

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

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## Abstract:

We use data from a partial population experiment to examine how Ugandan farmers access and learn about a new agricultural technology from farmers in their information networks. The experiment introduced the vitamin A-rich orange-fleshed sweet potato (OFSP) to participating farmer groups in 48 communities in Uganda. In each community, members of exactly one farmer group were offered propagable OFSP vines and trainings on OFSP cultivation. We study OFSP diffusion to nearby farmers who are not members of the participating farmer group (whom we call nonmembers). We use experimentally-induced variation in the number and density of nonmember's treated information neighbors, conditional on measures of network size, to identify the effects of increased information and resources within a network on OFSP diffusion. Nonmembers with at least one treated information neighbor are more likely to adopt OFSP. In contrast, among nonmembers who adopted OFSP in the intervention's first season, those with higher treated information network densities are less likely to have disadopted by the fourth

season. We interpret the results as evidence that nonmembers, at the start of the first season, search their information networks for a neighbor that can provide to access OFSP vines. Those that gained access act as Bayesian learners, gathering from their network dispersed information about OFSP management or imitable signals that discourage disadoption.

## 1. Introduction

New agricultural technologies have tremendous potential to improve the welfare of the rural poor. Yet, many technologies that are thought should be profitable or welfare-enhancing are not widely adopted (citation). Farmers that choose not to adopt or to delay adoption may face various constraints on adoption, including lacking planting material or lacking information about how to manage the crop (citation). Study of the constraints on the adoption of new agricultural technologies has a rich tradition (Ryan and Gross 1943, Griliches 1957, Feder, Just and Zilberman 1985) and research is ongoing (Duflo *et al* 2008). In developing countries, where sources of planting material and information like agricultural extension or agribusiness firms are frequently not present, social networks often act as substitutes for these formal markets (Fafchamps 2006). Recent research has explored the role of social networks in managing existing technologies (Conley and Udry 2010) and the adoption of new technologies (Bandiera and Rasul 2006).

We explore the role information networks in the diffusion and disadoption dynamics of a new agricultural technology, new varieties of the orange-fleshed sweet potato (OFSP). OFSP is conventionally biofortified (bred) to have more bioavailable provitamin A. Sweet potatoes are vine-propagated and produce a great excess of vines, which can be transplanted, fed to livestock or eaten by humans, although human vine consumption is uncommon in our sample.

Recent empirical results suggest in a variety of contexts that individuals learn from their peers when deciding whether or not to adopt a new technology and how to manage the technology. Most published studies find that peers effect adoption rates or how quickly farmers learn about the new technology. These studies vary widely in their definition of the social reference group, data collection methods, identification strategy and results. Foster and Rosenzweig (1995) find that farmers learn from others in the community in a sample of adopters of a variety of high-yielding corn in India. Bandiera and Rasul (2006) show that farmers in Mozambique are responsive to the sunflower adoption decisions of peer farmers. In contrast, Duflo *et al* (2006) found no evidence that Kenyan farmers learn about fertilizer application from their peers. Kremer and Miguel (2006) find negative peer effects in the take-up of deworming drugs in Kenya.

More recently, researchers have tended to define the peer group through individuals' self-reports of who their peers are, as do Bandiera and Rasul (2006) and Oster and Thornton (2010). Duflo and Saez (2003) allow individuals to pick whom they will bring to an event to learn more about retirement savings options. In contrast, Udry and Conley (2010) ask farmers explicitly about a set of potential links.

This work contributes to a small but influential literature on social learning in developing countries. The context and research design had several advantages. First, we know of no other experimental results on network effects in agricultural technology diffusion. Many of the particularly burdensome issues with econometric identification under social interaction (Manski 1993, 2000) are lessened with experimental data.

Second, farmers are not directly treated may access OFSP vines through networks, but cannot do so formal markets. OFSP vines multiply quickly, so constraints on accessing OFSP planting material are likely to depend on the distribution of vines across the community network topology and the agent's location within the topology, not on the aggregate number of vines in the community. Quantitative data suggests that they are rarely sold. 95 percent of farmer to farmer OFSP vine transactions were gifts. OFSP vines and other sweet potato vines are treated similarly.

Third, we employ network data from 48 communities. This allows us to estimate network effects averaged across topologies, allaying concerns about bias due to idiosyncratic network topologies that are present in studies with just one or few networks.

Fourth, to our knowledge these are the first experimental results subsistence crop adoption. Previous work in Ghana (Conley and Udry, 2010) and Mozambique (Bandiera and Rasul 2006) focus on crops primarily intended for the market or input use (Duflo et al 2006). The benefits and costs of learning about a cash crop and learning about a subsistence crop may differ if, for example, men tend to grow cash crops and women tend to grow subsistence crops.

Fifth, our network data elicitation method is more appropriate for sampled data (Santos and Barrett 2008) and avoids some potential biases with listing links, the most commonly-used network data elicitation method.

We use data from a partial population experiment embedded in a randomized controlled trial of OFSP in Uganda, as first articulated by Moffit 2001. All members of the participating farmer group in each of 48 communities received propagable OFSP vine cuttings August 2007 and trainings on how to grow OFSP and its nutritional benefits<sup>1</sup>. Data were collected on 14 members of the participating farmer group in each community, whom we call *treated farmers*. In order to study diffusion, data were also collected on 5 households near the farmer group that were not members of the participating farmer group, whom we henceforth call *nonmembers*. Nonmembers are the focus of this paper. For all sampled farmers, data on pre-intervention social and informational connections to four (other) nonmembers in the sample and four other treated farmers were collected. Thus, the object of study is spillover in OFSP adoption from treated farmers to nonmember farmers.

We use experimentally-induced variation in nonmembers' pre-intervention connectivity to treated farmers to estimate the impact of information networks on within-community OFSP diffusion. We define an information neighbor – a member of the agent's information network – as a farmer with whom the agent had a conversation about farming or health in the period 6 to 18 months before the intervention's start. Our primary identification assumption is that the likelihood of a social link being with treated farmer – as opposed to with a nonmember – is constant across the population, conditional on observable characteristics of the agent's household and other farmer group member and nonmember households in the community. In practice, we regress OFSP adoption on treated network density – the proportion of treated farmers in the agent's information network – quadratic nonmember network density and, specification-dependent, covariates and community fixed effects.

Researchers have noted that endogenous network formation (citation) may bias estimates that use network data. Note that agricultural policies are more likely to manipulate the information topology by strategically treated farmers, not by randomly assigning information links. This is in

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<sup>1</sup> The intervention was a randomized controlled trial. Data were collected on control farmer groups. Since OFSP adoption rates are near zero in the control groups we do not use these data. There were two treatment arms. 36 farmer groups were randomly assigned to receive 12 trainings over two years. 12 farmer groups were randomly assigned to receive 12 trainings over one year. Farmer group were divided among the treatment arms to detect differences in OFSP intake between the arms. Power was not designed to be sufficient to detect differences in other outcomes. Preliminary analysis suggests that there are no differences between the arms in terms of adoption rates, acreage under OFSP or farming knowledge.

contrast to education policies, where manipulating links by strategically assigning students to classrooms is the most operable margin (citation). Thus we are not particularly concerned about endogenous network formation as biasing policy-relevant parameters. All results should be interpreted as conditional on an equilibrium of a network formation game (which we will not specify).

We find that nonmembers with at least one treated information neighbor are more likely to adopt OFSP. In contrast, having adopted, nonmembers with higher treated information network densities are less likely to disadopt. We interpret the results as evidence that farmers first perform a targeted search to access OFSP vines, gaining access through a treated farmer, and act as Bayesian learners, gathering dispersed information about OFSP management or imitable signals in order to better manage the OFSP crop.

## **2. Context**

### **2.1. 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 develop micronutrient-denser staple food crops and introduce them 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, nearly 20% percent of children age 6-59 months are vitamin A deficient (USHS 2006). Currently, the leading treatment of VAD is vitamin A supplementation programs of young children and pregnant and lactating women. In total, \$450 million is spent annually on vitamin A supplementation. Supplementation programs are more cost effective in places closer to urbanized areas and incur small but recurring costs. Thus, OFSP may be a more cost-effective and sustainable way to reduce VAD in rural areas. If widespread adoption of provitamin A-dense crops is cost effective, this strategy could

complement supplementation and reduce the need for recurrent expenditures on supplementation.

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, conduct joint marketing and interface with NGOs and government agricultural extension agents. While some meet frequently and are very active, others are generally inactive, activating in response to specific government or NGO programs. Many farmer groups primarily have women members (about 70% of sampled farmer group members are women). Many farmers groups are inactive, having been formed for a project that had ended. Some participating farmer groups were active prior to the start of the intervention while others were inactive.

All farmer group members were offered OFSP vines and trainings. 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 one agricultural promoter and one nutrition promoter from each treated farmer group. The promoters were selected through nomination and voting by farmer group members. After receiving training, promoters conducted a series of intensive trainings with farmer group members. NGO extension agents also provided technical assistance.

The evaluation sample consists of 84 participating farmer groups in as many communities. Farmers groups with more 20 or more members were eligible for the evaluation sample. If two eligible farmers groups are the same community one was deemed ineligible. A community is defined as the LC1s (villages) in which the farmer group operates. Many farmers are members of more than one farmer group, but by design no one in the farmer groups in the evaluation sample are members of another participating farmer group. In several cases, farmer groups did not have 14 households with a child aged 3 to 5. These farmer groups were given the option of recruiting more members with a child aged 3 to 5 in order to remain in the evaluation sample. All farmer groups who were offered the opportunity did successfully recruit the required numbers of new members with children under age. Recruited members are no more or less likely to grow OFSP in season 1 or in season 4.

The farmer groups were randomized into three groups. 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 12 trainings over two years while 12 farmer groups received 6 trainings over one year. In August 2009, just after endline data were collected, all members of control farmer groups received OFSP vines. The program is being evaluated by researchers at the International Food Policy Research Institute (IFPRI).

Four varieties of OFSP were introduced in REU. Compared to the traditional staple sweet potato varieties, OFSP varieties are extremely dense sources of provitamin A. Relative to traditional white- and yellow-fleshed varieties, it matures two weeks quicker, spoils quicker after harvest, and dries out quicker during the two dry seasons. Otherwise, OFSP and traditional varieties have similar agronomical properties. All varieties have two growing seasons per year, from February to June and from August to November. July, July, December and January are drier months, during which time sweet potatoes may remain in the field but are not productive. 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. Farmers can distinguish between OFSP and traditional varieties by examining the plants' leaves. It is also straightforward to distinguish varieties based on the appearance of the rootstock.

OFSP has been shown to improve vitamin A status of children in controlled feeding trials (van Jaarsveld et al, 2005). The most noticeable difference between OFSP and traditional varieties is that OFSP has bright orange flesh. Traditional varieties are most commonly white, though several yellow-fleshed varieties are cultivated. Anecdotally, OFSP acceptance is quite high, especially among women, children, and younger adults. OFSP is sweeter and, anecdotally, children appear to like it.

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. It is these potential indirect beneficiaries that are our object of study. In particular, we look at adoption in OFSP production, not consumption. 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. Thus, most OFSP consumption is from own stocks.

## 2.2. Evaluation design and data

Data were collected in July and August 2007, just prior to OFSP vines being distributed, on 14 farmer group member households, whom we call *treated farmers*, in each of the 84 communities. In order to study spillovers, 5 nearby households that are not members of the participating farmer group were sampled, whom we call *nonmembers*<sup>2</sup>. In particular, data on household demographics, agricultural production and nutrition and sweet potato farming knowledge were collected. After the intervention ended, all households were targeted for resurvey. Attrition rates were relatively low for a two-year followup – 8 percent among treated farmers and 12 percent among nonmembers. In addition to repeating baseline data collection, the endline survey recorded data on program participation and social networks.

Social network data were collected for all households in the sample, both treated farmers and nonmembers. Data were collected on trust, frequency of communication and instances of advice exchanged among these farmers, as well as membership in acquaintance, social and information networks. We asked if the respondent knows members of the other household, had conversations with members of the other household between 6 and 18 months prior to the intervention, had conversations about farming or health with members of the other household between 6 and 18 months prior to the intervention, and how frequent were those conversations.

To reduce survey costs and respondent burden, each household was asked about her or his social links to a subset of other sampled households, a method called random matching within sample (Santos and Barrett 2008). A subset of four resurveyed treated households and four resurveyed sampled nonmembers was drawn at random at the community level, so each agent is asked about the same subset of farmers. We refer to this subset of 8 sampled households as the *networks*

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<sup>2</sup> While most of farmer groups are in only one village (called an LC1), some have members in two or more nearby villages. In such cases, the five nonmembers with a child aged 3 to 5 were selected at random from the village with the most farmer group members. Nonmembers are not members of the participating farmer group but may be members of other active or inactive farmer groups that did not participate in REU.

*subsample*. We targeted  $19 \times 8 = 152$  relationships between households each community, totaling 7296 targeted relationships<sup>3</sup>.

In the first season of the intervention, 90 percent of treated households adopted OFSP. In the fourth season, only 67 percent were growing OFSP. Households near treated farmer groups (which we call *nonmember households*) 57 percent adopted in the first season of the intervention, and 43 percent were growing OFSP after four seasons (Figure 1). We will examine the role of social connectivity on these numbers.

### 3. Empirical strategy

#### 3.1. Identification

We use experimentally-induced variation in farmer's treated network density to estimate social effects on diffusion and adoption-disadoption dynamics. To outline our identification strategy, we first describe a naïve strategy using nonexperimental data, a strategy used with experimental data, and then the extension used in our strategy.

Throughout our paper we consider both access of OFSP vines and information about OFSP. These are potentially very different ways in which network influence farmer decisions about OFSP. If all farmers are willing to share OFSP vines, then a farmer with just one treated neighbor is sufficient to enable OFSP adoption. In contrast, managing a new technology requires many small pieces in information which may be dispersed throughout a population of farmers exposed to trainings or having grown OFSP in the past.

A naïve strategy to estimate information network effects might regress the adoption outcome on the number or proportion of adopters in the farmer's information network. Even conditional on overall network size, such a strategy may yield biased results. A common a feature of social

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<sup>3</sup> 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.

groups is homophily (“birds of a feather flock together”), meaning that people who share characteristics are also more likely to be linked. Thus, this strategy may misattribute correlation in outcomes among information neighbors to network effects when an omitted variable, such as entrepreneurship, underlies correlation. Suppose that farmers are homophilic on entrepreneurship, which is unmeasured but correlated with the likelihood of adopting OFSP. Then such estimates may be biased upwards, in that having an additional adopting friend would not increase the likelihood of a farmer adopting (as much as implied by the estimate). Conditioning on own and peer observable characteristics may lessen this bias but may not correct for it entirely.

Suppose that the treatment is randomly assigned to farmers. In this case, the number of social links to treated farmers will be random, conditional on the total number of social links. The researcher could regress the adoption outcome on treated network density and nonmember network density. Assuming that we enter nonmember network density into the regression appropriately (most flexibly, by using a quadratic, say) such a procedure should yield an unbiased intent-to-treat estimate.

Now suppose that the treatment is given to all farmer group members but not to any nonmembers. At least four issues arise. First, farmer group members may differ from nonmembers. On its own, this is only an issue if we want to compare farmer group members to nonmembers, which we don’t do. We only compare nonmembers to other nonmembers. As such, our results should be interpreted as representative of the nonmember population, not of the overall village population.

Second, some nonmembers may be who are more (or less) likely to link to farmer group members than other nonmembers for unobserved reasons. For example, it may be that entrepreneurial nonmembers have more information neighbors in farmers groups than does the nonmember population at large. If this is true, and included covariates do not fully account for any potential effect of entrepreneurship on adoption, we will misidentify the effect of entrepreneurship as a treated network effect. Note, however, that since programs to introduce OFSP are unlikely to be able to modify, let alone measure, entrepreneurship, treated network effect estimates will still be externally valid for scaling-up such a program. Moreover, if the correlations between entrepreneurship and treated network variables are similar in other

populations, these estimate will still be valid. However, our interpretation of the effects as network effects will be wrong. We test for such effects in Table 4.

Third, treated network density may be correlated with farmer group member characteristics. That is, nonmembers may be more likely to link to farmer group members with certain characteristics (for example farmer group members who are more entrepreneurial). If those characteristics are also correlated with adoption outcomes, then we may misattribute to network effects the impact of those characteristics. As above, this is only an issue when we try to generalize these results beyond programs that employ farmer groups. We test for such effects in Table 5.

Fourth, farmers can select the group to which they belong. This is called *group selection bias* or endogenous network formation. Ugandan farmers certainly can move from one community to another but the households in our sample are not very mobile. However, farmers choose their information network from among farmers in the community. Since we asked each farmer to report whether or not eight other farmers in the community 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. We do not consider this a major obstacle to obtaining meaningful policy-relevant results, as most agricultural intervention give a product and information to a subset of the population but do not manipulate the information links themselves. In contrast, education policy is often concerned with how to assign student to classrooms. In such a context, endogenous network formation would be very important to consider.

Fifth, *a priori* we do not know the appropriate method of assigning neighbor status. Thus social or acquaintance network may actually be the most appropriate way to define neighbor status that influences adoption behavior. We use several survey questions to define five different networks. We can then test for causal effects of acquaintance or other networks on adoption outcomes. We examine acquaintance, social, information, trusted information and well-trusted information networks. Household X is considered to be an acquaintance neighbor if the respondent answers

yes to the question “Do you know a member of household X.” We did similarly for other network types. Social neighbors are households with whom the respondent conversed in the period between 18 and 6 months prior to the intervention’s start. Information neighbors are households with whom the respondent conversed about farming or health in the period between 18 and 6 months prior to the intervention’s start. Trusted information neighbors are information neighbors whose information on farming or health is as or more trustworthy than information from close friends and relative. Well-trusted information neighbors are information neighbors whose information on farming or health is more trustworthy than information from close friends and relative. Mean treated network densities for these networks are presented in Table 1. To test for the effects of other types of networks, we use the same econometric strategy, detailed below, and then compare coefficients.

In practice, we assume that nonmember information network density is representative of overall information network density. The average nonmember household population is 152, while the average number of farmer group member households is 28. Since the nonmember household population constitutes the 85% of the community population, it seems reasonable to use the density of the nonmember information network to approximate the farmer’s overall information network density.

### 3.2. Econometric strategy

To estimate the effect of other farmers’ memberships in the farmer’s information network, we estimate linear probability model, at times using fixed effects. Because adoption rates in control communities is near zero, we use data only on households in the 48 communities in which there was a treated farmer group<sup>4</sup>. In most of our models, we have one main object of interest, the impact of one of three functions of the number of treated neighbors  $T_{ci}$  on OFSP adoption or disadoption  $y_{vi}$ . The three variables, which use separately but present together in tables, are treated (information) network density, treated (information) network size, and an indicator for the household having at least one treated information neighbor. We condition on farmer group size  $F_c$  the nonmember household population  $L_c$ , a quadratic of nonmember network density  $N_{ci}$ ,

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<sup>4</sup> 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.

and a quadratic of nonmember network size ( $N_{vi} * N_v^N$ ). Let  $y_{vi}$  be an indicator equal to one of the farmer is growing OFSP and zero otherwise. Then we estimate:

$$y_{ci} = \alpha + T_{ci}\gamma + Z\theta + \epsilon_{ci},$$

$$\text{where } Z\theta = P_c^T\psi_T + P_c^N\psi_N + N_{ci}\theta_1 + N_{ci}^2\theta_2 + (N_{ci} * P_c^T)\theta_3 + (N_{ci}^2 * P_c^N)\theta_4. \quad (1)$$

We can also expand on this equation to address a number of potential threats to identification. First, conditioning on household characteristics  $X_{ci}$  will lessen concerns that observable farmer characters correlated with treated information network density or having at least one treated information neighbor are driving results. Second, we can condition on characteristics of the sample means of characteristics of farmer group members  $X_c^T$  and of nonmembers  $X_c^N$ . Doing so lessens concerns that observable characteristics of *potential* information sources drive results. Third, we can condition on characteristics of the sample means of characteristics of treated neighbors  $X_{ci}^T$  and of nonmember neighbors  $X_{ci}^N$ . Doing so lessens concerns that observable characteristics of *actual* information sources drive results. The resulting equation is:

$$y_{ci} = \alpha + T_{ci}\gamma + Z\theta + X_{ci}\beta_1 + X_{ci}^T\beta_2 + X_{ci}^N\beta_3 + X_c^T\beta_4 + X_c^N\beta_5 + \epsilon_{ci}. \quad (2)$$

In addition, we might be concerned that in communities with high outcomes and much social connectivity, unobservable community-level variables that are correlated with local network variables, like community population dispersion, are behind network results. As such, we estimate a model with community fixed effects  $\eta_c$  instead of community-level covariates (where  $Z\theta$  includes only variables that vary within communities):

$$y_{ci} = T_{ci}\gamma + Z\theta + \eta_c + \epsilon_{ci}. \quad (3)$$

In most cases, fixed effects estimates should be considered conservative estimates on the effects of network variables on outcomes. We also run fixed effects estimates with covariates  $X_{ci}$ ,  $X_{ci}^T$ , and  $X_{ci}^N$ .

Finally, we also estimate a model that tests if farmers respond to the adoption decisions of their treated information neighbors. In particular, we use the proportions of treated  $T_{cit}^A$  and nonmember  $N_{cit}^A$  information neighbors growing OFSP. We also employ lags of those variables.

$$\begin{aligned}
y_{cit} = & \alpha + N_{ci,t-1}^A \varphi_l^N + T_{ci,t-1}^A \varphi_l^T + N_{cit}^A \varphi^N + T_{cit}^A \varphi^T + T_{ci}^D \varphi + T_{ci} \gamma \\
& + (T_{ci} * F_c) \omega + Z\theta + X_{ci} \beta_1 + X_{ci}^T \beta_2 + X_{ci}^N \beta_3 + X_c^T \beta_4 \\
& + X_c^N \beta_5 + \epsilon_{ci}.
\end{aligned} \tag{1}$$

## 4. Results

Descriptive statistics on household characteristics network characteristics, and variables that vary by season are shown in Tables 1, 2 and 3. We estimate results on initial OFSP adoption in Section 4.1. We find that having at least one treated information neighbor increased the likelihood of initially adopting OFSP. To understand why this is, we estimate several models meant to test if this effect is due to nonmembers joining the farmer group, acquiring OFSP vines from an REU representative, community promoter or other farmers (section 4.2), or the OFSP vine endowments of the nonmember's information network. We find that having more information neighbors increased the likelihood of reporting receiving OFSP vines from a community promoter, but not from REU directly. In Section 4.3, we estimate quasi-treatment effects of networks on subsequent OFSP adoption, with an emphasis on whether or not nonmembers are growing OFSP in season 4. We find that among nonmembers who adopted OFSP in season 1, those with denser treated information networks are less likely to disadopt. To test for plausible mechanisms, we estimate networks effects on joining the farmer group during the intervention, attending farmer group meetings, adapting advice networks to include more farmer group members, more adopting members or more adopting nonmembers, ETC (Section 4.4).

### 4.1. Tests for balance of household and network characteristics on quasi-treatment variables

Our identification assumption is that, conditional on nonmember network variables, treated information network density, treated information network size and having at least one treated information neighbor are uncorrelated with other variables that influence the adoption outcomes. This is impossible to formally test but if these network variables are uncorrelated with observables that might influence adoption outcomes then some concerned about validity of the treated network variables may be lessened. Results of these tests are shown in Tables 4 and 5.

Each cell is a separate regression with community fixed effects and standard errors clustered at the community level. Columns test for balance across three key treated network variables – treated information network density, treated information network size, and whether or not the nonmember household has at least one treated information neighbor. Columns also use three different specifications. The first includes does not include community fixed effects and includes only nonmember network density as a covariate. The second adds community fixed effects. The third uses a quadratic of treated information network density and size. The third specification most closely matches our preferred specifications; the others included for reference in case the quadratic or the community fixed effects obscure important differences.

Table 4 tests for balance on household characteristics. Indicators for irrigated land and polygamy and household size are correlated with treated network variables in one or more specification. Table 5 tests for balance on the mean of characteristics of information neighbors. Only the mean household size of information neighbors differs across on quasi-treatment variables.

We not much concerned that our sample is unbalanced in terms of observable characteristics. Of the 270 tests conducted, 16 were statistically significant at confidence level 95, not much more than the 13.5 that might be expected by chance.

Nonetheless, we include the three unbalanced variables -- Indicators for irrigated land and polygamy and household size -- among our covariates. In addition, we include an indicator for grew (any) sweet potato in first season 2007, the number of household members aged 0-2 at baseline and the number of household members aged 3-5 at baseline, mother's less father's age, and Acres with good soil in first season 2007. We also include the two distance based variables, to ensure that the estimated social effects are not simply proxies for geographic distance.

#### **4.2. Initial OFSP adoption**

We estimate the effects of experimentally-induced variation in treated network density on OFSP adoption outcomes.

Our main results on exposure of information networks on initial OFSP adoption are in Table 6. We find that having farmers with fully-dense treated information networks are 26 percentage points more likely to adopt OFSP in the first season of the intervention (column 1). This effect holds at 95 percent confidence. When community fixed effects are included, the effect fades to 12 percentage points and is not statistically significant (column 2). Given that the average farmer group size is 28 members, the estimated effect of treated information network size on initial OFSP (column 3) is similar in magnitude to the estimated effect treated information network density. Again, the effect fades when community fixed effects are included (column 4). Households with at least one information neighbor are between 19 and 37 percentage points more likely to adopt OFSP initially. We prefer the estimate of 23 percentage points in the specification with community fixed effects and covariates. Note that specifications that condition on covariates suggest larger effects having a treated information neighbors than specifications that do not. The coefficient from the specification without covariates may embody effects of endogenous network formation. The coefficient from the specification with covariates may contain less influence from endogenous network formation, to the extent that the process of network formation is based on included observables.

Different networks may have different effects on adoption. Social networks may or may not gather information or provide access to OFSP vines. We examine the associations between various definitions of network membership and initial OFSP adoption in Table 7. Each cell is a regression. We examine acquaintance, social, information, trusted information and well-trusted information networks. We find that strong and consistent effects of treated network density and size in specification without community fixed effects for all network types except social network. These effects are not present under community fixed effects. Initial OFSP adoption is higher in communities with denser networks and larger network sizes, but within communities, nonmembers with denser networks or larger network sizes are not more likely to adopt OFSP initially. Thus, network topology may be more important than the farmer's position within the topology. However, the result that having at least one treated information neighbor increased the likelihood of adopting OFSP suggests that there is a role for the farmer's position within the topology.

### 4.3.Mechanisms of initial OFSP adoption

While nonmembers who try OFSP must always leverage a social connection to get propagable vines, we have not yet addressed exactly how they do so. We test for effects of connectivity to treated farmers on joining the farmer group and on whether and how OFSP vines were received. We find that nonmembers with more treated neighbors are not more likely to join the farmer group and are more likely to get OFSP vines from a community promoter.

#### 4.3.1.Changes in farmer group membership

Nonmembers may gain access to OFSP vines by joining the participating farmer group. In the endline, we asked nonmember households if a member of the household is a member of the participating farmer group, currently and as of June 2007, just prior to the baseline survey. Thirty percent of nonmembers report having been a member of the participating farmer group in June 2007, a few months before intervention's start<sup>5</sup>. Farmer groups were not required to turn away new members and REU did not in particular encourage or discourage new members from joining (or existing members from leaving the farmer group). Indeed, nonmembers who report being member of the participating farmer group in June 2007 are 30 percentage points more likely to grow OFSP in season 1. This estimate is reduced to 16 percentage points when community fixed effects are included. We now turn to the question of whether nonmembers with more treated information neighbors are more likely to report being members of the participating farmer group in June 2007.

We recorded the rosters of participating farmer groups in order to draw a sample from the group in advance of the baseline survey. At this time, we asked the village (called an "LC1") chairperson of the village with the most members of the participating farmer group, in consultation with the farmer group chairperson, to list of all households in the community with at least one child between the ages of 3 and 5. Households with members in the participating farmer group were excluded from the list. The list was used to draw the sample of nonmembers.

There are four reasons why nonmembers might report being a member of the participating farmer group in June 2007. First, they may indeed official members of the group. However, we

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<sup>5</sup> We continue call "nonmembers" all farmers who were not on the list of members of the participating farmer group.

cannot think of a motivation for village and farmer group chairpersons to list farmer group member households on both the membership roster and the village nonmember sample lists.

Second, nonmembers may be mistaken about having joined the group. Farmer group membership is relatively fluid, so it could be that some nonmembers considered themselves to be members of the farmer group (because, for example, they had attended a farmer group meeting previously) but were not member according to official records. Third, nonmembers may be mistaken about when they joined the group. Fourth, nonmembers may be lying about having joined the group by that time. We cannot distinguish between these three reasons, but we can test if nonmembers that know more treated neighbors are more likely to report being members of the participating farmer group in June 2007. Estimates of the effect of connectivity to treated farmers on membership are in Panel A of Table 8. Many associations are negative and only one association is statistically significant. We interpret these results as suggesting that farmers with more treated information neighbors are not more likely to report being a member of the participating farmer group in 2007.

While given our data it is not possible to directly test the hypothesis that social connectivity encourages nonmembers to join the farmer group in turn giving them access to OFSP vines, in Panel B of Table 8 we test this indirectly by interacting treated and nonmember network variables with an indicator variable equal to 1 if the nonmember reported being a member of the participating farmer group in June 2007 and equal to 0 otherwise. These regressions are valid heterogeneous treatment effects estimators if farmers were indeed members of the farmer group in June 2007 (or if decision to report membership in June 2007 is unrelated to the decision to adopt)<sup>6</sup>. When community fixed effects are included, the coefficient on the interaction of reporting being a member in June 2007 and treated information network size is statistically significant (columns 5 and 6). Without community fixed effects (column 4), this coefficient is smaller and not statistically significant. This suggests that joining a farmer group may be important only in community of a certain size. This effect is present only in communities with larger farmer groups. Thus, social connectivity to treated farmer groups may encourage OFSP

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<sup>6</sup> If membership in June 2007 is indeed outcome, as it seems to be, then the regressions include an outcome as an independent variable and should not be considered valid. However, they could still informally show that the role of social connectivity in the adoption process is largely unrelated to the nonmembers reporting having been a member in June 2007.

adoption through facilitating members in larger farmer groups, but not in smaller farmer groups (results available upon request). The average partial effect of each network variable is statistically significant and larger than in specifications that aren't interacted with reporting being a member in June 2007 (as in Table 7). Thus, the impacts of treated network variables are larger and estimated more precisely for farmers that report being members of the participating farmer group in June 2007 than for those who do not, even though reporting being a member is uncorrelated with treated network variables.

It may be the case that different treated networks – such as social or acquaintance networks – importantly determine reporting being a member of the participating farmer group in June 2007. Only acquaintance network density and size in specifications without community fixed effects are associated with higher likelihoods of reporting being a member of the participating farmer group in June 2007, and these effects are sensitive to the way in which nonmember network variables are included as conditioning variables. This suggests that types of networks other than information networks are not important determinants of reporting being a member of the participating farmer group in June 2007 either. We interpret these results as suggesting that while reporting being a member of the participating farmer group in June 2007 is an important mechanism through which farmers adopt OFSP in season 1, farmers did not use their treated information networks to gain access to the farmer group.

#### **4.3.2. Who do nonmembers get OFSP vines from?**

Nonmembers may acquire OFSP vines directly from REU, from a community promoter or from other farmers. Table 3 shows who adopting nonmembers received OFSP vines from, by season. In season 1, 53 percent of adopting nonmembers received OFSP vines from a promoter, 43 percent received OFSP vines from an NGO extension agent. Only 4 percent received OFSP vines from a (non-promoter) farmer. In Table 9, we test for impacts of having treated neighbors on whether and from whom farmers received OFSP vines in season 1. We find that having a greater treated information network density or having at least one treated information neighbor increases the likelihood having received OFSP from a community promoter but does not increase the

likelihood of having received OFSP vines from an NGO agricultural extension agent or the likelihood of receiving IFSP vines from another farmer. Promoters were paid to promote OFSP to farmer group members but were not discouraged from promoting OFSP to nonmembers. Yet, it seems that nonmembers did gain access to OFSP through community promoters in Season 1. While many nonmembers accessed OFSP vines through a promoter, we do not know if they went directly to a promoter or used another farmer as an intermediary, who put the nonmember in touch with the promoter. We also do not know which farmer actually donated the OFSP vines to the nonmember.

#### **4.4. Information neighbor effects in subsequent adoption and disadoption**

Some farmers who adopt OFSP initially may disadopt, while other who do not adopt initially may adopt in later seasons. We test for effect of treated information neighbors on OFSP cultivation after season 1 in Table 10. Panel A shows effects treated network effects on OFSP cultivation in season 4, first using all nonmembers and then splitting the sample into nonmembers who adopted OFSP in the first season and those who did not. We see here no effects in season 4 of treated information neighbors on farmers not adopting OFSP initially. Initial adopters who have treated information neighbors are much more likely to be growing OFSP in season 4. The effects of treated information network density and size are large, precisely estimated and sustained in specifications with fixed effects and covariates. Initially-adopting nonmembers with the densest treated information networks are between 36 and 45 percentage points more likely to cultivate OFSP in season 4 than are initially-adopting nonmembers with the least-dense treated information networks. Having at least one treated information neighbor is associated with a 31 percentage point higher likelihood of cultivating OFSP in season 4, but this effect is not present in specifications with fixed effects. Nonmembers with at least one treated information neighbor are much more likely to adoption OFSP initially, but nonmembers with denser or larger treated information networks are more likely to sustain that adoption into season 4. Using pooled data on Seasons 2 to 4 and splitting the sample between those who were cultivating OFSP in the previous season and those not yields similar results. Among those not growing OFSP, treated networks do not cause adoption, but among those already growing OFSP, treated networks are protective against disadoption.

Table 11 estimates impacts for season 2, 3 and 4 for all nonmembers, potential disadopters (nonmembers growing OFSP in the previous season), and potential disadopters (nonmembers not growing OFSP in the previous season). Treated network effects in seasons 2, 3 and 4 on nonmembers not growing OFSP are small and imprecisely estimated. Treated network effects in seasons 2, 3 and 4 on nonmembers who were growing OFSP are larger and relatively imprecisely estimated unless pooled across years. The effects are stronger and more precisely estimated in each subsequent season. Thus, season 4's effects are strong and more precisely estimated than season 3, and season 3's are stronger and more precise than season 2's. This may be random chance, or it may be that that treated network effects grow in strength over time.

#### **4.5. Why do information neighbors protect against disadoption?**

[Future work]

### **5. Robustness checks**

We estimate the effects of social connectivity to treated and nonmember farmers using a subsample of sampled farmers, which we call the networks subsample. Since the networks subsample was randomly selected from among the sample, variables should be balanced within and outside of the networks subsample. Table 12 tests for balance in household characteristics and adoption outcomes of nonmembers between the networks subsample and sampled households not included in the networks subsample. Thirty-one percent of treated farmers and 86 percent of nonmember farmers are in the networks subsample. The samples are balanced on treated network variables and all other variables used in the analysis.

There are several potential concerns about our measures of the treatment – treated network density and size and having at least one treated network neighbor. The first is that there may be recall bias, specifically bias induced by the treatment. If adopting nonmembers gained treated information neighbors during the intervention and reported that these were pre-intervention information neighbors, then we might estimate an impact of pre-intervention information

networks when in fact our treatment measures would better be considered as outcome of intervention.

We test for balance in network density variables across nonmembers in the communities of treated and control farmer group in Table 13. While the network variables are consistently higher in treated than control communities, the effect is small and statistically insignificant. Treated information network density is 3 percentage points greater in treated communities and nonmember information network density is 4 percentage points greater in treated communities. When covariates, including nonmember treated network density, are added, coefficient on treated information networks density implies a 0.3 percentage point difference, a statistically insignificant difference. Relative to control communities, 7.5 percentage points more nonmembers in treated communities have least one treated information neighbor. When covariates are included, this difference is reduced to 4 percentage points. Neither of these differences is statistically significant. We are unconcerned about the potential for treatment-induced recall bias because none of these differences are statistically significant and the magnitude of the bias is relatively small.

Nonmember household characteristics are well balanced on observables across treatment and control groups (Table 14).

## Conclusion

We examined how Ugandan farmers access and learn about a new agricultural technology from farmers in their information networks. Our most salient results support on a two-step model of the diffusion process of OFSP. Farmers must gain access to propagable OFSP vines. In addition, farmers must gather information about OFSP, either in advance or after of adopting the crop. This could be information about how to manage, market or consume the OFSP or the information could consist of signals from other farmers about the crop's profitability, health benefits, or social acceptability. We find that nonmembers with at least one treated information neighbor are more likely to adopt OFSP. In contrast, among nonmembers who adopted OFSP in the intervention's first season, those with higher treated information network densities are less likely to have disadopted by the fourth season. We interpret the results as evidence that

nonmembers, at the start of season 1, searched their information networks for a neighbor that can provide to access OFSP vines. Those that gained access act as Bayesian learners, gathering from their network dispersed information about OFSP management or imitable signals that discourage disadoption.

In addition, we find evidence that networks facilitated OFSP diffusion through community promoters. Nonmembers with larger or denser treated information networks were more likely receive OFSP vines from community promoters. Future research should examine whether increasing the number of promoters, better-training promoters, or offering promoters encouragement to promote the crop beyond the farmer group might encourage diffusion.

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### Percentage of Farmers in Treated Communities Growing OFSP by Season and Farmer Group Membership Status

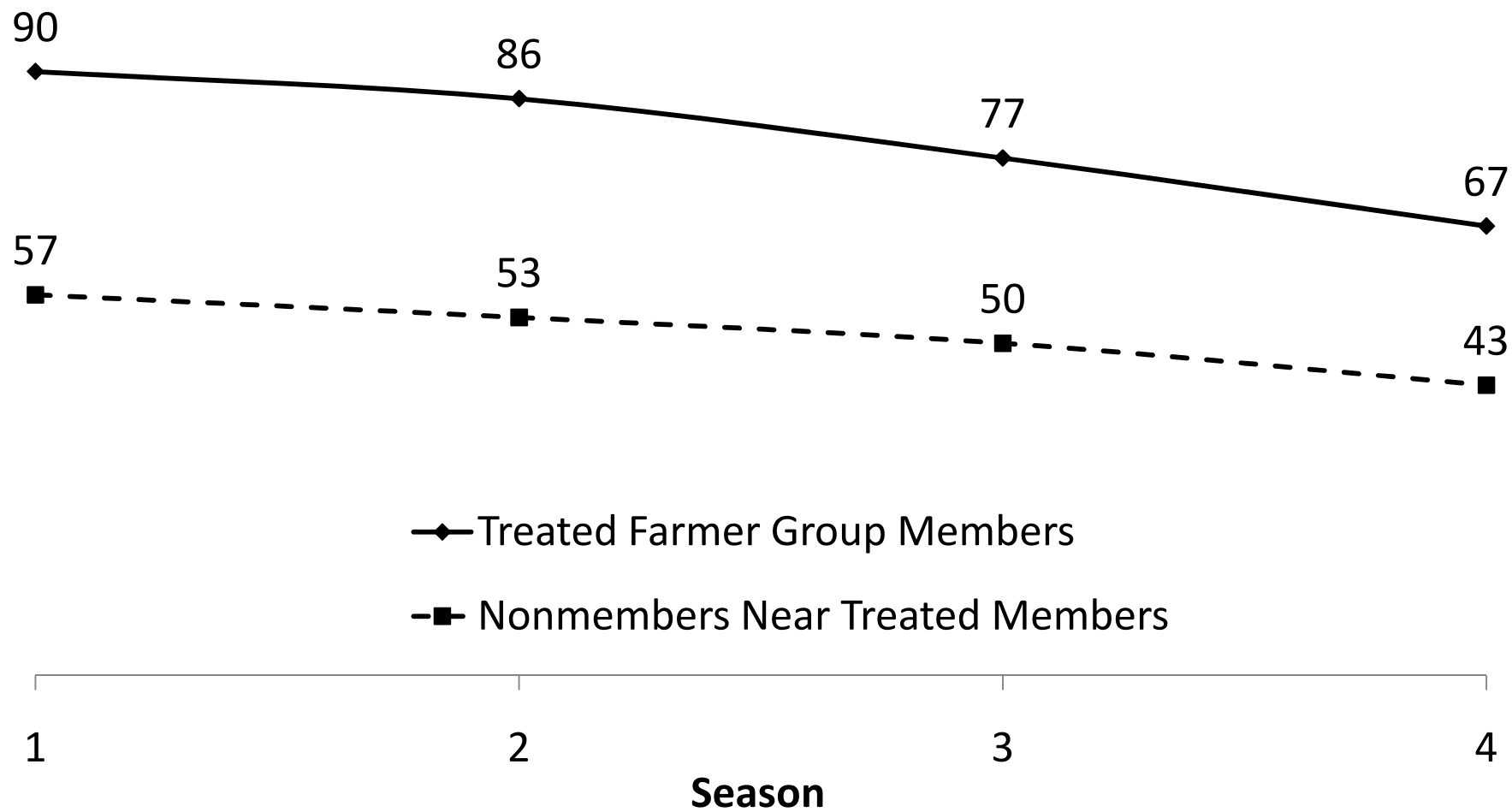


Table 1. Household Descriptive Statistics in Communities with a Treated Participating Farmer Group

	Farmer group member Households [N=621]				Nonmember Households [N=208]			
	Mean	SD	Min	Max	Mean	SD	Min	Max
<i>Household characteristics</i>								
Acres cultivated in first season 2007	2.77	2.94	0.07	35.00	2.15	1.77	0.09	12.50
Acres under (any) sweet potato in first season 2007	0.26	0.48	0.00	9.80	0.19	0.24	0.00	2.00
Grew (any) sweet potato in first season 2007	0.76	0.43	0.00	1.00	0.69	0.46	0.00	1.00
Grew OFSP in first season 2007	0.00	0.07	0.00	1.00	0.01	0.12	0.00	1.00
Had access of lowlands in first season 2007	0.43	0.50	0.00	1.00	0.41	0.49	0.00	1.00
Acres with good soil in first season 2007	1.81	3.29	0.00	50.02	1.60	2.61	0.00	27.13
Any irrigated land in first season 2007	0.04	0.19	0.00	1.00	0.05	0.21	0.00	1.00
Polygamous	0.21	0.41	0.00	1.00	0.22	0.41	0.00	1.00
Maximum household education	7.82	3.19	0.00	15.00	7.16	2.84	0.00	15.00
Mother's age	31.31	6.10	16.11	51.00	30.39	6.51	17.07	47.00
Father's minus mother's age	7.23	5.04	-4.00	57.00	6.23	4.55	-4.00	25.00
Household size	5.40	2.51	1.00	23.00	5.13	2.37	1.00	13.00
Number of children under age 3 at baseline	0.87	0.74	0.00	5.00	1.08	0.77	0.00	4.00
Number of children ages 3 to 5 at baseline	1.27	0.60	0.00	6.00	1.10	0.65	0.00	3.00
Mother's age imputed	0.19	0.39	0.00	1.00	0.19	0.40	0.00	1.00
Father's minus mother's age imputed	0.29	0.45	0.00	1.00	0.27	0.44	0.00	1.00
Kilometers to farmer group meeting place	0.52	0.51	0.00	3.58	0.73	0.67	0.03	4.19
Kilometers to average sampled farmer group member	0.60	0.29	0.00	1.59	0.67	0.30	0.00	1.47

Table 2. Network Descriptive Statistics in Communities with a Treated Participating Farmer Group

	Treated Households (farmer group members) [N=621]				Unreated Households (nonmembers) [N=208]			
	Mean	SD	Min	Max	Mean	SD	Min	Max
<i>Household characteristics</i>								
Pre-intervention nonmember acquaintance network density	0.83	0.28	0.00	1.00	0.82	0.26	0.00	1.00
Pre-intervention treated acquaintance network density	0.94	0.16	0.00	1.00	0.85	0.24	0.00	1.00
Pre-intervention nonmember social network density	0.61	0.38	0.00	1.00	0.62	0.36	0.00	1.00
Pre-intervention treated social network density	0.79	0.29	0.00	1.00	0.65	0.34	0.00	1.00
Pre-intervention nonmember information network density	0.35	0.37	0.00	1.00	0.32	0.33	0.00	1.00
Pre-intervention treated information network density	0.55	0.37	0.00	1.00	0.37	0.36	0.00	1.00
Pre-intervention nonmember trusted info network density	0.26	0.33	0.00	1.00	0.28	0.31	0.00	1.00
Pre-intervention treated trusted info network density	0.45	0.35	0.00	1.00	0.31	0.33	0.00	1.00
Pre-intervention nonmember well-trusted info network density	0.13	0.24	0.00	1.00	0.14	0.24	0.00	1.00
Pre-intervention treated well-trusted info network density	0.25	0.28	0.00	1.00	0.20	0.26	0.00	1.00
Nonmember information network density, year 2 of intervention	0.39	0.38	0.00	1.00	0.35	0.34	0.00	1.00
Treated information network density, year 2 of intervention	0.61	0.35	0.00	1.00	0.40	0.35	0.00	1.00
Pre-intervention nonmember acquaintance network size	26.03	8.65	0.00	50.00	23.74	9.98	0.00	50.00
Pre-intervention treated acquaintance network size	132.23	87.57	0.00	330.00	132.41	87.25	0.00	330.00
Pre-intervention nonmember social network size	22.17	10.95	0.00	50.00	18.27	11.61	0.00	50.00
Pre-intervention treated social network size	95.22	85.44	0.00	330.00	100.83	84.93	0.00	325.00
Pre-intervention nonmember information network size	15.39	11.45	0.00	50.00	10.40	10.95	0.00	48.00
Pre-intervention treated information network size	56.89	76.06	0.00	330.00	53.71	68.15	0.00	325.00
Pre-intervention nonmember trusted info network size	12.49	10.59	0.00	50.00	8.88	10.52	0.00	48.00
Pre-intervention treated trusted info network size	45.22	71.21	0.00	325.00	47.08	65.89	0.00	325.00
Pre-intervention nonmember well-trusted info network size	6.86	8.29	0.00	50.00	5.57	7.68	0.00	32.00
Pre-intervention treated well-trusted info network size	23.52	53.81	0.00	325.00	25.02	51.17	0.00	325.00
Nonmember information network size, year 2 of intervention	16.96	11.22	0.00	50.00	11.43	10.88	0.00	48.00
Treated information network size, year 2 of intervention	62.34	75.81	0.00	330.00	60.35	70.74	0.00	325.00
Number of people with whom of respondent conversed in month before the endli	36.88	49.06	0.00	500.00	41.31	68.97	0.00	600.00
Kilometers to farmer group meeting place	0.52	0.51	0.00	3.58	0.73	0.67	0.03	4.19
Kilometers to average sampled farmer group member	0.60	0.29	0.00	1.59	0.67	0.30	0.00	1.47

Table 3. Descriptive statistics for Nonmembers by season

	Season 1	Season 2	Season 3	Season 4
Proportion of nonmembers not growing OFSP	0.43	0.47	0.50	0.57
Proportion of nonmembers growing OFSP	0.57	0.53	0.50	0.43
Of nonmembers not growing OFSP last season, proportion adopting		0.14	0.16	0.13
Of nonmembers growing OFSP last season, proportion disadopting		0.23	0.23	0.21
Number of nonmembers acquiring OFSP vines	120	22	14	11
Proportion of adopting nonmembers who received OFSP vines from				
Promoter	0.53	0.41	0.07	0.00
NGO extension agent	0.43	0.09	0.29	0.00
Farmer who is not a promoter	0.04	0.50	0.64	1.00
Number of farmer group members acquiring OFSP vines	573	38	25	28
Proportion of adopting nonmembers who received OFSP vines from				
Promoter	0.52	0.11	0.08	0.07
NGO extension agent	0.47	0.11	0.12	0.04
Farmer who is not a promoter	0.02	0.79	0.80	0.89

Table 4. Tests for balance on household characteristics across treated network variables

Dependent variable	Treated Information Network					At Least One Treated Information Neighbor			
	Density		Treated Information Network Size			Neighbor			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Acres cultivated in first season 2007	0.212 (0.494)	0.399 (0.598)	0.368 (0.566)	0.001 (0.013)	0.006 (0.019)	0.005 (0.018)	-0.253 (0.291)	-0.203 (0.360)	-0.233 (0.324)
Acres under (any) sweet potato in first season 2007	0.024 (0.044)	-0.005 (0.045)	-0.004 (0.044)	-0.001 (0.001)	-0.001 (0.002)	-0.001 (0.002)	0.052 (0.038)	0.027 (0.040)	0.041 (0.040)
Grew (any) sweet potato in first season 2007	0.100 (0.102)	-0.006 (0.090)	-0.017 (0.092)	0.000 (0.003)	0.000 (0.003)	0.000 (0.003)	0.137* (0.075)	0.056 (0.062)	0.053 (0.063)
Grew OFSP in first season 2007	-0.064 (0.059)	-0.018 (0.026)	-0.022 (0.029)	-0.002 (0.002)	-0.001 (0.001)	-0.001 (0.001)	-0.036 (0.040)	-0.017 (0.028)	-0.026 (0.033)
Had access of lowlands in first season 2007	-0.255** (0.101)	-0.245* (0.129)	-0.220* (0.130)	-0.004 (0.004)	-0.008* (0.005)	-0.008 (0.005)	-0.139 (0.086)	-0.209** (0.102)	-0.179 (0.113)
Acres with good soil in first season 2007	0.391 (0.603)	-0.027 (0.691)	0.139 (0.591)	0.021 (0.020)	-0.006 (0.022)	-0.001 (0.018)	-0.241 (0.297)	-0.213 (0.415)	-0.037 (0.300)
Any irrigated land in first season 2007	-0.0733* (0.041)	-0.127** (0.053)	-0.119** (0.051)	-0.001 (0.001)	-0.005*** (0.002)	-0.005** (0.002)	-0.064* (0.037)	-0.093** (0.042)	-0.087* (0.047)
Polygamous	0.050 (0.089)	0.173* (0.102)	0.206* (0.102)	0.000 (0.003)	0.004 (0.004)	0.006 (0.004)	0.060 (0.069)	0.135** (0.064)	0.192*** (0.066)
Maximum household education	0.167 (0.718)	0.125 (0.869)	0.120 (0.884)	-0.024 (0.021)	-0.016 (0.026)	-0.014 (0.026)	-0.433 (0.491)	-0.549 (0.616)	-0.653 (0.661)
Mother's age	1.535 (1.527)	2.294 (1.985)	2.586 (1.961)	0.036 (0.047)	0.035 (0.077)	0.041 (0.076)	0.679 (1.086)	0.423 (1.425)	0.698 (1.364)
Father's minus mother's age	-0.010 (1.055)	-0.505 (0.831)	0.010 (0.827)	-0.004 (0.031)	-0.023 (0.032)	-0.005 (0.033)	-0.148 (0.792)	-1.419* (0.740)	-0.717 (0.706)
Household size	1.127* (0.600)	1.489** (0.680)	1.614** (0.690)	0.017 (0.020)	0.037 (0.026)	0.042 (0.026)	0.348 (0.390)	0.441 (0.430)	0.558 (0.438)
Household members aged 0-2 at baseline	-0.253 (0.165)	-0.125 (0.196)	-0.106 (0.197)	-0.006 (0.005)	-0.004 (0.007)	-0.003 (0.007)	-0.084 (0.136)	0.052 (0.159)	0.077 (0.164)
Household members aged 3-5 at baseline	-0.011 (0.178)	-0.040 (0.218)	-0.049 (0.210)	-0.001 (0.005)	0.000 (0.007)	-0.001 (0.007)	0.005 (0.121)	-0.103 (0.154)	-0.124 (0.164)
Community Fixed effects	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
<i>Included Nonmember information network variables</i>									
Density	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No
Quadratic of Density and Size	No	No	Yes	No	No	Yes	No	No	Yes

Each cell is an OLS regression. Standard errors, in parentheses, are clustered by community. N=208.

Table 5. Tests for balance on mean information neighbor characteristics across treated network variables

Dependent variable	Treated Information Network						At Least One Treated Information Neighbor		
	Density		Treated Information Network Size				Neighbor		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Acres cultivated in first season 2007	0.067 (0.522)	-0.429 (0.272)	-0.379 (0.289)	-0.005 (0.020)	-0.009 (0.009)	-0.008 (0.010)	0.974** (0.474)	0.179 (0.132)	0.317* (0.186)
Acres under (any) sweet potato in first season 2007	0.025 (0.078)	-0.025 (0.032)	-0.022 (0.035)	-0.001 (0.003)	-0.001 (0.001)	-0.001 (0.001)	0.167 (0.112)	0.028 (0.019)	0.040 (0.027)
Grew (any) sweet potato in first season 2007	0.130 (0.105)	0.015 (0.044)	0.011 (0.050)	0.002 (0.003)	0.000 (0.002)	0.000 (0.002)	0.123* (0.062)	0.0335* (0.017)	0.030 (0.019)
Grew OFSP in first season 2007	0.004 (0.004)	0.002 (0.002)	0.001 (0.001)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.001 (0.001)	0.000 (0.000)	-0.001 (0.001)
Had access of lowlands in first season 2007	0.072 (0.108)	0.054 (0.052)	0.060 (0.055)	0.002 (0.003)	0.003 (0.002)	0.003 (0.002)	-0.011 (0.069)	-0.015 (0.018)	-0.014 (0.024)
Acres with good soil in first season 2007	0.051 (0.572)	-0.252 (0.252)	-0.224 (0.265)	0.000 (0.020)	-0.004 (0.009)	-0.003 (0.009)	0.468 (0.426)	0.143 (0.124)	0.184 (0.160)
Any irrigated land in first season 2007	0.007 (0.056)	-0.004 (0.029)	-0.004 (0.031)	0.000 (0.002)	0.000 (0.001)	0.000 (0.001)	0.006 (0.015)	-0.003 (0.006)	-0.005 (0.010)
Polygamous	-0.164** (0.080)	-0.031 (0.023)	-0.033 (0.024)	-0.005 (0.003)	-0.001 (0.001)	-0.001 (0.001)	-0.071 (0.050)	0.001 (0.010)	-0.009 (0.010)
Maximum household education	-0.025 (0.655)	-0.279 (0.305)	-0.253 (0.331)	0.011 (0.025)	-0.010 (0.012)	-0.010 (0.013)	0.404 (0.490)	-0.056 (0.133)	0.000 (0.171)
Mother's age	1.038 (1.271)	-0.664 (0.705)	-0.751 (0.699)	0.057 (0.042)	-0.030 (0.027)	-0.033 (0.027)	1.246 (0.983)	-0.248 (0.190)	-0.493 (0.332)
Father's minus mother's age	-0.636 (0.918)	-0.336 (0.541)	-0.327 (0.565)	-0.025 (0.029)	-0.017 (0.020)	-0.017 (0.021)	0.132 (0.594)	0.218* (0.128)	0.189 (0.146)
Household size	0.034 (0.440)	-0.601** (0.257)	-0.606** (0.258)	0.008 (0.015)	-0.0209** (0.010)	-0.0213** (0.010)	0.438 (0.286)	0.044 (0.092)	0.007 (0.137)
Household members aged 0-2 at baseline	-0.218 (0.154)	-0.063 (0.068)	-0.074 (0.069)	-0.006 (0.005)	-0.001 (0.003)	-0.002 (0.003)	-0.153 (0.096)	0.007 (0.031)	0.004 (0.040)
Household members aged 3-5 at baseline	-0.153 (0.097)	-0.051 (0.065)	-0.055 (0.063)	-0.006 (0.004)	-0.002 (0.002)	-0.003 (0.002)	-0.018 (0.069)	0.035 (0.023)	0.013 (0.021)
Community Fixed effects	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
<i>Included Nonmember information network variables</i>									
Density	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No
Quadratic of Density and Size	No	No	Yes	No	No	Yes	No	No	Yes

Each cell is an OLS regression. Standard errors, in parentheses, are clustered by community. N=208.

Table 6. Information Network Effects in Initial OFSP Adoption

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Treated info network density	0.268** (0.118)	0.119 (0.113)	0.118 (0.121)							-0.133 (0.304)	-0.334 (0.365)	-0.456 (0.405)
Treated info network size				0.008* (0.004)	0.004 (0.004)	0.004 (0.004)				0.004 (0.008)	0.007 (0.013)	0.007 (0.015)
At least one treated information neighbor							0.259*** (0.083)	0.194** (0.085)	0.233*** (0.086)	0.273** (0.117)	0.269** (0.107)	0.369*** (0.122)
Quadratic nonmember network density and size	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Community fixed effects	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Covariates	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes

Notes: All specifications use a linear probability model. Standard errors are clustered by community. N=208.

Table 7. Effects of Various Networks in Intial OFSP Adoption

Network type	Treated Network Density			Treated Network Size			Has at least one treated information neighbor		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Acquaintance	0.458*** (0.125)	0.1450 (0.108)	0.0247 (0.121)	0.00881** (0.004)	0.0057 (0.004)	0.0014 (0.005)	0.404*** (0.083)	-0.0285 (0.179)	-0.2130 (0.263)
Social	0.1930 (0.122)	0.0046 (0.094)	0.0209 (0.112)	0.0057 (0.004)	0.0000 (0.004)	0.0010 (0.004)	0.1120 (0.125)	0.0140 (0.092)	0.1100 (0.101)
Information	0.268** (0.118)	0.1190 (0.113)	0.1180 (0.121)	0.00825** (0.004)	0.0044 (0.004)	0.0041 (0.004)	0.259*** (0.083)	0.194** (0.085)	0.233*** (0.086)
Trusted information	0.243** (0.118)	0.0727 (0.113)	0.0767 (0.135)	0.00751** (0.004)	0.0024 (0.004)	0.0021 (0.005)	0.156* (0.088)	0.1210 (0.079)	0.169** (0.074)
Well-trusted information	0.316** (0.144)	0.0919 (0.142)	0.1180 (0.162)	0.00993** (0.005)	0.0029 (0.005)	0.0029 (0.006)	0.0889 (0.077)	0.0320 (0.077)	0.0882 (0.074)
Community									
Fixed effects	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Covariates	No	No	Yes	No	No	Yes	No	No	Yes

Each cell reports a key coefficient and community-clustered standard error from a separate regression. Each row uses a different network definition. N=208.

Table 8. Nonmembers Joining the Participating Farmer Group and Initial OFSP Adoption

	Treated Information Network Density			Treated Information Network Size			At Least One Treated Information Neighbor		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
<b>Panel A: Dependent variable is "Reports being a member in June 2007"</b>									
Reports being a member in June 2007	0.0844 (0.114)	-0.1020 (0.098)	-0.0938 (0.100)	0.0000 (0.004)	-0.00640* (0.004)	-0.0064 (0.004)	0.0775 (0.079)	-0.0066 (0.076)	0.0226 (0.075)
<b>Panel B: Dependent variable is "Adopted OFSP in Season 1"</b>									
Reports being a member in June 2007	0.317*** (0.116)	0.176 (0.154)	0.167 (0.161)	0.308*** (0.111)	0.154 (0.152)	0.147 (0.161)	0.273** (0.134)	0.122 (0.185)	0.104 (0.183)
Treated [Network Variable]	0.235* (0.135)	0.0665 (0.133)	0.0549 (0.135)	0.00758* (0.004)	0.00365 (0.004)	0.00306 (0.005)	0.217** (0.086)	0.128 (0.090)	0.152* (0.083)
Reports being a member in June 2007 X Treated [Network Variable]	0.0202 (0.184)	0.273 (0.200)	0.306 (0.217)	0.00245 (0.005)	0.0124* (0.006)	0.0132** (0.006)	0.0644 (0.142)	0.216 (0.161)	0.244 (0.162)
Average Partial Effect of [Network Variable]	0.255 (0.168)	0.340** (0.162)	0.361* (0.188)	0.010** (0.005)	0.016*** (0.006)	0.016** (0.006)	0.281** (0.138)	0.344** (0.143)	0.396** (0.153)
Community Fixed Effects	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Covariates	No	No	Yes	No	No	Yes	No	No	Yes

Each column reports a separate linear probability model; community-clustered standard errors are in parentheses. [Network Variable] refers to the variable named in the column header. N=208.

Table 9. Information Network Effects on OFSP Vine Source in Season 1

	Number of observations with outcome	Treated Information Network Density		Treated Information Network Size		At Least One Treated Information Neighbor	
		(1)	(2)	(3)	(4)	(5)	(6)
Did not receive	87	-0.200* (0.108)	-0.0315 (0.124)	-0.215*** (0.077)	-0.0018 (0.004)	-0.00580* (0.003)	-0.182** (0.083)
NGO Extension Agent	52	0.0235 (0.086)	-0.0724 (0.102)	0.0569 (0.068)	-0.0016 (0.003)	0.0004 (0.003)	0.1000 (0.092)
Community Promoter	64	0.180* (0.094)	0.1040 (0.118)	0.158** (0.074)	0.0034 (0.004)	0.0052 (0.003)	0.0816 (0.091)
Non-promoter farmer	5	-0.0034 (0.020)		-0.0002 (0.014)		0.0002 (0.001)	
Covariates		No	Yes	No	Yes	No	Yes
N		208	203	208	203	208	203

Each column is a separate multinomial logit regression. Community-clustered standard errors are in parentheses. All specifications include quadratics of nonmember network density and size. The average of marginal effects are reported for the variable indicated in the column header and outcome indicated in the row header.

Table 10. Network effects on OFSP Cultivation, Adoption and Disadoption After Season 1

Subsample	N	Treated Network Density			Treated Network Size			At least one treated information neighbor		
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
<b>Panel A. Dependent variable: OFSP Cultivation in Season 4</b>										
All nonmembers	208	0.360*** (0.079)	0.213** (0.096)	0.241** (0.103)	0.0101*** (0.003)	0.00783** (0.004)	0.00841** (0.004)	0.274*** (0.063)	0.180** (0.085)	0.191** (0.090)
Did not adopt in season 1	90	0.0218 (0.120)	-0.1710 (0.114)	-0.0950 (0.154)	-0.0008 (0.004)	-0.0069 (0.004)	-0.0064 (0.006)	0.0409 (0.104)	-0.0554 (0.099)	0.0289 (0.104)
Adopted in season 1	118	0.448*** (0.123)	0.364** (0.144)	0.423** (0.192)	0.0114*** (0.004)	0.0123** (0.005)	0.0136** (0.006)	0.314*** (0.096)	0.1350 (0.123)	0.0791 (0.176)
<b>Panel B. Dependent variable: OFSP Cultivation in Seasons 2-4, pooled</b>										
Did Not Grow OFSP in previous season	292	0.1140 (0.075)	-0.0553 (0.088)	0.0628 (0.088)	0.00477* (0.003)	-0.0026 (0.004)	0.0021 (0.004)	0.100* (0.051)	-0.0280 (0.068)	0.0526 (0.066)
Grew OFSP in previous season	332	0.203*** (0.062)	0.132* (0.077)	0.0991 (0.086)	0.00458** (0.002)	0.00541** (0.002)	0.0048 (0.003)	0.174*** (0.055)	0.125* (0.066)	0.152** (0.069)
Community Fixed effects		No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Covariates		No	No	Yes	No	No	Yes	No	No	Yes

Each cell reports on a separate regression. The reported coefficient is that of the variable named in the column header. Each row used a different subsample. Community-clustered standard errors are in parentheses. The dependent variable is dichotomous OFSP cultivation in season 4.

Table 11. Network effects on OFSP Cultivation, Adoption and Disadoption After Season 1, By Season

	N	Treated Network Density			Treated Network Size			At least one treated information		
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
<b>Panel A: All nonmembers</b>										
Season 2	208	0.342*** (0.112)	0.1570 (0.112)	0.1690 (0.120)	0.0113*** (0.003)	0.0064 (0.004)	0.0067 (0.004)	0.375*** (0.069)	0.300*** (0.071)	0.308*** (0.086)
Season 3	208	0.402*** (0.113)	0.238* (0.139)	0.295** (0.129)	0.0123*** (0.004)	0.00899* (0.005)	0.0104** (0.005)	0.330*** (0.076)	0.1720 (0.104)	0.205** (0.087)
Season 4	208	0.360*** (0.079)	0.213** (0.096)	0.241** (0.103)	0.0101*** (0.003)	0.00783** (0.004)	0.00841** (0.004)	0.274*** (0.063)	0.180** (0.085)	0.191** (0.090)
<b>Panel B: Nonmembers not growing OFSP in the previous season</b>										
Season 2	89	0.308** -0.126	0.0141 -0.143	0.101 -0.214	0.0114** -0.00448	-0.000593 -0.00639	0.00494 -0.00749	0.242*** -0.0773	0.106 -0.101	0.133 -0.144
Season 3	96	0.107 -0.133	-0.0734 -0.129	0.159 -0.146	0.00571 -0.00479	-0.00417 -0.00537	0.00604 -0.00616	0.0939 -0.0812	-0.139 -0.0846	0.0557 -0.0925
Season 4	105	-0.101 -0.0807	-0.176 -0.115	-0.245* -0.134	-0.00327 -0.00235	-0.00617 -0.00431	-0.00861* -0.00507	-0.0353 -0.0712	-0.107 -0.119	-0.178 -0.133
<b>Panel B: Nonmembers growing OFSP in the previous season</b>										
Season 2	118	0.0725 (0.113)	0.0200 (0.131)	-0.0271 (0.084)	0.0028 (0.003)	0.0029 (0.004)	0.0025 (0.003)	0.187* (0.100)	0.1310 (0.085)	0.0464 (0.094)
Season 3	111	0.235** (0.114)	0.1540 (0.172)	0.2060 (0.142)	0.0038 (0.003)	0.0055 (0.006)	0.0084 (0.006)	0.1180 (0.104)	0.0078 (0.163)	0.0435 (0.099)
Season 4	103	0.301** (0.128)	0.300** (0.141)	0.2350 (0.186)	0.00720** (0.003)	0.0103** (0.005)	0.0071 (0.005)	0.206* (0.104)	0.303** (0.140)	0.2870 (0.191)
Community Fixed effects	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	
Covariates	No	No	Yes	No	No	Yes	No	No	Yes	

Each cell reports a key coefficient and community-clustered standard error from a separate regression. The coefficient reported is named in the column header. The dependent variable is dichotomous OFSP Adoption in the season named in the row header.

Table 12. Balancing tests for networks subsample

	Networks			
	subsample		Rest of Sample	
	Mean	SE	Mean	SE
Pre-intervention cultivated total area	1.96	(0.04)	2.35	(0.24)
Pre-intervention cultivated area under sweet potatoes	0.19	(0.01)	0.22	(0.05)
Pre-intervention grew any sweet potatoes	0.72	(0.01)	0.69	(0.04)
Grew OFSP in the two seasons before the intervention	0.01	(0.00)	0.01	(0.00)
Pre-intervention access to lowlands	0.41	(0.01)	0.45	(0.06)
Pre-intervention area with good soils	1.46	(0.05)	1.30	(0.27)
Pre-intervention, had irrigated lands	0.06	(0.01)	0.03	(0.03)
Polygamous	0.19	(0.01)	0.27	(0.06)
Max Education	7.07	(0.08)	6.22	(0.47)
Mother's Age	30.38	(0.14)	29.57	(0.84)
Mother's - Father's Age	6.42	(0.13)	6.79	(0.74)
HH Size	5.14	(0.05)	4.68	(0.31)
Num Children Under 3	1.06	(0.02)	1.08	(0.11)
Num Children Ages 3-5	1.17	(0.02)	1.14	(0.10)
Mother's Education Imputed	0.16	(0.01)	0.15	(0.04)
Mother's - Father's Age Imputed	0.25	(0.01)	0.26	(0.05)
Kilometers to farmer group meeting place	0.74	(0.01)	0.77	(0.08)
Average kilometers to farmer group member	0.68	(0.01)	0.69	(0.03)
Treated Acquaintance Network density	0.80	(0.01)	0.86	(0.04)
Nonmember Acquaintance Network density	0.81	(0.01)	0.82	(0.03)
Treated Social Network density	0.61	(0.01)	0.64	(0.04)
Nonmember Social Network density	0.58	(0.01)	0.60	(0.05)
Treated Information Network density	0.35	(0.01)	0.35	(0.04)
Nonmember Information Network density	0.30	(0.01)	0.30	(0.04)
Treated Trusted Information Network density	0.30	(0.01)	0.31	(0.04)
Nonmember Trusted Information Network density	0.26	(0.01)	0.27	(0.04)
Treated Well-Trusted Information Network density	0.18	(0.01)	0.15	(0.03)
Nonmember Well-Trusted Information Network density	0.13	(0.00)	0.12	(0.03)
At least one treated information neighbor	0.61	(0.01)	0.58	(0.07)
Treated Information Network density, 2009	0.37	(0.01)	0.39	(0.04)
Nonmember Information Network density, 2009	0.33	(0.01)	0.33	(0.04)
Observations	185		23	
Percent of observations in networks subsample	89%			

Estimated using community fixed effects. Community-clustered standard errors are in parentheses. N=208. The networks sample doesn't differ statistically significantly for any variable.

Table 13. Tests for balance on network density across treatments

Mean value of household characteristic:	Treatment - Control		Treatment - Control, with covariates	
<i>Pre-intervention networks</i>				
Treated Social Network density	0.076	(0.054)	0.0394	(0.041)
Nonmember Social Network density	0.0934*	(0.056)		
Treated Information Network density	0.0313	(0.048)	0.00382	(0.033)
Nonmember Information Network density	0.0399	(0.048)		
Treated Trusted Information Network density	0.00838	(0.048)	-0.00839	(0.036)
Nonmember Trusted Information Network density	0.0394	(0.046)		
Treated Well-Trusted Information Network density	0.0411	(0.030)	0.0418	(0.027)
Nonmember Well-Trusted Information Network density	0.0231	(0.027)		
At least one treated information neighbor	0.075	(0.060)	0.0408	(0.060)
<i>During-intervention networks</i>				
Treated Acquaintance Network density	0.0799*	(0.043)	0.0716**	(0.035)
Nonmember Acquaintance Network density	0.0248	(0.037)		
Treated Information Network density, 2009	0.0656	(0.051)	0.00956	(0.036)
Nonmember Information Network density, 2009	0.0527	(0.045)		

Each row is an OLS regression with community fixed effects and standard errors clustered by community. N=208.

Table 14. Tests for balance on household characteristics across treated network connectivity

Mean value of household characteristic:	Treatment - Control	
Acres cultivated in first season 2007	0.315	(0.222)
Acres under (any) sweet potato in first season 2007	-0.00939	(0.034)
Grew (any) sweet potato in first season 2007	-0.0548	(0.079)
Grew OFSP in first season 2007	0.00215	(0.014)
Had access of lowlands in first season 2007	-0.0208	(0.063)
Acres with good soil in first season 2007	0.355	(0.302)
Any irrigated land in first season 2007	-0.0194	(0.026)
Polygamous	0.0262	(0.045)
Maximum household education	0.481	(0.348)
Mother's age	0.275	(0.744)
Father's minus mother's age	-0.544	(0.500)
Household size	0.141	(0.299)
Household members aged 0-2 at baseline	0.0511	(0.098)
Household members aged 3-5 at baseline	-0.162**	(0.077)
Kilometers to farmer group meeting place	-0.0225	(0.111)
Mean kilometers to sampled farmer group members	-0.0212	(0.045)

Each row is an OLS regression with community fixed effects and standard errors clustered by community. N=208.