost-effectiveness, with the first-hour discount as the most cost-effective way to expand acres leveled and perfect targeting as the most cost-effective means of increasing the number of farmers leveling. This figure also depicts the net gain or loss for the service provider, which is computed as profit (based on revenue and cost in Table 5.1) plus the Rs. 18,000 subsidy. Based on these estimates, service providers would clearly resist the district and landholding strategies. Since perfect targeting is not feasible, the first-hour discount clearly emerges as the most cost-effective, viable strategy. The fact that providers offering this first-hour discount just break even when they do not receive the subsidy provides yet stronger evidence that this may be a viable strategy, but keep in mind that these provider costs assume no financing or overhead costs associated with doing business as a service provider.

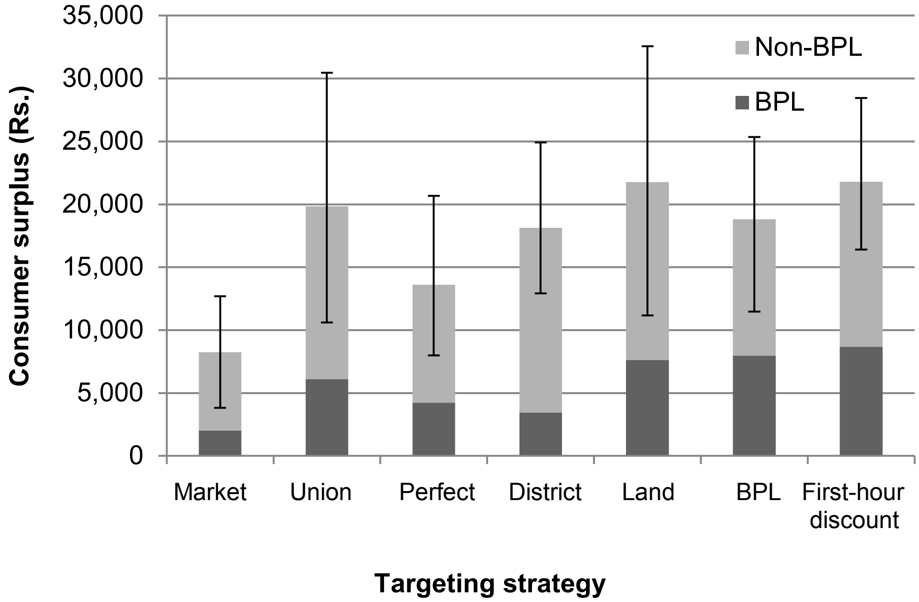
Figure 5.2—Cost-effectiveness of targeting strategies per acre leveled and per farmer leveling



Source: Authors.
Notes: Rs. = Indian rupees. BPL = below-poverty-line status (whether household head has an official BPL card). Bubble size indicates profit for private laser land leveling service provider adjusted for Rs. 18,000 subsidy.

As the final step in this *mutatis mutandis* approach, we use a welfare metric to evaluate the targeting strategies. We estimate consumer surplus by segment as in equation (7), where the segments correspond to the targeting dimension for each strategy. As with the estimated acres in LLL, we bootstrap these consumer surplus calculations to generate confidence intervals. Figure 5.3 shows the results for this welfare metric. The estimated consumer surplus varies widely across these strategies, but the confidence intervals often overlap. The first-hour and land targeting strategies generate the highest consumer surplus—with the first-hour strategy generating slightly more consumer surplus among BPL cardholders—followed by the uniform, BPL, and district strategies. Based on the confidence intervals, however, only the first-hour and district strategies generate more consumer surplus statistically than the market outcome.

Figure 5.3—Consumer surplus by targeting strategy with 90 percent confidence intervals and distribution of consumer surplus by below-poverty-line status



Source: Authors.
Note: BPL = below-poverty-line status (whether household head has an official BPL card).

6. PILOT MARKET TEST OF FIRST-HOUR DISCOUNT STRATEGY

Building on the insights of our experimental laser land leveling auction, we conducted a pilot market test for LLL custom-hire services in May–June 2012. Although this pilot was not designed as a full market experiment, it provides a useful complement to the experimental auction–based analysis above. This section briefly describes the structure of this out-of-sample pilot test and discusses the results.

Immediately after conducting the 2012 round of auctions, we—in collaboration with our LLL service provider—launched a second round of LLL for auction winners whose willingness to pay was greater than the price drawn at the auction. Alongside the laser leveling for these households, we extended service to selected villages and households within or near the locations of our existing sampling frame. Specifically, we constructed a sampling frame for this pilot that included all 24 villages from our original sample (the "sample villages"); 2 randomly selected adjacent villages for each of these sample villages, for a total of 48 "adjacent villages"; and 3 randomly selected nonadjacent villages within a 2.5 km radius of each sample village, for a total of 72 "nonadjacent villages." In each of these 144 villages, our field team hung posters that had been designed in conjunction with our service provider specifically for this pilot market test. The standard poster, which is included as Appendix B, briefly described LLL, stated the price of these services (Rs. 600 per hour), and provided a phone number to call for more information or to schedule the services. Half of the 144 villages were randomly selected to receive a discount of Rs. 300 for the first hour of laser leveling. In villages that were offered this discount, a sticker was mounted on the standard poster indicating that this first-hour discount was offered to any farmer in the village (see Appendix B). Our fieldworkers were trained to hang three posters in the most visible locations possible in each village and to discuss LLL with inquiring farmers in the village according to a predefined LLL script.

Several patterns in the data we collected from this market test[25] are worth noting. First, only 43 farmers interested in leveling a total of 61 plots responded to the poster offer, more than half of whom had actually talked in person to the fieldworker who placed the LLL posters in their village. This suggests that in a context where word of mouth is the dominant way to learn about new technologies or practices, posters alone are unlikely to elicit significant uptake. Second, farmers in our sample villages, who were much more likely to have some familiarity with LLL given the leveling that occurred in the project in 2011, were interested in leveling more and larger plots than those in adjacent and nonadjacent villages. This seems to be a reflection of very limited social network linkages between even adjacent villages: None of the farmers outside our sample villages knew any of the farmers included in our main sample in these villages. Third, the first-hour discount had a pronounced effect on uptake. While on the surface this is consistent with the high price elasticity of demand below the market price that is evident in our experimental demand curves, patterns in the response to the discount suggest that other factors may be relevant as well. The fact that farmers in adjacent and nonadjacent villages expressed an interest in LLL only when the discount was offered (that is, only farmers in sample villages with some familiarity with LLL expressed interested without the discount) implies that this price sensitivity may be more accurately interpreted as an unfamiliarity or uncertainty response. Clearly, this pilot test is too limited to support any conclusive findings, but these preliminary patterns will help us formulate and test different delivery strategies for LLL in ongoing collaboration with LLL service providers and other partners.

[25] We collected data for this market experiment in three ways. First, each time a farmer called the LLL services number, which rang to the fieldwork coordinator, he asked several questions to get a profile of those expressing interest in the service. Second, for farmers who scheduled and received these services, we collected the same leveling data from our service provider that we had collected for those in our main sample (leveling time, setup time, and so on). Finally, while farmers' plots were being leveled, we conducted a more detailed survey that included a social networks module to determine whether the farmers knew any of the sample farmers in the sample villages and, if so, how and how well.

7. CONCLUSION

For many agricultural technologies, information asymmetries and incompatible incentives constrain the ability of private agents—rural entrepreneurs, small- and medium-scale enterprises, or large firms—to market technological products and services to small-scale, resource-poor farmers. Often, governments choose broad, unspecific subsidies to promote the rapid diffusion of these technologies. However, such untargeted subsidies are often an inefficient remedy to inherent market failures. One reason why more efficient and more effective alternatives are overlooked is that public policymakers and corporate decisionmakers lack information about poor farmers' valuation of new agricultural technologies. This vague and incomplete understanding of how different farmers value a technology differently often prevents practical exploration of targeted support mechanisms by both the public and private sectors that can translate into new technological opportunities for smallholders and agricultural productivity gains for society.

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 laser land leveling 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 and more subtle differences across other dimensions. We exploit these differences in targeting simulations that show how it is possible to bring more land under LLL at a lower cost by segmenting markets by observable characteristics, across which technology demand differs. Simulations also show that it is possible to bring more land under LLL at a lower cost by segmenting markets more implicitly, that is, using a first-hour-free discount. This latter strategy is particularly appealing where policymakers aim to simultaneously provide poor smallholders with access to new technologies while also encouraging market growth and rural enterprise development.

The methodology and analysis in this paper provide insight into the targeting considerations and tradeoffs associated with promoting a resource-conserving technology such as LLL among small-scale, resource-poor farmers through public subsidies, private discounts, or some combination thereof. In ongoing work, we extend our analysis to address several related issues. First, we evaluate the impacts of LLL on input use, yields, and profitability among farmers. We do this by drawing on household- and plot-level data from successive intraseasonal survey rounds of households that were part of the randomized controlled trial of LLL that was integrated into the experimental auction design through a post-auction lottery. These findings will enable us to explore more precisely the private and public benefits of different segmentation and subsidy strategies. Second, there are more rigorous ways to formulate targeting strategies based on the metrics we currently use. For example, it might be possible to construct optimization routines that simultaneously take into account the subsidy cost and LLL providers' costs. These routines would then enable us to choose a targeting strategy along a given dimension that maximizes consumer surplus while satisfying a zero-profit constraint for LLL providers.

APPENDIX A: MARKET-SEGMENTATION STRATEGIES FOR THE DISSEMINATION OF NEW PRODUCTION TECHNOLOGIES

This document describes the structure and content of the experimental auction we will use to elicit farmers' valuation of laser land leveling (LLL) and to randomize the delivery of LLL services to interested farmers. We will involve all of our sample farmers in these auctions. Prior to launching the final auction in a particular village, the project manager / coordinator will have to arrange a location, date, and time for each phase of the auction so these details can be included in farmers' auction invitation.

Welcome and Introduction

"Thank you for participating in this auction. As a token of our appreciation, we have given each of you Rs. 100 as you arrived today. This money is yours to keep. During this auction, you will work with a helper (enumerator). At any point, if you have questions, feel free to ask your helper.

"Last year we introduced you to laser land leveling. We then conducted the same kind of auction as we will conduct today. Just like in last year's auction, in today's session we will give you an opportunity to custom hire LLL services for your own land. Compared to last year, you may know more this year about LLL because you may have seen how it works on your own land or on the land of another farmer. We hope this will help you assess more accurately how valuable you think LLL would be on your own land. Before we continue, do you have any questions about LLL?"

"Just like last year, we will use a simple market exercise to give you a chance to hire LLL services for your own plots. Because you may actually purchase these services, it is important for you to understand how the market exercise will work. The market exercise is not a competitive auction. This means that ***you will never be competing against the other farmers in the market exercise.*** This makes your job easy: ***All you have to do is determine how much you think LLL services are worth to you***—without regard to how much the same LLL services may be worth to other farmers."

"Before we continue we would like to emphasize two points:

1. Each of you is different and has unique plots. These differences may mean that, at a given price, you choose to purchase LLL services for your plots while another farmer may not. This is perfectly normal. ***Because we want to know what you think, we will keep conversations with your helper as private as possible.***
2. Your participation in this auction and the survey is part of a research project. As such, ***we are here as a research team, not a sales team.*** We are not here to promote LLL. We simply want to understand how beneficial you think LLL would be to you as a farmer."

Practice Auction

"Since these market exercises will eventually involve real money and real LLL services, we want to be certain that you understand the market process. To help you, we will conduct a practice sweets auction using sweets to demonstrate how the auction will work."

"We have sweet X available for purchase. <*Describe sweet in detail.*> Does anyone have any questions about this sweet?"

"In order for you to actually buy sweets today and participate in the practice sweets auction, we will give you Rs. 20. You can use this money to buy sweets or keep as you like."

"We would like to know if you would be willing to purchase sweet X at different prices. We will begin with a practice round to demonstrate how the market exercise will work. Your helper will ask you this question for several different prices. Please talk with your helper privately. Each helper will take you to a private place in this area to ensure that your conversations remain private."

Each worker will work separately and quietly with each farmer to complete the first pricing card. Start by asking, "If sweet X cost Rs. 2, would you want to purchase it?" Put a checkmark in the box under 2 if he says "Yes." Continue asking for Rs. 4, Rs. 6, etc. until he says "No." At this point, say, "It sounds like you are not willing to pay more than [highest price with a checkmark] for sweet X. Is this right?" Once he is satisfied, turn to the next farmer and conduct the same procedure.
NOTE: The farmer need not see or have his/her attention focused on the pricing card. As much as possible, this process should be oral. Showing the pricing card will confuse or intimidate some farmers.

Sweet X, practice	1	*Price of each sweet (Rs.):*	*2*	*4*	*6*	*8*	*10*
	2	**Purchase sweet X?**	√	√	√		
	3	*Price card drawn (circle)*	*2*	*4*	*6*	*8*	*10*
	4	*Total purchase price*					

"Now that you've completed your purchase decision (row 2), we'll describe how we will determine the price of the sweet. We asked you whether you were willing to buy sweet X at 5 different prices. We have prepared 5 cards with each of these prices."

Show each card separately and announce the price as you hold up the card for everyone to see.

"To determine what the price will be, we will mix up these cards and ask one of you to choose one. The price card that is drawn will be the price."

Have one of the farmers draw a price card. Hold up and announce the drawn card. Explain that if they said they would like to buy sweet X at this price, this is the price they will pay. Each helper will circle the corresponding price on the pricing cards of the farmers they are helping.

Emphasize that in this market exercise they must consider their decision at each price carefully because they do not know which price could be the real price in the exercise. As long as they make their decision at each price carefully, they will be happy no matter what price is drawn. That is, if the price is higher than their checkmarks, they will be happy that they didn't get the sweet because the price is too high. If the price is below their highest checkmark, they will be happy that they are able the purchase the sweet at such a price. Tell the participants to ask their helpers if they have any questions.

"We will now conduct a real market exercise for sweets. This time you will pay real money for real sweets. This market will be like the first, except we will also offer a second sweet, sweet Y, for purchase. <*Describe sweet Y.*> Just like the first time, we will ask you about 5 potential prices. For each of these prices, your job is to decide whether you would like to buy sweet X or sweet Y or both. Just like before, remember: ***it is important that you would be happy with any of your decisions because you don't know what the price will be.***"

*Each enumerator will work privately with his farmer to complete the next pricing card. We will always talk through the prices and purchasing decisions by column. This means that the conversation will start with something like this: "**If the price was Rs. 2, would***

***you choose to purchase sweet X or sweet Y or both?**" Continue asking this question for each price and checking the appropriate boxes. Remind the farmer as needed that any of the prices could be drawn, so they need to make sure they would be happy with their purchase decision no matter what price is drawn.*

Sweet X / Y, REAL	*1*	*Price of each sweet (Rs.):*	*2*	*4*	*6*	*8*	*10*
	2i	**Purchase sweet X?**	√	√	√	√	√
	2ii	**Purchase sweet Y?**	√	√			
	3	*Price card drawn (circle)*	*2*	*4*	*6*	*8*	*10*
	4	*Total purchase price*					

"Now that you've made your decisions, we will determine the sweet price. Instead of drawing a price now as we did before, we drew the price card before and put it in this envelope. Just like before, you have to decide whether to purchase the sweets at each price without knowing what the price will be. This means you must consider each price carefully so you are happy with your decision no matter what price is in this envelope."

Hold up the card and announce the price. Explain that if they decided to buy one of the two sweets at that price, they will pay that price and get the sweet. If they decided to buy both sweets at that price, they will pay that price for each sweet—meaning they would pay a total of two times the price and get both sweets.

"Now, let's see what price card is in this envelope."

Have a farmer pull out the card, hold it up and announce the price. Conduct transactions as necessary.

"Any questions about how this market exercise works?"

LLL Services Auction

"Now that you understand how the market works and are familiar with LLL, we are ready to proceed to the market exercise for actual LLL services on your land. This market for LLL services will be similar to the sweets auction. ***Just like before, your job is to decide which plots of your land, if any, you would like to have leveled at different LLL prices. Just like before, the outcome of the real auction will be real: you will actually pay money to receive real LLL services on your land.***

"While the LLL market exercise is very similar to the sweets market, there is one important difference: Just like last year, you will neither receive nor pay for the LLL services today. Instead, for any LLL services you purchase today, we will schedule a convenient time in the near future to level your land. In your village, we plan to schedule LLL services during the week of __________. You will pay for the services at that time. A member of our research team will be your contact and coordinator for these services. <*Introduce the coordinator / monitor for the village.*> If you purchase LLL services in today's market, you will work with him so you can coordinate when exactly your land will be leveled. Are there any questions about how we will arrange to schedule the leveling of your land if you purchase the services today?

"In the sweets market, we asked you whether you would like to buy two different kinds of sweets. In the LLL market, we will ask you whether you would like to purchase LLL services on different plots. Just like each type of sweet is different, each plot is unique. Before beginning, we need you to help identify the plots on which you will be bidding for laser land leveling services. Your enumerator has the names of the various plots you have discussed with our survey team over the past year and will discuss these plots with you to make sure we understand what plots you will be bidding on."

Each enumerator will confirm with his farmers that the Intras-seasonal Survey (ISS) plot names match the auction plot names on the auction card (as copied from LimeSurvey). The enumerator will also confirm whether each plot was laser leveled before the previous kharif *season. If there are any mismatches between plots, the enumerator will carefully work with the farmer to understand what auction plot corresponds to each ISS plot. The enumerator will then write the correct auction plot name next to each ISS plot and neatly cross out any errors. Likewise, if there is an error regarding the LLL status of a plot the enumerator will correct this on the paper survey. After making any changes, the enumerator will call over a supervisor to make sure these changes are made properly. These corrections will be put into LimeSurvey at the conclusion of today's auction.*

"Now that we have confirmed what plots you will bid to have LLL service on, we will continue the LLL market exercise. Your helper will next ask you how long you think it will take to LLL each plot. You should base this estimate on what you have learned about LLL and on your familiarity of your plot. Keep in mind that the time it takes to level a plot will vary based on how big and how uneven the plot is. A very uneven plot that is one acre can take 8 hours, while a less uneven acre plot can take 3 hours. If you know about how long it might take to level one of your plots with conventional techniques, you can use this to help you estimate the LLL time: LLL should take a little more than half as long to level the same plot."

Enumerators will need careful training to be able to help their farmers to estimate the LLL time. They can remind the farmer of things they learned in the information session.

"Just like in the sweets market, your task is simply to decide whether or not you would like to level each of your plots at different prices. In the LLL market, we will ask you about each of 10 different prices. These 10 prices are the same as last year. . ***In recent years, across different states in India from different LLL service providers, the price of custom-hire LLL has ranged between about Rs. 400 and Rs. 800 per hour. Since most of the custom-hire LLL prices we will ask you about have actually been paid by farmers somewhere in India, it is important that you consider each price as if it could be a real price.***

"Like the sweets market, we will draw a price card to determine which price will count. The price card that determines the LLL price in this year's auction may be different than last year's auction price. Since any of the 10 prices could be drawn, it is important to think carefully about each decision. Above all else, we want you to be happy with your decisions no matter which price card is drawn.

"You might remember that in last year's auction, we had limited capacity to level land and had to use a lottery to determine which farmers received and paid for LLL services. This year, we have more capacity to level. This means that **every** farmer who wants LLL services at the final drawn price will receive and pay for these services. You should make your decision carefully at each price because—in the real exercise—these decisions will determine whether you pay to have your land leveled."

There may be questions from some farmers—who remember the lottery well—about this change.

"Your helper will now ask you whether you would like to purchase LLL services for each of your plots at each price level. Please remember to keep your conversations private."

Enumerators will work with their farmers to complete the first LLL pricing card. This process will happen in two steps. First, talk about only the unleveled plots listed. They should work down each price column, asking, "Would you like to custom hire LLL for *unlevelled plot A (name) at a price of Rs. 250 per hour?" Check the corresponding box if the answer is "Yes," proceed to the next plot: "For this Rs. 250 per hour, would you like to custom hire LLL for unleveled plot B (name)? For plot C (name)?" Then move to the next column: "For a price of Rs. 300 per hour, would you like to custom hire LLL for plot A? Plot B? Plot C?" Enumerators should ask each of their farmers to decide for each price and check the box accordingly. They should not skip around. After the enumerators are done talking about all unleveled plots, move to the list of leveled plots. Work down each price column, asking, "In the hypothetical situation that this plot A was not leveled last year, would you have liked to custom hire LLL at a price of Rs. 250 per hour?" Check the corresponding box if the answer is "Yes." Now proceed to the next leveled plot. Enumerators should ask each of their farmers to decide for each price and check the box accordingly.*

Enumerators may need to walk through the total cost of leveling at each price to help farmers understand the implications of their bidding behavior on their total LLL bill.

Household ID:__________ **Are the plot names for this farmer correct? Y N** **1 Farmer's estimate of time to LLL**						**Practice** **Price of LLL (Rs./hour)**									
	ISS plot name	*Auction plot name*	*Acres*	*LLL*	*Hrs*	*250*	*300*	*350*	*400*	*450*	*500*	*550*	*600*	*700*	*800*
A															
B															
C															

"Now that you have completed your LLL custom hire decisions, we are ready to determine the price for this practice exercise. We have one card for each price here."

Show each card and read the price, then put them in a pile and shuffle them up. To emphasize the potential range of prices, say, "Suppose we drew this Rs. 800/hour card." Hold up the card. "For very uneven land, a 1-acre plot could cost over Rs. 6,000to level at this price. If the plot was fairly even, it could cost less than Rs. 2,000 to level." Move to a low card and say, "If instead we drew this Rs. 250/hour card, the uneven plot could cost Rs. 2,000 or more and the even plot could cost as little as Rs. 500. It is important for you to take each of the prices seriously."

"Just like last year and just like in the sweets auction, before this session began we drew one of these price cards and put it in this envelope. This price is likely different than the price card we drew last year. Let's pull this price card out to conclude this practice LLL market."

Have a farmer draw a price card. Announce the drawn price and have the enumerators discuss the outcome. The enumerators should discuss an estimated total cost based on the drawn price and the farmer's estimated LLL time per plot.

"In a moment, we will repeat this LLL market exercise for real. In that exercise, you may actually custom hire LLL on your land. If you do, you will pay the drawn price per hour of LLL service on each plot you want leveled. ***Based on your estimate of time required for LLL for each plot, you will know approximately how much the service will cost. When our provider actually levels your plots, the actual time required may be longer or shorter than your estimate. He will charge you based on the actual time it takes to completely level your land. We are committed to providing a high quality leveling service, and your coordinator (______________) will accompany the provider to ensure excellent service.***

"Are there any questions about how this LLL custom-hire service will be arranged or provided, or how the actual cost will be determined?

"Let's proceed with the real LLL market exercise. You've had one year to think about LLL and how valuable you think it would be on the plots you cultivate. Based on everything you've learned about LLL and know about your plots, you will now finalize your decisions for each price."

Enumerators will work with their farmers as above. Enumerators can copy over the plot details and then begin asking the questions as above. Those enumerators working with farmers who leveled plots will need to follow the mini-script above to elicit hypothetical WTP for leveled plots.

Household ID:__________ **Are the plot names for this farmer correct? Y N** **1 Farmer's estimate of time to LLL**						**Real**									
						Price of LLL (Rs/hour)									
	ISS plot name	*Auction plot name*	*Acres*	*LLL*	*Hrs*	*250*	*300*	*350*	*400*	*450*	*500*	*550*	*600*	*700*	*800*
A															
B															
C															

"Now that you've made your final decisions we will determine the price. Again, we have predrawn a price card and put it in this envelope. We will show you the price in this envelope in a minute and determine who buys and receives LLL services this year."

Set the envelope aside but somewhere visible so farmers can see that the envelope is waiting to be opened to reveal the real price. It is important that farmers understand that we are just pausing for a minute to ask a few more questions before wrapping up the auction.

"Before revealing the price in the envelope, we have one last market exercise for you that will help us understand even better how much you think LLL is worth to you. Like the practice auction, no one will receive LLL services based on this auction. Even though this auction is therefore hypothetical, we ask you—as a matter of self-respect and honesty—to make these auction decisions as if they were real."

We may want to allow enumerators to talk privately with their farmers to ensure full understanding of these points.

"Like many agricultural inputs and services, agricultural credit or loans might be useful for financing LLL custom-hire services because these services can cost a lot of money. Several years ago, the government of India introduced the Kisan Credit Card to make it easier for farmers to get cash loans for agricultural purchases. We have discussed the possibility of using the Kisan Card to get a cash loan to pay for LLL with the lead bank in Gorakhpur. Soon, farmers may indeed be able to use a Kisan Card to get a short-term loan to pay for LLL. This loan would be repaid over 12 months at an interest rate of 7 percent.

"If you had the option of a Kisan Card loan on these terms to pay for LLL services on your plots, would you be interested? If so, would having the option of a Kisan Card loan change whether you would be willing to level each of your plots at different prices? Your helper will now help you respond to these important questions. As we mentioned before, although this is a hypothetical exercise, we ask you—as a matter of self-respect and honesty—to take these questions seriously and respond as if the exercise were real."

Enumerators now complete the Kisan Credit table with each of their farmers. They begin by repeating the question 'would you be interested?' If the farmer says, 'No' the enumerator should follow up with, "OK, so what you are saying is with a Kisan Card loan to pay for LLL you would not be willing to pay more for LLL on your plots?" If the farmer says s/he would be interested, the enumerator proceeds to fill out the Kisan Card table for each plot and price combination.

Household ID:__________ **Are the plot names for this farmer correct? Y N** **1 Farmer's estimate of time to LLL**						***4*** *Interested in credit for LLL?* ***Y N*** *With credit option*									
						Price of LLL (Rs./hour)									
	ISS plot name	*Auction plot name*	*Acres*	*LLL*	*Hrs*	*250*	*300*	*350*	*400*	*450*	*500*	*550*	*600*	*700*	*800*
A															
B															
C															

"We thank you for your time and interest throughout this exercise. We are also very grateful for all the time you have given us over the past year. We will return after the *rabi* harvest to ask some final questions for all of you, whether or not you receive any laser land leveling.

"We are now ready to reveal the price in this envelope. <*Pick up the envelope from the visible place where it was placed.*> Remember that this is the real price that corresponds to your decisions during the real LLL auction and will determine who receives LLL services and how much they will pay. Now, let's pull out the price card."

Pull out the card and announce the price. Enumerators will work privately with their farmers to determine what the final price means for them. Processing of forms and wrap-up. Enumerators should talk to the auction "winners" and the LLL monitor to determine feasible dates for scheduling of LLL services. All should be cognizant of the village's estimated date for completion of the wheat harvest, as LLL services can only be provided once harvest is complete.

APPENDIX B: STANDARD POSTER USED IN PILOT MARKET TEST

Two or three of these posters were placed in each of the 144 villages included in the market trial. Translation: Laser Land Leveling Services at Rs. 600/hour. To make your farm better leveled, contact Gautam Singh (7830562097). Benefits of laser land leveling: (right column on the poster in black) Saves water, reduces irrigation time, saves fertilizer, reduces weeds, and gives better yield.

First-Hour Discount Sticker

Half of the 144 villages in the pilot market trial were randomly selected to receive a first-hour discount. In these "treated villages," the following discount sticker was attached to each of the standard posters. Translation: *Hurry! Rs. 300 off on first hour of use.*

जल्दी करें ! प्रयोग के पहले घंटे पर
Rs 300 की बचत

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