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Female social networks and learning about a new technology in eastern Uttar Pradesh, India

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Female social networks and learning about a new technology in eastern Uttar Pradesh, India

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Abstract

Despite evidence of the importance of differences in the source and type of information that women and men acquire, there is a persistent assumption that these gender dimensions of information acquisition are irrelevant to decision-making in cereal systems in South Asia. Yet women do play a fundamental role in many agricultural decisions and thus have a stake in the choice of technologies selected by the household. The paper attempts to understand women's involvement in agricultural female networks and if they learn about a new agricultural technology, laser land leveling, through their social networks. Further, the study analyzes whether these female network effects have any influence on household demand for the new technology. Data for this study was collected as part of a research project on laser land leveling in 24 villages drawn randomly from three districts of eastern Uttar Pradesh, India. A binding experimental auction was conducted to elicit demand for a new technology, laser land leveling (LLL), with a randomly selected group of farmers, of which 80 percent were male household heads. The study finds evidence that factors that shape farmers' wives networks are very different from those that shape links between their husbands. Overall, women who are poorer and less educated tend to have more agricultural information contacts than wealthier and more educated women. We find that if a wife has an adopting wife in her network, her husband bid Rs. 81 more in the auction than if she did not. While we cannot say that the network effect through the wives is stronger, we can say there is evidence that there are separate and significant male and female network effects.

1. Introduction

Household economic decisions are typically modeled as those of a unitary household, where all members pool their resources, which are then allocated to a consumption bundle that maximizes the sum of individuals' weighted individual utilities. Over the last three decades, a growing body of literature suggests collective models that account for divergent resources and preferences within the household (Alderman, et al., 1995, Fisher, et al., 2000, Jones, 1986, Manser and Brown, 1980, McElroy and Horney, 1981, Strauss and Thomas, 1995, Udry, 1996, Udry, et al., 1995). Yet in spite of the literature on the intra-household dynamics of economic decision-making, much of the literature on learning and technology adoption in agriculture still tends to assume a unitary household where information flows into the household through a single member—the male household head—via his interactions with his fellow farmers, extension agents, and other sources of agricultural information. Based on the information he gathers, he will select the technology that maximizes the utility of his household.

Rural women in developing countries are deeply involved in agriculture. They are often involved in tilling, planting, weeding, harvesting, crop protection, grain storage, and food production—and thus have a stake in the choice of technologies selected by the household. Consequently we would expect women to seek information about agriculture and agricultural technologies that could better their lives and the lives of their families. Yet few studies that we are aware of consider differences in information available to members of the same household, specifically differences between women and men. At best, these studies control for women-headed households and conclude that female headship constrains access to information and, as a result, access to technology (see Peterman et al. 2011). Likewise, we are unaware of many studies that treat agricultural technology decisions as a joint process between husbands and wives (exceptions include Fisher et al., 2000 and Zapeda and Castillo, 1997).

Gender norms, time constraints, low literacy levels, and language barriers may prevent females from learning about or obtaining information on agricultural technologies from extension agents, farmer organizations, market traders, input dealers, financial institutions, and male farmers outside their immediate family (Doss, 2001). In a unitary household framework women would be presumed to learn from their husbands, however information sharing is often incomplete (Fletschner and Mesbah, 2011, World Bank, 1994). Consequently women often rely on informal social networks to obtain information, and these networks often consist entirely of other women (Aryeetey, 1995, Doss and Morris, 2000, Fletschner and Mesbah, 2011, International Fund for Agricultural Development, 1998, Meinzen-Dick, et al., 2010, Quisumbing and Pandolfelli, 2010). If women have different information sources than their husbands, they may be able to contribute additional or different information to the household's discussion of a new technology. They may also bring similar information from different sources, reducing the amount of uncertainty or ambiguity surrounding a technology and leading to increased adoption.

In this paper we use gender-disaggregated social network data from Eastern Uttar Pradesh (EUP), India to show the overlap (or lack thereof) between the social networks of male farmers and those of their wives. We then estimate the factors that influence the formation of these gender-specific networks. By using an experimental auction that introduces a new agricultural technology—laser land leveling—we demonstrate that female social networks transmit information about the technology between women in male-headed households. Finally, we show that for women with a higher degree of empowerment, gaining information about the technology from her own networks increases her husband's demand for the technology in a second auction. In section 2 we provide some background on the importance of social networks in technology dissemination, intra-household bargaining and technology choice, and laser land leveling. In section 3 we discuss the study setting and data collection. In section 4 we present results on male and female network composition and formation. In section 5 we present data on women's role in agricultural decision-making and estimate (female) network effects on household demand for the technology. In section 6 we discuss the implications of our findings and offer some concluding remarks.

2. Background

Social networks and agricultural information

Information about agricultural technologies is a valuable resource for farmers in developing countries as these technologies have potential to improve their farm productivity and profitability. (Fletschner and Mesbah, 2011). Yet reaching many small and isolated farmers directly with information about new technologies is costly. Public extension has very limited resources, and private input dealers will benefit more from reaching out to larger farmers with more resources (Anderson and Feder, 2004, Birner, et al., 2009, Feder, et al., 2011). Consequently, current extension strategies are usually based on the assumption that farmers learn about technologies and their suitability through their own social networks; extension encourages "progressive" or "model" farmers to adopt a new technology in the hopes that others will follow (Anderson and Feder, 2004).

Female farmers—both female household heads and women in male-headed households—are generally even more dependent on social networks to access information about agricultural technologies. Because of gender norms, women may not be able to interact with extension agents visiting the village. Communication with agents could also be made difficult because of linguistic barriers, as women sometimes only speak highly local dialects.[1] Women's lack of mobility may prevent them from interacting with extension agents or input dealers outside of the village. Women may also not be seen as agricultural decision-makers, particularly in male-headed households, and are therefore not targeted by extension workers (Doss, 2001, Fletschner and Mesbah, 2011, Quisumbing and Pandolfelli, 2010).

Despite evidence that females rely heavily on social networks to acquire information, the vast majority of empirical literature on network effects uses the household, and implicitly the household head, as the unit of analysis.[2] Existing studies do not allow for the possibility that males and females in the same households belong to distinct social networks, and therefore receive different amounts of information, or different information, than each other. If each individual's information influences household decision-making, then research solely focusing on the networks of household heads does not capture a potentially important conduit of agricultural information.

Network formation

As a first step to understanding the role of female social networks in information dissemination, we examine the composition of the social networks of husbands and wives in the same sample of agricultural households in EUP. We then estimate the determinants of link formation within each set of networks. Presumably, individual forms a network link with another individual if the

[1] We found this to be the case in the study site; many women spoke Bhojpuri, but not standard Hindi.
[2] A notable study on network links between females is Oster and Thornton (2012), who at Nepali girls' social networks and the dissemination of menstrual cups.

benefits of doing so exceed the costs (Jackson and Wolinsky, 1996). In the case of an agricultural network link, these benefits would include the probability of getting helpful information about weather, input and output markets, input use, crop diseases, and new technologies. They could also include social benefits, such as the enjoyment of talking about agriculture to a certain individual. The costs could include both the probability of getting bad information and the time and effort needed to maintain the link. Information links do not necessarily need to be reciprocal (Bala and Goyal, 2000); it is entirely possible that farmer 1 would seek information from farmer 2 at some cost but farmer 2 would not seek information from farmer 1. This cost-benefit framework also helps explain why (male) farmer 1 would seek information from (male) farmer 2 but not (male) farmer 3, but the wife of farmer 1 would seek information from the wife of farmer 3 but not the wife of farmer 2.

In many instances, network links form between similar individuals along traits such as gender, ethnicity, religion, wealth, family, geography, and education (McPherson, et al., 2001). Homogeneity in networks can certainly be encompassed in a flexible cost-benefit framework if individuals place a benefit on association with people similar to themselves. It is possible that links are formed from a combination of social identity and self-interest; Santos and Barrett (2010) econometrically estimate the importance of each in the formation of agricultural information links among Ghanaian farmers. They find that although both identity and self-interest matter, self-interest matters to a greater extent. Conley and Udry (2010) find that farmers not only form information links with farmers of the same gender, clan, and age groups, but also with individuals with differing wealth. Maertens and Barrett (2013) find that Indian cotton farmers' links are correlated to both social-factors such as sub-caste and agricultural factors such as soil-quality. Notably, they find that non-progressive farmers tend to form information links with progressive farmers, but that these links are not reciprocated, indicating self-interest.

Network effects and social learning

Second, we estimate whether, and to what degree, agricultural information is transmitted through male and female social networks and whether that information transfer leads to increased demand for a new technology. Empirical research on network effects is difficult for two main reasons: (1) defining the relevant network for each individual, and (2) econometric identification of network effects in the presence of the reflection problem (Manski, 1993).

Many of the seminal papers in the social network literature assume that the relevant network includes all of the farmers in a village (Besley and Case, 1994, Foster and Rosenzweig, 1995, Munshi, 2004) or a subset of their village as defined by religion, caste, or some other demographic variable (Munshi and Myaux, 2006). While defining networks in this manner certainly captures many if not most of a farmer's contacts, the village—or a demographic grouping within the village—is a very rough approximation of the group of people from whom farmers learn. As stated in the previous sub-section, network formation within the village depends on a variety of social and economic factors.

Consequently, many recent studies have employed surveys that elicit farmers' social networks directly. In some studies, survey respondents are asked about their social networks in an open-ended fashion, where a respondent is asked to list other people in her social network (Cai, 2013, Duflo, et al., 2006, Kremer and Miguel, 2007). In other studies, respondents are asked about their relationships with some or all of the other individuals in the sample (Conley and Udry, 2010, Maertens, 2013, McNiven and Gilligan, 2012), which in some cases includes all other residents of the village or other pertinent group (Ngatia, 2012, Oster and Thornton, 2012, Walker, 2011). In this paper each individual (male and female) selects his or her network contacts from the entire sample of farmers or farmers' wives in the study. We discuss the details of how we solicited these links in Section 3.

The other pervasive problem in the empirical literature on network effects is the reflection problem (Manski, 1993). Because networks are endogenously formed, it is difficult to determine if they behave similarly or use similar technologies because one person is learning from or imitating another, or because they share observed and unobserved characteristics and experience similar shocks. Some observational studies of network effects on agricultural technology adoption have used creative identification strategies, often in conjunction with panel data, to identify network effects (Baerenklau, 2005, Bandiera and Rasul, 2006, Conley and Udry, 2010, Foster and Rosenzweig, 1995, Maertens, 2013, Munshi, 2004). Others have used randomized interventions (randomized controlled trials) to identify network effects (Cai, 2013, Duflo, et al., 2006, Magnan, et al., 2013).[3] This study uses a randomized intervention, the details of which we discuss in Section 3.

Laser land leveling in India

Before discussing our sample and data collection process, we provide some background on the technology in question for this paper: laser land leveling (LLL). In flood-irrigated rice-wheat systems of the Indo-Gangetic Plains, 10-25 percent of irrigation water is lost because of poor management and uneven fields. Uneven fields can also lead to inefficient use of fertilizers and chemicals, increased biotic and abiotic stress, and low yields (Jat, et al., 2006). LLL is a process of precisely smoothing the land surface using a laser-guided drag scraper attached to a tractor, which reduces undulations to a height of 1 to 2 cm compared to traditional leveling methods that achieve reductions to only 4 to 5 cm (Jat, et al., 2006).

The immediate benefit of LLL is a reduction in water use. This is particularly important in the Indo-Gangetic Plains, where groundwater is being extracted at increasingly unsustainable rates, and where farmers still rely on flood irrigation, which requires them to irrigate until the highest point of the field is submerged. Although Indian farmers do not pay unit charges for the water they use, most farmers must pump irrigation water and therefore incur savings in the form of diesel fuel costs from such a reduction in water usage. LLL has also been shown in agronomic trials to improve crop establishment and growth, thereby improving the efficiency of fertilizer use. These trials have also shown that LLL decreases weed pressure (Jat, et al., 2006), resulting in lower requirements for herbicides and manual weeding. Technologies that reduce weeding requirements may be particularly attractive to women if unpaid family female labor does a substantial amount of weeding, as is often the case in developing countries. Because of reduced biotic and abiotic stress, and more efficient input use, LLL can also increase yields (Jat, et al., 2006).

In India, LLL was initially introduced in western Uttar Pradesh in 2001. Since then, the technology has achieved widespread acceptance in some areas of the Indo-Gangetic Plains (IGP)—notably in the agriculturally progressive Indian states of Haryana and Punjab. Since 2001, the number of laser land levelers has risen to 925 and the acreage under LLL has grown to

[3] Notable examples of network effects studies outside of agriculture that employ randomized controlled trials include Babcock and Hartman (2010), Duflo and Saez (2004), Kremer and Miguel (2007), Ngatia (2012), and Oster and Thornton (2012).

200,000 hectares in 2008. In contrast to these more agriculturally developed regions of India, LLL is new to the more heterogeneous and poorer region that is the focus of this study. Farmers in this region have smaller plots, and their production practices are less input intensive. Private LLL service providers have yet to extend their service networks to this quite different region, in part because the business models they have developed in the western IGP may not be viable in the EUP (Lybbert, et al., 2013). In this paper, we exploit the lack of familiarity with LLL in the region to study how farmers and their wives learn about this new technology. While LLL has been introduced very sparsely into EUP via small-scale demonstrations, our sampling design ensures that the farmers in our sample have little or no exposure to these demonstrations.

3. Study setting and data collection

Study setting and sample selection

Data for this study were collected as part of a project on laser land leveling in the Maharajganj, Gorakhpur, and Deoria districts of eastern Uttar Pradesh, India (see Lybbert et al. 2013 for details). Although Uttar Pradesh is part of the fertile Indo-Gangetic Plains, it is also home to 192 million people, and nearly 70 percent live in poverty (Alkire and Santos 2010). The majority of farmers in the study area cultivate rice during the summer monsoon (*kharif*) season, and wheat during the dry winter (*rabi*) season. Uttar Pradesh is in northern India, which is generally highly patriarchal and where women have relatively little autonomy compared to the south (Jejeebhoy and Sathar, 2001). Rice-wheat systems in eastern Uttar Pradesh typically depend heavily on female household labor for lower caste households, whereas for higher caste households female labor is usually hired (Paris, et al., 2000). Although our data suggests some evidence of such gender and caste divides in labor, the gender imbalance in labor is not as stark as the literature suggests. We give more detail in section 5.

The three districts chosen for this study represent the regional spectrum of productivity in rice-wheat cropping systems. In each district, four villages were randomly selected for inclusion in the study. These villages met the following criteria: (1) the villages were not flood-prone and thus farmers in these villages were consistently cultivating rice during the *kharif* season and wheat during the *rabi* season; (2) the population in the 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 conservation agricultural practices.[4] In an effort to measure inter-village (as well as intra-village) network effects, an additional four villages were randomly selected from among villages that were located along a 5 km radius from the village. Within each of these eight randomly selected villages, 20-24 farmers were randomly chosen from among all those cultivating plots of at least 0.2 acres, that is, the minimum plot size on which to laser land leveling can be conducted.[5] Our final sample size contains 478 farmers, 393 of whom are male.

Information session and baseline survey

Data collection centered on an experimental auction and lottery for LLL technology, and proceeded in several steps throughout the course of an entire agricultural year, which included one rice and one wheat season. The data collection began in May 2011, immediately following the *rabi* wheat harvest. First, the study team conducted an information session with the randomly selected household heads (82% of whom were male) to introduce the mechanics of LLL and its potential benefits and drawbacks. We refer to the 478 household heads as "farmers", and wives of the 393 male household heads as "wives". Wives did not attend these information sessions. The information sessions consisted of a short informational video on LLL, the distribution of a picture brochure, and a question and answer session with a non-sample farmer who had previously received LLL services. The script for the information session was explicitly non-promotional and meant to establish the study as a research endeavor rather than a marketing exercise.

After introducing farmer to LLL, the study team explained that in a few days, each household head would participate in an auction where they could obtain real LLL services in exchange for (their own) money. Because demand for LLL, as indicated by farmer willingness to pay in the auction, is a key variable in this study (as explained later), we took care to prevent farmers from anchoring their expectations on a specific price. In the information session farmers were therefore informed that LLL custom-hiring prices in other parts of India varied between Rs. 400-800 per hour in recent years. In providing this price range, farmers were encouraged to

[4] Data from the baseline survey indicate that this strategy was effective: only six farmers in the sample reported ever having heard of laser land leveling.

[5] Data from the baseline survey indicate that the vast majority of farmers in the sample had three or fewer eligible plots of more than 0.2 acres/plot; 75 percent had four or fewer eligible plots.

evaluate the value of the service in terms of their specific plot qualities and cropping practices, and not on a specific price they might believe to be "fair" for all farmers based on, say, other custom hire services. Farmers were further informed that the bid options in the auction would range from Rs. 250-800 per hour. This price range was printed on the picture brochure provided to all participants for reference.

After the information session, a baseline survey was conducted to collect information household demographics, wealth and assets, non-farm income sources, agricultural production, and plot-specific cropping and water management practices.

Household head network survey and first experimental auction

On a pre-determined date, the survey team returned to each village to conduct the auction. Before the auction, enumerators conducted a distinct social network module in which they asked sample farmers a series of questions about their relationship with the other farmers in their own village and paired village. Among others, these questions included, "with who do you discuss agricultural issues such as weather, input and output prices, and technologies?" In this paper we deal principally with these agricultural information contacts, although we also discuss the role of family and friends.

The auction was conducted with the farmer, which included both male and female household heads. Wives in male-headed households were not present. Each farmer was assigned an enumerator to privately guide them through the auction process and record their responses. In the auction, each farmer listed up to three plots he or she would most like leveled. For each plot, the farmer estimated how long it would take to laser level the plot using the amount of time they thought it would take to traditionally level the plot as a benchmark. Enumerators used this estimate to help farmers estimate the total cost of leveling for different prices per hour of leveling.

Plot-by-plot, the enumerator recorded whether or not the farmer was willing to pay for leveling at ten different prices between 250 and 800 Rupees per hour. Following several practice round, farmers completed the entire price card with their assigned enumerators and, and in the spirit of a Becker-DeGroot-Marschak (1964) mechanism, the auction price was revealed using pre-selected binding LLL price (Rs. 350/hour, Rs. 300/hour, or Rs. 250/hour).[6] At the conclusion, enumerators described over 80 percent of farmers as having understood the experiment very well or fairly well.

To circumvent the reflection problem in estimating network effects, and to experimentally measure input savings under LLL, we randomly allocated the technology to half of the farmers who won the auction. To do this, we divided farmers who bid at or above the selected into treatment and control groups using a 50-50 lottery stratified by bid size. Farmers were informed that the lottery was the only fair way of determining LLL service recipients due to a limited number of available LLL units and operators to provide LLL to all those qualifying in the auction. Construction of these treatment and control groups enables 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 to the broader research project that we briefly discuss later in this paper.

Several days after the auction, farmers who won the lottery to receive LLL services were contacted to agree on a date and time before the *kharif* rice planting at which leveling would be conducted by a private service provider contracted for the study. A member of the research team accompanied these providers as they leveled the plots of lottery winners to ensure compliance with the auction outcomes (i.e., the agreed-upon plots and price for leveling) and to collect additional data on leveling time and non-leveling time (i.e., set up and transportation time) required for each plot.

Input use and first wives' survey

After leveling, we conducted a series of surveys to monitor input use for all sample farmers in order to estimate input use savings (primarily irrigation) under LLL. During two of these surveys, enumerators conducted individual surveys with the wives of the male farmers participating in the study. If the main female in the household was not the wife of the household head, we surveyed her. Throughout the paper we refer to all main females in male-headed households as "wives." The first wives survey was conducted in February 2012 and contained

[6] Following the first auctions in which a binding auction price of Rs. 350/hour and Rs. 300/hour were selected, it was decided that a lower price of Rs. 250/hour would be used to ensure a larger pool of treatments and controls to randomize.

questions about network connections with other wives in the sample. To do this, enumerators used the photo directories of sample farmers and asked questions like, "With which of these men's wife, mother, sister, or daughter do you discuss agriculture?" Of the 393 male household heads, we were able to collect data from 335 females in those households. 269 of these women were the wife of the household head, one was a sister, 37 were a mother, 2 were a daughter, and 26 classified themselves as "other."

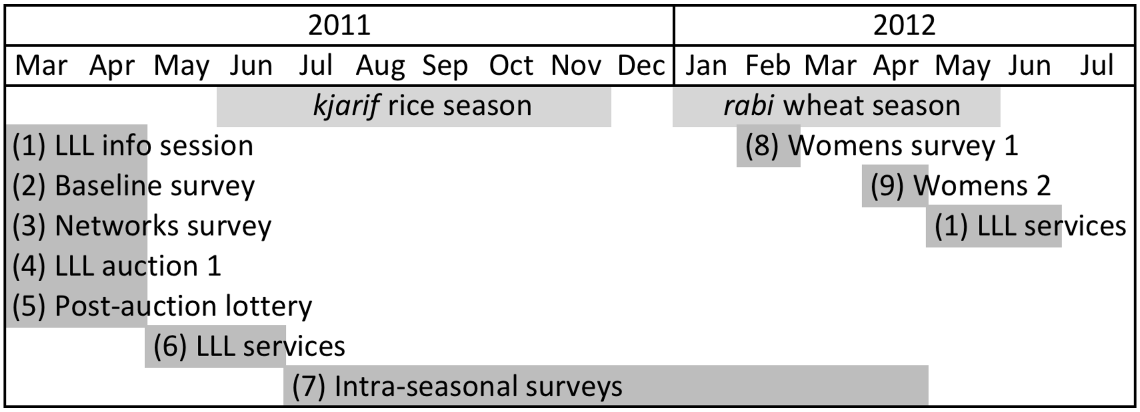
The survey also contained questions about if and how the wives learned about LLL and their opinions about various potential benefits of the technology. The survey also asked a series of general questions about how women learn about agriculture, and what aspects of agriculture they discuss with their husbands and with other women in the village, and some questions pertaining to their personal history that could affect her status within the household: district and state of birth, proximity of father and brothers, age at marriage, age, and education. Finally, the survey asked about formal group membership.

Second experimental auction and second wives' survey

To measure farmer demand after one year of exposure to the technology, we conducted a second auction following the *rabi* wheat season in April 2012. The second auction was conducted in the same manner as the first with the exception that farmers could bid on any of their plots that were not laser leveled in 2011 and that there was no lottery following the auction.

Following the second auction, the study team conducted a second survey with the wives, containing questions specifically about their involvement in the process of deciding how much the farmer would bid in the second auction. Enumerators asked wives if they were aware of the second auction, if they discussed various aspects of LLL with their husband before the auction and to what extent, and if they influenced or tried to influence their husband's bidding in the auction. The project timeline can be found in Figure 1.

Figure 1. Project timeline



4. Network composition and formation

How male and female networks are formed, and how they might differ, has implications for how extension can leverage social networks to disseminate technologies. In this section we present descriptive statistics on the size and composition of the independent social networks of farmers and their wives. By regressing link formation on individual characteristics, we attempt to shed some light on the factors that influence male and female network link formation.

Network composition

Network links between sample farmers in the same village are rather rare. Any two farmers in the sample present two potential network links: farmer 1 can claim farmer 2 as a link and farmer 2 can claim farmer 1 as a link. In a village with 20 sample households there are therefore 20 ×19 × 2 = 76 potential links. In our data we have data on 9,306 potential links between two farmers (either male or female household heads), 6,338 between two male farmers, 5,721 between two wives, and 320 between two female household heads. We also have data on 1,178 potential connections between a farmer's wife and a female household head and 1,324 potential connections between a male and female household head (of different households). Because of the context of the study we focus agricultural information links, but will briefly touch on other links as well.

There are very few agricultural connections in our sample, even compared to other studies that have found farmers discuss agricultural matters with few other farmers in their village (Conley and Udry, 2010, Maertens, 2013, Santos and Barrett, 2010). Only 3.5% of possible agricultural links between farmers exist. If we consider only such links between male farmers, 4.5% of possible links exist. Females claim only 2% of possible links to male farmers, and only 0.6% of links to other female farmers. No male farmer claims a female farmer as a network link. Network links based on agriculture are similarly rare between farmers' wives; only 4% of such potential links exist. Farmers' wives claimed 5% of possible links to female farmers.

While in some contexts women mostly interact with women they met through their spouse (presumably their husbands' friends' wives) (Fischer and Oliker, 1983), this is not the case in our village setting in northern India. We find surprisingly little overlap between the households a farmer's network contact reside in, and those that his wife's network contacts reside in. In our sample there 5,721 such possible dual links between households, and only 14 exist (0.2%). The probability of an information link existing between two wives whose husbands share an information link (5.2%) is only slightly greater than the probability they share a link if their husbands do not (4.0%), and this difference is not significant using a Mann-Whitney test (p=0.42). In our sample, it is clear that the information networks of male farmers and their wives are very distinct, which has implications on how information about agriculture and agricultural technologies disseminates within a village. A summary of agricultural information links between farmers and their wives can be found in the top half of table 1.

Links based on broader interactions are similarly rare. Farmers only claim 5.5% of other sample farmers in their village as friends or family, although between female household heads these links are much more common at 12.8%. For farmer's wives we did not ask directly about "friendship", but instead if they have conversations about household, family, and children's issues with other sample wives. Only 3.5% of these links exist. However, between wives whose husbands are friends or family these links exist 6.8 of the time, a significant difference (p=0.00). These dual "friends and family" links are still quite rare, only existing in 0.5% of possible cases. While we do see more evidence of overlap between friends and family links, these dual links are still quite rare. A summary of friends and family links between farmers and their wives can be found in the top half of table 1.

Table 1. Summary of potential and actual within-village links in sample

	Unidirectional link	Possible intra-village links	Actual intra-village links	Percent
Agri	Farmer to farmer (either gender)	9,306	317	3.5

	Male farmer to Male farmer	6,338	289	4.5
	Female farmer to female farmer	320	2	0.6
	Male farmer to female farmer	1,324	0	0
	Female farmer to male farmer	1,324	26	2.0
	Wife to wife	5,721	231	4.0
	Wife to female farmer	1,178	59	5.0
	Dual household links	5,721	14	0.2
	Wife to wife | husband linked	269	14	5.2
Friendship link	Farmer to farmer (either gender)	9,306	507	5.5
	Male farmer to Male farmer	6,338	436	6.9
	Female farmer to female farmer	320	41	12.8
	Male farmer to female farmer	1,324	16	1.2
	Female farmer to male farmer	1,324	14	1.1
	Wife to wife	5,721	199	3.5
	Wife to female farmer	1,178	61	5.2
	Dual household links	5,721	27	0.5
	Wife to wife | husband linked	400	27	6.8

Notes: For male farmers, friendship is defined by farmer 1 stating farmer 2 is a friend. For farmers' wives, friendship is defined if wife 1 has conversations with wife 2 about household, family, and children's issues.

Network formation

Male farmers' and their wives have substantially different networks of agricultural information contacts, and also of friends and family, loosely defined. Now we turn to the question of how these networks are formed. To do this, we regress the binary variable of whether a unidirectional link exists from farmer (or wife) i to farmer (or wife) j in village v for i,j = 1 to N_v, $i \neq j$ onto characteristics of i and variables capturing similarities and differences between the two. We write the econometric model as:

$$L_{ijv} = X_{iv}'\beta_1 + X_{ijv}'\beta_2 + \varepsilon_v + \mu_{ijv}, \tag{1}$$

where L_{ijv} = 1 if i claims j as a network link in village v and 0 if not. X_{iv} contains variables pertaining to characteristics of i, X_{jv} contains variables pertaining to characteristics of j, and X_{ijv} contains a series of variables that are 1 if i and j share a characteristic and 0 if they do not, and also difference in age and distance between residencies. We include village fixed effects to account for unobserved village heterogeneity. This specification is similar to the one used in Maertens (2013), Santos and Barrett (2010), and in the appendix of Conley and Udry (2010). First we estimate (1) for agricultural information links between farmers and between farmers' wives. For comparison we then estimate (1) for "friendship" linkages between farmers and between farmers' wives. In all regressions we use a logit specification to account for the binary dependent variable.

We begin by looking at agricultural information links between farming household heads (Table 2, columns 1, 2, and 3). Older household heads, 82% of which are male, are more likely to have an agricultural information link with another farmer than younger ones. Farmers are more likely to have links with farmers closer to them in age. Perhaps surprisingly, female farmers are more likely to have an agricultural information link with another farmer. Farmers are also more likely to have an agricultural information link with a farmer of the same gender. Farmers are more likely to have agricultural information links with farmers of the same wealth level, but not necessarily farmers from the same caste. More educated farmers are more likely to have agricultural information links, and farmers are more likely to share links with farmers of similar educational levels. High caste farmers are more likely to have agricultural information links, but not necessarily with other high caste farmers. Farmers are also more likely to have agricultural information links with farmers who live in closer proximity. Non-progressive farmers are more likely to talk to other farmers about agriculture, and more likely to do so with progressive farmers. These results hold when we examine only male household heads (Table 2, columns 2 and 3).

The factors that shape agricultural information link formation between farmer's wives are very different than the factors that shape these links between their husbands (Table 2, column 4). Poorer wives are more likely to have agricultural information links with other wives. Similarly, wives from lower castes are more likely to have links. Unlike their husbands, age does not play a significant role in wives' network formation. Distance does also not have a significant effect. Unlike men, less educated women are more likely to discuss agriculture with other women, especially more educated women. Non-progressive and progressive women are more likely to discuss agriculture with each other, but the relationship is not unidirectional, as it is for their husbands.

Overall, women who are poorer and less educated tend to have more agricultural information contacts than wealthier and more educated women. This is consistent with the literature on gender and agriculture in South Asia; wealthier and higher caste women tend to be less involved in agriculture (Jejeebhoy and Sathar, 2001, Paris, et al., 2000). Wives' agricultural information networks are also more heterogeneous than those of their husbands, which could indicate that leveraging female information networks could be a promising avenue to inclusive dissemination of agricultural technologies.

Table 2. Determinants of agricultural information link formation

Dependent variable: Agricultural info link {0.1}	(1) All farmers	(2) Male farmers	(3) w/ wife data	(4) Wives
Rich (top 50th percentile of wealth index)	0.00299	0.00316	0.00637	-0.0212***
	(0.00479)	(0.00619)	(0.00692)	(0.00418)
Progressive (as named by peers)	-0.00670*	-0.0122***	-0.0113**	0.0156
	(0.00377)	(0.00446)	(0.00485)	(0.0202)
General caste	0.00778	0.0170**	0.0213**	-0.0145**
	(0.00602)	(0.00864)	(0.00963)	(0.00599)
Sex	-0.0170*			
	(0.00931)			
Age (years)	0.000455**	0.000431*	0.000522**	-5.82e-05
	(0.000195)	(0.000248)	(0.000264)	(0.000280)
Education (years)	0.00286***	0.00311***	0.00289***	-0.00979**
	(0.000644)	(0.000793)	(0.000850)	(0.00429)
Same wealth level	0.00912**	0.0125**	0.0109*	-0.000724
	(0.00444)	(0.00583)	(0.00614)	(0.00487)
Same progressiveness	-0.0192***	-0.0226***	-0.0249***	-0.0148***
	(0.00282)	(0.00366)	(0.00385)	(0.00571)
Same caste level	0.00182	0.00213	0.00205	0.00123
	(0.00435)	(0.00557)	(0.00584)	(0.00630)
Same sex	0.0334***			
	(0.0109)			
Age difference (years)	-0.000604***	-0.000642***	-0.000734***	4.89e-06
	(0.000134)	(0.000171)	(0.000183)	(0.000183)
Education difference (years)	-0.00276***	-0.00307***	-0.00320***	0.000934
	(0.000420)	(0.000529)	(0.000568)	(0.00235)
Household distance (km)	-0.0167**	-0.0176*	-0.0142	-0.00717
	(0.00728)	(0.00914)	(0.00975)	(0.00686)
Observations	9,306	6,338	5,721	5,721

Logit specification used, marginal effects reported. Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. Village fixed effects included, not reported.

Next we look at determinants of friendship linkages between farmers (Table 3 columns 1, 2, and 3) and farmers' wives (Table 4). Again, female farmers are more likely to have friendship linkages than men, but all farmers are more likely to be friends with farmers of the same sex. More educated farmers are more likely to have friends, and more likely to be friends with farmers of similar educational levels. Unlike for agricultural information contacts, age does not have a role in friendship link formation. Distance also does not significantly impact friendship formation between farmers. For farmers' wives, friendships are more likely to exist between women of similar age, education, and that live close to one another (Table 3, column 4). These factors are very different than those that shape agricultural information links between women.

Table 3. Determinants of friendship link formation

Dependent variable: Agricultural info link {0.1}	(1) All farmers	(2) Male farmers	(3) w/ wife data	(4) Wives
Rich (top 50th percentile of wealth index)	0.00135	0.00256	0.00503	0.00124
	(0.00514)	(0.00668)	(0.00744)	(0.00503)
Progressive (as named by peers)	0.00561	0.00565	0.00909	0.000590
	(0.00511)	(0.00628)	(0.00696)	(0.0188)
General caste	0.00420	0.00597	0.00444	-0.00433
	(0.00675)	(0.00856)	(0.00904)	(0.00594)
Sex	-0.102***			
	(0.00841)			
Age (years)	0.000139	0.000150	8.46e-05	0.000136
	(0.000218)	(0.000276)	(0.000298)	(0.000255)
Education (years)	0.00269***	0.00334***	0.00296***	0.00336
	(0.000710)	(0.000856)	(0.000929)	(0.00276)
Same wealth	0.00318	0.00352	0.00109	0.00399
	(0.00446)	(0.00572)	(0.00606)	(0.00475)
Same progressiveness	-0.00652	-0.00765	-0.00890*	-0.00233
	(0.00403)	(0.00498)	(0.00529)	(0.00593)
Same caste level	0.00708	0.00752	0.00791	0.00609
	(0.00553)	(0.00679)	(0.00721)	(0.00572)
Same sex	0.0660***			
	(0.0151)			
Age difference (years)	0.000104	0.000143	0.000183	-0.000284*
	(0.000148)	(0.000189)	(0.000203)	(0.000172)
Education difference (years)	-0.00126***	-0.00168***	-0.00153**	-0.00422**
	(0.000460)	(0.000570)	(0.000616)	(0.00174)
Household distance (km)	-0.00467	-0.00611	-0.00543	-0.0119*
	(0.00628)	(0.00775)	(0.00820)	(0.00688)
Observations	0.00135	0.00256	0.00503	0.00124

Logit specification used, marginal effects reported. Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. Village fixed effects included, not reported.

5. Gender-disaggregated network effects on LLL demand

Wives' agricultural information networks overlap very little with those of their husbands, and are formed in a different manner. In this section of the paper we examine if information coming into the household through the wife impacts demands for an agricultural technology, laser land leveling. To do this we use an empirical specification similar to Kremer and Miguel (2007), Oster and Thornton (2012), and Magnan et al. (2013).

$$y_i = \beta_1 \cdot f\_adopt_i + \beta_2 \cdot f\_wouldbe_i + \beta_3 \cdot f\_netsize_i + X_f\beta_4 + \varepsilon_i \quad (2)$$

In (2), y_i is willingness to pay in the second experimental auction described in section 3, f_adopt_i is a binary variable for the wife having at least one agricultural information contact in an adopting household, $f\_wouldbe_i$ is the number of wives in her network from households who won the auction and therefore qualified for the lottery to adopt LLL, and $f\_netsize_i$ is the wife's total network size. An essential feature of the identification strategy is that conditional on $f\_wouldbe_i$, f_adopt_i is random by design. The parameter β_1 is therefore the network effect on household demand for LLL coming through the wife's network.

The results of (2) can be found in column 1 of table 4. We find that if a wife has an adopting wife in her network, her husband bid Rs. 81 more in the auction than if she did not. This is an increase of around 25%. From section 4 it should be clear that there is little overlap between husbands' and wives' networks, but to ensure that the wife's network links are not acting as proxies for their husbands' links we expand the model to:

$$y_i = \beta_1 \cdot f\_adopt_i + \beta_2 \cdot f\_wouldbe_i + \beta_3 \cdot f\_netsize_i + X_f\beta_4 + \beta_5 \cdot m\_adopt_i + \beta_6 \cdot m\_wouldbe_i + \beta_7 \cdot m\_netsize_i + X_m\beta_8 + \varepsilon_i. \quad (3)$$

We find that if the husband has an adopting farmer as a network link his bid in the auction will be Rs. 69 higher, and that the result of the network effects through the wife's network links are unaffected. While we cannot say that the network effect through the wives is stronger, we can say there is evidence that there are separate and significant (to the 0.1 confidence level) male and female network effects (Table 4, column 2).

Next we estimate (2) and (3) using linkages of friendship and family rather than agricultural information links. We find no friendship network effects for husbands or wives on demand for LLL (Table 4, column 4). This is a similar finding to Conley and Udry (2010). Although we are confident our experimental design eliminates the reflection problem, the lack of network effects based on friendships provides additional support that the network effects in columns 1-3 of Table 4 are not spurious. As an additional test we regress WTP from the 2011 auction, before any farmer had adopted LLL, onto agricultural information links and find no effect (results not shown).

Table 4. Gender disaggregated network effects on WTP

Dependent variable:	Ag information contacts		"Friends and family"	
WTP in 2012 Auction	(1)	(2)	(3)	(4)

Adopting wife in wife's network {0,1}	80.70*	93.27*	19.11	21.79
	(46.84)	(48.05)	(40.89)	(41.88)
Number qualifying wives in wife's network	-22.30	-12.58	3.36	3.44
	(25.88)	(27.32)	(24.34)	(24.88)
Number of wives in network	3.08	2.33	3.41	3.38
	(4.82)	(4.92)	(6.58)	(6.64)
Wife's education	3.11	0.02	-7.33	-7.28
	(10.75)	(11.45)	(10.40)	(10.54)
Wife is progressive according to peers	-116.42**	-128.00***	-37.90	-38.67
	(45.10)	(46.19)	(38.87)	(39.29)
Adopting farmer in husband's network		68.90*		-3.14
		(41.63)		(37.94)
Number of qualifying farmers in husband's household		14.79		8.64
		(34.32)		(21.59)
Number of farmers in husband's network		-11.50		-2.98
		(18.13)		(7.08)
Husband's education		-0.15		-1.23
		(2.92)		(2.62)
Husband is progressive according to peers		14.82		22.39
		(28.87)		(26.76)
Constant	273.20***	242.18***	289.56***	287.41***
	(60.47)	(77.65)	(63.42)	(64.11)
Observations	178	178	190	190

IV linear regression with lottery winning contacts instrumenting for adopting contacts. Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. District fixed effects included, not reported.

6. Concluding remarks

Economists typically model household decisions from the point of view of one individual who maximizes a single optimization problem given a single set of endowments and constraints. The emerging literature on social networks, information, and technology adoption has also adopted this unitary household framework. In this paper we used social network data from farmers and their wives to demonstrate that men and women in the same households have very different social networks and thus different access to information regarding agricultural technologies. We estimated models of network formation and found that the underlying factors that shape network linkages between male farmers are different than those shaping their wives social networks. Furthermore, we find that for both genders agricultural information networks and friendship networks are distinct from one another.

Male farmers that are socially better-off (higher wealth, caste, and education) have more agricultural information links than their less well-off counterparts. The opposite is true for their wives. We also find that male agricultural information networks are more homogenous than female networks in terms of wealth, age, and education level. The fact that poorer women have larger agricultural information networks, and that female networks tend to be more heterogeneous, has implications for extension. Reaching out to women who are agricultural leaders in the community could result in wider and more inclusive dissemination of agricultural information than reaching out to male agricultural leaders.

Ultimately, agricultural information dissemination is only useful if it leads to adoption of beneficial technologies. Using results from a randomized allocation of a new technology, laser land leveling, we found that female as well as male network effects lead to increased demand for the technology. From a policy perspective, it is therefore important to identify how network characteristics and architectures influence the performance of institutions that are dependent on social capital to improve agricultural productivity, manage natural resources, and improve returns to marketing, for example rural producer organizations cooperative societies, and self-help groups (Markelova, et al., 2009, Vasilaky, 2013).

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