Access and Learning through Information Networks in Agricultural Technology Adoption and Diffusion: Results from a Partial Population Experiment in Uganda

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Abstract:

We examine how Ugandan farmers respond to their information neighbors when deciding to adopt and disadopt a new agricultural technology, the provitamin A-rich orange-fleshed sweet potato (OFSP). The context is a partial population experiment, in which some households within a social network receive propagable OFSP vines and trainings on OFSP cultivation while others do not. We use variation in the extent to which farmers report relying on treated farmers for farming information prior to the intervention – and thus variation in the information content of the farmer's information network – to identify the effect of having more information neighbors on adoption and disadoption. Relative to the literature, strengths of this analysis include a robust validation of the peer group definition, the ability to use community fixed effects and the ability to use peer characteristics to reduce econometric issues common to studies of social interactions. We present results for both treated and untreated farmers. We find that untreated farmers gain access to OFSP through their treated information neighbors, while that the treated farmers likely get information from farmer group meetings – and thus the importance of social links dissipates over time. In contrast, untreated farmer get information from their treated information neighbors – and thus the importance of social links grows over time as their neighbors attend more farmer group meetings. In addition, we find that untreated farmers tend to disadopt when their treated neighbors disadopt. Large-scale programs to distribute new agricultural technologies often rely on such peer-to-peer technology diffusion to be successful. Our work suggests that diffusion is occurring through social connections and thus can be leveraged when designing such programs.

Introduction

New agricultural technologies have tremendous potential to improve the welfare of the rural poor. Yet, many new technologies that seem profitable in demonstration plots are not widely adopted. Farmers that choose not to adopt or to delay adoption may face many constraints on adoption. In some cases, information about shape of the production function may be one of the major constraints in a variety of technologies. In developing countries, where formal markets are frequently missing, social networks often act as substitutes (Fafchamps 2006).

Recent empirical results suggest that individuals learn from their peers when deciding whether or not to adopt a new technology and how to manage the technology. The decision being modeled and the pathway through which information is transferred vary by study. Most studies use some threshold measure of social connectivity to establish the set of people from whom the individual might learn. Foster and Rosenzweig's 1995 seminal study village mean values of input use to study learning from others. More recently the peer group is defined by individuals' self-reports of who their peers are (Oster and Thornton 2010, Udry and Conley 2010, Bandiera and Rasul 2006). For example, Duflo and Saez (2003) allow individuals to pick whom they will bring to an event to learn more about retirement savings options.

We explore peer effects in agricultural technology adoption using data from a randomized controlled intervention in Uganda of the provitamin A-rich orange-fleshed sweet potato (OFSP). In the intervention, farmers in treated farmer groups received propagable vine cuttings as well as trainings on how to grow OFSP and its nutritional benefits in August 2007. Baseline data on treated farmer group members, their untreated neighbors, and control farmer groups were collected just prior to the intervention and after two years (four OFSP growing seasons) on topics including OFSP adoption, farming practices, nutrition knowledge, OFSP consumption, vitamin A intake and serum retinol levels as a biomarker of vitamin A status in the blood. In addition, respondents were asked whether a randomly selected subset of treated and untreated farmers were part of their farming advice network (peers), and whether they had given OFPS vines to, or received OFSP vines from, each of these farmers. These data provide the basis for measuring social network effects on adoption decisions.

Our primary goal is see if how farmers with different levels of social exposure to the new agricultural technology. Since practical social programs are unlikely to directly manipulate each untreated subject's social connectivity to treated subjects, we make no attempt to establish social exposure as explicitly causal. Instead, we argue that heterogeneity in social exposure to the treatment explains a significant portion of farmer's adoption behavior. These results can be used to better target future social programs.

This work contributes to a small but influential literature on social learning in developing countries. We hope to advance this literature in the following ways.

First, once OFSP vines are adopted by farmers in a community, they are available to all farmers who are directly socially connected to those adopters. This is because OFSP vines multiply quickly. In any given season farmers must cull unwanted vines. Despite being consumable by humans (and healthy) they are often used as animal feed. Anecdotal experience suggests that these spare vines are given away. Quantitative data suggests that they are rarely sold: 5 percent of OFSP vine transactions involve sales while the rest were gifts. OFSP vines and other sweet potato vines are treated similarly.

Second, other studies use data from just a few communities. Because we use data that span 48 communities, the risk having selected a community with an unusual social structure is minimized. In addition, we can employ community fixed effects that make our inference robust to community-specific shocks, which are called correlated effects in the social interactions literature (Manski 1993, 2000).

Third, we present experimental results on a subsistence crop. Previous work in Ghana (Conley and Udry, 2010) and Mozambique (Bandiera and Rasul 2006) focus on crops primarily intended for the market. This is important because the motives behind learning about a cash crop and learning about a subsistence crop may differ, especially if women specialize in the substance crop.

Fourth, like Conley and Udry (2010) we employ the technique of random matching within sample to generate the sample on which we collect social connectivity data. In effect, random matching within sample randomly samples both nodes (individuals) and arcs (relationships), giving unbiased estimates of link formation and other dyadic outcomes (Santos and Barrett 2008) as well as unbiased estimates of individual-level estimates. The alternative method is to ask individual to lists their closest friends or the farmers from which they learn about farming. However, this method may introduce bias even at moderate sample ratios (Santos and Barrett 2008). The bias associated with respondent recall of their closest associates – both in terms of the number of associates and the composition of the associates – has not (to our knowledge) been properly quantified either in theory or empirically. Thus, using lists to generate a control variable of network size may not properly control for unobserved social characteristics such as gregariousness.

Fifth, as in Oster and Thornton (2010), our partial population experiment allows us to distinguish between treated and untreated associates. While Oster and Thornton can gainfully employ a list method (they sample entire classrooms), our relatively low sample ratio encourages the use of matching with sample to generate an individual- and dyadic-representative sample.

We define the an information neighbors as a household with whom the respondent talked with about farming or health between 6 and 18 months before the start of the intervention. We distinguish treated (farmer group member) peers from untreated (nonmember) peers for two reasons. First, treated peers received OFSP vines which they can grow and give or sell to other farmers and information about nutrition and OFSP cultivation that they can tell other farmers. Second, treated farmers are members of a farmer group and untreated members in general are not, and so may behave differently in ways that differentially affect their peers. In our analysis we use the share of treated farmers who are in the farmer's information networks ("peer share of treated farmers"), the peer share of untreated farmers and the overall social network size. Henceforth, we refer to other farmers in a farmer's farming information network as peers. Note that these measures are not the proportions of other farmers in one's information network who are treated or untreated – which would not measure the size of the network – but rather the proportions of all treated or untreated farmers who are in the farmer's network – which does capture the size of the network. In addition, we examine whether or not farmers respond to their peers' adoption decisions, similar to Bandiera and Rasul (2006). In particular, we use the share of treated peers who are growing OFSP and the share of untreated peers who are growing OFSP.

The data show that each treated farmer gave or sold OFSP vines to another 1.2 farmers on average during the two year intervention (de Brauw *et al*, 2010). However, these direct transfers of the new technology are not the only way in which interaction with treated farmers could affect another farmer's decision to adopt the crop. There are several possible behavioral motivations for these peer-to-peer effects. These exchanges may be motivated by information exchange, imitation or technology transfer or what characteristics of peer networks. We present results that form a basis for study of these mechanisms and motives.

The intervention

The HarvestPlus Reaching End Users (REU) project is testing biofortification as a strategy to reduce micronutrient malnutrition in Uganda. Biofortified crops are (conventionally or otherwise) bred to have more micronutrients. Biofortification programs introduce micronutrient-denser staple food crops to subsistence farming households to improve nutrition. The REU project introduced provitamin-A-rich OFSP cultivars in rural Southern and Eastern Uganda to reduce vitamin A deficiency (VAD) in the population. Vitamin A deficiency impairs the immune system and visual functioning, resulting in increased morbidity, mortality and blindness. In Uganda, 27.9% percent of children age 6-59 months and 51.9% percent of women age 15-49 years had vitamin A deficiency in 2000 (UBOS and ORC Macro, 2001). Currently, the leading treatment of VAD is vitamin A supplementation programs of young children and pregnant and lactating women that cost $450 million annually. If widespread adoption of provitamin A-dense crops is cost effective, this strategy could reduce the need for these costly recurrent expenditures in many populations.

The intervention ran from August 2007 to August 2009. It focused on farmer groups and employed a modified roll-out design. Farmer groups are formed by smallholder farmers who come together to promote best practices, share information and conduct joint marketing. The evaluation sample includes 84 farmer groups in as many communities, which were randomized into three groups, as well as nearby households to study spillovers. 48 farmer groups were assigned to receive propagable OFSP vine cuttings, 5kg of each of the four varieties. Of these 48 farmer groups, 36 received two years of trainings while 12 received only one year. The trainings were on the nutritional benefits of vitamin A and technical trainings on growing, cooking and marketing OFSP. The remaining 36 farmer groups were assigned to a control group that would receive the same amount of OFSP vine cuttings at the end of the two-year intervention. NGO-based agricultural extension agents trained an agricultural promoter and a nutrition promoter from each treated farmer group. The promoters were selected via nomination and voting by farmer group members. Promoters conducted a series of intensive trainings with farmer group members. The extensionists also provided technical assistance. The program is currently being evaluated by the International Food Policy Research Institute (IFPRI).

Four varieties of OFSP were introduced in REU. Compared to the traditional staple sweet potato varieties, the OFSP varieties are extremely dense sources of provitamin A. Relative to traditional white- and yellow-fleshed varieties, it matures two weeks quicker, rots quicker after harvest, and dries out more easily during the two dry seasons. Otherwise, OFSP and traditional varieties have similar agronomical properties. All varieties have two growing seasons per year. OFSP has been shown to improve vitamin A status of children in controlled feeding trials (van Jaarsveld et al, 2005). Unlike seeds, sweet potato vines cuttings cannot be stored and must be transplanted quickly to the recipient, which provides a heightened setting for examining the role of social interactions in technology diffusion. The primary beneficiaries of the REU project are members of farmer groups who receive the crop and trainings. Others may benefit indirectly by consuming purchased OFSP and by acquiring OFSP vine cuttings in order to grow OFSP themselves. Most farmers grow sweet potatoes for home consumption, but some market small amounts as well. There is an emerging market for OFSP, but as of the endline survey the quantities of marketed OFSP were quite small, though likely to increase.

While in communities with treated farmer groups 90 percent of sampled treated households and 57 percent of sampled untreated households adopted OFSP in the first season[1], only 67 and 43 percent were growing OFSP after four seasons (Figure 1). Since each treated household was given 20 kg of OFSP at the beginning of season 1 (analysis to confirm this is underway), adoption rates are initially high. We look at the role of peers in subsequent disadoption rather than the timing of adoption.

Data

[1] The high rate of diffusion to untreated households reflects both the ease with which OFSP can spread and some program leakage as well. Analysis on the relative contributions of these factors is underway.

Data were collected on 14 treated households in each of the 84 communities. In order to study spillovers, 5 untreated households in the village of each farmer group were sampled. Data were also collected on the relationships between all the households -- among treated households, between treated and untreated household, and among untreated households. The trust, frequency of communication and instances of advice exchanged among these farmers were collected.

Questions on social networks, the diffusion of OFSP vines and the diffusion of information on OFSP, vitamin A and child feeding were added to the July 2009 endline survey. We resampled the 14 treated households and 5 untreated households cover in the baseline. We use data only on households in the 48 communities in which there was a treated farmer group[2]. We refer to households with treated farmer group members as treated households and other households as untreated. As asking each person about her social contacts with the 18 other sampled households within the community would have been prohibitive, from each community a subset of 4 sampled treated households and 4 sampled untreated households who were successfully re-contacted in the endline survey were selected. We refer to this subset of 8 sampled households as the *networks subsample*. The farmer group member (in treated households) or primary farmer (from untreated households) from each of the 19 sampled households were asked about their relationships with the sampled alters. Barrett and Santos (2007) call this method *random matching within sample*. Thus, data were collected on the relations between all sampled households (including households in the networks subsample) and households in the networks subsample. However, households were not asked questions about their relationships to household not in the networks subsample. We targeted 19*8=152 relationships between sampled households and sampled alters in each community, totaling 7296 targeted relationships[3]. We asked if the respondent knows members of the sampled alter household, had conversations with

[2] There were actually two treatment arms. One, operating in 36 communities, provided two years of trainings and technical backstopping. Another, operating in 12 communities, provided only one year of these services. Extensive analysis of the impacts of these treatment arms suggests few differences. Hence, we do not distinguish between the communities in the various treatment arms.

[3] This method was implemented as follows. First, sampled households were ordered at random. The five nonmembers were assigned odd numbers starting at 1 with the first nonmember household in the order. Then, according to their random order, members were assigned available numbers, the first five of which are even, starting at 2 with the highest ranked farmer group member household. In the survey each household was asked about the eight other households with the lowest rank that didn't attrit from the survey and aren't the household itself. As a result, each household is asked about exactly eight others. Note that, since five nonmembers were sampled in each community, each nonmember was asked about the other four nonmembers. In some cases, due to attrition, 5 member and 3 nonmember households were in the networks subsample.

members of the sampled alter household between 6 and 18 months prior to the intervention, had conversations about farming or health with members of the sampled alter household between 6 and 18 months prior to the intervention, and how frequent were those conversations.

Model and Identification Strategy

We use data from a randomized partial-population experiment in which some famers are given OFSP vine cuttings and trainings while others are not. Both treated and untreated farmers vary in their in the shares of treated (untreated) farmers who are in the household's information network, which we refer to as peer shares of treated (untreated) farmers. Farmers' information networks will contain different amounts of information due to both who the farmer knows (for example, if that peer farmer is treated) and who chooses to adopt OFSP during the intervention. A farmer with more information neighbors may have more access to information in general. But farmers that have more treated farmers as information neighbors may more easily access OFSP vines and more easily learn about growing OFSP.

We make the case that the peer share of treated farmers is exogenous, conditional on the peer share of untreated farmers and a set of covariates employing household characteristics and the mean values of the characteristics of the peers. Other researchers (Kremer and Miguel 2007, Oster and Thornton 2010) make the similar assumption that measures of the number of informed (or treated) peers, conditional on the total size of the social network, is informative. Our approach has the advantage that sampled alters (the either other households in each community about which each respondent is asked) are randomly selected (as in Conley and Udry 2010).

Manski describes three non-exclusive effects that might lead an agent and her peers to have a correlated outcome. E*ndogenous effects* and *exogenous effects* are two types of peer effects. Manski also describes *correlated effects*, which may bias other peer effect estimates if omitted. The effects of peers' outcomes that influence the agent's adoption decision are called *endogenous effects*. An *endogenous effects* effect is when a farmer responds to the adoption decision of other farmers or when a farmer responds to any behavioral changes like a change in consumption that changes local prices. In contrast, an *exogenous effect* (or *peer characteristic effect*) is when a peer's characteristic affects the agent's decision. For example, people with similar characteristics may choose to associate with one another, co-locate, socialize with each other, or share information about livelihood activities. That farmers with similar characteristics make similar adoption decisions doesn't necessarily imply that farmers imitate or learn from each other. Suppose higher-educated farmers generate village-level positive spillovers on the likelihood of adoption. Then if the peer education variable is omitted from the estimating equation the coefficient on peer adoption will be biased away from zero. All these effects must be included in a model of peer effects.

Several estimation issues remain. First, simultaneity bias occurs when the agent's outcome both affects and is affected by the outcomes of other agents. This results in overestimates of peer effects, as the correlation estimated in the coefficient on the peer's outcome reflects both the effect of the peer on the agent and the effect of the agent on the peer. Manski (1993) calls this the reflection problem: how can an observer know if a person causes her reflection in the mirror to move, or if the reflection causes the person to move? This bias can be avoided by randomly assigning agents to social groups (Moffitt 2001), observing the agents making decisions in sequence (panel data) or instrumental variables. The issue is greatly lessened in larger social groups. (So it would be very serious for roommates as in Sacerdote 2001, but less serious for farmers with information networks of, say, 20 other farmers, as we see in the study site in Uganda.)

Second, effects of environmental variables shared by the agent and her peers on the adoption decision are called c*orrelated effects,* or group-level *common shock effects*. Common shocks like prices or weather may affect outcomes. All specifications use community-level fixed effect or a large set of community-level variables to remove community-level variation from common shocks.

Third, farmers can select the group to which they belong. This is called *group selection bias* or endogenous network formation. While Ugandan farmers certainly can move from one community to another, we do not consider this sort of selection process. However, farmers choose their information network from among farmers in the community. Since we asked each farmer to report whether or not 8 sampled alters are in her information network, we use a peer group that is defined at the individual level. Group selection bias is a concern if estimates are to be applied to another situation or policy with a different group selection process, in which case estimates would not have external validity. Our estimate use pre-intervention measures of peer groups. In the case of the REU program, estimates under pre-intervention group selection are more appropriate since the program, if scaled up, would be scaled up areas with similar a group selection process. Thus, we do not consider this a major obstacle to obtaining meaningful results.

To estimate the effect of other farmers' memberships in the farmer's information network, we estimate linear probability model using community and, where appropriate, season fixed effects (η_v and η_t). The community fixed effects control for community-level common shocks (or correlated effects, in Manski's terms). Because each farmer has different members in her information network, the proportion of treated ($E_v[N_{vij}|T_{vj} = 1]$) and untreated ($E_v[N_{vij}|T_{vj} = 0]$) farmers who are information neighbors households vary across households. N_{vij} is equal to 1 if sampled alter household j is in i's pre-intervention information network and 0 otherwise. Since the social connectivity of the household was not randomized, it is not surprising households are unbalanced along several observable dimensions, as shown in Table 1.. As such, estimates generally include a set of household-level covariates X_{vi}[4]. We control for peer characteristic effects (called exogenous effects by Manski) by conditioning on the within-community, within-treatment status means of the same set of covariates; $E_v[X_{vj}|N_{vij} = 1, T_{vj} = 1]$ for treated farmers in the community and $E_v[X_{vj}|N_{vij} = 1, T_{vj} = 0\,]$ for untreated farmers in the community, where E_v indicates the expectation taken over community v, X_{vj} is the characteristic of farmer $j \neq i$ in the network subsample in community v. Below, y_{vi1} is an indicator variable equal to 1 if farmer i in community v adopted OFSP in the first season after the start of the intervention and 0 otherwise:

$$\begin{aligned} y_{vi1} = {} & E_v[N_{vij}|T_{vj} = 1]\gamma_{PT} + E_v[N_{vij}|T_{vj} = 0\,]\gamma_{P-T} \\ & + E_v[X_{vj}|N_{vij} = 1, T_{vj} = 1]\beta_{PT} \\ & + E_v[X_{vj}|N_{vij} = 1, T_{vj} = 0\,]\beta_{PT'} + X_{vi}\psi + \eta_v + \epsilon_{vi1}. \end{aligned} \tag{1}$$

Estimates from this model include peer group selection effects and simultaneity effects. Standard errors of all specifications are clustered at the community level. Regressions are

[4] The variables, all were measured in the season before the intervention started, are: maximum education of household members, whether or not the farmer's fields is irrigated, household size, and total area under cultivation.

always run separately for treated farmers and for untreated farmers. We also estimate a model in which the exposure to treated farmers is instead represented by a set of indicator variable equal to 1 if at least some number of sampled alters is an information neighbor and 0 otherwise. That is, $1[E_v[N_{vij}|T_{vj} = 1] > x]$. The three variables are $x = 0$, $x = 0.5$, and $x = 1 - \rho$ where ρ is a small positive number.

Similar models estimate the role of social connectivity in the (again, dichotomous) decision to continue growing OFSP (y_{vit}) in season t of farmer i who grew OFSP in season $t - 1$. As such, season 1 is excluded from the model). We also add in season fixed effects η_t, as shown below.

$$\begin{aligned} y_{vit} = E_v[N_{vij}|T_{vj} = 1]\gamma_{PT} &+ E_v[N_{vij}|T_{vj} = 0]\gamma_{P-T} \\ &+ E_v[X_{vj}|N_{vij} = 1, T_{vj} = 1]\beta_{PT} \\ &+ E_v[X_{vj}|N_{vij} = 1, T_{vj} = 0]\beta_{PT'} + X_{vi}\psi + \eta_v + \eta_t \\ &+ \epsilon_{vit}. \end{aligned} \tag{2}$$

The coefficients of interest are the two γ terms. If $\gamma_{PT} > 0$ then a farmer is more likely to grow OFSP if a larger proportion of treated farmers are her information neighbors, suggesting that connectivity to information about the crop or to propagable vines is an important determinant of initial adoption or continued growing of OFSP. If $\gamma_{P-T} > 0$, it suggests that farmers with larger networks are more likely to adopt or continue growing OFSP – that gregariousness, not directed connectivity to informed or endowed farmers – is an important determinant. To estimate the effect of treated and untreated peers adopting OFSP, we add current and lagged mean values to the estimating equation, as well as test various types of fixed effects to demonstrate robustness of the model. If farmers respond to the previous adoption decisions of their peers, this would fit our general ideas about Bayesian learning models where farmers observe their peers outcomes and respond. If instead farmers and their information neighbors decide to adopt or disadopt at the same time, it suggests that farmers are not learning through a lagged process of observing outcomes, but rather something more dynamic and quicker. For example, if farmers discuss with each other their plans for the next season, they may come to the same decision through some group process, suggesting that learning from others is very important.

We estimate a model that tests if farmers respond to the adoption decisions of their treated information neighbors. First, we test if farmers respond to the proportions of current and lagged treated and untreated neighbors growing OFSP. Second, we test if farmers respond to neighbors' adoption or disadoption decisions. In both cases we use linear probability specifications with season fixed effects, adding community fixed effects and household fixed effects in some specifications:

$$\begin{aligned} y_{vit} = &+E_v[y_{vj,t-1}|N_{vij} = 1, T_{vj} = 1]\theta_{NT,t-1} \\ &+ E_v[y_{vjt}|N_{vij} = 1, T_{vj} = 1]\theta_{NT,t} \\ &+ E_v[y_{vj,t-1}|N_{vij} = 0, T_{vj} = 1]\theta_{NT,t-1} \\ &+ E_v[y_{vjt}|N_{vij} = 0, T_{vj} = 1]\theta_{NT,t} + \eta_{vi} + \eta_t + \epsilon_{vit}. \end{aligned} \quad (3)$$

Illustrated is the model employing season and household fixed effects. Thus, the variation identifying the set of θ parameters is within a household changes over time in the proportions of treated and untreated neighbors and non-neighbors growing OFSP. If farmers learn from (or imitate) neighbors, than the neighbor coefficients will be positive and non-neighbor coefficients will be close to zero. If farmers learn sequentially, responding in one season to neighbors' signals in the previous season, then $\theta_{NT,t-1}$ should correlated with the disadoption decision. If instead farmers get together at the start of a season and discuss what would be best to plant, then we would see $\theta_{NT,t}$ positive. While an observation that farmers and their neighbors make the same concurrent OFSP cultivation decision may be due to unobserved characteristics or shocks, it is hard to come up with a story that affects only subsets of farmers who are information neighbors and not subsets of farmers who are not information neighbors (where community fixed effects are included).

Results

We use the shares of treated and untreated farmers who are information neighbors to test if connectivity to treated household or information network size is associated with different OFSP adoption outcomes. As such, we first test to see if these proportions of treated and untreated farmers who are information neighbors are correlated with basic demographic variables. Table 1 shows descriptive statistics for these covariates for treated and untreated farmers, as well as other variables used in the analysis. As expected, treated farmers have larger proportions of treated farmers as neighbors (0.56) than do untreated farmers (0.36). The proportions of untreated farmers as neighbors are similar for treated (0.35) and untreated (0.32) farmers. Also shown are household characteristics and the means of treated and untreated peers by treated and untreated farmers. Time-varying outcome variables – whether or not the farmer is growing OFSP, the acreage under OFSP and the OFSP share of total acreage – are also shown for treated and untreated farmers. Note that 90 percent of treated farmers grew OFSP in season 1. With no added input costs, almost all treated farmers were willing to give the new type of sweet potato a try. In addition, 57 percent of untreated farmers grew OFSP in season 1. This number is larger than might be expected, but the untreated farmers could acquire vines in several ways. First, they could join the farmer group, in which case it would be hard for NGO staff delivering to distinguish between new farmer group members and old members. Second, they could find out when OFSP vines were to be delivered to the farmer group and then hang around that day and ask for vines. In this case, if there were extra vines they might have received some. Third, they could get OFSP vines from a treated social contact. Fourth, they could get OFSP vines from an untreated social contact who already acquired OFSP vines. This is because sweet potatoes need not be planted during any specific time during the season; thus, a farmer could plant vines culled by another farmer and the two farmers could harvest at roughly the same time. Finally, the proportions of treated and untreated neighbors who are growing OFSP in each season are presented.

Later, associations between social connectivity variables and adopt outcomes will be examined. If social connectivity is higher correlated other variables that may influence adoption, then it will be difficult to interpret social connectivity parameter estimates. Consider as well the claim that information connectivity to treated farmers is as-if randomly assigned, when conditional on overall information network size. A first hurdle in substantiating this claim is to shows that, conditional on overall network size, the proportion of treated farmers who are information neighbors is uncorrelated with variables that might influence OFSP adoption. This is akin to running the standard battery of balancing tests to validated randomization into treatment and control groups – in practice, variables found to be correlated with the treatment assignment conditioned on in treatment effect estimates. We borrow from this econometric method here. Tables 2 and 3 show selected baseline determinants of social connectivity for untreated farmers.

We are interested the determinants of social connectivity to treated farmers conditional on overall network size. Thus, regression uses a different a dependent demographic variable, which is regressed on the proportion of treated farmers who are neighbors, the proportion of treated farmers who are neighbors (representing within-community information network size) and a constant. Equations are linear models with community fixed effects and standard errors clustered at the community level. For treated farmers, the highest education of a household member and pre-intervention cultivated area are increasing in the proportion of treated farmers who are neighbors (and statistically significant at $p<.05$). Untreated households (Table 3) that have more treated farmers as information neighbors are have larger households and are less likely to have irrigated lands. These variables will be included in regressions as covariates where appropriate. In addition, we include the means of these variables for treated neighbors and untreated neighbors to control of exogenous effects, as suggested by Manski (1993). When fixed effects at or below the community level are not employed, unless otherwise noted the within-community averages of these variables over treated farmers and over untreated farmers are included as well.

As discusses earlier, we estimate social connectivity to treated and untreated farmers using a subsample we call "sampled alters." The household in the networks subsample were randomly chosen from our sample and so household characteristics should be similar between the networks subsample and sampled households not in the networks subsample. Table 4 test for balance in household characteristics and adoption outcomes between the networks subsample and other sampled households. Thirty-one percent of treated farmers and 86 percent of untreated farmers are in the networks subsample. Among treated farmers, differences are not more what might be expected by chance. Among untreated farmers, those in the networks subsample have a higher maximum household education (7.29 versus 6.26 years) and have more other untreated farmers as acquaintances (84 percent versus 68 percent, $p<.05$), social neighbors (64 versus 52 percent) and information neighbors (33 versus 21 percent). Throughout our analyses we condition on the proportion of untreated farmers who are information neighbors, intending that this be a proxy for social network. The network size of our subsample is 12 percentage points more dense than the rest of the sample, but this information is in general only used as a control. Among both untreated and treated farmers, those in the networks subsample have similar social connectivity to (other) treated farmers.

Table 5 displays descriptive statistics focusing on measures of social connectivity. The measure used throughout the paper is label in the Table as "Talked to about farming or health in the year before the intervention." Table 5 shows proportion and the distributions of this variable and other candidate connectivity variables. We will return to this table after discussing results on the role of social connectivity to (other) treated farmers on initial OFSP adoption.

Table 6 tests for associations between connectivity to treated farmers and OFSP adoption in the first season after the intervention's start for treated farmers. Of particular interest is the form in which the information likely the farmer is to have other treated farmers as an information neighbor. Columns (1) to (4) show results from regressions with a set of variables indicating the sample proportion of treated farmers who are the farmer's information neighbors. Indicators are for 1 or more, at least half, and all treated farmers being neighbors. Columns (5) to (8) instead use the proportion of other treated farmers who are information neighbors. In all cases the regressions condition on the proportion of untreated farmers who are information neighbors. Because untreated farmer households make up the vast proportion of households in the community, we interpret this variable as the sample proportion of households in the community who are the farmer's information neighbors. Columns (1) and (5) are unconditional linear probability models; no fixed effects are included. Columns (2) and (6) add district fixed effects (the study spans three districts) and covariates. Covariates are maximum education of household members, whether or not the farmer's fields are irrigated, household size, and total area under cultivation. In addition, the sample means of these variables for treated neighbor and untreated neighbors are included to control for exogenous effects. Finally, the sample means of these variables for all treated and untreated farmers are included. Thus, we condition on the maximum education of household members (and the other covariates) in five ways. This precludes using a large set of variables as covariates using standard methods. In addition, two geographic controls – household's distance in km to the farmer group meeting place and household's distance to the sample centroid of (other) farmer group members – were included. The geographic controls are in general not statistically significant – see Tables 8 and 9 for the results. Where they are, we note so. Results with and without the geographic controls are qualitatively similar. Columns (3) and (7) include community fixed effects but not covariates. Finally, Columns (4) and (8) include both community fixed effects and covariates.

Results in columns (1) to (4) consistently show an 8 to 9 percentage point increase in initial OFSP adoption when all treated farmers in the subsample network are the farmer's information neighbors relative to when two or more of the (on average 4) network subsample farmers are the farmer's information neighbors. These results are statistically significant at the 99 percent level. The effects of having at least one treated farmer as an information neighbor or two or more treated farmers as information neighbors are small in magnitude are not statistically significant. Columns (5) to (8) use the proportion of treated farmers who are information neighbors. Results suggest an additional 7 to 9 percentage point increase likelihood of initial OFSP adoption when all treated farmers are neighbors over when no treated farmers are neighbors. Results using indicator variables show that all this increase in likelihood is concentrated in changes in the proportion near one rather than changes near one half or near zero. We show later (in table X) that these results are most pronounced under using our definition of information neighbors. Treated farmers who are very well connected other treated farmers are significantly more likely to adopt OFSP.

In contrast, untreated farmers with just one treated farmer as an information neighbor are 25 percentage points ($p<.01$) more likely to adopt OFSP in the first season of the intervention than untreated farmers with no treated farmers as information neighbors (Column 4 of Table 7). Column (8) shows results of effect of the proportion of untreated farmers who are information neighbors on initial OFSP adoption among untreated farmers. Estimates imply a 21 percentage point effect ($p<.1$), which column (4) suggests is entirely concentrated having the first treated farmer as an information neighbor. Other specifications are largely consistent with the ones reported here.

Taken together, the estimates of the effect of treated farmers who are neighbors on initial OFSP adoption suggest vastly different mechanism underlying the effects. Our interpretation is that untreated farmers, who must get access to OFSP vines, can do so by knowing just one farmer with OFSP vines. In contrast, treated farmer already have access to OFSP vines so their initial adoption decision may depend on exposure to information or to social reference effects. We conjecture that treated farmers that don't get information from the vast majority of other farmers in their farmer group are not fully integrated into the farmer group's activities at the start of the intervention. Therefore they may be more likely to have information constrains that precluded initial adoption.

Throughout our regressions we use variables specifying the farmer's social connectivity to (other) treated and (other) untreated farmers. While we could attempt to specify any number of different relationships between farmers, the most relevant for this analysis is weather the farmers get information about farming or health from other farmers. We ask respondents about several different measures of social connectivity. First, we if the other farmer knows who the other farmers is – is if, of they are acquaintances. Second, we ask if the respondent had a substantive conversation with the other farmer in the period between 6 and 18 months prior to the intervention. This is a candidate measure of the membership in the farmer's social network. Third, we ask if the respondent had a substantive conversation with the other farmer about farming or health in the period between 6 and 18 months prior to the intervention. It is this dichotomous variable that we use to define an information neighbor. Table 5 presents means for and categorical variables that represent these definitions.

Tables 8 and 9 present estimates of the effects of social connectivity to treated farmer on initial OFSP adoption among treated and untreated farmers, using various definition of social connectivity. They also condition on two geographic variables that may influence the likelihood of adoption. While we employ community fixed effects we do not condition on other covariates – though we still include the proportion of untreated farmers who are information neighbors – in order to accentuate any potential significance of the geographical variables. If acquaintances matter then the weak ties – as in Grannovetter (1973) – may an important determinant of initial OFSP adoption. Columns (1) and (2) of Tables 8 and 9 suggest that having more treated acquaintances doesn't matter for either treated or untreated farmers' initial OFSP adoption decision. However, having more untreated acquaintances clearly does matter for untreated farmers – having many acquaintances versus none increases the likelihood of initial OFSP adoption by 35 to 37 percentage points. Our preliminary interpretation of this finding is that social network size – as opposed to information network size – is a better proxy for unobservable differences in farmer type like gregariousness that may be correlated with neighbor exposure to the treatment and the likelihood of adoption.

If having conversations with more treated farmers about any topic – but not in particular about farming or health – is a more important determinant of adoption, then it would suggest that information about farming and health doesn't affect the decision to initial adopt OFSP. Columns (3) and (4) show results for the number and proportion of treated farmers talked to in the year before the intervention. As none of the coefficients are significant in either table, it suggests that information about OFSP is indeed more important that a simple social contact. As for acquaintances, having talked to more farmers in the years prior to the intervention increases the likelihood of initially adopting OFSP by 37 to 38 percentage points. It is striking that such an association is not at all present in columns (5) and (6), where the effect of having talked to more farmers about farming or health – our definition of information neighbor – is estimated. The effect on untreated farmer initial OFSP adoption of having more untreated information neighbors is small is in general small in imprecisely estimated.

Having adopted OFSP, a farmer may disadopt or continue to grow OFSP in subsequent growing seasons, a decision that may be influences by their access to information about OFSP. Larger networks or networks oriented toward treated farmers may being in more information and altar the farmer's decision. The effects of information on the decision to disadopt may vary across farmers making the decision and across the source of the information. Consider a model where farmers learn about the household welfare effects of OFSP from their own experience and that of others (as in, say, Foster and Rosensweig 1995). Farmers initially adopting OFSP may learn more quickly about OFSP's true welfare effects if more treated farmers are their information neighbors or if they have larger information networks. However, it is ambiguous whether the information will help farmers learn more quickly that OFSP is not beneficial (and thus the farmer disadopts) or whether the information will help farmers learn more quickly that OFSP is indeed beneficial (and thus the farmers continues growing OFSP). Moreover, a number of theories about social norms and "fitting in" – or trying not to fit in – could be important for some or all farmers. Finally, it may be information is not a constraint for some farmers, in which case connectivity to treated farmers will not matter. Thus, the empirical effects having more treated farmers as information neighbors are ambiguous.

Table 10 shows the effects of information network variables on the linear probability of continued OFSP cultivation among farmers growing OFSP in the previous season. Panel B shows treated farmers and Panel B shows untreated farmers. All specifications include community fixed effects and household characteristics, our preferred specification from the initial adoption regressions in Tables 2 and 3. Columns (1) to (3) show specifications using indicator variables of social connectivity to treated farmers for the second, third and fourth season after the start of the intervention. Columns (4) to (6) show results using the proportion of treated farmers who are information neighbors for the second, third and fourth season after the start of the intervention.

For treated farmers who grew OFSP in season 1, those with at least one treated farmer as an information neighbor are 9 percentage points ($p<.05$) more likely to grow OFSP in season 2 (column 1). Likewise, those with all (sampled alter) treated farmers as information neighbors (column 4) were also 9 percentage points more likely to grow OFSP in season 2; this result is significant at the 90 percent confidence level. The 9 percentage point effect is similar in magnitude to the effect in season 1, but the operative threshold for social connectivity's impact on growing OFSP has changed: among treated farmers the likelihood of initial adoption jumped when all treated farmers were her information neighbors but the likelihood of continuing to grow OFSP in season 2 jumped when just one farmer was an information neighbor. Since treated farmers have the option to attend farmer group meetings about OFSP -- and most do actually attend – it is likely that information is not a constraint on the OFSP production function for most of these farmers. For treated farmers, having more treated farmers as information neighbors supports initial adoption and adoption in season 2 but this effect fades over time, suggesting that the information constrain loosens as time passes. It may be that attending subsequent farmer group meetings in seasons 2 and later loosened the information constraint.

Results on continued OFSP adoption for untreated farmers suggest that each additional connection to treated farmers and overall information network size may be important. Untreated farmers who adopt OFSP in season 1 are 15 percentage points more likely to continue growing OFSP in season 2 ($p<.1$ in column 1 and $p<.05$ in column 4) when the proportion of untreated farmers who are information neighbors increases from zero to one. In season 3, farmers with a larger proportion of treated farmers who are information neighbors are 25 percentage points ($p<.1$) more likely to continue growing OFSP. In season 4, farmers with a larger proportion of treated farmers who are information neighbors are 28 percentage points ($p<.05$) more likely to continue growing OFSP. In contrast to treated farmers, for untreated the effect of having more treated farmers as information neighbors seems to grow over time. This suggests that social vectors of information become more important over time. More analysis is needed to determine how and why this effect appears to be growing.

Farmers may also respond to the decision of others to adopt or disadopt OFSP. We examine whether farmers respond to the adoption and disadoption decisions of their information neighbors in the previous period. We also test if farmers decide to disadopt OFSP in the same period as their information neighbors. The estimated coefficient will contain both the effect of neighbors on the farmer and the effect of the farmer on neighbors, but this simultaneity bias is small since communities are quite large; the mean (minimum) household population of a community is 206 (35) and the mean (minimum) farmer group size is 27 (16). Because our measure of the information network is below the community level and differs for each farmer, we can estimate the associations between neighbor and farmer behavior under community fixed effects as well as household fixed effects.

Table 11 shows estimates the effects of the proportions of treated and untreated neighbors growing in the previous and current seasons on treated adopters' decision to continue growing OFSP. All regressions include season fixed effects. The first three columns show results for treated farmers and columns (4)-(6) show results for untreated farmers. Columns (2) and (4) additionally included community fixed effects and covariates. In these specifications the proportions of treated and untreated farmer who are information neighbors are included as controls. Results are robust to excluding these controls. Column (3) and (6) include household fixed effects. Results for treated farmers vary depending on how and if fixed effects are included but the results for untreated farmers are consistent across specifications. Column (1) shows that adopting treated farmers that have more treated information neighbors growing OFSP are more likely to grow OFSP themselves. The effect is 31 percentage points and statistically significant. However, this association may be due to community-level variation in adoption. That is, in communities where more treated neighbors are growing OFSP, the farmer is also more likely to grow OFSP, perhaps for reasons totally unrelated to the farmer's social network. Indeed, the proportion of untreated neighbors growing OFSP is associated with a 12 percentage point increase in the likelihood of growing OFSP.

Column (3) employs within-household variation over time in social connectivity to adopting farmers. Variation in the proportion of treated neighbors growing OFSP is associated with 24 percentage points in the likelihood of growing OFSP for treated farmers. This is similar in magnitude the OLS result shown in column (1). Column (2) employs community fixed effects in addition to season fixed effects. Interestingly, this specification suggests that treated farmers are generally unresponsive to within-community variation in the number of neighbors growing OFSP. Thus, it is likely that the entirety of the effect is due to community-level variation – a correlated effect in Manski's language. For example, some farmer group may be more organized or the land in some communities may be more suitable for OFSP cultivation. Column (4)-(6) present consistent evidence of sustained network effects on untreated farmers. Column (4), which estimates the effect of lagged and current period adoption among treated and untreated farmers, suggests that current adoption among all neighbors is important in sustaining OFSP cultivation. The effect of the proportion of untreated farmers growing OFSP does not survive community or household fixed effect specifications, suggesting that across-community variation in this proportion is driving the result. The proportion of treated farmer growing OFSP in the current period is associated with a 44 percentage point increase ($p<.01$) in the likelihood of continuing to grow OFSP. Under community and household fixed effects specifications we see 32 and 38 percentage point increases. This suggests that within-community variation in social connectivity to treated adopting is driving this result. Throughout, results for lagged connectivity to adopting farmers do not appear to be influential. We believe that the most parsimonious explanation for current period connectivity being more important is that farmers are able to discuss the next season's cultivation decision. Among farmer group members, farmer group meetings are an obvious venue for such communication. Nonmembers will have time to discuss the how well the previous season went and could discuss their intentions to each other or give advice that may result in making similar decision.

Conclusion

This paper examined how Ugandan farmers respond to their information neighbors when deciding to adopt and disadopt a new agricultural technology, the provitamin A-rich orange-fleshed sweet potato (OFSP). We leveraged data collected on treated farmers, nearby untreated farmers, and the social relationships among treated and untreated farmers, in order to test if farmers adopt or disadopt OFSP in accord with their social connectivity to treated or untreated farmers and with the adoption and disadoption decisions of their information neighbors, as opposed to their community in general. We find that untreated farmer gain access to OFSP through their treated information neighbors, that the treated farmers likely get information about OFSP from farmer group meetings – and thus the importance of social links dissipates over time – whereas untreated farmer get information from their treated information neighbors – and thus the importance of social links grows over time as their neighbors attend more farmer group meetings. Additionally, we find that untreated farmers make tend to disadopt in accordance with the decisions of their treated neighbors but treated farmers do not.

We find strikingly different results for treated and untreated farmers. These results appear to be in accordance with their different levels of access to propagable OFSP vines and information about growing OFSP. Treated famers that do did not talk to the vast majority of their farmer group member peers are nine percentage points less to adopt initially. Since they received OFSP vines from the program, we interpret this as an effect as representing an information constraint. In contrast, for untreated farmers, having at least one treated famer as a (pre-intervention) information neighbors is a major determinant of initial adoption. Since a farmers need know only one treated farmer to acquire a few OFSP vines, we interpret this result as evidence that untreated farmer gain access of OFSP vines though their treated information neighbors.

Over time, untreated adopting farmers become less likely to disadopt if they have more treated information neighbors, while the effect of having treated information neighbors on treated adopting farmers fades over time. This implies that the information constraint on treated farmers in loosening – likely due to having attended more farmer group meeting about OFSP – but that untreated farmers may be relying more and more on information from treated neighbors – a result consistent with the implication that treated farmer are learning more over time from attending farmer group meetings.

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Figure 1. Percentage of Farmers in Treated Communities Growing OFSP by Season and Farmer Group Membership Status

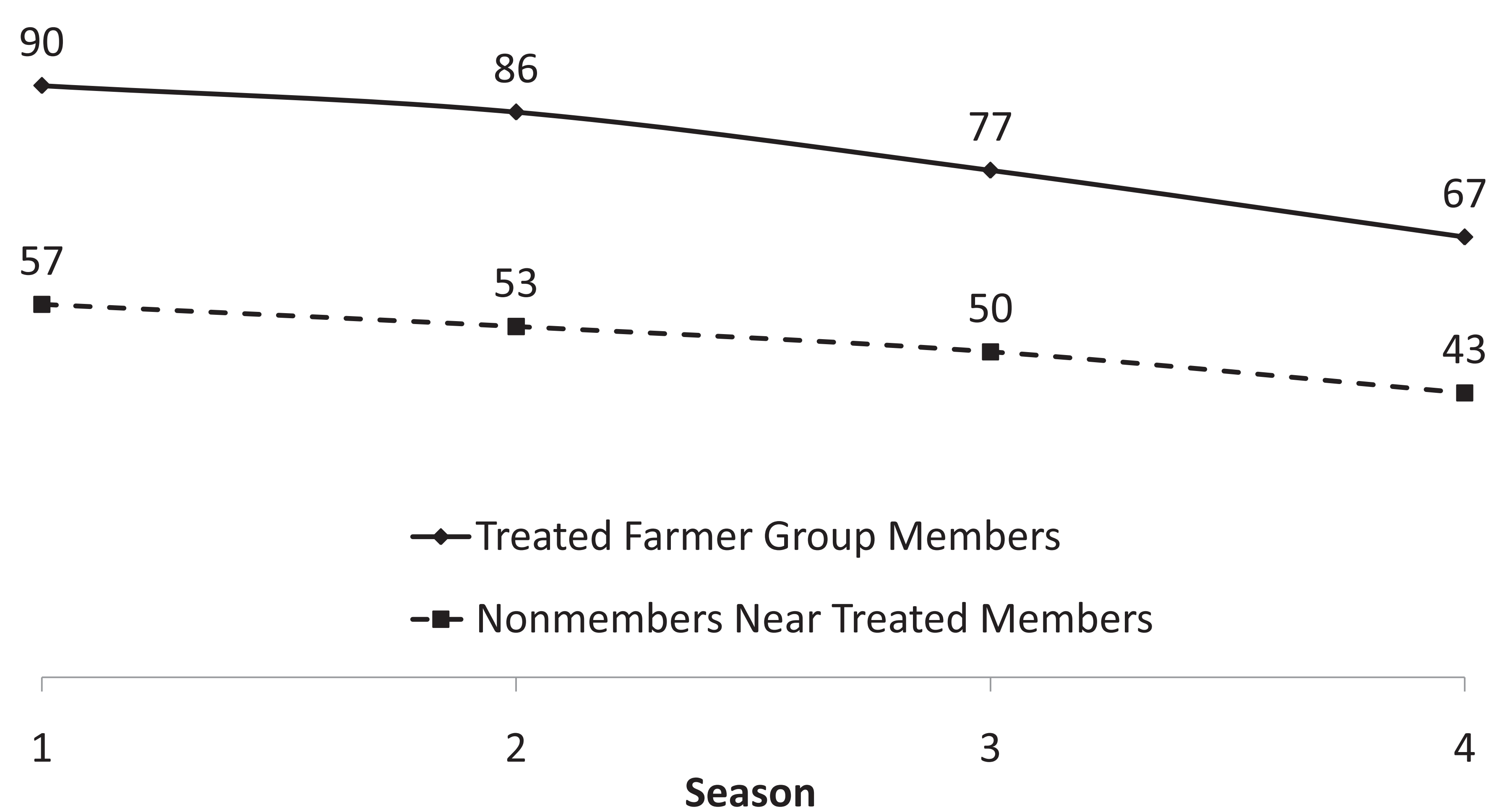

Table 1. Descriptive Statistics.

	Treated Households (farmer group members) [N=621]				Unreated Households (nonmembers) [N=208]			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Peer share variables								
Peer share of treated farmers	0.56	0.37	0.0	1.0	0.36	0.36	0.0	1.0
Peer share of untreated farmers	0.35	0.37	0.0	1.0	0.32	0.33	0.0	1.0
Household characteristics								
Polygamous	0.21	0.41	0.0	1.0	0.22	0.41	0.0	1.0
Maximum household education	7.82	3.19	0.0	15.0	7.16	2.84	0.0	15.0
Mother's age	31.33	6.09	18.0	51.0	30.39	6.51	17.1	47.0
Father's minus mother's age	7.24	5.04	-4.0	57.0	6.24	4.55	-4.0	25.0
Household size	5.40	2.52	1.0	23.0	5.13	2.37	1.0	13.0
Means of untreated peer characteristics								
Polygamous	0.15	0.28	0.0	1.0	0.15	0.30	0.0	1.0
Maximum household educaation	6.58	2.54	0.0	15.0	6.26	2.55	0.0	15.0
Mother's age	28.33	5.23	17.1	47.0	28.41	5.39	17.1	45.0
Father's minus mother's age	5.03	3.78	-4.0	23.0	4.70	3.79	-4.0	23.0
Household size	4.75	2.06	1.0	13.0	4.66	1.92	2.0	12.0
Means of treated peer characteristics								
Polygamous	0.15	0.27	0.0	1.0	0.12	0.26	0.0	1.0
Maximum household educaation	7.65	2.77	0.0	15.0	7.24	2.94	0.0	15.0
Mother's age	31.08	4.75	20.0	48.0	30.26	5.14	20.0	47.0
Father's minus mother's age	6.46	3.57	-4.0	31.0	6.18	4.15	-4.0	31.0
Household size	5.24	1.85	1.0	13.0	5.10	1.96	2.0	12.0

	Treated Households (farmer group members) [N=621]				Unreated Households (nonmembers) [N=208]			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Season 1								
Grow OFSP	0.90	0.30	0.0	1.0	0.57	0.50	0.0	1.0
OFSP acreage	0.16	0.19	0.0	1.6	0.09	0.13	0.0	1.0
OFSP share of acreage	0.12	0.19	0.0	1.0	0.07	0.15	0.0	1.0
Share of treated neighbors growing OFSP	0.89	0.26	0.0	1.0	0.88	0.27	0.0	1.0
Share of untreated neighbors growing OFSP	0.48	0.44	0.0	1.0	0.46	0.44	0.0	1.0
Season 2								
Grow OFSP	0.86	0.35	0.0	1.0	0.53	0.50	0.0	1.0
OFSP acreage	0.28	0.48	0.0	9.0	0.14	0.23	0.0	2.0
OFSP share of acreage	0.15	0.17	0.0	1.0	0.07	0.11	0.0	0.6
Share of treated neighbors growing OFSP	0.86	0.29	0.0	1.0	0.80	0.36	0.0	1.0
Share of untreated neighbors growing OFSP	0.45	0.45	0.0	1.0	0.42	0.45	0.0	1.0
Season 3								
Grow OFSP	0.77	0.42	0.0	1.0	0.50	0.50	0.0	1.0
OFSP acreage	0.23	0.34	0.0	4.0	0.15	0.24	0.0	1.5
OFSP share of acreage	0.13	0.16	0.0	1.0	0.08	0.12	0.0	0.6
Share of treated neighbors growing OFSP	0.78	0.34	0.0	1.0	0.71	0.40	0.0	1.0
Share of untreated neighbors growing OFSP	0.39	0.43	0.0	1.0	0.39	0.44	0.0	1.0
Season 4								
Grow OFSP	0.67	0.47	0.0	1.0	0.43	0.50	0.0	1.0
OFSP acreage	0.16	0.23	0.0	2.0	0.10	0.17	0.0	1.0
OFSP share of acreage	0.09	0.11	0.0	1.0	0.05	0.10	0.0	0.8
Share of treated neighbors growing OFSP	0.63	0.41	0.0	1.0	0.56	0.44	0.0	1.0
Share of untreated neighbors growing OFSP	0.37	0.42	0.0	1.0	0.34	0.44	0.0	1.0

Table 2. Baseline determinants of social connectivity for treated farmers

	Proportion of treated farmers who are information neighbors		Proportion of untreated farmers who are information neighbors		Constant	
Polygamous	0.072	(0.06)	-0.039	(0.06)	0.184***	(0.03)
Mother has 6+ years of Education	0.071	(0.05)	-0.004	(0.04)	0.230***	(0.02)
Max Education	1.132**	(0.45)	0.066	(0.47)	7.175***	(0.20)
Mother's Age	0.641	(0.86)	1.617*	(0.91)	30.40***	(0.41)
Mother's - Father's Age	0.806	(0.60)	0.283	(0.78)	6.687***	(0.37)
HH Size	0.736*	(0.41)	-0.176	(0.39)	5.053***	(0.18)
Num Children Under 3	-0.061	(0.11)	0.074	(0.11)	0.873***	(0.05)
Num Children Ages 3-5	0.011	(0.10)	0.114	(0.10)	1.227***	(0.04)
Mother's Education Imputed	-0.001	(0.05)	0.008	(0.05)	0.181***	(0.02)
Mother's Age Imputed	-0.005	(0.06)	0.008	(0.05)	0.191***	(0.02)
Total cultivated area	0.919**	(0.42)	-0.656	(0.45)	2.489***	(0.17)
Cultivated area under sweet potatoes	0.040	(0.08)	-0.038	(0.09)	0.253***	(0.02)
Grew any sweet potatoes this season	-0.001	(0.05)	0.030	(0.05)	0.747***	(0.02)
Grew OFSP this or last season	-0.006	(0.01)	0.008	(0.01)	0.006***	(0.00)
Household has lowlands access	0.009	(0.07)	0.053	(0.08)	0.405***	(0.03)
Cultivable area with good soils, acres	0.487	(0.31)	-0.308	(0.27)	1.653***	(0.17)
Household had cultivable irrigated lands	0.016	(0.03)	-0.013	(0.02)	0.032***	(0.01)

Table 3. Baseline determinants of social connectivity for untreated farmers

	Proportion of treated farmers who are information neighbors		Proportion of untreated farmers who are information neighbors		Constant	
Polygamous	0.173*	(0.10)	0.060	(0.14)	0.134***	(0.04)
Mother has 6+ years of Education	-0.074	(0.12)	0.022	(0.15)	0.285***	(0.03)
Max Education	0.125	(0.87)	0.436	(0.82)	6.971***	(0.27)
Mother's Age	2.294	(1.99)	-2.847	(1.91)	30.46***	(0.72)
Mother's - Father's Age	-0.505	(0.83)	3.519***	(1.27)	5.296***	(0.38)
HH Size	1.489**	(0.68)	-0.001	(0.74)	4.590***	(0.19)
Num Children Under 3	-0.125	(0.20)	0.061	(0.20)	1.108***	(0.06)
Num Children Ages 3-5	-0.040	(0.22)	0.286	(0.25)	1.020***	(0.06)
Mother's Education Imputed	-0.078	(0.07)	-0.063	(0.10)	0.184***	(0.03)
Mother's Age Imputed	-0.118	(0.09)	-0.007	(0.12)	0.238***	(0.03)
Total cultivated area	0.399	(0.60)	0.121	(0.58)	1.968***	(0.18)
Cultivated area under sweet potatoes	-0.005	(0.04)	-0.014	(0.07)	0.198***	(0.02)
Grew any sweet potatoes this season	-0.006	(0.09)	-0.115	(0.11)	0.726***	(0.03)
Grew OFSP this or last season	-0.018	(0.03)	0.017	(0.01)	0.015	(0.01)
Household has lowlands access	-0.245*	(0.13)	-0.019	(0.15)	0.504***	(0.03)
Cultivable area with good soils, acres	-0.027	(0.69)	0.904	(1.01)	1.319***	(0.23)
Household had cultivable irrigated lands	-0.127**	(0.05)	0.021	(0.06)	0.0878***	(0.02)

Table 4. Balancing tests for networks subsample

	Treated farmers					Untreated farmers				
	Networks subsample		Rest of Sample			Networks subsample		Rest of Sample		
	Mean	SE	Mean	SE		Mean	SE	Mean	SE	
Polygamous	0.18	(0.03)	0.23	(0.01)		0.22	(0.01)	0.22	(0.08)	
Mother has 6+ years of Education	0.24	(0.03)	0.28	(0.01)		0.28	(0.01)	0.19	(0.06)	
Max Education	7.82	(0.18)	7.83	(0.08)		7.29	(0.06)	6.26	(0.39)	**
Mother's Age	31.50	(0.41)	31.19	(0.18)		30.59	(0.21)	28.94	(1.47)	
Mother's - Father's Age	6.97	(0.29)	7.35	(0.13)		6.12	(0.15)	7.03	(1.04)	
HH Size	5.49	(0.15)	5.36	(0.07)		5.24	(0.06)	4.38	(0.39)	*
Num Children Under 3	0.82	(0.04)	0.88	(0.02)		1.09	(0.02)	1.05	(0.14)	
Num Children Ages 3-5	1.23	(0.04)	1.29	(0.02)		1.11	(0.02)	1.02	(0.12)	
Mother's Education Imputed	0.18	(0.02)	0.19	(0.01)		0.13	(0.01)	0.17	(0.06)	
Mother's Age Imputed	0.19	(0.02)	0.19	(0.01)		0.19	(0.01)	0.21	(0.07)	
Pre-intervention cultivated total area	2.74	(0.15)	2.77	(0.07)		2.16	(0.04)	2.09	(0.25)	
Pre-intervention cultivated area under sweet potatoes	0.28	(0.03)	0.26	(0.01)		0.20	(0.00)	0.15	(0.03)	
Pre-intervention grew any sweet potatoes	0.77	(0.02)	0.75	(0.01)		0.67	(0.01)	0.78	(0.07)	
Grew OFSP in the two seasons before the intervention	0.00	(0.00)	0.01	(0.00)	*	0.01	(0.00)	0.01	(0.00)	
Pre-intervention access to lowlands	0.45	(0.03)	0.42	(0.01)		0.40	(0.01)	0.50	(0.08)	
Pre-intervention area with good soils	1.65	(0.17)	1.88	(0.07)		1.69	(0.05)	0.92	(0.37)	*
Pre-intervention, had irrigated lands	0.06	(0.01)	0.03	(0.01)		0.04	(0.01)	0.09	(0.06)	
Initial OFSP adopter	0.91	(0.02)	0.90	(0.01)		0.58	(0.01)	0.49	(0.09)	
Grew OFSP in season 2	0.85	(0.02)	0.87	(0.01)		0.55	(0.01)	0.42	(0.06)	*
Grew OFSP in season 3	0.78	(0.02)	0.77	(0.01)		0.51	(0.01)	0.38	(0.09)	
Grew OFSP in season 4	0.67	(0.02)	0.67	(0.01)		0.44	(0.01)	0.40	(0.07)	
Proportion of treated farmers who are acquaintances	0.93	(0.01)	0.94	(0.00)		0.85	(0.01)	0.81	(0.05)	
Proportion of untreated farmers who are acquaintances	0.81	(0.02)	0.84	(0.01)		0.84	(0.01)	0.69	(0.05)	**
Proportion of treated farmers who are social neighbors	0.79	(0.02)	0.78	(0.01)		0.66	(0.01)	0.60	(0.06)	
Proportion of untreated farmers who are social neighbors	0.62	(0.02)	0.60	(0.01)		0.64	(0.01)	0.52	(0.06)	*
Proportion of treated farmers who are info neighbors	0.57	(0.02)	0.54	(0.01)		0.38	(0.01)	0.29	(0.07)	
Proportion of untreated farmers who are info neighbors	0.38	(0.02)	0.33	(0.01)		0.33	(0.01)	0.21	(0.06)	*
Observation	191		431			182		26		
Percent of observations in networks subsample	31%					86%				

Table 5. Descriptive Statistics on the Alternative Neighbor Definitions

	Treated	Untreated	Treated	Untreated
	Links to Treated		Links to Untreated	
Means				
Acquaintance	0.94	0.85	0.83	0.82
Talked to in the year before the intervention	0.78	0.65	0.61	0.62
Talked to about farming or health in the year before the intervention	0.55	0.37	0.35	0.32
Talked to about farming or health in the second year of the intervention	0.61	0.40	0.39	0.35
Acquaintance				
At least one	1.00	1.00	0.96	0.99
At least half	0.96	0.84	0.83	0.78
All	0.83	0.64	0.66	0.61
Talked to in the year before the intervention				
At least one	0.96	0.88	0.83	0.87
At least half	0.75	0.61	0.54	0.54
All	0.57	0.36	0.40	0.37
Talked to about farming or health in the year before the intervention				
At least one	0.82	0.64	0.59	0.59
At least half	0.47	0.30	0.27	0.21
All	0.29	0.13	0.17	0.10
Talked to about farming or health in the second year of the intervention				
At least one	0.86	0.69	0.64	0.64
At least half	0.54	0.30	0.31	0.24
All	0.32	0.15	0.19	0.11

Table 6. Effect of Social Connectivity on Initial OFSP Adoption for Treated Farmers.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
At least one treated farmer is an information neighbor	0.048	0.046	0.038	0.040				
	(0.050)	(0.043)	(0.045)	(0.044)				
At least half of sampled treated alters are information neighbors	-0.035	-0.034	-0.031	-0.034				
	(0.039)	(0.038)	(0.037)	(0.036)				
All sampled treated alters are information neighbors	0.101***	0.0894***	0.0995***	0.0948***				
	(0.036)	(0.032)	(0.033)	(0.032)				
Proportion of treated farmers who are information neighbors					0.0914**	0.0855**	0.0916**	0.0829**
					(0.045)	(0.042)	(0.041)	(0.041)
Proportion of untreated farmers who are information neighbors	-0.034	-0.037	-0.031	-0.039	-0.020	-0.027	-0.019	-0.026
	(0.036)	(0.039)	(0.036)	(0.040)	(0.036)	(0.037)	(0.035)	(0.038)
Constant	0.865***	0.925***	0.869***	0.934***	0.857***	0.916***	0.856***	0.918***
	(0.041)	(0.167)	(0.039)	(0.187)	(0.031)	(0.164)	(0.031)	(0.180)
Fixed Effects	None	District	Community	Community	None	District	Community	Community
Covariates	No	Yes	No	Yes	No	Yes	No	Yes
Observations	621	619	621	619	621	619	621	619

Table 7. Effect of Social Connectivity on Initial OFSP Adoption for Untreated Farmers.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
At least one treated farmer is an information neighbor	0.241***	0.283***	0.204**	0.254***				
	(0.088)	(0.088)	(0.079)	(0.087)				
At least half of sampled treated alters are information neighbors	0.024	0.017	0.041	0.011				
	(0.084)	(0.089)	(0.079)	(0.080)				
All sampled treated alters are information neighbors	-0.099	-0.093	-0.133	-0.147				
	(0.104)	(0.092)	(0.091)	(0.092)				
Proportion of treated farmers who are information neighbors					0.269**	0.298**	0.206*	0.205*
					(0.117)	(0.123)	(0.106)	(0.106)
Proportion of untreated farmers who are information neighbors	0.083	0.070	0.113	0.087	0.036	0.047	0.081	0.071
	(0.129)	(0.111)	(0.110)	(0.113)	(0.130)	(0.114)	(0.117)	(0.117)
Constant	0.389***	0.158	0.403***	0.364	0.457***	0.202	0.468***	0.396
	(0.067)	(0.652)	(0.064)	(0.654)	(0.059)	(0.678)	(0.058)	(0.671)
Fixed Effects	None	District	Community	Community	None	District	Community	Community
Covariates	No	Yes	No	Yes	No	Yes	No	Yes
Observations	208	208	208	208	208	208	208	208

Table 8. Neighbor effects in Intial OFSP Adoption Among Treated Farmers Under Various Definitions of Neighbor

	Acquaintance		Talked to in the year before the intervention		Talked to about farming or health in the year before the intervention	
	(1)	(2)	(3)	(4)	(5)	(6)
		-0.143		0.014		0.011
At least one treated farmer is a neighbor		(0.09)		(0.08)		(0.04)
At least half of treated farmers are		0.068		0.045		0.032
neighbor		(0.08)		(0.05)		(0.03)
		-0.006		0.003		0.0701**
All treated farmers are neighbors		(0.04)		(0.04)		(0.03)
Proportion of treated farmers who are	-0.005		0.050		0.0919**	
neighbors	(0.10)		(0.06)		(0.04)	
Proportion of untreated farmers who are	-0.013	-0.022	0.0634*	0.058	-0.020	-0.040
neighbors	(0.05)	(0.05)	(0.03)	(0.04)	(0.04)	(0.04)
	-0.024	-0.021	-0.016	-0.015	-0.018	-0.018
Distance to Farmer Group Meeting Place	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Average Distance to Sampled Treated	0.066	0.067	0.065	0.067	0.071	0.070
Farmers	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)
Constant	0.889***	0.973***	0.792***	0.785***	0.823***	0.838***
	(0.09)	(0.08)	(0.04)	(0.07)	(0.03)	(0.04)
Observations	622	622	622	622	622	622

All specifications use a linear probability model with community fixed effects

Table 9. Neighbor effects in Intial OFSP Adoption Among Untreated Farmers Under Various Definitions of Neighbor

	Acquaintance		Talked to in the year before the intervention		Talked to about farming or health in the year before the intervention	
	(1)	(2)	(3)	(4)	(5)	(6)
At least one treated farmer is a neighbor		-0.037		0.020		0.180**
		(0.19)		(0.12)		(0.09)
At least half of treated farmers are neighbor		0.065		0.009		-0.005
		(0.13)		(0.11)		(0.11)
All treated farmers are neighbors		0.000		-0.020		-0.160
		(0.08)		(0.09)		(0.10)
Proportion of treated farmers who are neighbors	0.134		-0.025		0.107	
	(0.12)		(0.11)		(0.12)	
Proportion of untreated farmers who are neighbors	0.351**	0.370**	0.382***	0.367***	0.165	0.191
	(0.17)	(0.17)	(0.13)	(0.13)	(0.14)	(0.13)
Distange to Farmer Group Meeting Place	-0.047	-0.053	-0.078	-0.073	-0.059	-0.068
	(0.10)	(0.10)	(0.10)	(0.10)	(0.09)	(0.09)
Average Distance to Sampled Treated Farmers	-0.096	-0.100	-0.126	-0.125	-0.113	-0.097
	(0.13)	(0.13)	(0.14)	(0.14)	(0.13)	(0.15)
Constant	0.265	0.353	0.488***	0.461***	0.595***	0.528***
	(0.20)	(0.23)	(0.15)	(0.17)	(0.11)	(0.13)
Observations	208	208	208	208	208	208

All specifications use a linear probability model with community fixed effects

Table 10. Effect of Social Connectivity on OFSP Cultivation for Treated and Untreated Farmers who grew OFSP last season.

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Treated farmers						
At least one treated farmer is an information neighbor	0.0753**		-0.057		0.038	
	(0.037)		(0.054)		(0.064)	
At least half of sampled treated alters are information neighbors	0.013		0.024		-0.029	
	(0.025)		(0.044)		(0.050)	
All sampled treated alters are information neighbors	0.002		-0.008		-0.052	
	(0.028)		(0.034)		(0.046)	
Proportion of treated farmers who are information neighbors		0.0902*		-0.027		-0.016
		(0.051)		(0.049)		(0.075)
Proportion of untreated farmers who are information neighbors	0.0981**	0.0834*	0.0773*	0.0797*	0.025	-0.004
	(0.049)	(0.048)	(0.044)	(0.043)	(0.055)	(0.057)
Constant	1.317***	1.333***	1.052***	1.018***	1.299***	1.314***
	(0.267)	(0.268)	(0.310)	(0.305)	(0.364)	(0.357)
Observations	559	559	533	533	479	479
Panel B. Untreated farmers						
At least one treated farmer is an information neighbor	0.161		-0.117		0.188	
	(0.102)		(0.132)		(0.156)	
At least half of sampled treated alters are information neighbors	0.058		0.259**		0.041	
	(0.079)		(0.113)		(0.113)	
All sampled treated alters are information neighbors	-0.241*		0.122		0.131	
	(0.124)		(0.162)		(0.152)	
Proportion of treated farmers who are information neighbors		0.126		0.297**		0.363**
		(0.118)		(0.134)		(0.153)
Proportion of untreated farmers who are information neighbors	0.161*	0.130	-0.172	-0.179	-0.090	-0.092
	(0.091)	(0.095)	(0.145)	(0.141)	(0.145)	(0.139)
Constant	0.704	0.756	0.431	0.338	1.452**	1.367**
	(0.508)	(0.510)	(0.450)	(0.488)	(0.630)	(0.618)
Observations	118	118	111	111	103	103

Table 11. Effects of Current and Lagged OFSP Cultivation Decision of Treated and Untreated Information Neighbors on the OFSP Cultivation Decisions Adopting Treated and Untreated Farmers

	Treated Farmers			Untreated Farmers		
	(1)	(2)	(3)	(4)	(5)	(6)
Proportion Of Treated Neighbors						
growing OFSP, Lagged	0.067	-0.071	0.117*	0.025	0.058	0.074
	(0.076)	(0.063)	(0.063)	(0.094)	(0.109)	(0.176)
growing OFSP, Current	0.321***	0.052	0.245***	0.440***	0.324***	0.383***
	(0.070)	(0.078)	(0.081)	(0.094)	(0.105)	(0.125)
who are information neighbors	0.037	0.010		0.200***	0.144	
	(0.036)	(0.034)		(0.064)	(0.089)	
Proportion Of Untreated Neighbors growing OFSP						
growing OFSP, Lagged	-0.049	0.012	0.092	-0.126	-0.141	-0.132
	(0.049)	(0.053)	(0.069)	(0.082)	(0.096)	(0.112)
growing OFSP, Current	0.133***	0.074	0.043	0.172*	-0.038	0.136
	(0.044)	(0.046)	(0.058)	(0.086)	(0.111)	(0.125)
who are information neighbors	0.015	0.0731**		-0.095	-0.031	
	(0.030)	(0.028)		(0.065)	(0.087)	
Observations	1576	1571	1576	332	332	332
Fixed effects	Season	Season and Community	Season and Household	Season	Season and Community	Season and Household
Household time-invariant covariates	No	Yes	-	No	Yes	-
Season	2 to 4	2 to 4	2 to 4	2 to 4	2 to 4	2 to 4

All regressions are linear probability models with standard errors clustered at the community level.
Observations are farmers who grew OFSP in the previous season. Thus, season 2-4 are represented.